Enchytraeids and earthworms (Annelida: Clitellata: Enchytraeidae, Lumbricidae) of parks in the city of Brno, Czech Republic

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Abstract

In 2006–2008 soil-dwelling annelids were studied in old parks in the central part of Brno (Czechia). The sites fell into three distinct size classes: 16–18 ha, 1.7–2.7 ha and lawns of 100 m². Earthworms were sampled by the Electro-octet Method and enchytraeids by wet funnel extraction from soil cores. Mean enchytraeid densities were low, not exceeding ca. 6100 ind. m^{-2}. Mean earthworm densities ranged between 109 and 295 ind. m^{-2}. Per park, 3 to 13 enchytraeid species and from 2 to 6 earthworm species were found, for all parks pooled 9 enchytraeid and 8 lumbricid species. Epigeic earthworm species were almost absent. Species richness in the largest and medium-sized parks was similar for both taxa. In enchytraeids lowest species numbers were found in the smallest plots, in earthworms in one of the 100 m² plots, whereas the other one hosted as many or more species than two of the medium-sized parks. Assemblages sampled in small woods in different parks were more similar to each other than to those of lawns from the same parks. Assemblages of the smaller parks had higher percentages of *Buchholzia* spp., *Enchytraeus* spp. and *Henlea ventriculosa*, probably indicating higher disturbance levels. Three enchytraeid species were first records for the Czech Republic.

Keywords: annelids, soil, urban ecology, fauna

1. Introduction

Soil annelids have mostly been studied either in agricultural settings (hay meadows, pastures, orchards, arable fields) or in forests – from anthropogenic monocultures to natural woodlands. Although the ecology of the urban environment has become topical in the last third of the 20th century, not too many studies have dealt with annelids in urban soils. This is surprising because the importance of these taxa for soil structure, decomposition and thus soil fertility, has been known for a long time, and their ability to indicate soil properties and contamination has also been widely accepted (Lee 1985, Edwards & Bohlen 1996, Jänsch et al. 2005, Hartley et al. 2008). The urban environment includes a wide range of habitats from very highly disturbed ones, as for instance land in the vicinity of metal processing or chemical industry (active at present or in the past), to more stable ones, in particular private gardens

and urban greens, maintained in a more natural state. Although the fauna of large cities is generally impoverished compared to the surrounding countryside, with species richness decreasing along an urbanisation gradient, it can still be very rich and some groups can reach higher abundance in cities than in their environs (Luniak 2008). Earthworms can reach high densities in disturbed urban greens whereas other soil fauna, including enchytraeids and other mesofauna, reach lower densities than in comparable but more natural habitats (Banaszak & Kasprzak 1978).

Earthworms have been studied far more often in urban habitats than enchytraeids. Data are available for assemblages in different types of urban greens in the Polish cities Warsaw, Cracow and Poznan (Pilipiuk 1981, Bankowska et al. 1985, Kasprzak 1987, Pižl & Sterzynska 1991, Rozen & Mazur 1997), in the German cities Munich, Bonn-Bad Godesberg, Hamburg, Dorsten, and Wulfen (Bauchhenss 1982, Esser 1984, Schulte et al. 1989, Keplin 1993, 1995, Keplin & Broll 1997), and in Brussels, Belgium (Pižl & Josens 1995a, b, Pižl 1999a, Tiho & Josens 2000). Outside Europe, earthworms were studied in Eskisehir, Turkey (Misirlioglu 2002), New York and Moscow, USA (Steinberg et al. 1997, Smetak et al., 2007), in seven cities in Australia (Abbott 1982, Baker et al. 1997) and in Accra, Ghana (Mainoo et al. 2008).

Only three broader sets of data on enchytraeids in urban parks were published before our project, all from Central Europe: Warsaw, Poland (Kasprzak 1981, 1986), Bonn-Bad Godesberg (Schulte et al. 1989) and Berlin (Heck et al. 1999), both Germany. A species list from a single lawn in the Sanssouci park at Potsdam, Germany, was published by Möller (1971). Another comparable data set from Germany available to us was an unpublished report on the annelid assemblage of a lawn in the Amsinckpark, an urban park in Hamburg, sampled in 1992 and 2002 (Graefe et al. 2003). Data on terrestrial (and aquatic) Clitellata published from the Swedish Nationalstadsparken in Stockholm (Erséus et al. 1999) are difficult to compare in our context as they were collected in a wide range of terrestrial and aquatic habitats, often in very natural settings, although close to the urban environment.

In 2006–2008 we studied soil-dwelling annelids in six urban parks in the central part of Brno, a medium-sized (ca. 370 000 inhabitants) Central European city situated in the south-east of the Czech Republic. The selected parks differed in size, falling into three distinct size classes. One of the major objectives of this project was to assess and to compare the composition and diversity of soil annelid fauna in the individual parks. Four factor groups were considered: soil properties (in particular soil chemistry), vegetation (lawn vs. woodland), park size, and park history. All parks selected for the study had been greens for a long time, but there were still marked differences in the time span of their existence. However, even in cases of well-documented park history, reliable information on modifications of the terrain, including removal of or import of soil material, was rarely available. Further aspects studied within the project were the effect of soil compaction by human treading, the effect of soil contamination by airborne pollutants, and the potential effect of exotic trees on soil annelids, see Pižl & Schlaghamerský (2007), Schlaghamerský et al. (2009), and Pižl et al. (2009).

The closest site to the studied parks at which the enchytraeid fauna had been previously studied was the Brno municipal forest in the western outskirts of Brno (Šídová & Schlaghamerský 2007), situated ca. 4 km to the north-west of Špilberk park. The next site with data on enchytraeids and earthworms was a floodplain forest 40 km to the south-east of downtown Brno (Pižl 1998, 1999b, Schlaghamerský 2007). These data are of interest as the largest and oldest park in Brno (Lužánky) had been created at the site of a former alluvial forest. This park is also the only one in Brno from which data on other invertebrates were published: In the 1970s this park hosted a rich assemblage of carabid and staphylinid beetles with many species characteristic for floodplain forests (Šustek 1979).

2. Materials and methods

Study sites

Six parks in the central part of Brno were selected for the study (Tabs 1, 2), falling into distinct size categories: Lužánky and Špilberk (16–18 ha), Koliště (south-eastern section), Schreberovy zahrádky and Tyršův sad (1.7–2.7 ha), and two distinct plots, 100 m^2 each, within the park complex Denisovy sady. The farthest distance between individual parks studied was ca. 2.2 km between the western-most plot sampled within the Špilberk park and Schreberovy zahrádky, the eastern-most park studied. All sites have a long history as urban greens and are isolated from other, similar habitats.

Tab. 1   General characteristics of the studied parks in the city of Brno and number of sampling points (elektro-oktet sampling points for earthworms, soil cores for enchytraeids) taken per site (in Denisovy sady sampling covered equally two 100 m^2 plots in the Kapucínské zahrady and Fons salutis parts of the park).

Site	Lužánky	Špilberk	Koliště	Schreberovy zahrádky	Tyršův sad	Denisovy sady
Area (ha)	17.9	16.2	2.7	2.4	1.7	1.7
Age (years)	> 200	145	145	42	124	> 180
Land cover of sampled areas	lawns with trees	lawns with trees; wood	lawn	lawns with trees	lawn; wood	lawns
Bedrock	loess	ultrabasic igneous rock; loess	rubble	loess	loess	ultrabasic igneous rock
Soil	Cherno-zems; Gleyic Fluvisols	Cambisols; Luvisols	Anthro-posols	Chernozems	Anthro-posols	Anthro-posols
Earthworm sampling points	30	12	12	24	9	6
Enchytraeid sampling points	78	24	48	42	14	12

Tab. 2   Mean chemical parameters of the studied parks in the city of Brno (measured separately for lawn and wood habitats in the parks Špilberk and Tyršùv sad; in all other parks the data refer to lawns, partially with interspersed trees).

	pH	Cox	Pv	Na	K	Ca
Park (– habitat)	(KCl)	[%]	[mg kg^{-1}]	[mg kg^{-1}]	[mg kg^{-1}]	[mg kg^{-1}]
Lužánky	7.14	4.2	28	79	251	7654
Špilberk – lawn	7.08	8.8	56	14	375	6860
Špilberk – wood	7.06	9.7	74	13	362	6746
Koliště	7.4	2.5	42	28	221	8340
Schreberovy zahrádky	7.02	6.1	23	15	243	6632
Tyršův sad – lawn	7.04	10	25	33	34	4553
Tyršův sad – wood	7.16	5.9	84	12	397	6166
Fons salutis	7.06	6.5	412	33	664	8961
Kapucínské zahrady	7.16	5	263	38	465	13760

However, assessing the degree of isolation of the annelid assemblages was not straightforward. In particular the larger parks are subdivided by paved, asphalted or gravel roads or paths for pedestrians, bikers (in some parks) and the occasional motor vehicle used for park maintenance. On the other hand, the Koliště site is part of a belt of greens (some 8 ha in total) preserved in place of the former town fortifications along approximately one-fourth of the perimeter of the historic old town. In the north it is only separated by a narrow street from another part of the park. Thus we took proper streets as distinct, isolating boundaries of the parks, whereas we arbitrarily considered narrower roads within these boundaries as potentially surmountable barriers for the annelids studied. In any case, the sites studied are situated well apart from each other and most have been without any connection potentially allowing active migration of annelids between them for at least 150 years. There are two exceptions where a full separation probably occurred only some 60 years ago: 1) the two small plots studied within the Denisovy sady park complex were separated by the construction of Husova street in the 1940s; 2) the construction of streets and houses probably had become an insurmountable barrier for an active migration between the parks Lužánky and Schreberovy zahrádky (0.7 km distance) by the same time. Further details on the individual parks (study plots) are given in Tabs 1–2 and below; the latter are based in particular on Bína & Folk (1983), Emodiová (1983), Přibyl (1994), Pacáková (1999), and Pánková (2004).

Lužánky: the oldest public urban park in Czechia. It dates back to the 13th century, when a lot west of the Ponávka brook (250 m a.s.l.), including a farm building, alluvial meadow and woodland, was donated to a monastery. Since 1578 it was owned by the Jesuits who gradually transformed the area into a park-like garden. In 1786 the garden became the property of the city of Brno. Further land was added and the total of ca. 20 ha was transformed into a public park in French style, opened in 1788. In 1841 the park was connected by a tree-lined avenue with the Koliště greens and enlarged, to include the foot of the slopes of Černá pole ('Black fields'– after the black soil) east of Ponávka brook. From 1846 onwards the park was turned into an English-style park or landscape garden. Large areas were turned into lawns and many domestic and exotic trees were planted. The gradual enlargement of the park to the south and west led to a total area of some 27 ha. At the turn of the 20th century the park area was somewhat reduced in the east and by 1913 the polluted Ponávka brook had been culverted

below ground. Today most of the park is covered by lawns with interspersed trees (mostly deciduous, often exotic) but also areas resembling small woods are present. The original soils are Chernozem in about half of the area and hydromorphic, gleyey soil (Luvisols) in the other half along the original course of the Ponávka brook. In 2005 an artificial channel supplied by recirculating water has been constructed in the park as a reminiscence of this brook. This recently disturbed area was excluded from our sampling. Sampling was conducted in lawns with interspersed trees in the eastern, south-eastern and central part of the park.

Špilberk: The park was established in 1861–1862 on the hill (225 m–280 m a. s. l.) around Špilberk castle, overseeing the central part of Brno. The castle was built in the 13th century and from that time the upper part of the hill was bare of vegetation. Before the end of the 16th century, when vineyards and orchards were established at its foot, the rocky slopes were sparsely vegetated by woody plants. In the 17th century modern fortifications were built and most trees were cleared. The slopes were probably also used for pasturage. In the 18th century vineyards, orchards and vegetable gardens were established on the lower slopes once again. In 1820 the fortress was given up. Planting of woody vegetation started immediately and in 1861 a landscape park was established. Many modifications of the terrain and massive planting of trees (deciduous and coniferous, domestic and exotic species) were conducted already in the beginning of the 1860s, but trees were planted up to 1887. In 1888 a municipal gardening enterprise was established on the southern slope – this area was added to the park in the 1930s. Today most of the park is a mosaic of lawns with single trees, transitions from lawns to open woods, and small woods or areas densely covered by shrubs, all that on slight up to steep slopes. A gradual reconstruction of the park has been going on since the 1990s, first in the northern part where in particular the park avenues were repaired. In 2006 the steep and rocky south-western slopes were rebuilt and replanted. This most recently affected part was excluded from our sampling. Sampling was conducted in a lawn with few interspersed trees in the western part at the main gate of the fortifications, in a lawn with many interspersed trees almost on hill top to the east of the castle area, and in two small deciduous woods on the northern slope.

Kolište: Already in 1793 avenues of deciduous trees were planted on the foreground (glacis, kolište) of the city fortifications along the northern and eastern boundary of the old town. The city wall was torn down in 1831 and in 1835 greens including further tree avenues were established, encircling the city centre in the north, east and south. Soon after, large parts in the south were lost to new development projects, in particular to the railway station. Further fortifications were torn down and in 1861 the north-eastern part of the green belt became the Kolište park (its name changed several times). The 'bedrock' of the park soil is thus a mighty layer of rubble. In 1863 the Kolište park was fragmented by the construction of streets and open space was gradually lost to buildings erected successively from 1846 till 1965 (some were later demolished). We studied one of the largest fragments (2.7 ha of a total of ca. 8 ha), bordered by the four-lane Kolište street (with heavy car traffic) in the east, Za divadlem street in the west, Malinovského square in the south, and Jesuitská street in the north. This part of the park had been reconstructed in the second half of the 1990s. A green strip, some 6 m wide, between the edge of Kolište Street and a low hedge presenting the park's formal border, is used by citizens walking their dogs, resulting in a compacted path and a lawn with abundant dog excrements. This strip as well as the inner part of the park was included in our study.

Schreberovy zahrádky: A cemetery was established on this site in 1854, when the area was arable land at the border of the city. The cemetery was closed and abandoned in 1884. Allotments – a so-called Schreber garden colony – were established in 1908 and in 1964 the land was turned into a public park. The total area of the park is 2.5 ha. Sampling was conducted in lawns with interspersed trees and covered all better preserved park lawns.

Tyršův sad: A part of the city's old, abandoned cemetery located here was used as an urban park since 1883. In 1902 a municipal botanical garden was founded in this part and in another adjacent part of the former graveyard (in the south-eastern part of the present park). In 1922 the entire area became a public park again. The park was reconstructed in the second half of the 1990s. Those areas that were particularly affected and are now partially paved were excluded from our study. The studied parts consisted of the central lawn with some interspersed trees and of a large area with old trees (domestic and exotic ones, mostly deciduous) in the south-eastern corner, with the ground resembling a forest floor.

Denisovy sady: Situated on a rocky outcrop of south-western exposure with old city fortifications topped by the cathedral, this area became a landscape park in the course of the 19th century (called Františkov or Franzensberg at that time). From 1815 onwards fertile soil was imported and spread on the rocky slopes (ultrabasic igneous rock) and many species of trees were planted with the intent to create a botanical garden. However, most did not survive for long due to the dry, sun-exposed conditions. In 1939–1941 the park was separated by the construction of a street into an upper part and a lower one called **Fons salutis** (Studánka or Pramen zdraví in Czech) after a spring present here. Connected by a walkway, a part of the former monastery gardens, the **Kapucínské zahrady** ('Capuchin Gardens'), on terraces on the eastern, shadier slope below the cathedral, was administratively merged with the Denisovy sady in 1999 (but is separated by brick terraces with stairways). The terraces on which these greens are located were reconstructed in 1995. An extensive reconstruction of the central part of the park above Husova street (Denisovy sady proper) had been completed in 2005. This included terrain remodelling, covering large areas with pavement or gravel, import of new soil and application of pesticides on the replanted slopes. We selected two small areas, each ca. 100 m^2, not affected by this reconstruction: a lawn forming the largest, rather isolated and homogenous part of the Fons salutis section below the very busy Husova street and a square plot of lawn within the Kapucínské zahrady section, situated in a corner made of walls supporting the uppermost slope of the hill with the cathedral on top.

Soil properties: In all parks soil samples to a depth of 10 cm for the analysis of soil properties were taken close to where soil annelids were sampled. The measured parameters and their average values are presented in Tab. 2 (means based on all analysed samples except those taken in compacted foot paths). The soil pH (KCl) was slightly above 7 at all sites. Also carbon and calcium contents were high at all sites, although the differences between parks were considerable. Phosphorus contents were the highest in the small lawn plots at Kapucínské zahrady and Fons salutis (probably due to input of dog excrements), whereas the former cemetaries did not show particularly elevated concentrations.

Sampling and sample processing

Enchytraeids were sampled by a soil corer with a working area of 17 cm^2, allowing for sampling down to 18 cm depth (depending on the soil properties at the time of sampling). Usually samples were taken down to 12 cm. The soil cores were subdivided into 3 cm thick layers which were stored separately. Enchytraeids were extracted from these subsamples over 48 h by the wet funnel method according to Graefe, i.e. without heating (Kobetičová & Schlaghamerský 2003): specimens were collected after the first 24 h (incl. water exchange) and at the end of the extraction. Soil samples prior to extraction and the water-filled Petri dishes with extracted enchytraeids were stored at ca. 8 °C for the shortest time possible before being processed. Enchytraeids were counted and identified alive to species (to genus in case of most juveniles) using a light microscope with Nomarski contrast and magnification up to 400x. Reference specimens of enchytraeid species are kept in ethanol or as whole mounts by the first author.

Destructive sampling would not have been acceptable in the case of parks and therefore earthworms were sampled using the Electro-octet Method (Thielemann 1986). The employed Worm Ex III device had a circular working area of 1250 cm^2 from which the earthworms were collected. Earthworms leaving the soil outside of this circle were also collected but stored separately. The device was operated as long as earthworms were observed leaving the soil but for at least 20 min. The collected earthworms were preserved in 7 % formaldehyde solution and later identified to species. Only specimens from the circular working area were used for computing density and measuring biomass.

The sampling scheme (number and arrangement of sampling units) was designed to cover the major habitat types (lawns and 'woods') typical of each park in question; it focused on the lawns as the most homogeneous and comparable habitat type, present in all parks studied. At each earthworm sampling point, two soil cores for enchytraeid extraction were taken. As several other questions were studied within the project – e.g., effects of soil compaction or contamination – the sampling design was adjusted to serve these purposes as well (see above for references). The total numbers of sampling points per park are given in Tab. 1 (in the case of enchytraeids all soil cores were counted separately). To have representative, comparable data sets, we tried to match the sample size with the area and heterogeneity of the individual parks. In this respect the given numbers can be misleading, having apparently little relation to park size; particularly the Špilberk park might look undersampled. However, in the case of Lužánky and Schreberovy zahrádky 6 and 12 soil cores and 3 and 6 earthworm sampling points, respectively, were situated in compacted soil of unofficial foot paths with low annelid densities. Another 6 soil cores and 4 earthworm sampling points in each of the two parks were located at the foot of grown trees where the soil also supported only minimal densities (Schlaghamerský et al. 2009). At Lužánky and Koliště 24 soil cores and 12 earthworm sampling points per park were taken along transects from an edge of the park to its central part shortly after a drought period; annelid densities were very low in these samples. In contrast, the other parks, sampled mainly or only for faunistic data, were all sampled at dates when conditions for soil annelids (soil moisture and ambient temperatures at the time of sampling and in the preceding weeks) seemed suitable.

Statistical analysis

Mean densities and their standard error of the mean (SE) were computed based on all samples taken in each park or habitat (lawn vs. wood). The only exception were samples taken in footpaths and in points at 1 m distance from linden trees as exceptionally low densities were found in these situations. Two methods were used to analyse and visualise the similarity of the annelid assemblages found in individual parks. Qualitative presence-absence data of species were used for a cluster analysis (BioDiversity Professional 2.0 Program) based on the entire annelid assemblage (Lumbricidae and Enchytraeidae) as well as separately for the two families studied. Quantitative data had to be standardised by samples to reduce the effect of different numbers of individuals collected in the individual parks. Thus the percentage representation (dominance) of species was used. An indirect gradient analysis (ordination) was conducted on these data, separately for the two families (because of the very different densities of macro- and mesofauna). As Detrended Correspondence Analysis confirmed a short main gradient (< 3.0), we based our analysis on a linear model and conducted a Principal Component Analysis (Canoco 4.5).

3. Results

Based on a total of 1724 enchytraeids and 1501 earthworms, 29 enchytraeid and 8 lumbricid species were identified (Tabs 3–4). Annelid species belonging to other families were not found. From 3 to 13 enchytraeid species and from 2 to 6 earthworm species were found per park.

Enchytraeid species number was not lower in medium-sized parks than in the largest parks. Lowest species numbers were found in the two 100 m^2 plots. In earthworms highest species richness was found in the Špilberk park and the lowest in the Kapucínské zahrady plot. In all other parks 4–5 species were found except Koliště with only 3 earthworm species. The highest mean density of enchytraeids, 6103 ± 1157 ind. m^{-2} ($\pm$ SE), was found in the park Schreberovy zahrádky (all samples pooled except those from footpaths and from soil at the foot of linden trees, where much lower densities were found). The lowest enchytraeid density, 2059 ± 331 ind. m^{-2} ($\pm$ SE), was found in the Kapucínské zahrady plot. However, in one of the lawns sampled in the Špilberk park even fewer enchytraeids were found with the same sampling effort (515 ± 353 ind. m$^2 \pm$ SE).

Highest earthworm densities were recorded in the Lužánky park, 295 ± 44 ind. m^{-2} ($\pm$ SE), while low earthworm densities were found in the lawns of the Špilberk park and in the Koliště park, 109 ± 34 and 117 ± 29 ind. m^{-2} ($\pm$ SE), respectively.

Cluster analysis (Fig. 1) shows that the species composition of all annelids was most similar between the woods sampled in the parks Špilberk (both woods pooled) and Tyršův sad, and the species composition of these assemblages was more similar than that of the lawns sampled in the same parks. All annelid assemblages from lawns (with a varying amount of interspersed trees and a varying degree of anthropogenic disturbance by soil compaction or contamination) ended up in a second cluster.

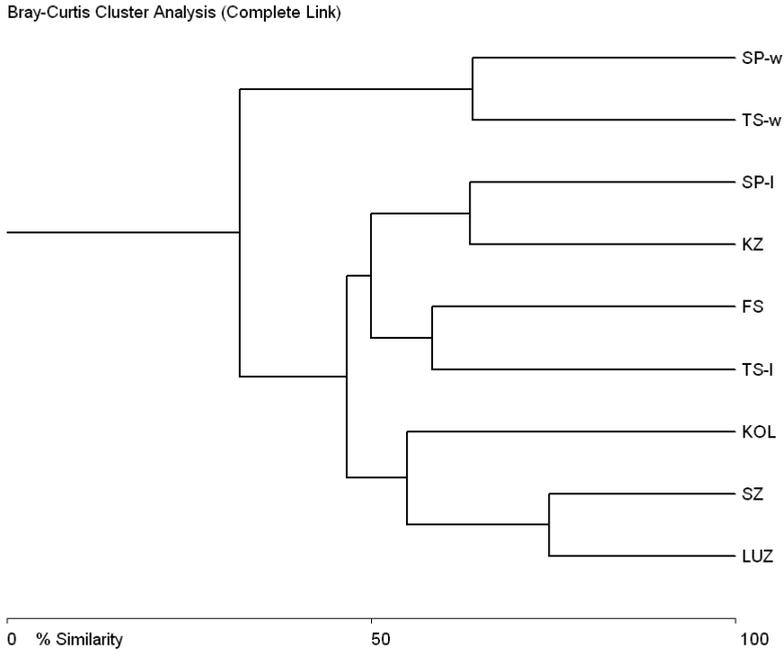Bray-Curtis Cluster Analysis (Complete Link)

Fig. 1   Cluster analysis of annelid assemblages of parks in Brno (separately for lawns and woods when also woods were sampled) based on presence-absence data. For abbreviations of parks (habitats) see Tab. 3.

Within this group, the assemblages from the parks Lužánky and Schreberovy zahrádky were most similar, being further associated with the Koliště assemblage. The assemblage from the Špilberk lawns (pooled) was most similar to that of the species-poor assemblage in the Kapucínské zahrady plot. Looking at the same analysis for enchytraeids alone, the Lužánky and Schreberovy zahrádky assemblages were most similar, again clustering together with the assemblage of the Koliště park (Fig. 2). Enchytraeid species composition also confirmed the similarity between the lawns at Špilberk and Kapucínské zahrady. The Tyršův sad wood assemblage, however, was more similar to two assemblages in lawns of other parks than to that of the Špilberk woods. Looking at earthworms alone, the assemblages of the Tyršův sad lawn and the Koliště lawn were identical and those of the woods in the Špilberg and Tyršův sad parks formed one cluster together with the assemblages of the Špilberk and Schreberovy zahrádky lawns (Fig. 3).

Principal component analysis (PCA) based on percentages of earthworm species showed a close similarity of the habitats (lawn and wood) studied within the Špilberk park (Fig. 4). This was in particular caused by the dominance of *Lumbricus rubellus*, *Octolasion tyrtaeum* and *O. lacteum* at these sites. Another distinct group was formed by the earthworm assemblages in the Koliště and Tyršův sad lawns with a high dominance of *L. terrestris*. In enchytraeids, PCA revealed a high dissimilarity of three assemblages, both between each other and compared to the rest (Fig. 5). These were the assemblages of the Špilberk woods, Špilberk lawns and the Tyršův sad wood.

Tab. 3   Enchytraeid species list with dominance data for the parks (and separately for lawns and woods sampled) studied in Brno. Percentages of individuals (dominance) are based on all specimens identified at least to genus. Per site (habitat) values for identified and not identified specimens, species number, and density with standard error of the mean are given. First species records for Czechia in bold. (LUZ: Lužánky; ŠP: Špilberk; KOL: Koliští; SZ: Schreberovy zahrádky; TS: Tyršův sad; KZ: Kapucínské zahrády; FS: Fons salutis; tot: total; l: lawn; w: wood).

	LUZ-tot	ŠP-l	ŠP-w	ŠP-tot	KOL	SZ	TS-l	TS-w	TS-tot	KZ	FS
Achaeta eiseni Vejdovský, 1877	13		15.5	10.4	3.8	20.6	14.9	29.7	21.4		
Achaeta microcosmi Heck & Römbke, 1991			41.9	28	4.3	10.1		18.9	8.3		
Achaeta hallensis Möller, 1976	0.6	1.6	1.6	1.6	5.3	1.2		5.4	2.4	22.2	
Achaeta pannonica Graefe, 1989	4.8	1.6		0.5	5.8	4.6		2.7	1.2		
Achaeta spp.	1.2		3.1	2.1	1.8					5.6	
Buchholzia appendiculata (Buchholz, 1862)	5.4							24.3	10.7		8.5
Buchholzia fallax Michaelsen, 1887	0.2					0.3					
Buchholzia spp.	4.8					0.3		2.7	1.2		6.4
Enchytraeus buchholzi s. l. Vejdovský, 1879	5.6	12.5	0.8	4.7	9.4	6.1	10.6	5.4	8.3	22.2	27.7
Enchytraeus bulbosus Nielsen & Christensen, 1963					0.5						2.1
Enchytraeus spp.	12	3.1		1	8.6	19	8.5		4.8	11.1	17
Fridericia sp. 1. cf. *agricola* Moore, 1895					0.3						
Fridericia sp. 2. cf. *anomala* Košel, 1975					0.3		17		9.5		
Fridericia bulboides Nielsen & Christensen, 1959						0.3					
Fridericia christeri Rota & Healy, 1999	11	7.8	5.4	2.6	1.8	1.8	4.3	5.4	4.8		14.9
Fridericia conculcata Dózsa-Farkas, 1986	0.4										
Fridericia galba (Hoffmeister, 1843)	0.4		0.8	0.5		0.3					
Fridericia sp. 3. cf. *glandifera* Friend, 1911					0.3						
Fridericia sp. 4. cf. *globuligera* Rota, 1995							2.1		1.2		

Tab. 3   cont.

	LUZ-tot	ŠP-l	ŠP-w	ŠP-tot	KOL	SZ	TS-l	TS-w	TS-tot	KZ	FS
Fridericia hegemon (Vejdovský, 1878)					5.8						
Fridericia isseli Rota, 1994		1.6		0.5						16.7	
Fridericia sp. 5. cf. *lenta* Schmelz, 2003						0.3					
Fridericia maculata Issel, 1905		1.6		0.5							
Fridericia sp. 6. cf. *maculatiformis* Dózsa-Farkas, 1972	0.2										
Fridericia sp. 7. cf. *montafonensis* Schmelz, 1998							6.4		3.6		
Fridericia paroniana Issel, 1904	0.4					0.3					
Fridericia rendsinata Dózsa-Farkas, 1972							4.3		2.4		
Fridericia singula Nielsen & Christensen, 1961	1.6					0.3					
Fridericia sp. 8. cf. *ulrikae* Rota & Healy, 1999						0.9					2.1
Fridericia spp.	38.4	64.1	7.8	26.4	18.8	30.7	31.9	5.4	20.2	22.2	21.3
Henlea ventriculosa (Udekem, 1854)		6.3		2.1	32.7	2.5					
Henlea spp.					1						
Marionina sp. 1						0.6					
Stercutus niveus Michaelsen, 1888			28.7	19.2							
Number of identified specimens	500	64	129	193	394	326	47	37	84	18	47
Number of non-identified specimens	26	21	1	22	90	15	5	2	7	3	0
Number of species	12	7	6	11	12	13	7	7	11	3	5
Density (ind. m^{-2})	4403	4167	5833	5000	5956	6103	3824	2868	4461	2059	3456
Standard error of the mean	851	1671	940	953	991	1157	1356	1093	852	331	1484

Tab. 4 Earthworm species list with dominance data for the parks (and separately for lawns and woods sampled) studied in Brno. Percentages of individuals (dominance) are based on all specimens identified at least to genus. Per site (habitat) values for identified and non-identified specimens, species number, and density with standard error of the mean are given. For abbreviations of parks (habitats) see Tab. 3.

|	LUZ-tot	ŠP-l	ŠP-w	ŠP-tot	KOL	SZ	TS-l	TS-w	TS-tot	KZ	FS
Allolobophora chlorotica (Savigny, 1826)	1.6										1.7
Aporrectodea caliginosa (Savigny, 1826)	44.6	27.6	29.5	28.6	32.9	56.5	36.7	53	42.1	50	60
Aporrectodea rosea (Savigny, 1826)	6.8	9.5		4.5	4.3	17.9	3.8		2.5		5
Dendrobaena octaedra (Savigny, 1826)						0.3					
Lumbricus rubellus Hoffmeister, 1843			3.9	2.1							
Lumbricus terrestris Linnaeus, 1758	45.2	30.2	32.5	31.4	62.8	25	59.5	34.9	51.3	50	33.3
Octolasion lacteum (Oerley, 1881)	1.8	4.3	10.1	7.3		0.3		12.1	4.1		
Octolasion tyrtaeum (Savigny, 1826)		28.4	24	23.1							
Number of identified specimens	487	129	116	245	94	368	131	66	197	50	60
Number of species	5	5	5	6	3	5	3	3	4	2	4
Density (ind. m^{-2})	295.1	109.3	133.3	121.3	117.3	147.1	232	176	204	133.3	160
Standard error of the mean	43.9	35.7	30.2	22.6	29	27.6	66.6	32.3	35.4	5.3	28.1

Bray-Curtis Cluster Analysis (Complete Link)
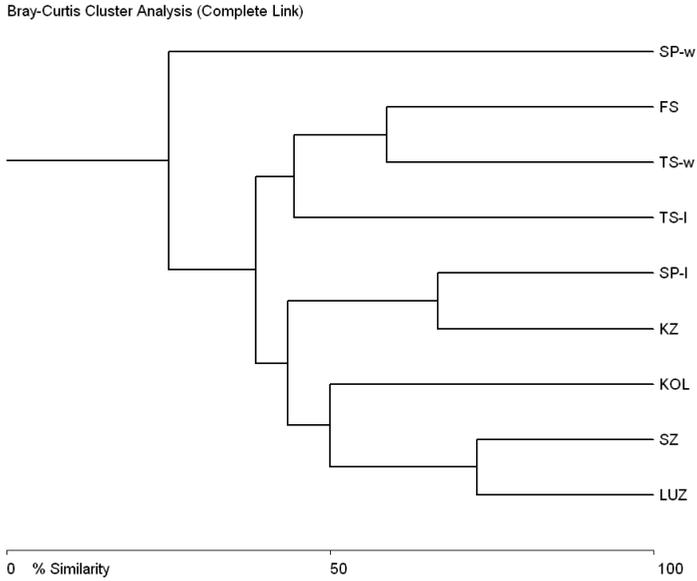
Fig. 2 Cluster analysis of enchytraeid assemblages of parks in Brno (separately for lawns and woods when also woods were sampled) based on presence-absence data. For abbreviations of parks (habitats) see Tab. 3.
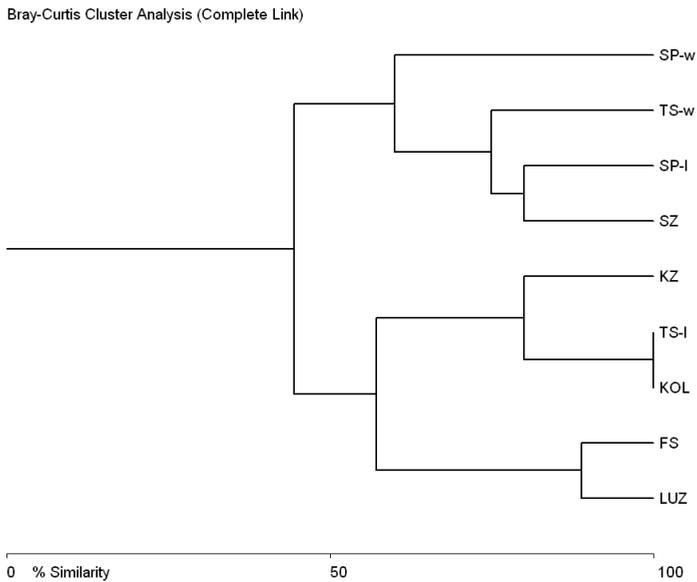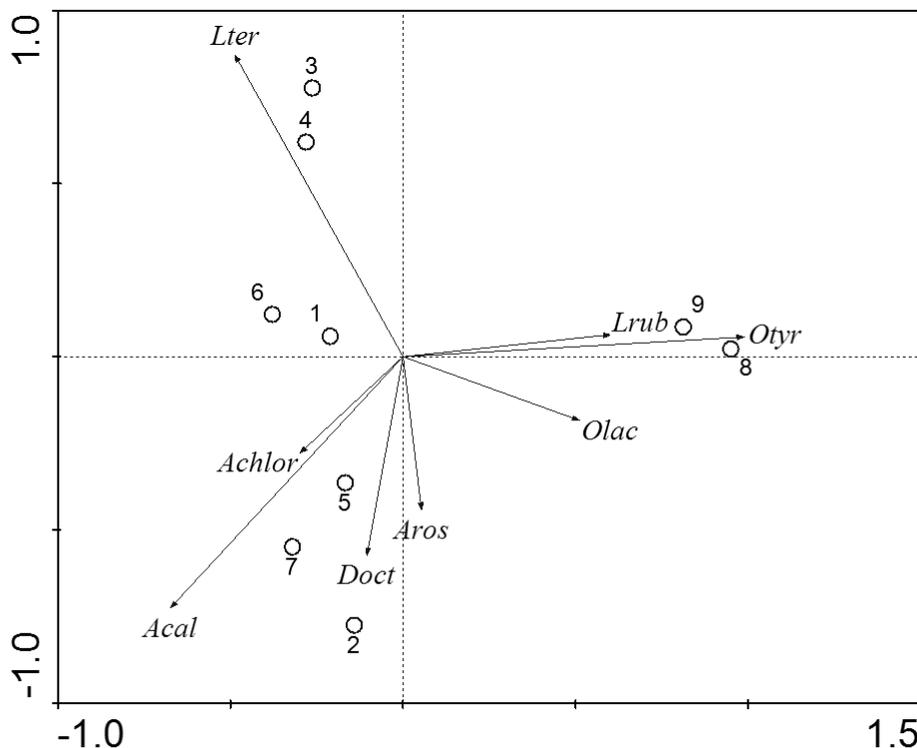
Bray-Curtis Cluster Analysis (Complete Link)

Fig. 3 Cluster analysis of earthworm assemblages of parks in Brno (separately for lawns and woods when also woods were sampled) based on presence-absence data. For abbreviations of parks (habitats) see Tab. 3.

Fig. 4   Principal Correspondence Analysis of earthworm assemblages of parks in Brno (separately
            for lawns and woods when also woods were sampled) based on dominance data.
            Eigenvalues: axis 1 - 0.48, axis 2 - 0.43 (1 = LUZ = Lužánky; 2 = SZ = Schreberovy
            zahrádky; 3 = KOL = Koliště; 4 = TS-l = Tyršův sad, lawn; 5 = TS-w = Tyršův sad, wood;
            6 = KZ = Kapucínské zahrady; 7 = FS = Fons salutis; 8 = SP = Špilberk, lawn; 9 = SP =
            Špilberk, wood.).

   The first was characterised by a high dominance (and abundance) of *Stercutus niveus*,
missing from all other parks or habitats studied. Further well represented species were
Achaeta eiseni and *Achaeta microcosmi*. This was also true for the wood in the Tyršův sad
park, but here the assemblage was further dominated by *Buchholzia appendiculata*. On the
other hand, the assemblage of the lawns in Špilberk park was dominated by *Fridericia*
juveniles that could not be identified to species (included in the analysis but not shown as a
separate item in the chart); one species – *F. maculata* – was found only in one lawn of the
Špilberk park. The assemblages of two other sites ended up close to each other and apart from
the rest (although less so than the above mentioned three): these were the small lawns at Fons
salutis and Kapucínské zahrady, both part of the Denisovy sady park. Their assemblages were
in particular characterised by the highest dominance of *Enchytraeus* spp. (33 % and 47 %,
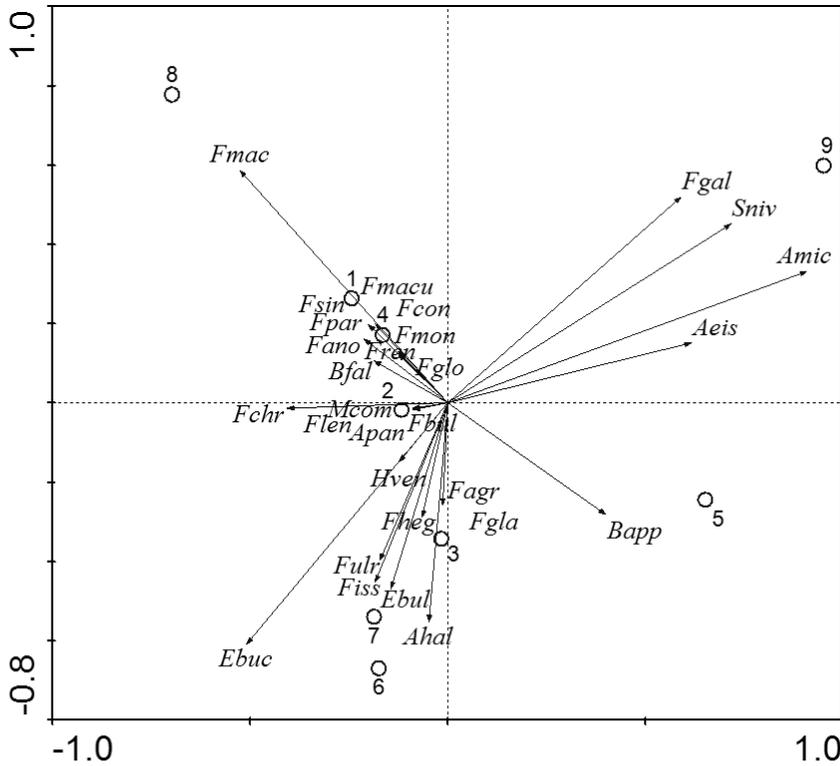respectively) compared to the other sites studied.

Fig. 5   Principal Correspondence Analysis of enchytraeid assemblages of parks in Brno (separately for lawns and woods when also woods were sampled) based on dominance data. Eigenvalues: axis 1 - 0.45, axis 2 - 0.16 For abbreviations of parks (habitats) see Fig. 4.

Taxonomic and faunistic notes:

Three enchytraeid species have been recorded for the first time in Czechia within this research project (Tab. 3). Some enchytraeid species were represented by very few specimens, often not fully mature or injured. Those eight *Fridericia* species that were identified only tentatively, are listed as *Fridericia* sp. 1–8 with their possible ('cf.') identity (or that of the most similar species) added. They were included as distinct species in the analyses.

Achaeta microcosmi: Seventy-eight specimens (17 subadults, 21 adults), 18 preserved. Specimens matched the description of *Achaeta microcosmi* Heck & Römbke, 1991: sperm funnel with asymmetrically extended collar, 5–6 x as long as wide, 1.5 x as long as body diameter, large seminal vesicle present (see Heck & Römbke 1991). In *A. vesiculata*, a similar species, the sperm funnel is only 3x as long as wide and shows no asymmetry; the seminal vesicle is small. This is the first report of *A. microcosmi* from Czechia. To our knowledge, this species has been reported only once before (from Bangor in Wales, U.K.) since its description from Frankfurt/Main in Germany (Moser & Römbke 2007).

***Achaeta hallensis*:** Sixty-six specimens (24 subadults, 30 adults), 6 preserved. First record from Czechia (already published without locality or taxonomic details in Pižl & Schlaghamerský 2007), second record after the original description. Möller (1974, 1976) reported the species from three field sites with Chernozem on loess near Halle (Germany) This species belongs to a group of *Achaeta* species of small body size lacking pyriform glands (formerly incorrectly 'setal follicles'). Graefe (1980, 1989, 2007) published several taxonomic papers on species from this group but when comparing them with related species he mentioned *A. hallensis* only once (Graefe 1980). In his description Möller (1974) wrote that cutaneous glands were distinct only dorsally, with two large, elongate glands being arranged in a row and filled with greenish irridescent granules. Comparing all known *Achaeta* species without pyriform glands, Christensen & Dózsa-Farkas (2007) assumed that these two conspicuous cutaneous glands were identical with the epidermal lense-shaped cells known from several other species, being present in one pair per segment, that is in a transverse row. This was the pattern found in the specimens found in Brno, although these dorsal lense-shaped cells were not always clearly visible. However, in some specimens, otherwise resembling *A. hallensis*, a few additional lense-shaped gland cells arranged laterally or ventrally in the first segments were observed (e.g. in one specimen one such cell was located laterally in segment II and further ones – probably pairwise – ventrally in III–V and VII; in another specimen a single one was present unilaterally on the ventral side of IV). Further characters given in the description of *A. hallensis* were in very good agreement with the Brno specimens. Only the seminal duct was often coiled in a dense spiral, which disagrees with Möller's statement ('Seminal ducts narrow, occasionally irregularly wound in a spiral.'– translated from German). The dorsal vessel pulsated in VII and VI, but in some specimens it seemed to start inconspicuously already in VIII. Adult or subadult specimens were 2–4 mm long (live) with 20–27 segments; this range overlaps with Möller's data but indicates that our material included somewhat bigger specimens. Some characters not mentioned by Möller (1974) but important for discrimination from some similar congeners, are the lateral openings of the spermathecae, the number of secondary pharyngeal glands, being 2 pairs in V and VI, and the number and position of preclitellar nephridia, being 2 pairs at VII/VIII and VIII/IX (single cases with 1 pair in VII/VIII or 1 pair in VII/VIII and a unilateral nephridium in VIII/IX were observed; 3 pairs from VII/VIII–IX/X in a single case). Body diameter of adult specimens in front of the clitellum 150–170 μm; sperm funnel ca. 100 μm long, 30 μm wide (ca. 0.6 x body width), sperm heads 35 μm long; clitellum open dorsally (narrow gap) and ventrally (gland cells ceasing on level with male copulatory organs).

***Achaeta pannonica*:** Fifty-three specimens (19 subadults, 20 adults), 7 preserved. Adult specimens 3–4 mm long (single one 2.2 mm only), with 25–39 segments (mostly 25–30, 2 specimens with 31, 1 with 34 and 39 segments, respectively). Graefe (1989) gave a range of 3–3.5 mm and 25–29 segments only. Also in contrast to the species description with only 2 pairs of preclitellar nephridia (VI/VII, VII/VIII) in 5 of the specimens. Often with inorganic concretion in the widened oesophagus in segment V (not mentioned in the species description). Other characters in good agreement with species description. Within Czechia also recorded in a floodplain forest ca. 50 km south of Brno (Schlaghamerský 2007). Described from a dry grassland in eastern Austria but also reported from alluvial soils on the Danube (Austria) and several localities in northern and western Germany (Graefe 1989), including urban and alluvial soils (Beylich & Graefe 2007). Most reported localities had fine-textured soils of low pH, being either alluvial deposits or derived from loess. The description

given by Möller (1971) for *A. camerani* (Cognetti, 1899) from an alluvial meadow and a pasture (untypical habitats for *A. camerani*) near Potsdam in eastern Germany shows that the found specimens were in fact *A. pannonica* (yet not known to science). Besides the epidermal (lense-shaped) gland pattern, these specimens also had an oesophagus widened in V (without appendices) with a calcareous concretion as found in the Brno specimens. From the close-by forest and grassland sites in then West Berlin, Heck et al. (1999) reported *A. pannonica* as the most abundant enchytraeid of open spaces, whereas *A. camerani* was only found in forests.

Fridericia conculcata: Two subadult specimens (one 42 segments, 8 mm long, the other 37 segments, 10 mm long), not preserved. Spermatheca with two stalked diverticula and long ectal duct, chaetal formula (2, 4, 3, 1, 0 – 0, 1 : 2, 3, 4, 0 (X–XI) – 1), oesophageal appendages short, unbranched, additional pharyngeal gland lobes in VII, coleomo-mucocytes with very few small refractile vesicles scattered in the pale matrix (according to description without vesicles), few medium-sized coelomo-lenticytes, subneural glands in XIII and XIV (in the first specimen possibly also in XV), 4 preclitellar pairs of nephridia, chylus in XIV(-XV) or XIII-XIV, origin of dorsal vessel at XVI/XVII or XVII/XVIII, massive sperm funnel (length ca. 1.5 x body diameter, length : width ≈ 4–5 : 1). Chaetae entirely missing dorsally in X–XV (and in some positions anteriad) or XII-XVII, in the first specimen also ventrally in XVI, XIX, and from XXI posteriad. The stalked spermathecal diverticula bent entad towards the tapering ampulla. Only in the first specimen some indication of a widened part of the spermathecal ectal duct at its orifice, possibly a small ectal gland. Seminal vesicles not seen. Despite this and some further slight differences from the species description given by Schmelz (2003) the identification of specimens is most probably accurate. A new species for the fauna of the Czech Republic.

Fridericia singula: Ten specimens (9 subadults, 1 adult), not preserved. Body thin, length 6.5 (adult!)–8.5 mm, 29–35 segments (adult: 33). Spermathecal ampullae proximally fused, with one broadly stalked, globular diverticulum each, ectal duct without gland; chaetal formula 1, 2, 3, 4 – 2 (3, 4) : 2, 3, 4 – (4, 3), 2, (1); 3 specimens with greyish seminal vesicle taking two segments; sperm funnel variable (not always fully developed?) – length ca ⅓ body diameter, length : width ≈ 2 : 1, in some (most mature?) specimens longer, more massive; 4 preclitellar pairs of nephridia (5 in one specimen); chylus in XI-XII or XII-XIII; origin of dorsal vessel at XVII (XIII or XIV in subadults); coelomo-mucocytes pale, without refractile vesicles, lenticytes small. Oesophageal appendages short, with wide lumen, in two specimens with two terminal branches (not branched according to Schmelz 2003). See also *F.* sp. 2, cf. *anomala*.

Fridericia sp. 1, cf. *agricola*: One subadult specimen, not preserved. Injured in XV/XVI, rear part partially torn off and decaying; total body length 7 mm, number of segments ca. 22 (short body probably the consequence of an earlier regeneration of the rear part). The anterior part full of coelomocytes complicating the observation of internal characters. Listed as close to *F. agricola* based on the following characters: chaetal formula 4 – 4, 2 : 4, (5) – 4; orifice of spermathecal ectal duct without gland; spermathecal ampullae with 2–4 (or even more?) sessile diverticula (one ampulla probably with only 2, the other with at least 4); coelomo-mucocytes about 30 μm long, coelomo-lenticytes minute, both numerous; 5 preclitellar pairs of nephridia (VI/VII-X/XI); large seminal vesicle in X–XI; body width ca. 325 μm; oesophageal appendages short (not well visible – with some terminal branches?); no subneural glands. This character combination led to *F. agricola* in the key by Schmelz (2003).

Small, short sperm funnel also in agreement with the description presented by Schmelz (2003). This species was described from lawns and meadows in Pennsylvania, U.S.A. Due to the frequent introduction of European soil-dwelling annelids into North America this does not exclude the possibility that this species occurs in Europe as well. Distinct from the other species identified in the present study, although its true identity remains unresolved.

Fridericia **sp. 2, cf. *anomala*:** Nine specimens (6 subadults, 3 adults), 4 preserved. Adults 9–12 mm long, thin, with 45–50 segments. Spermathecal ampullae proximally fused, with one sessile diverticulum each, ectal duct with small, sessile ectal gland; chaetal formula 2 – 2 : 2 – 2, in one specimen 3, 4, 2 (in XII!) – 3, 4, 2 : 4, (5) – 4, 3, 2; 2 specimens with greyish seminal vesicle in X-XI; sperm funnel short, length ca. Ľ body diameter, length : width » 2 : 1; 5 preclitellar pairs of nephridia; chylus in two segments between XIII-XV (between XI–XIII in subadults); origin of dorsal vessel at XVII (more anterior in subadults); coelomo-mucocytes with refractile vesicles, brownish, numerous, -lenticytes tiny, scarce. These specimens had characters of *F. anomala* as well as of *F. singula*. We recorded the latter in some other parks. We believe the two are not identical, in particular because of the presence of ectal glands and the differing shape of the spermathecae (resembling *F. anomala* in the present case). Our species might be identical with *F. singula* sensu Chalupský (see Schmelz 2003) as indicated by the (partially brownish) coelomo-mucocytes with refractile granules. Characters as chaetal formula, seminal vesicle and sperm funnel were variable and ambiguous (as in Chalupský's material). The description of *F. anomala* is poor, e.g. not giving the number of preclitellar nephridia (in our specimens 5 pairs, in *F. singula* 4) and the position of chylus cells.

Fridericia **sp. 3, cf. *glandifera*:** One subadult specimen (41 segments, 9 mm), not preserved. Spermatheca with ca. 4 (hemi-)spherical diverticula, one small ectal gland at orifice of ectal duct of medium length (there should be two large ectal glands in *F. glandifera*); chaetal formula 2, 3, 4 – 3, 2 : 4 – 4, (3), 2 (from XVIII); oesophageal appendages short, unbranched; subneural glands visible in XIV and XV, both with small area glareosa, tiny area glareosa also in XIII; coelomo-mucocytes pale, without distinct texture, -lenticytes numerous, small; large seminal vesicle in IX–XI. Sperm funnel somewhat larger than described (Schmelz 2003), approximately as long as body diameter, length : width ≈ 3 : 1, the collar hardly narrower than the funnel diameter, sperm heads intensely red-brown. The chylus in ½ XII-XIII and the origin of the dorsal vessel in XV had a somewhat more anterior position. So far, *F. glandifera* has not been recorded in Czechia.

Fridericia **sp. 4, cf. *globuligera*:** One adult specimen (44 segments, 7 mm long, 1 yolky egg in XII-XIII), not preserved. Spermatheca with two sessile diverticula and ectal duct of medium length with two large, stalked ectal glands and small area glareosa at orifice, chaetal formula 2, 3, 4 – 4, 3, 2 : (3), 4 – 4, 3, 2 (2 from XXIII posteriad), oesophageal appendages with one main branch and few thinner ones branching off proximally, chylus in (XIV-)XV, origin of dorsal vesel in XVII, numerous pale coelomo-mucocytes (no refractile vesicles) and -lenticytes, small, globular male copular organs, bursal slits with distinct transverse component, 5 preclitellar pairs of nephridia. In contrast to *F. globuligera* the sperm funnels were large (length ⅔ -¾ of body diameter, length : width ≈1.5 : 1, collar about ½ of maximum width) and a large seminal vesicle of pale grey colour was situated in all of X-XI.

***Fridericia* sp. 5, cf. *lenta*:** One subadult specimen, not preserved. Rear part regenerated, thus of small size (5 mm, 21 segments). Spermatheca with two elongate diverticula (containing no sperm, directed ectad) and long ectal duct with small sessile gland (? – hardly visible), 2 chaetae in all bundles, no subneural glands, coelomo-mucocytes small, without refractile vesicles, clitellum ventrally absent (but not yet fully developed), no conspicuous epidermal gland cells, short oesophageal appendages (proximal part with large lumen, wider than distal part). In contrast to *F. lenta* only four preclitellar nephridia in VII/VIII–X/XI were observed, the sperm funnel was only about ½ of the body diameter long and elongate (length : width ≈ 3 : 1), with a distinct somewhat narrower collar; no seminal vesicle was observed. However, no better match of characters than *F. lenta* was found. Within Czechia, *F. lenta* was reported from two grasslands in the White Carpathians, ca. 90 km to the south-east of Brno (Schlaghamerský & Kobetičová 2005, Schlaghamerský et al. 2007).

***Fridericia* sp. 6, cf. *maculatiformis*:** One adult specimen (small yolky egg), not preserved. Identified based on shape of the spermathecal ampulla and diverticula, chaetal formula (2 – 2 : 2 – 2), large pale coelomo-mucocytes withour refractile vesicles and very large and numerous coelomo-lenticytes, four preclitellar pairs of nephridia (VI/VII-IX/X), short unbranched oesophageal appendages, and the presence of subneural glands in XIII and XIV. However, smaller (25 segments, 5 mm) than given for this species, with small and sessile ectal gland of the spermathecal ectal duct, and with subneural gland in XIV larger than that in XIII. Seminal vesicle in XI, clitellum not well developed, sperm funnels hardly visible (length ca. ½ body width), male copulatory organs large, oval, the bursal slit with a short transverse component. Chylus probably present in XII, not very distinct. Thus several characters did not match *F. maculatiformis* but no other species was more similar to it.

***Fridericia* sp. 7, cf. *montafonensis*:** Three specimens (3 subadults), not preserved. Two specimens 10 mm long, with 47 and 45 segments, respectively; third specimen injured, incomplete. Chaetal formula (2), 3, 4 – 4, 3, 2 : 3, 4 – 4, 3, 2. Spermathecal ampulla with two diverticula, ental ducts proximally joined, ectal duct short with one large, stalked ectal gland; in agreement with *F. montafonensis*, but sperm only observed in the diverticula. Other characters not in full agreement with *F. montafonensis*: one large subneural gland in XV (in lateral view) observed in one specimen only (here clitellum not fully developed), in the other intact specimen no subneural glands were found, although the clitellum was developed (gland cells missing only between the male copulatory organs). Sperm funnel length ca. ¾ of body diameter, length : width ≈ 1.5 – 2 : 1 (somewhat larger size due to lateral depression during examination?); bursal slits with long transverse component; oesophageal appendages with a main trunk and several thinner branches distally, reaching VII; oval, pale coelomo-mucocytes (not lemon-shaped); five preclitellar pairs of nephridia; chylus (?) in XIV-XV; dorsal vessel originating in XVI; no distinct seminal vesicle. *F. montafonensis* has – to our knowledge – not been recorded since its description from a site in western Austria (Schmelz 1998).

***Fridericia* sp. 8, cf. *ulrikae*:** Four specimens (1 adult, 3 subadult), not preserved. All small for the species: the adult specimen with 47 segments (last four regenerated), 12 mm long (clitellum well developed, small yolky egg in XII), of the subadults (clitellum not well developed, no egg) two with 50 segments and ca. 10 mm long, one with 41 segments and 9 mm long. Identification as *F. ulrikae* was supported by the combination of the shape of spermatheca with 2 stalked diverticula and communicating separately with the oesophagus, chaetal formula (2, 3, 4 – 4, 3, 2 : 2, 3, 4, (5) – 4, 3, 2), short unbranched oesophageal appendages, numerous pale coelomo-mucocytes (and small –lenticytes), lack of subneural

glands or additional pharyngeal gland lobes, shape of sperm funnel (length ½ body width, length : width ≈ 2 : 1, collar narrower than maximum width), and four preclitellar pairs of nephridia (VI/VII–IX/X). The fully mature specimen had an elevated clitellum with hyaline and granulate gland cells arranged in an irregular, reticulate pattern, only missing between the male copulatory organs (however, the clitellum should be saddle-shaped in *F. ulrikae*). This specimen seemed to have (as *F. ulrikae*) a minute, sessile ectal gland (missing in the others) at the spermathecal ectal duct orifice. Chylus situated in XIV–XV (XIII–XIV in some subadults), dorsal vessel originating in XIX (XVII or XVIII in some subadults), both slightly more posteriad than described. Spermathecal diverticula not strongly bent ectad but only slightly so, or directed perpendicular to the ampulla, or even entad. Hitherto *F. ulrikae* has not been reported from Czechia.

Marionina **sp. 1:** One adult specimen (with small yolky egg in XII), not preserved. Length ca. 1.8 mm (live); 19 segments; chaetal formula: 2, 1 (VIII-XI) – 2 : (2), 3, 2 (IX-XI) – 2; in case of three chaetae per bundle, the inner two of equal length, the outer one slightly longer; three pairs of pharyngeal glands – first two dorsally connected, 3rd not connected, elongate; globular oesophageal diverticula in IV; spermathecae dorsally connected (?), communicating with oesophagus at its midline, ectal duct ca. three times as long as ampulla, without well visible ectal gland or glands along the ectal duct (somewhat rugged), ampulla globular but somewhat wider than long, with sperm in a central chamber; sperm funnel length about ½ of body diameter, legth : width ≈ 3 : 1; no seminal vesicle; coelomocytes oval, pale. Shape of brain and characters of nephridia not recorded. Originally the specimen was recorded as *M.* cf. *communis* Nielsen & Christensen, 1959 and as such published (Pižl & Schlaghamerský 2007) but several characters (in particular the body size and presence of oesophageal diverticula) seem in clear contradiction. Another candidate would be *M. hoffbaueri* Möller, 1971, but the presence of chaetal bundles dorsally in VII–XI, the absence of a seminal vesicle and the more elongate shape of the sperm funnel do not match its description.

*Stercutus niveus***:** Thirty-seven juvenile specimens, 15 preserved. Before this study three localities of this species had been published from the Czech Republic – a beech forest in the White Carpathians in south-eastern Moravia, a floodplain forest in southern Moravia (Schlaghamerský 2007) and an acidic and very dry, mixed forest on the western margin of Brno (Šídová & Schlaghamerský 2007).

4. Discussion

Earthworms: All earthworms found in Brno parks can be characterised as eurytopic. They occur in most of the European cities where earthworm fauna has been studied. Even in cities with a much more diverse earthworm fauna, they usually belong to the core and/or frequent species. The difference in species richness is therefore due to rare species occurring mainly in wooded parts of parks as well as due to differences in the number of parks studied, and the climatic conditions and soil characteristics in the respective cities. Surprisingly, representatives of epigeic earthworms were almost absent in the parks of Brno, most probably due to the way lawns and woods are managed.

A detailed review of data on earthworms in urban greens has been published by Pižl (1999a). The total number of earthworm species recorded in the Brno parks under study was lower than that found in Bonn-Bad Godesberg (Schulte et al. 1989), Warsaw (Pilipiuk 1981, Kasprzak 1987, Pižl & Sterzynska 1991) or Brussels (Pižl 1999a), where 14, 15 and 21

species and subspecies of earthworms were found, respectively. However, similar or lower numbers of species were recorded for instance from Moscow (USA) and Accra (Ghana) (Smetak et al. 2007, Mainoo et al. 2008). As far as the per site species richness is concerned, the earthworm assemblages of urban parks of Brno are not much different from those of other European cities, e.g. 5–8 species were observed in lawns in Bonn-Bad Godesberg and 2–10 species were observed in both lawns and woods in Brussels (Schulte et al. 1989, Pižl 1999a). The same is true for earthworm density, which varied largely in all cities studied (e.g. Pilipiuk 1981, Kasprzak 1987, Schulte et al. 1989, Pižl & Sterzynska 1991, Pižl 1999a). The higher earthworm density found in the lawn, compared to the wood of the park Tyršův sad, corresponds well with literature data. For example, Keplin (1995) found that densities varied from 57 to 224 ind. m^{-2} and were higher in grasslands than in tree or shrub groves in Dorsten (Germany), and Pižl (1999a) found higher densities under lawns than under woods in 15 of 17 parks in Brussels, in which both habitats were studied. However, earthworm density was slightly higher in wood plots than in lawns of the Špilberk park.

Enchytraeids: Before discussing enchytraeids we review previous studies in European urban greens.

Schulte et al. (1989) studied various types of truly urban habitats from very small areas of more or less vegetated soil, isolated by sealed surfaces, up to large areas of park lawns and abandoned land with ruderal vegetation. In total 14 earthworm species and 25 enchytraeid species were identified. According to the authors the true species richness of enchytraeids was 10–15 species higher but these species could not be identified with the level of taxonomic knowledge at that time (before a critical revision of the genus *Fridericia*). Of the numerous sites investigated, four park sites – three lawns and one marginal park area covered by shrubs – seem of particular interest for comparison with our results. The 'bedrock' was also similar, being partially alluvial clay and partially loess. The lawns were 1.7–22.5 ha in area, not older than 5 years, with a soil pH (CaCl$_2$) of 5.6–7.2. They hosted 7–9 earthworm species and 6–12 enchytraeid species per site (in total 10 and 20, respectively), reaching densities of ca. 250 ind. m^{-2} and 20 000 ind. m^{-2}, respectively. The marginal park area with shrubs had 200 m^2 and was not older than 10 years; soil (pH 6.7) was covered by about 10 cm of decomposing plant matter topped by up to 15 cm of wood chips. Here only 5 earthworm and 5 enchytraeid species were found, but whereas earthworm densities were somewhat lower than in the lawns, enchytraeid densities were about threefold, two thirds of the worms being concentrated in the upper organic layer. The richest enchytraeid assemblage was found in the largest lawn, which was temporarily waterlogged in some parts. *Marionina communis* (missing at the other sites), *Enchytraeus* spp. (in particular *E. minutus* and to a lesser extent *E. bulbosus*) and *Buchholzia appendiculata* were dominant. In the other lawns *Achaeta unibulba*, *Henlea perpusilla* and *Fridericia ratzeli* reached highest dominance. In the shrub belt the two above-mentioned *Enchytraeu*s species, *Fridericia bisetosa* and *F. galba* had a similar representation, while the fifth species, *H. perpusilla* was much less abundant. The genus *Fridericia* was present with 8 species at least and had a substantial quantitative share at all sites. *A. pannonica* was present in one lawn, not more than two *Achaeta* species were found per site.

Heck et al. (1999) reported data on forests, grasslands and some further urban habitats within the boundaries of then West Berlin. Some 12 of the 28 sites investigated seem of interest in the context of the present study. These include 7 park lawns with or without interspersed trees, 2 dry grasslands on soil partially formed on rubble, and 3 central

reservations between motorway lanes, covered by dry grassland with deciduous trees. In these sites the total number of enchytraeid species was 40 (including some preliminary identifications), ranging from 5 to 22 per site. The poorest site was a dry grassland on rubble (pH 7.1 – measured in H_2O?) and the richest a park lawn with interspersed oaks (pH 5.9). The site of highest species richness was also the site with highest enchytraeid density (ca. 26 000 ind. m^{-2}) and the site of lowest species richness had also the lowest density (ca. 3000 ind. m^{-2}). At nine of the compared sites the species number ranged between 11 and 18 species. However, Heck et al. (1999) pointed out that almost all of the study sites, including all non-forest sites, were probably undersampled. Remarkable was the high dominance of *A. pannonica* at many sites, reaching 60 % at one site and about 30 % at two sites. The highest number of *Achaeta* species at a single site was 4 and was only found at the above-mentioned species-richest site. At the two sites with lowest species richness this genus was absent and at most sites represented by only 1–2 species. The genus *Fridericia* reached often a very high representation (up to almost 90 %), being represented by a high number of species. The species-poorest assemblage was totally dominated by *F. bulboides* (84 %). One park lawn (pH 6.0) assemblage was very distinct by the high dominance of *C. glandulosa* (62 %).

Möller (1971) reported an assemblage of 27 enchytraeid species from a single lawn in the Marlygarten of the Sanssouci castle park at Potsdam. This seems an extraordinarily rich assemblage. Möller's study had a taxonomic focus and was based on a very high number of investigated specimens. Unfortunately published data do not allow a quantification of individual species. The soil was clayey sand of a pH of 5.7 (H_2O?) and a humus (org. C?) content of 3.2 %. The Marlygarten is a very old park created as a landscape garden in 1846/47 in place of a former kitchen garden. It is connected to further parts of the Sanssouci park, which has been in contact with agricultural landscape for a long time.

Graefe at al. (2003) found 24 enchytraeid species (1992 – 21 species, 2002 – 22 species), 5 lumbricid species and the 'polychaete' *Hrabeiella periglandulata* Pižl & Chalupský (1984) in a single lawn in the Amsinckpark in Hamburg. The mean pH ($CaCl_2$) of the upper 16 cm was about 4.2, the content of organic carbon about 2 %, phosphorus content ca. 794 mg kg^{-1}, calcium content ca. 1030 mg kg^{-1}, potassium content ca. 997 mg kg^{-1}, and sodium content ca. 211 mg kg^{-1} (Gröngröft et al. 2003). The soil was thus more acidic and of a lower calcium content than in the Brno parks (whereas P, K and N contents were much higher in Hamburg). High enchytraeid densities of ca. 25 000 and 75 000 ind. m^{-2} were found in 1992 and 2002, respectively. The species composition corresponded to the rather low pH, although the species number was remarkably high. Remarkable is the number of 6 *Achaeta* species reported (including some not yet described). Almost 2000 enchytraeids were identified to species by a very experienced specialist – we can therefore assume that the inventory has been exhaustive. The dominances of individual species differed substantially between the two samplings (being 10 years apart), but in general *Enchytronia parva* Nielsen & Christensen, 1959, *E. minor* Möller, 1971 and *Achaeta affinoides* (nomen nudum) were most dominant.

Kasprzak (1981, 1986) investigated 21 different plots in Warsaw (suburban ones not counted here). Of those, 9 plots were located in four parks, whereas the others were green areas at housing estates and along streets – the latter were called 'lawns in the centre of the town'(Kasprzak 1981) or 'streetside green areas'(Kasprzak 1986). Enchytraeid densities ranged from 3000 to 18 000 ind. m^{-2} in the park plots, with a maximum of 24 600 ind. m^{-2} in one streetside lawn. Altogether 22 enchytraeid species were found, of those 19 in parks, 12

in greens belonging to housing estates and 10 in streetside lawns. Individual parks hosted 7–14 species, individual plots sampled within these parks 5–12 species. Species numbers in housing estate greens were 3–8 and in streetside greens 2–7. Generally the genus *Fridericia*, represented by 11 species, had a very high dominance, reaching 48–92 % of individuals in the park plots. The genus *Achaeta* was represented by 4 species. This included *A. eiseni* and *A. bulbosa*, although both may be synonymous (U. Graefe, pers. comm.). *A. camerani* was reported from a single housing estate green and one might assume that this was in fact a related species, probably *A. pannonica*. Total densities reached by representatives of the genus *Achaeta* were very variable, ranging from 0 % to 15 % in individual park plots and up to 41 % in one streetside lawn (whereas this genus was not found at all in some of the other streetside lawns). The densities of *Enchytraeus* spp. in the parks were surprisingly low, not exceeding 3 %. In contrast, up to 82 % were found in one housing estate green and up to 16 % in two streetside lawns (whereas some other plots falling under these two categories had very low *Enchytraeus* densities). Higher densities were, in general, reached by representatives of the genus *Henlea*: up to 30 % in the park plots, up to 56 % in streetside greens and up to 68 % in housing estate greens.

In light of the information given above the total number of 29 enchytraeid species recorded in parks within the city of Brno seems not very high, compared with numbers of 24 and 27 species reported from single lawns in Hamburg (Graefe et al. 2003) and Potsdam (Möller 1971), respectively. It is also lower than found in the extensive study conducted in Berlin (Heck et al. 1999). However, it is higher than the 22 species reported by Kasprzak (1981, 1986) from a much higher number of greens in Warsaw and species numbers per park correspond as well. It is also similar to the number of enchytraeid species found in all types of greens investigated in Bonn-Bad Godesberg, exceeding the number found in the four park habitats alone. One has also to consider that all sites of the present study are located within the central part of the city and have been isolated from more natural habitats for a long time. Thus they were probably also exposed to higher disturbance levels, for instance by soil contamination or structural changes.

This makes them probably more similar to the localities studied in Warsaw (where we could further expect – similarly to Berlin – the effect of a high level of site disturbance in the past due to the vast destruction at the end of World War II). Comparing with data from Berlin, one has to bear in mind that this city has large and often interconnected areas of greens and many of the sites reported by Heck et al. (1999) were thus much less isolated than our parks in Brno. The Sanssouci park in Potsdam lies very close to some of these sites. It is of a similar age as the Lužánky park in Brno but less isolated. In the case of the Amsinckpark in Hamburg, the length of isolation was much shorter and its degree smaller than for most Brno parks under study. This landscape park was only created about 1880 at the outskirts of Lokstedt, a small town that became a quarter of Hamburg in 1938.

Mean enchytraeid densities were substantially lower in Brno than in the other cities except Warsaw, where enchytraeids reached similar or only slightly higher densities in many sampled plots.

One reason might be the more continental climate of Brno and Warsaw, with more pronounced dry spells reducing the populations. As a consequence of low densities in Brno the chance to miss some of the rarer species was higher. One way to compensate for low densities would have been to increase sampling intensity. Besides the growing costs of such

an undertaking, we were also limited by the fact that the sampled habitats were public parks and the number of extracted soil cores had to be kept in a reasonable proportion to the sampled area so as not to damage the overall appearance of the lawns (this applied in particular to the smaller lawns sampled). What has been said about species richness of the entire set of studied parks in Brno applies to individual parks accordingly: the highest species numbers of 13 in Schreberovy zahrádky and 12 in Lužánky seem low, in particular for soils with a pH about 7 and such a large park as Lužánky. The number for Schreberovy zahrádky can be considered realistic as we sampled all better preserved lawns and as other habitats cover only a small part of the park. The lower species richness in comparison to the above-mentioned published data might also be the consequence of high disturbance levels in the park (at present particularly soil compaction by treading). The Lužánky park was most probably undersampled, at least as far as areas with a denser woody vegetation were concerned. For the Špilberk park almost the same number of species (11) was ascertained based on lower sampling effort. As the sampling was mainly aimed at collecting faunistic data, it was conducted at a time when environmental conditions were considered optimal. Nevertheless one of the two lawns sampled was found to be almost lacking enchytraeids. The high species number found in Špilberk park was the consequence of sampling two distinct types of habitats – lawns and larger wooded areas. We found the highest earthworm species richness in Špilberk park and one can assume that it also hosts more enchytraeid species than actually found.

According to Schulte et al. (1989) the effect of area on species richness for the total (invertebrate) fauna is demonstrated at areas below 300–900 m^2 and for macrosaprophages (as earthworms) below 10–200 m^2. One could therefore assume that for saprophagous mesofauna, such as enchytraeids, this effect becomes important closer to the lower end of the range given for earthworms. The fact that we found similar species numbers in the largest and the much smaller 'medium-sized' parks would thus not be surprising.

Enchytraeid sampling in the park Tyršův sad had a very similar design as in Špilberk park, but exactly half the number of soil cores extracted in Špilberk park in both habitats were taken in the respective habitats within Tyršův sad. Nevertheless, the number of enchytraeid species found in both parks of very different size was exactly the same. It seems that a park of the size of Tyršův sad is large enough to host an enchytraeid assemblage not impoverished by effects of a habitat limited in area. Earthworm species richness of the two parks indicate that the park's area might already be a limiting factor to these larger annelids, although its 1.7 ha are still almost twice the limiting area given by Schulte et al. (1989).

Looking at the species composition of enchytraeid assemblages in Brno parks, one remarkable fact is the presence of up to four *Achaeta* species in several parks and here even within small sampling plots (one lawn in Koliště park and small 'woods' in the parks Špilberk and Tyršův sad). Such a high number of *Achaeta* species is unusual and of the compared greens only the Amsinckpark exceeded this number. Remarkable was also the high dominance reached by *A. microcosmi* and *A. eiseni* in the wooded areas. *A. pannonica*, however, did not reach such a high dominance as in some lawns in Berlin. Neither did the similar *A. hallensis*, which was found for the first time outside of arable soils near the German city of Halle. High species numbers and percentage representation of the genus *Fridericia* are in line with data from urban parks and grasslands elsewhere, particularly in soils with a pH approaching 7. Some of the species found in other studies of parks, for instance of the genera *Enchytronia*

and *Cognettia*, prefer soils of lower pH and their absence in our parks is therefore not surprising. Higher percentages of representatives of the genera *Enchytraeus* and *Buchholzia* indicate high disturbance levels of sites (Schulte et al. 1989). Not surprisingly, such a situation was found in the small Fons salutis park. In the other 100 m² plot – Kapucínské zahrady – no *Buchholzia* was found but *Enchytraeus* spp. made up for 33 % of the individuals and 22 % were reached by *A. hallensis*. As the lowest enchytraeid density was encountered here and the dominance values are based on 18 identified specimens only, their value for interpretation is very limited. A high proportion of *Buchholzia appendiculata* was also found in the Tyršův sad wood (adding to the difference of its assemblage from those of the other sites), whereas *Enchytraeus* spp. were scarce there. The Koliště park was characterised by a high dominance of *Henlea ventriculosa*, which was missing or scarce in the other parks. This and other *Henlea* species were abundant in many sites studied in Warsaw (see above) and might also indicate higher disturbance levels. *Enchytraeus* spp. reached about 19 % in the Koliště park, which was somewhat above the average for the parks in Brno; whereas the total dominance of all *Fridericia* spp. was low and no *Buchholzia* was found. It seems possible that the high similarity of the enchytraeid assemblages of the parks Lužánky, Schreberovy zahrádky and – to a lesser degree – Koliště might be the consequence not only of similar conditions but also of proximity and the fact that some interconnection between these sites existed for a long time (as described above). The high similarity of the enchytraeid assemblages of the wooded sites was particularly due to the similarly high representation of *A. microcosmi* and *A. eiseni*. One of the two small woods sampled at Špilberk park differed from all other sites by the presence and dominance of *Stercutus niveus*. This species differentiated the wood habitat or even the entire Špilberk park as such from all other parks. *S. niveus* is a typical woodland species and was also found at low numbers in a municipal forest in the western outskirts of Brno (Šídová & Schlaghamerský 2007). The soil of the sites sampled in this municipal forest was acidic and the assemblages found differed from that of the parks (having only a high dominance of *A. eiseni* in common). *S. niveus* was also abundant in a floodplain forest south of Brno (Schlaghamerský 2007) where also *A. pannonica* was found. The enchytraeid assemblage of this floodplain forest was richer and distinct from that of any of the Brno parks under study.

5. Acknowledgements

6. References

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