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New data on the Oniscidea, Diplopoda and Chilopoda from urban parks of Bucharest

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Abstract. The urban invertebrate fauna, and especially the Oniscidea, Diplopoda and Chilopoda (among the dominant groups of the arthropod decomposer and predator community in many habitats) are an interesting but under-investigated aspect of the Romanian invertebrate fauna. Our intention was to continue and develop our previous studies on the fauna of Bucharest and to provide a more complete inventory of the Oniscidea, Diplopoda and Chilopoda species recorded so far in Bucharest and to detail the differences in the number of species between the investigated parks.
In addition, we report observations on three Oniscidea species, two Diplopoda species and ten Chilopoda species, some of them recorded for the first time in the Romanian Plain.

Key words: urban fauna, edaphic arthropods, Bucharest.

Introduction

Due to the rapid urban world population growth (one of the main challenges of the 21st century), the biodiversity recorded in and on the edge of human settlements, have an essential contribution in countering the global loss of biodiversity (Müller & Werner 2010).

Within this context, the knowledge on the urban invertebrate fauna (or of certain groups belonging to it, such as Oniscidea, Diplopoda and Chilopoda) represents an important aspect (Giurginca 2006, Ion 2008). Our study is part of a wider trend: in Europe alone, many urban and suburban areas have been selected for the study of the myriapod and isopod fauna: Moscow (Lokshina 1960), Copenhagen (Enghoff 1973), London (Davis 1979), Göteborg (Andersson 1983), Rome (Zapparoli 1992), Bonn-Bad Godesberg (Frund 1989, Schulte et al. 1989), Vienna (Christian 1996; Christian & Szeptycki 2004), Poznan (Leśniewska 1996), Budapest (Korsós 1992; Korsós et al. 2002; Vilisics & Hornung 2009), Sofia (Stoev 2004), Skopje (Gorgievska et al. 2008), Warsaw (Jedryczkowsky 1982, Wytwer 1995), Madrid (Ruiz 2009), Olomouc (Riedel et al. 2009), Zurich, Lugano and Lucerne (Vilisics et al. 2012), Shumen (Bachvarova 2015). In Romania, besides the study of Giurginca (2006), there are only two other studies, one in Beiuş (Bodin et al. 2013) and Salonta (Ferenţi et al. 2015).

The three animal taxa studied here (Oniscidea, Diplopoda and Chilopoda) belong to the macrofauna (4–80 mm), like most soil invertebrates, according to the classification of the soil fauna based on the body length (Eisenbeis 2006). Although trophic interactions in soils are still not clearly understood, these three groups may be considered as „key species" in ecosystems (e.g. Paoletti & Hassall 1999, Giurginca et al. 2010). Isopods and diplopods are involved in the first steps of comminution of litter and are classified as primary decomposers or saprophytophages, producing a large quantity of faecal pellets with a high content of undecomposed material, thereby facilitating a further colonization by free-living micro-organisms and making the material ready for the next step in the decomposition process (Eisenbeis 2006). Moreover, some isopods feed on their own faeces and can be classified as secondary decomposers (Eisenbeis 2006) and also may move litter deeper into the soil (Stork & Eggleton 1992). Both Isopoda and Diplopoda are also important as vectors of vesicular arbuscular mycorrhizal (VAM) fungi (Stork & Eggleton 1992). Furthermore, Chilopoda are the dominant invertebrate predators in soil, some of them being sit-and-wait predators, while others search for prey in mineral soil (Ferlian et al. 2012).

Despite being a part of the soil arthropod communities with high diversity and abundance, there are no comprehensive data currently available for several city parks of Bucharest, regarding the Oniscidea, Diplopoda and Chilopoda (Giurginca 2006, Tabacaru & Giurginca 2004-2005, Ion 2008). These studies contain only partial data and do not allow us to fully comprehend their distribution across the urban parks of Bucharest. As a

consequence, we have continued data collection and developed this study with the aim to describe the biodiversity of the Oniscidea, Diplopoda and Chilopoda within the Bucharest urban area in a more comprehensive way.

These data may be useful, as in the case of natural habitats, in the planning and management of urban recreational green areas and in developing and protecting biodiversity, by decreasing the intensity and the level of distortion due to human activity (Zapparoli 1992, Hachtel et al. 2008, Bachvarova et al. 2015).

Material and methods

Our main sampling sites are located in four urban parks, in different areas of Bucharest, namely Herăstrău Park, National Park, Tineretului Park and "Al. I. Cuza" Park (Fig. 1). Sampling took place between April 2005 and August 2015. The material was collected by hand, with tweezers, as at first we used only a qualitative approach. Attempts to use pitfall traps proved inefficient, as the traps were disturbed or destroyed by animals (dogs and rodents) and especially by humans. Three of the sampling sites were visited twice a month (Herăstrău, Tineretului and "Al. I. Cuza" Parks), while National Park was visited weekly.

In order to understand the species compositions and the differences in the number of species found in Bucharest, we provide below a short description of the climate of the city and of the four urban parks.

The climate is temperate-continental, influenced by the characteristics of the contact area of the eastern continental masses with the western and the southern ones. The predominant eastern winds determine an excessive climate, with hot summers and relatively cold winters (APM Bucureşti 2007). Belonging by its climate to the "Bărăganului Plain" type of climate, Bucharest presents a deficiency in humidity in comparison with the optimum average value (APM Bucureşti 2007). The annual average temperature is 10–11°C, the coldest month being January (with an average of −2.9°C), while the warmest is July, with an average of 22.8°C (APM Bucureşti 2007).

The relative humidity reaches the highest value (RH = 87%) also in January and the lowest in July (RH = 69%); the annual average humidity is 77% (Cândea 2008).

Herăstrău (44°28'14.15"N, 26°04'56.66"E) is a large park of 187 ha (Berindei & Bonifaciu 1978). It has a relatively large tree-cover, with a lot of bushes, but the herbaceous carpet covers a relatively limited surface (Giurginca 2006).

Although covering only 54 ha (Berindei & Bonifaciu 1978), the National Park (44°26'05.78"N, 26°08'40.95"E) presents a wide range of tree species with numerous bushes and hedges. There are only a few species of herbaceous plants (Giurginca 2006).

For Tineretului Park (44°24'20.54"N, 26°06'21.82"E), a park with a surface of 80 ha (Berindei & Bonifaciu 1978) we note the presence of a varied tree-cover, bushes and herbaceous species (Giurginca 2006).

The "Al. I. Cuza" Park (44°25'31.81"N, 26°09'12.73"E) is a medium-sized park of 85 ha (Berindei & Bonifaciu 1978), with wide grassy spaces and relatively small tree-cover.

There are two additional sampling points: Iancului Square (44°26'28.15"N, 26°08'08.82"E) and 13 Septembrie Road (44°25'27.78"N, 26°05'16.68"E). The first one represents the sole finding of a Chilopoda species inside a house. The second one represents an abandoned terrain surrounded by buildings; we sampled it only twelve times during the period of our study because it is situated in the most anthropogenically impacted area of Bucharest.

Results

Thirty-three species of invertebrates were found within the urban parks of Bucharest: seventeen species of Oniscidea, six species of Diplopoda and ten species of Chilopoda (Table 1).

The Oniscidea belong to 8 families, the Diplopoda - to 3 families, and the Chilopoda - to 5 families.

As some of the Isopoda and Diplopoda have already been presented in Giurginca (2006), here we discuss only the species collected between 2006 and 2015.

The species of **Oniscidea** are as follows:

Family Ligiidae Brandt & Ratzeburg, 1831

Ligidium germanicum Verhoeff, 1901.

Distribution: from southeastern Germany and northern Italy to southern Poland, Romania, Bessarabia and northern Greece (Schmalfuss 2003). Known from Banat, Oltenia, Moldavia and Transylvania (Giurginca & Ilie 2003). This is the second record of the species in the Romanian Plain, the first being from the western part of the Romanian Plain (Ferenți & Covaciu-Marcov, 2014). Found only in the National Park, in a moist and shaded place in a clump of *Celtis* mixed with *Ulmus* and *Fagus*, devoid of herbaceous vegetation and a thick layer of leaf litter.

Family Philosciidae Kinahan, 1857

Chaetophiloscia sicula Verhoeff, 1908.

Distribution: Canary Islands, southern France, Corsica, Italy, Sicily, central Greece (Schmalfuss 2003) and Romania (Giurginca & Vănoaica 2002). Up to now, *Ch. sicula* was recorded in Romania only in Dobrogea. Found in Herăstrău (in a mixed group of *Populus*, *Fraxinus*, *Acer* and *Ulmus*) and in the National Park (in a mixed group of *Celtis*, *Ul-*

Figure 1. Sampling points locations in Bucharest (A- Herăstrău Park; B- Iancului Square; C- National Park; D- "Al. I. Cuza" Park; E- 13 Septembrie Road; F- Tineretului Park).

mus, *Fagus*, *Carpinus* and *Acer*), in moist, shaded places, under stones and wood pieces and under a rotten tree stump.

Family Trachelipidae Strouhal, 1953

Trachelipus difficilis Radu, 1950.

Distribution: Poland, Slovakia, Hungary and Romania (Schmalfuss 2003) - here originally considered by Radu as endemic for the area between Săvârşin and Coşteiu (Hunedoara) (Radu 1985), but later found also in the Southern Carpathians, in the Piatra Craiului Massif (Giurginca et al. 2006). This is the first record of the species in the Romanian Plain. In Bucharest, found both in National and Herăstrău parks, in moist and shaded places, in the same habitat with *Ch. sicula*.

The **Diplopoda** are the following:

Family Julidae Leach, 1814

Megaphyllum transsylvanicum (Verhoeff, 1897).

Distribution: Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Hungary, Romania, Bessarabia, Russia, Serbia, Turkey (the European part) and Ukraine (Makarov et al. 2004). In Romania, it is sometimes found in caves (Tabacaru et al. 2004) but also in soil and moss covered scree (see Nitzu et al. 2011). This is the first record of the species in the Romanian Plain. Found only once, in the National Park, in a moist and shaded place, in a mixed group of *Celtis*, *Ulmus*, *Fagus*, *Carpinus* and *Acer* along with the previous two species.

Cylindroiulus arborum Verhoeff, 1928.

Distribution: Austria, Belgium, Germany, Czech Republic, Slovakia, Romania, Poland, Lithuania, Hungary, Ukraine, Greek mainland, Bulgaria and Macedonia (Makarov et al. 2004). Found only in the Herăstrău Park in a mixed group of *Populus*, *Fraxinus*, *Acer* and *Ulmus*, under a rotten tree stump.

The **Chilopoda** are represented by 10 species:

Family Dignathodonthidae Cook, 1895

Henia illyrica (Meinert, 1870).

Distribution: Poland, Germany, Czech Republic, Slovakia, Austria, Hungary, NE Italy, Croatia, Bosnia, Montenegro, Serbia, Macedonia, Albania, Bulgaria, Romania, Greece, Turkey, Caucasus (Stoev 2001). In Romania known from Transylvania, Banat, Muntenia and Dobrogea (Matic 1972). We have found it only in the Herăstrău Park, in moist and shaded places, in a clump of *Populus*, *Fraxinus*, *Acer*, *Betula* and *Ulmus*.

Family Geophilidae Leach, 1815

Clinopodes flavidus C. L. Koch, 1847.

Distribution: Poland, Czech Republic, Slovakia, Austria, Italy, Slovenia, Bosnia, Montenegro, Serbia, Macedonia, Albania, Bulgaria, Romania, Greece, Turkey, Cyprus, Syria, Israel, Crimea, Caucasus (Stoev 2001, Mitić & Tomić 2002). In Romania known from Banat, Muntenia, Oltenia, and Dobrogea (Matic 1972). We have also checked our material for possible confusions with *C. carinthiacus* and *C. verhoeffi* ; the arrangement of coxal pores into clusters and the short extent of the pore fields on the posterior leg-bearing segments are exclusively diagnostic for *C. flavidus* (see Bonato et al. 2011).

We have found it in Tineretului (under *Tilia*, *Platanus* and *Ulmus*) and Herăstrău parks (in a

Table 1. The checklist of the Oniscidea, Diplopoda and Chilopoda species recorded at six sampling points from parks and other urban areas of Bucharest; the number of sampling visits and the number of individuals from each species is also given.

No.	Species (species marked with * have been presented in Giurginca 2006)	Herăstrău Park 16 sampling visits	Iancului Square 1 sampling	National Park 10 sampling visits	"Al. I. Cuza" Park 1 sampling	13 Septembrie Road 12 sampling visits	Tineretului Park 11 sampling visits
Oniscidae							
1.	*Ligidium germanicum* Verhoeff, 1901			3 ex.			
2.	**Hyloniscus riparius* (C. Koch, 1838)	27 ex.			2 ex.		
3.	**Haplophthalmus danicus* Budde-Lund, 1880	50 ex.					1 ex.
4.	**Platyarthrus attanassovi* Verhoeff, 1936	1 ex.		2 ex.			
5.	*Chaetophiloscia sicula* Verhoeff, 1908	5 ex.		1 ex.			
6.	**Cylisticus convexus* (De Geer, 1778)	21 ex.		100 ex.			7 ex.
7.	**Cylisticus transilvanicus* Verhoeff, 1908						61 ex.
8.	**Porcellionides pruinosus* (Brandt, 1833)	25 ex.		10 ex.	20 ex.		8 ex.
9.	**Porcellio laevis* (Latreille, 1804)			1 ex.			
10.	**Protracheoniscus politus politus* (C. Koch, 1841)						3 ex.
11.	**Trachelipus rhinoceros* (Budde-Lund, 1885)	1 ex.		2 ex.			6 ex.
12.	*Trachelipus difficilis* (Radu, 1950)	1 ex.					
13.	**Trachelipus rathkii* (Brandt, 1833)	5 ex.		29 ex.			6 ex.
14.	**Trachelipus nodulosus* (C. Koch, 1838)			4 ex.	2 ex.		41 ex.
15.	**Trachelipus arcuatus* (Budde-Lund, 1885)	2 ex.		1 ex.		2 ex.	30 ex.
16.	**Armadillidium vulgare* (Latreille, 1804)	87 ex.		34 ex.	6 ex.	77 ex.	71 ex.
17.	**Armadillidium nasatum* Budde-Lund, 1885	1 ex.				3 ex.	
Diplopoda							
1.	**Brachydesmus superus* Latzel, 1884	6 ex.		20 ex.			1 ex.
2.	**Bulgardicus bucarestensis* Tabacaru & Giurginca, 2005			1 ex.			
3.	**Megaphyllum unilineatum* (C. L. Koch, 1838)					22 ex.	
4.	*Megaphyllum transsylvanicum* Verhoeff, 1897			1 ex.			
5.	**Cylindroiulus boleti* (C. L. Koch, 1847)	62 ex.					
6.	*Cylindroiulus arborum* Verhoeff, 1928	14 ex.					
Chilopoda							
1.	*Henia illyrica* (Meinert, 1870)	3 ex.					
2.	*Clinopodes flavidus* C. L. Koch, 1847	3 ex.					1 ex.
3.	*Geophilus flavus* (De Geer, 1778)						1 ex.
4.	*Lithobius parietum* Verhoeff, 1899	11 ex.		1 ex.	2 ex.		4 ex.
5.	*Lithobius nigripalpis* L. Koch, 1867	6 ex.					
6.	*Lithobius forficatus* (Linnaeus, 1758)	20 ex.					
7.	*Lithobius crassipes* L. Koch, 1862						2 ex.
8.	*Cryptops hortensis* (Donovan, 1810)	1 ex.			1 ex.		1 ex.
9.	*Cryptops anomalans* Newport, 1844	2 ex.					
10.	*Scutigera coleoptrata* (Linnaeus, 1758)		1 ex.				
	Total (species/park)	22	1	15	6	4	16

mixed group of *Populus*, *Fraxinus*, *Acer*, *Betula* and *Ulmus*), under stones, in a partially shaded place, in the same habitat as the previous species. An additional aspect is the finding in the Herăstrău Park of several individuals of *Clinopodes flavidus polytrichus*. It differs from typical *C. flavidus* by having the most anterior trunk metasternites covered with more dense setae, but the apparent hairiness is variable, both within and between populations, without any clear geographic pattern, sometimes specimens of both *C. flavidus polytrichus* and *C. flavidus* being recorded together, from the same locality (Bonato & Minelli 2014).

Finding *C. flavidus polytrichus* only in the Herăstrău Park (but not in the other parks of Bucharest, and especially not in the Tineretului Park, where we have collected typical *C. flavidus*), points to the insular character of the urban fauna, due to its isolation in limited areas, namely (but not only) in city parks.

Geophilus flavus (De Geer, 1778).

Distribution: Spread across almost the entire Europe. In Romania, all over the country (Matic 1972). It was found only in the Tineretului Park, under stones, in a partially shaded place, under *Platanus* and *Ulmus*.

Family Lithobiidae Newport, 1844

Lithobius* (*Lithobius*) *parietum Verhoeff, 1899.

Distribution: Bulgaria, Croatia, Greece, Romania, Bessarabia, Poland, Slovenia, Ukraine, Hungary (see Zapparoli 2013). In Romania, it was found only at low altitudes, in Dobrogea, Muntenia, Moldavia, and the Cerna Valley (Negrea 2006).

Found in all the four parks: in Herăstrău (under *Fraxinus*, *Ulmus*, *Betula* and *Acer*) and in the National Park (under *Ulmus*, *Fagus*, *Carpinus* and *Celtis*), the species was collected from a moist and shaded place, in the Tineretului Park it was found in a partially shaded place (under *Platanus* and *Ulmus*), while in the "Al. I. Cuza" Park, *L. parietum* was collected under stones, in a dry and grassy place (mainly *Agropyron*, *Hordeum*, *Polygonum*, *Setaria* and *Lolium*).

Lithobius* (*Lithobius*) *nigripalpis L. Koch, 1867.

Distribution: Romania, Serbia, Macedonia, Bulgaria, continental and insular Greece, Crete and Turkey (Stoev 2001); recorded from North Dobrogea (Babadag and Niculiţel) (Matic 1966) and South Dobrogea (Movile Cave drillings) (Negrea 2006) and from Băile Herculane (Cerna Valley) (Matic 1966). Recently, it was found in Muntenia (Gava 2009) and in Bucharest (Ion 2008). Unlike the previous species, it was found only in the Herăstrău Park, under stones, in a shaded place (under *Fraxinus*, *Acer*, *Ulmus* and *Tilia*).

Lithobius* (*Lithobius*) *forficatus (Linnaeus, 1758).

Distribution: North Africa, Europe, Turkey, Caucasus, introduced in Iceland, North and South America, Saint Helena and Hawaii (Stoev 2001); in Romania found across the entire country (Matic 1966). Found only in the Herăstrău Park, together with *L. nigripalpis*, under stones, in a shaded place.

Lithobius* (*Monotarsobius*) *crassipes L. Koch, 1862.

Distribution: Scandinavia, Ireland, Netherlands, Germany, ex-Czechoslovakia, Romania, Bulgaria, Russia, Tunisia, Algeria, Iberian Peninsula, France, Switzerland, Italy, Austria, Slovenia, Croatia, Bosnia, Macedonia, Serbia, Albania, Greece, Turkey, Syria, Jordan, Central Asia (Stoev 2001). In Romania, it is widespread in low-altitude forests (Negrea 2006). Found only once in the Tineretului Park, in a shaded place, under a rotten tree (under a group of mixed group of *Picea*, *Celtis* and *Acer*).

Family Cryptopidae Newport, 1844

Cryptops hortensis (Donovan, 1810).

Distribution: Macaronesia, Europe, Caucasus, introduced in North America and Saint Helena Island (Stoev 2001). In Romania known from Muntenia, Banat and northern Moldavia (Matic & Negrea 1966).

Found in the "Al. I. Cuza" Park, under stones, in a dry and grassy place (mainly *Agropyron*, *Hordeum*, *Polygonum* but also a few bushes like *Syringa* and *Berberis*); in contrast, in Herăstrău (under *Fraxinus*, *Acer*, *Ulmus* and *Tilia*) and Tineretului parks (under *Fagus*, *Platanus*, *Ulmus* and *Fraxinus*), it was collected from moist and shaded places.

Cryptops anomalans Newport, 1844.

Distribution: Belgium, Germany, ex-Czechoslovakia, Hungary, Switzerland, Austria, Romania, Ukraine, Tunisia, Algeria, Spain, France, Italy, Slovenia, Croatia, Bosnia, Serbia, Macedonia, Bulgaria, Albania, Greece, Turkey, introduced in England (Stoev 2001, Mitić & Tomić 2002). In Romania, it was recorded from Transylvania, Banat and Dobrogea (Negrea 2006). Found only once in the Herăstrău Park, under stones, in a shaded place under *Fraxinus*, *Acer*, *Ulmus* and *Populus*.

Family Scutigeridae Gervais, 1895

Scutigera coleoptrata (Linnaeus, 1758).

Distribution: Circum-Mediterranean, relatively frequent in the southern part of Romania (Banat, Muntenia, Dobrogea) (Matic & Negrea

1966, Negrea 2006). During this study it was found only once, inside a house.

Discussions

Among the eight families of Oniscidea, the most represented is the Trachelipidae, with six species. The Trichoniscidae, the Cylisticidae, the Porcellionidae and the Armadillidiidae are represented each by two species, while the Ligiidae, Philosciidae and Platyarthridae are the most poorly represented - by only one species.

Most of the 17 species of Oniscidea are widespread or even cosmopolitan species. This is the case for *Armadillidium vulgare*, *Porcellio laevis*, *Porcellionides pruinosus*, *Hyloniscus riparius*, *Cylisticus convexus*, *Trachelipus arcuatus*, *T. nodulosus*, *T. rathkii* (Schmalfuss 2003).

As far as our information goes (Radu 1985), this is the first record of *Trachelipus difficilis* in the Romanian Plain, although the species was also recorded in a plains location in North-Western Romania (Ferenţi & Covaciu-Marcov, 2012; Ferenţi et al. 2013).

Up to the present, *Ch. sicula* was known in Romania only from Dobrogea - from the two drillings dug close to the Movile Cave, from a depth of −3 m down to −18 m; it was never found above the depth of −3 m (Giurginca et al. 2009). As such, this is the first record of the species in a location outside Dobrogea. In our opinion, *Trachelipus difficilis* and *Chaetophiloscia sicula* represent two relict species from the fauna of the ancient forests of the Codrii Vlăsiei, today remaining only as scattered and diminished forest patches, some of them included within the Bucharest metropolitan area.

Also, we should note that *Ch. sicula* was found in a patch of urban forest, in Baltimore (Hornung & Szlávecz 2003).

The Diplopoda are represented by a lower number of species and individuals than the Oniscidea. In fact, among the three families of Diplopoda found in Bucharest, only the Julidae are recorded by four species, the other two families (Anthroleucosomatidae and Polydesmidae) are recorded by only one species.

Among the ten Chilopoda species, *H. illyrica*, *G. flavus*, *Cl. flavidus*, *L. forficatus*, *Cr. hortensis* and *Sc. coleoptrata* are widespread in Romania (Matic 1966 & 1972; Negrea 2006), and, as such, it is logical to find them in the urban parks of Bucharest. *Lithobius parietum* and *L. nigripalpis* have already been recorded from Bucharest: the first species by Matic (1966), but without pinpointing the location, and the second by Ion (2008), in Izvor and Cişmigiu parks.

Nine species of Chilopoda (out of 24) have been found in several forests around Bucharest and inside the city: *L. forficatus* (Comana, Cernica, Chitila and Căldăruşani forests), *L. nigripalpis* (Comana Forest), *L. parietum* (Comana, Chitila, Scroviştea forests), *L. crassipes* (Comana and Pantelimon forests), *Cl. flavidus* (Comana Forest), *G. flavus* (Comana and Pustnicul forests), *H. illyrica* (Comana and Cernica forests), *Cr. anomalans* (Comana Forest) and *Sc. coleoptrata* (Comana Forest) (Dărăbanţu et al. 1969; Matic 1954, 1964, 1966, 1972; Matic & Negrea 1967; Matic & Prunescu 1961; Negrea 2006; Negrea et al. 1970; Verhoeff 1901). A series of species like *L. agilis*, *G. proximus* and *G. pygmaeus*, *Sc. cingulata* have not been collected in Bucharest (but are recorded from the forests around the city) perhaps due to their narrower ecological preferences. Until now there are no studies on the Oniscidea and the Diplopoda from the forests around Bucharest.

Table 2 shows the species recorded both in Bucharest and in other cities where the soil fauna was studied. In only one case, namely in London (Davis 1979), the investigation covered all three groups of soil dwellers, as we did in Bucharest. Chilopoda is the best-studied group in the urban areas of Europe (known from 13 out the 20 cities taken into account in the table).

As the table points out, the most frequently found isopod in urban areas is *A. vulgare* (recorded from eight cities), followed by *H. riparius* and *Tr. rathkii* (recorded from seven cities). The most frequently found millipede is *Br. superus* (collected from 10 cities); among centipedes, *L. forficatus* was identified in 13 cities, that is virtually every city in which the centipede fauna was studied.

The cities most similar in faunal composition with Bucharest are Shumen and Budapest (with 13 species in common), due to their location within the same general geographic region.

There are differences in the number of species found in the investigated parks: 22 species in the Herăstrău Park, 16 in the Tineretului Park, 15 in the National Park and only 6 in the "Al. I. Cuza" Park (Table 1). These can be mainly attributed to the differences in the areas of the investigated parks: the Herăstrău Park (187 ha) has more than twice the size of the Tineretului Park (80 ha) and

Table 2. Bucharest species of Oniscidea, Diplopoda and Chilopoda recorded from other cities of Europe: Mo-Moscow; Co-Copenhagen; Lo-London; Go-Göteborg; Ro-Rome; Bo-Bonn-Bad Godesberg; Vi-Vienna; Po-Poznan; Bu-Budapest; So-Sofia; Wa-Warsaw; Ma-Madrid; Ol-Olomouc; Ho-Hodonin; Ji-Jičín; Zu-Zurich; Lug-Lugano; Luc-Lucerne; Sh-Shumen; Be-Beiuş; Sa-Salonta (the cities are taken from the references cited in the Introduction).

Species	Mo	Co	Lo	Go	Ro	Bo	Vi	Po	Bu	So	Wa	Ma	Ol	Ho	Ji	Zu	Lug	Luc	Sh	Be	Sa
Oniscidea																					
L. germanicum																					
H. riparius									X				X			X	X	X		X	X
H. danicus									X				X				X			X	X
Pl. attanassovi																					
Ch. sicula																					
Cyl. convexus									X				X			X		X		X	X
Cyl. transsilvanicus																					
Por. pruinosus			X						X				X			X					
P. laevis																					
Prot. politus politus									X											X	
Tr. rhinoceros																					
Tr. difficilis																					
Tr. rathkii			X						X				X			X	X	X			X
Tr. nodulosus									X												X
Tr. arcuatus																				X	
A.vulgare			X						X				X			X	X	X		X	X
A.nasatum									X							X	X	X			
Diplopoda																					
Br. superus	X	X	X						X		X		X	X	X	X	X				
Bul. bucarestensis																					
Meg. unilineatum									X					X	X				X		
Meg. transsylvanicum																			X		
Cyl. boleti									X					X	X				X		
Cyl. arborum									X		X										
Chilopoda																					
H. illyrica							X			X				X	X				X		
Cl. flavidus					X		X	X						X	X				X		
Geo. flavus		X			X	X	X	X			X			X	X				X		
Lith. parietum																			X		
Lith. nigripalpis										X									X		
Lith. forficatus		X	X	X	X	X	X	X		X	X			X	X				X		
Lith. crassipes		X		X				X			X			X	X				X		
Cr. hortensis		X		X	X	X	X	X		X		X									
Cr. anomalans			X		X	X	X			X									X		
Sc. coleoptrata					X					X		X							X		

of the "Al. I. Cuza" Park (85 ha) and more than three times the size of the National Park (54 ha).

Due to its size, the Herăstrău Park represents a much more heterogeneous environment than the other parks: it is in fact a mosaic of open, grassy spaces, alternating with wide areas covered by trees and bushes. Unlike this park, the Tineretului Park and the "Al. I. Cuza" Park have much more grassy places and, more importantly, less tree-cover. Instead, the National Park has only small areas of grass, thus explaining the high number of species found across it. Due to the greater extent of the tree-cover, the Herăstrău Park and the National Park provide higher humidity micro-habitats than the other two parks.

However, we would like to point out to a serious limiting factor for the number of invertebrate species from Bucharest. Each spring and autumn, in a so-called "spring/autumn cleaning", the parks administrations remove the leaf-litter and, in certain spots, the large stones and the fallen branches that represent the shelter of the Oniscidea, Diplopoda and Chilopoda. In this respect, the Tineretului Park and the "Al. I. Cuza" Park, the most open parks of the four, are the most disadvantaged because each spring, in March, the leaf-litter is almost completely removed. Also, during the last two years (2014, 2015), the "Al. I.

Cuza" Park was "developed", i.e. several new alleys were opened by removing a patch of trees and areas of grass and bushes.

Unlike these two parks, the National Park has been somehow neglected and, as such, the park still has large areas with tree-cover and abundant bushes. The situation is still better in the Herăstrău Park - there are areas where the leaf-litter is removed twice a year, but, there are still wide areas where the leaf-litter is left in place.

Nine potentially toxic metals have been found in samples of soil and three species of Oniscidea and one of Diplopoda from three urban parks of Bucharest (Giurginca et al. 2008); some of them might be due to the community-level disinfection programs (Ion 2008), with potentially serious negative impacts.

Besides using improved chemicals in disinfection programs in the parks, other scientifically supported practices to reduce the negative impacts of herbicides and/or pesticides should be considered such as a runoff prevention program in order to reduce the loss of sediment, nutrients and possible pollutants into the parks lake (a program necessary for instance in the Herăstrău and Tineretului parks) and avoiding to apply herbicides/pesticides on saturated soils or non-target surfaces (e.g. concretes, plastic) since it will likely increase chemical runoff during subsequent rains or snows (Cole et al. 1997; Bell & Moss 2006).

One of the aims of our study was to develop a series of basic suggestions in order to enhance the urban parks soil-dwellers populations. One significant suggestion is to reduce ecological fragmentation within the existing parks, where „islands" of trees are separated from each other: solutions might range from eliminating/reducing regular lawn mowing to replanting trees (Ward 2003a; Ward & Gurney 2003). Related to this aspect, activities such as tree hazard abatement, vegetation mowing and pruning, trail maintenance and drainage management (that can impact negatively the park fauna) can be done sensitively to enhance the biodiversity within the parks (Ward 2003b). In this context, the removal of hazardous trees has a serious negative impact since hazardous trees provide habitat for a variety of cavity-nesting birds and are a source of large woody debris (habitat used by the Diplopoda, for instance), so they should only be removed if they pose a real safety risk. Also, the removal of the stumps and roots of hazardous trees in areas close to the parks lake should be avoided to prevent soil disturbance. Large woody debris resulting from hazardous tree abatements should be left on site to enhance habitat for soil invertebrates (Ward 2003b).

Another key suggestion in order to successfully manage the biodiversity of the urban parks is to inventory and monitor the existing soil fauna and their potential in supporting fauna habitat (Ward 2003b; Ward & Gurney 2003). As a consequence, the awareness and sensitivity of the authorities responsible for the park management and the general public should be increased to the value of the biodiversity from the urban parks through signage, brochures, educational sessions (Ward 2003b).

All these facts point to the necessity to further extend our study on most parks of Bucharest, in order to assess the distribution of the fauna according to the urbanization gradient.

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