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Change in the zoogeographical structure of ants (Hymenoptera: Formicidae) caused by urban pressure in the Sofia region (Bulgaria)

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Abstract

A comparison of the zoogeographical peculiarities of the myrmecofauna in urban and non-urban habitats in Sofia region is performed. The proportion of the widespread Holarctic species was twice as high in the urban as compared to the non-urban sites. Also Euro-Caucasian elements are well represented in the urban sites. The share of South-Transpalaearctic, Eurasian steppe and Boreo-Montane elements is low or such elements are absent from the urban sites.

Key words: Ants, Formicidae, urban landscape, Bulgaria, zoogeography.

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Introduction

Comparatively few investigations exist on the change of zoogeographical structure of ants in urban areas. It is well known that widespread invertebrate species are common in urban environments compared to its surroundings (KLAUSNITZER 1990). This pattern has been observed for ants in different parts of the world: Japan – Tokyo and Chiba (KONDOH 1978, YAMAGUCHI 2004), Kitakyushu (KONDOH & KITAZAWA 1984); USA – Raleigh (North Carolina) (NUHN & WRIGHT 1979), urban zones on the Atlantic coast (KING & GREEN 1995 – in MCINTYRE 2000); Europe – Warsaw (PISARSKI & CZECHOWSKI 1978, BANASZAK & al. 1978, CZECHOWSKI & al. 1979, PISARSKI 1982, PISARSKI & CZECHOWSKI 1987, CZECHOWSKI & al. 1990, CZECHOWSKI & PISARSKI 1990, CZECHOWSKI 1991), Espoo (VEPSÄLÄINEN & WUORENRINNE 1978), Liege (GASPAR & THIRION 1978), Garraf (Barcelona) (RESTREPO & al. 1985), Leipzig (RICHTER & al. 1986), Köln (LIPPKE & CÖLLN 1991, BEHR & al. 1996), Gönnersdorf (BEHR & CÖLLN 1993), Mainz (DAUBER 1995, DAUBER 1997, DAUBER & EISENBEIS 1997), Wien (SCHLICK-STEINER & STEINER 1999), Linz (AMBACH 1999). Generally, each urban fauna is a selection from the regional species pool, therefore, depending on a city's geographical position, species from the respective zoogeographical zone prevail (PISARSKI & KUĹESZA 1982, VEPSÄLÄINEN & PISARSKI 1982). PISARSKI & VEPSÄLÄINEN (1987) note that the share of Palaearctic ants is up to 90 % in European cities of the temperate climatic zone while that of European species is relatively small. In Mainz European and Holarctic ant species prevail (DAUBER 1995). In Warsaw Palaearctic and South-Eurosiberian ants constitute the bulk of the fauna (PISARSKI & CZECHOWSKI 1987).

Many authors studied the possibility to use ants as bioindicators on the basis of functional groups (ANDERSEN 1990, 1995a, b, 1997a, b, c, d, ANDERSEN & SPARLING 1997, VANDERWOUDE & al. 1997a, b, CHUDZICKA & SKIBIŃSKA 1998, PECK & al. 1998, NEW 2000, READ & ANDERSEN 2000, HOFFMANN & al. 2000, ANDERSEN & al. 2002, HOFFMANN & ANDERSEN 2003). Anthropogenic disturbances have a different impact on different ant species, dependent on their ecological needs (PĘTAL 1980, ANDERSEN 2000). The main anthropogenic factors are: disturbance of the structure of habitats, changes in microclimate and nutrition resources (ANDERSEN 1990, 1995a). Unfortunately, most of the species of ants from the above mentioned studies do not exist in the European myrmecofauna and thus direct comparisons are not possible.

In this study we investigate changes in the zoogeographical structure of the ant fauna in both urban and rural landscape of the city of Sofia. We discuss the possibility of using the zoogeographical structure of ants for bioindication in urban landscapes.

Material and methods

The city of Sofia is situated at 550 m a.s.l. on average, the average annual temperature is around 10.2 °C and the average annual rainfall is around 560 mm (BLUSKOVA & al. 1983). The urban area covers approximately 220 km^2 (KOVACHEV 2005). The central part of the city is situated at approximately 42° 41' N and 23° 19' E. With respect to climate, Sofia is situated relatively near (c. 120 km) to the border between temperate and submediterranean climates.

The material for the present study was collected in 2003 - 2005. It is kept in the collection of V. Antonova in the Central Laboratory of General Ecology of the Bulgarian Academy of Sciences. Fifty-six of the localities were situated in the urban greenery ("urban" sites in Fig. 1): wooded and open areas in parks, green yards along transport corridors and streets; amounting to a total of ten "forest" sites and 46 "meadow" sites (Fig. 1). Another eight localities are situated in the vicinity of Sofia ("non-urban" sites in Fig. 1), at the foot of Vitosha, Lyulin and Lozen Mountains; amounting to a total of two "forest" sites and six "meadow" sites. The non-urban sites are situated not higher than 150 m above the average altitude of the city with distance up to 10 km from the city ring road.

The urban forest localities are situated within the Sofia GLOBENET sites described by PENEV & al. (2004). Species compositions of plant communities are mostly anthropogenic. Most of the sites are situated in oak forests (50 - 90 years old) with prevalence of the mesophilous in-

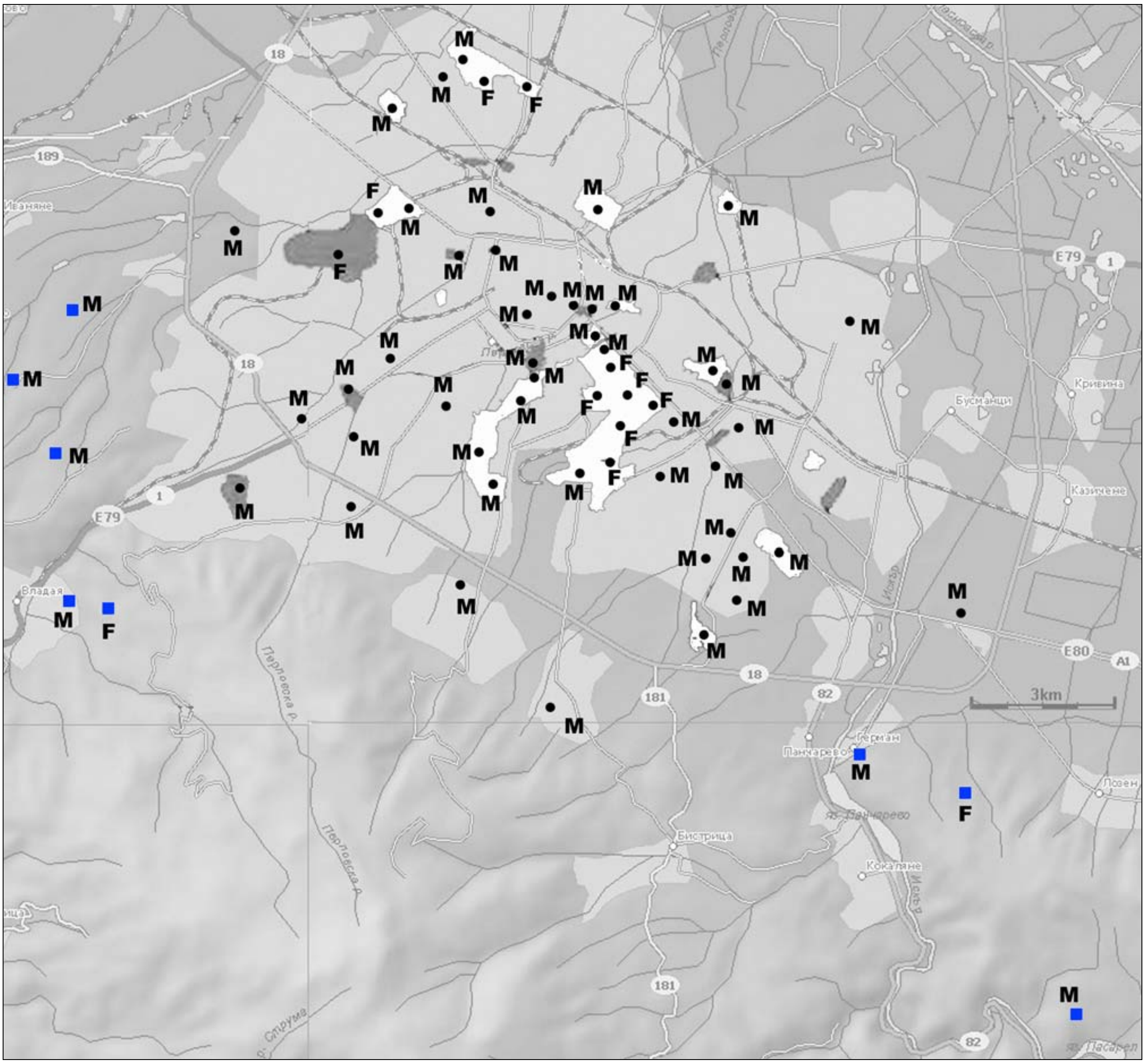


Fig. 1: Sampling sites in Sofia city and surroundings. M - meadow; F – forest; ■ - non-urban site; ● – urban site.

troduced Red Oak (*Quercus rubra* L.) (formation Querceta rubrae). The sites in open urban areas were chosen on the basis of prevalence of the dominant plant species: *Poa* spp., *Festuca* spp., *Phleum pratense* L., *Avena fatua* L., *Setaria viridis* (L.), *Cynodon dactylon* PERS., *Dactylis glomerata* L., *Trifolium* spp., *Taraxacum officinale* WEBBER, *Bellis perennis* L., *Capsella bursa-pastoris* MED., and *Plantago* spp. Similar plant communities were chosen around the city, in the non-urban sites (Fig. 1).

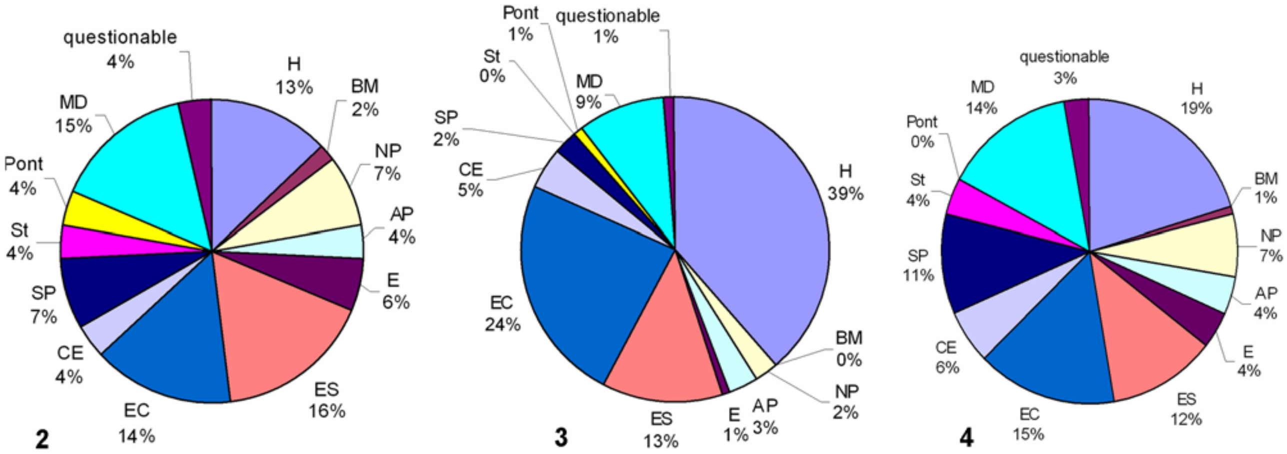
For the purpose of the present study the direct sampling method (BESTELMEYER & al. 2000) was used. In the forest sites ant colonies were searched in the leaf litter, in the ground (up to 25 cm depth), under stones, under the bark of trees, in logs and nuts. In the meadow sites colonies were searched in the ground, in the grass turf and under stones. The sampling area per site was approximately 1 ha and search was conducted for 4 hours per site. The total number of colonies we found is 1634. Ants were determined to species level by use of the keys of ATANASSOV & DLUSSKY (1992), SEIFERT (1996), and CZECHOWSKI & al. (2002).

The zoogeographical classification of ants was taken from ATANASSOV (1952) and CZECHOWSKI & al. (2002), with some changes and additions.

The reliability of differences in percentage within each zoogeographical category between the city and its vicinity was tested with the "Differences between two percentages" two-sided significance test available in Statistica for Windows 5.0 (STATSOFT 1995), which is suitable for analysing data from uneven sampling design.

Tab. 1: Zoogeographical classification of the ant species in Sofia and its surroundings. BM – Boreo-Montane; NP – North-Transpalaearctic; H – Holarctic; AP – Amphipalaearctic; E – European; ES – Euro-Siberian s.str.; EC – Euro-Caucasian; CE – Central-European; SP – South-Transpalaearctic; St – Eurasian steppe; Pont – Pontic; MD – Mediterranean s.str. ⟶

No.	Species	Zoogeographical element	Sofia	Surroundings
1.	*Ponera coarctata* (LATREILLE, 1802)	MD	+	
2.	*Myrmica rubra* (LINNAEUS, 1758)	H	+	
3.	*Myrmica ruginodis* NYLANDER, 1846	NP	+	+
4.	*Myrmica rugulosa* NYLANDER, 1849	ES	+	+
5.	*Myrmica scabrinodis* NYLANDER, 1846	H	+	+
6.	*Myrmica schencki* VIERECK, 1903	H	+	+
7.	*Myrmica specioides* BONDROIT, 1918	CE	+	
8.	*Myrmica sulcinodis* NYLANDER, 1846	BM	+	+
9.	*Myrmica rugulososcabrinodis* KARAWAJEW, 1929	Pont	+	
10.	*Myrmica lonae* FINZI, 1926	ES	+	+
11.	*Myrmica salina* RUZSKY, 1905	ES	+	
12.	*Myrmica sabuleti* MEINERT, 1861	ES	+	+
13.	*Stenamma debile* (FOERSTER, 1850)	EC	+	
14.	*Solenopsis fugax* (LATREILLE, 1798)	MD	+	+
15.	*Temnothorax nylanderi* (FOERSTER, 1850)	CE	+	+
16.	*Temnothorax affinis* (MAYR, 1855)	EC	+	
17.	*Temnothorax tuberum* (FABRICIUS, 1775)	ES	+	+
18.	*Temnothorax unifasciatus* (LATREILLE, 1798)	EC	+	+
19.	*Messor structor* (LATREILLE, 1798)	MD		+
20.	*Tetramorium* cf. *caespitum* (LINNAEUS, 1758)	H	+	+
21.	*Tetramorium hungaricum* RÖSZLER, 1935	MD	+	
22.	*Tetramorium moravicum* KRATOCHVIL, 1941	?	+	+
23.	*Myrmecina graminicola* (LATREILLE, 1802)	AP	+	+
24.	*Dolichoderus quadripunctatus* (LINNAEUS, 1771)	ES	+	+
25.	*Tapinoma erraticum* (LATREILLE, 1798)	MD	+	+
26.	*Plagiolepis pygmaea* (LATREILLE, 1798)	MD	+	+
27.	*Plagiolepis taurica* SANTSCHI, 1920	St		+
28.	*Camponotus vagus* (SCOPOLI, 1763)	ES	+	+
29.	*Camponotus aethiops* (LATREILLE, 1798)	MD	+	+
30.	*Camponotus ligniperda* (LATREILLE, 1802)	E		+
31.	*Camponotus piceus* (LEACH, 1825)	MD	+	+
32.	*Camponotus fallax* (NYLANDER, 1856)	ES	+	+
33.	*Camponotus truncates* (SPINOLA, 1808)	EC	+	
34.	*Prenolepis nitens* (MAYR, 1853)	Pont	+	
35.	*Lasius niger* (LINNAEUS, 1758)	H	+	+
36.	*Lasius platythorax* SEIFERT, 1991	NP?	+	+
37.	*Lasius brunneus* (LATREILLE, 1798)	EC	+	+
38.	*Lasius alienus* (FOERSTER, 1850)	H	+	+
39.	*Lasius paralienus* SEIFERT, 1992	E	+	+
40.	*Lasius psammophilus* SEIFERT, 1992	E	+	
41.	*Lasius flavus* (FABRICIUS, 1782)	H	+	+
42.	*Lasius citrinus* EMERY, 1922	SP	+	+
43.	*Lasius balcanicus* SEIFERT, 1988	?	+	
44.	*Lasius fuliginosus* (LATREILLE, 1798)	AP	+	+
45.	*Formica fusca* LINNAEUS, 1758	NP	+	+
46.	*Formica cinerea* MAYR, 1853	EC	+	+
47.	*Formica rufibarbis* FABRICIUS, 1793	ES	+	+
48.	*Formica cunicularia* LATREILLE, 1798	EC	+	+
49.	*Formica gagates* LATREILLE, 1798	SP	+	+
50.	*Formica pratensis* RETZIUS, 1783	SP	+	+
51.	*Formica rufa* LINNAEUS, 1761	NP	+	+
52.	*Formica sanguinea* LATREILLE, 1798	SP	+	+
53.	*Polyergus rufescens* (LATREILLE, 1798)	EC	+	+
54.	*Cataglyphis nodus* (BRULLÉ, 1832)	St		+



Figs. 2 - 4: Zoogeographical structure of the ants, based on frequency of occurrence of species, of (2) all sites of the studied region, (3) the sites in the urban area, and (4) the sites in the non-urban area. BM – Boreo-Montane; NP – North-Transpalaearctic; H – Holarctic; AP – Amphipalaearctic; E – European; ES – Euro-Siberian s.str.; EC – Euro-Caucasian; CE – Central-European; SP – South-Transpalaearctic; St – Eurasian steppe; Pont – Pontic; MD – Mediterranean s.str.

Tab. 2: Species with significant differences between their frequencies of occurrence in urban and non-urban areas.

Species	**Zoogeographical element**	**Frequency of occurrence in Sofia**	**Frequency of occurrence in vicinity**	**P-level of differences**
Camponotus aethiops	Mediterranean s.str.	0	37.5	0.0000
Camponotus ligniperda	European	0	37.5	0.0000
Camponotus piceus	Mediterranean s.str.	1.78	37.5	0.0003
Messor structor	Mediterranean s str.	0	25.0	0.0003
Formica rufa	North-Transpalaearctic	0	25.0	0.0003
Plagiolepis taurica	Eurasian steppe	0	25.0	0.0003
Cataglyphis nodus	Eurasian steppe	0	25.0	0.0003
Myrmica schencki	Holarctic	5.40	37.5	0.0035
Formica sanguinea	South-Transpalaearctic	1.78	25.0	0.0050
Formica gagates	South-Transpalaearctic	0	12.5	0.0085
Myrmica sulcinodis	Boreo-Montane	0	12.5	0.0098
Lasius citrinus	South-Transpalaearctic	19.60	62.5	0.0102
Formica pratensis	South-Transpalaearctic	8.90	37.5	0.0242

Results and discussion

The number of species found in the studied region is 54 (Tab. 1). Among them 44 (81 %) belong to the Euro-Siberian complex, 8 (15 %) to the Mediterranean complex and the zoogeographical status of 2 species (4 %) was not properly identified (Fig. 2).

Within the Euro-Siberian complex, the highest percentages (by number of species) are represented by Euro-Siberian s.str. (16 %), Euro-Caucasian (14 %) and Holarctic (13 %) elements. The other categories of the same complex are represented by less than 4 species (7 %, Fig. 2). There are only 8 (15 %) Mediterranean s.str. species. Considering that the total percentage of Mediterranean ant species in Bulgaria is 34.3% (ATANASSOV & DLUSSKY 1992), the percentage of this group is relatively low in our study area. The small share of Mediterranean species is probably caused by the relatively high altitude of the city of Sofia situated in a kettle surrounded by mountains.

We counted the frequency of occurrence of each species for the urban and non-urban sites separately. On that basis we summarized the percentage share of the zoogeographical categories for the urban and non-urban areas separately. The share of the Holarctic species is almost twice as high in the urban area (39 %) in comparison to the non-urban area (19 %), which is illustrated by Figures 3 and 4. Also Euro-Caucasian elements are more frequent in urban (24 %) compared to non-urban sites (15 %). Figure 3 shows the uneven representation of the particular zoogeographical categories in the urban area while in Figure 4, non-urban area, the proportions are relatively balanced. The most widespread Holarctic species in Sofia that are more frequent in urban than in non-urban sites are *Tetramorium* cf. *caespitum* (LINNAEUS, 1758) (77 % frequency of occurrence in urban and 62 % in non-urban sites) and *Lasius niger* (LINNAEUS, 1758) (66 % in urban and 50 % in non-urban zone). Euro-Caucasian species with higher frequency of occurrence in the urban than in the non-urban zone are: *Formica cinerea* MAYR, 1853 (61 % in urban and 50 % in non-urban zone), *Temnothorax affinis* (MAYR, 1855) (11 % in urban and 0 % in non-urban zone) and *Stenamma debile* (FOERSTER, 1850) (5 % in the urban and 0 % in the non-urban zone). Hence, the most widespread species represent the bulk of the myrmecofauna in the urban area. This assertion is in accordance with other similar studies on urban myrmecofaunas (PISARSKI & KUĹESZA 1982, VEPSÄLÄINEN & PISARSKI 1982, PISARSKI & CZECHOWSKI 1987, KLAUSNITZER 1990).

Among all species, only thirteen have statistically significant differences in their frequency of occurrence (Tab. 2). We may conclude that the share of these thirteen species decreases in – and some are even absent from – the urban area. All South-Transpalaearctic, Eurasian steppe and Boreo-Montane species found in the studied region are more abundant in the non-urban area. Among the other zoogeographical categories only single species differ in their frequencies of occurrence (3 Mediterranean, 1 North-Transpalaearctic, 1 Holarctic and 1 European species). Thus, the species mentioned in Table 2 may be considered as indicators for the non-urban zones in the studied region. They show a weak tolerance to urban pressure.

We may conclude that the prevalence of widespread Holarctic species in the urban area may serve as indicator of urban pressure. Most of these species can be characterized by wide ecological tolerance and this may explain their prevalence in almost all urban habitats. The small share or the absence of South-Transpalaearctic, Eurasian steppe and Boreo-Montane elements may be also a consequence for urban pressure. Thus, the zoogeographical structure may be used for purposes of bioindication. Further studies in regions with similar climate conditions are needed to strengthen this evidence.

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Zusammenfassung

Zoogeographische Aspekte der Ameisenfauna der Region Sofia werden behandelt. Insbesondere werden urbane und nicht-urbane Lebensräume verglichen. Der Anteil weitverbreiteter holarktischer Arten war in den urbanen Lebensräumen doppelt so groß wie in den nicht-urbanen. Desgleichen waren euro-kaukasische Elemente in der urbanen Zone gut vertreten. Hingegen ist der Anteil süd-transpaläarktischer, eurasischer Steppen- und boreo-montaner Elemente in der urbanen Zone niedrig, oder diese Elemente fehlen hier völlig.

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