

Classification of Ant Assemblages (Hymenoptera: Formicidae) in Green Areas of Sofia

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Abstract: The myrmecofauna of the green areas in Sofia City was extensively sampled by qualitative and quantitative methods to assess spatial variation in species composition of ant assemblages. The cluster analysis of the assemblages based on presence/absence data resulted in grouping into two main clusters: woody and open habitats. The assemblages of the open areas further divided into two groups: grassy habitats and artificial biotopes (asphalt coverings and agricultural land). Most of the assemblages in open areas clearly demonstrated the impact of urbanization by grouping into three main zones depending on the distance from the city centre: central, peripheral and rural.

Key words: ants, urban ecology, communities, cluster analyses

Introduction

The urban myrmecofauna in Europe is well studied in several cities: Warsaw (PISARSKI, CZECHOWSKI 1978, 1987, PISARSKI 1982, CZECHOWSKI ET AL. 1990, CZECHOWSKI, PISARSKI 1990, CZECHOWSKI 1991), Espoo (VEPSÄLÄINEN, WUORENRIINNE 1978), Liege (GASPAR, THIRION 1978), Garraf (Barcelona) (RESTREPO *et al.* 1985), Leipzig (RICHTER *et al.* 1986), Köln (LIPPKE, CÖLLN 1991, BEHR *et al.* 1996), Gönnersdorf (BEHR, CÖLLN 1993), Mainz (DAUBER 1995, 1997, DAUBER, EISENBEIS 1997), Wien (SCHLICK-STEINER, STEINER 1999), Linz (AMBACH 1999). The ants of Sofia have not been studied extensively so far. The first paper dealing with the species composition of the ants of Sofia was published by LAPEVA-GJONOVA, ATANASOVA (2004), and followed by a paper by ANTONOVA, PENEV (2006). ANTONOVA (2004) published some data on interspecific relations in ants.

Most of the ecological characteristics of a big city vary in a directional way from the periphery to the city center, thus forming the so-called “urban-

to-rural” gradient (KLAUSNITZER 1990). Further, the concept of “urban-to-rural” gradient was developed by McDONNELL, PICKET (1990), and as soil and litter invertebrates were concerned, this concept was extensively applied in the international project GLOBENET (NIEMELÄ *et al.* 2000). Urban-to-rural changes in species composition and assemblages in the framework of GLOBENET were studied on carabid beetles (NIEMELÄ *et al.* 2000, NIEMELÄ *et al.* 2002, VENN *et al.* 2003, STOYANOV, PENEV 2004), spiders and carabid beetles (ALARUIKKA *et al.* 2002), opilionids (MITOV, STOYANOV 2004), mollusks (DEDOV, PENEV 2004).

The paradigm of the urban-to rural gradient assumes that complex changes in biotic communities along the gradient may be demonstrated by particular components of the biota (for example community characteristics of various taxonomic groups) (McDONNELL *et al.* 1997 and McINTYRE 2000). Such an approach was applied in Sofia GLOBENET project

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which was extended from studies on ground beetles to several other groups of soil mesofauna, including ants (PENEV *et al.* 2004).

In this study we investigate how species compositions of ant assemblages of various habitats within the urban landscape of Sofia vary in space. We discuss the possibility of using some of the species as indicators for urban pressure in grasslands and forests.

Material and Methods

Study Area

The city of Sofia is situated on an average at 550 m a. s. l., the mean annual temperature is around 10.20 C and the mean annual rainfall (for the period 1987-1996) is around 560 mm (KOVACHEV 2005). The urban area covers approximately 220 km². 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 to the border between temperate and Sub-Mediterranean climates (ca. 120 km North).

Fifty-six of the sampling sites were situated in the urban greenery: wooded and open areas in the parks, green yards, along transport corridors and streets (25 of them, sampled by quantitative and qualitative methods, are shown on Fig. 2). Another eight localities were sampled in the vicinity of Sofia, at the foothills of Vitosha, Lyulin and Lozen mountains. The rural sites were situated not higher than 150 m above the average altitude of the city with distance up to 10 km from the city ring road (3 of them, sampled by quantitative and qualitative methods, are shown on Fig. 2).

In Sofia, forest localities were situated within the Sofia GLOBENET sites described by PENEV *et al.* (2004). The origin of the plant communities is mostly artificial. Most of the sites are situated in oak forests (50-90 years old) with prevalence of the introduced mesophilous Red Oak (*Quercus rubra* L.) (formation *Querceta rubrae*). The sites in open 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., *Plantago* spp. Similar plant communities were chosen around the city, in rural regions.

The material for the present study was collected in 2003-2005. It is preserved in the collection of V. Antonova in CLGE-BAS.

We used a direct sampling method (BESTELMEYER *et al.* 2000) to collect ants. The species were determined after ATANASSOV, DLUSSKY (1992), SEIFERT (1996) and CZECHOWSKI *et al.* (2002).

The differences in ant assemblages were studied by agglomerative and disjunctive clustering methods using BIODIV (BAEV, PENEV 1993) and TWINSpan (HILL 1979, JONGMAN *et al.* 1987) software. The agglomerative clustering method was performed on the basis of the similarity index of Czekanowski-Dice-Sørensen and Unweighted Pair-Group Method using arithmetical averages UPGMA (SNEATH, SOKAL 1973).

Results and Discussion

The dendrogram resulting from the clustering of presence/absence data (Czekanowski-Dice-Sørensen similarity index) (Fig. 1) showed a clear distinction of two groups of ant assemblages at similarity about 17%, inhabiting woody and open habitats, respectively.

One of the main groups consisted mainly of meadows and the other one is formed by partly or fully wooded fragments. The meadow fragments further divide at about 42% similarity into two groups. The left group consists of the assemblages of fragments situated near the city ring road and the right one is formed by assemblages from the central parks.

In the right group, the sampling plot in North Park is separated at around 36% similarity. The rest of the sites form two clusters at around 37% similarity. One of them includes the forest parts of Borisova gradina Park (b1Q – b4Q) and Loven Park (eQ). The other one consists of the remaining ant assemblages in forest plots and the meadow sites in Borisova gradina Park (b1M), Central cemetery (cM), West Park (wM) and the yard of American college (yM). The highest similarity among the ant assemblages (over 85 %) is between I and IV fragment of Borisova gradina Park (b1Q and b4Q). The following pairs of assemblages of high similarity are those from Oborishte Park (oM) and City Garden (tM) (80%), Malashevtsi cemetery (mM) and Hilton hotel Park (hM) (80%).

Finally, it could be concluded that there are two main factors affecting spatial variation of ant com-

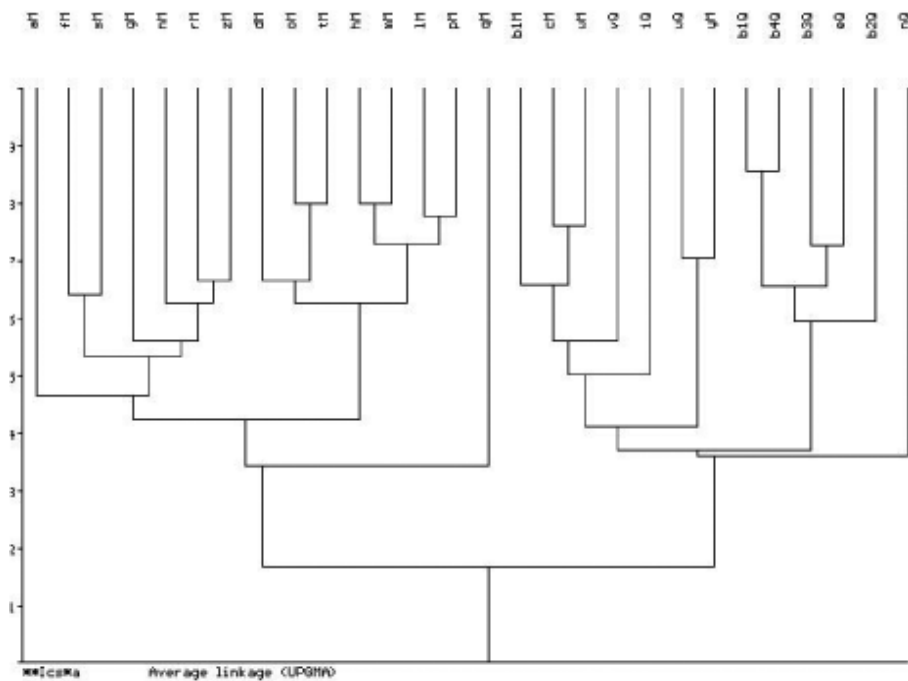


Fig. 1. Similarity of ant assemblages by fragments (Czekanowski-Dice-Sørensen index of similarity, qualitative data). Legend: M – meadows; Q – woods; w – West Park; b1 – Borisova gradina Park – fragment 1; b2 – Borisova gradina Park – fragment 2; b3 – Borisova gradina Park – fragment 3; b4 – Borisova gradina Park – fragment 4; s – South Park; n – North Park; d – Doktorska gradina Park; o – Oborishte Park; c – Central cemetery; m – Malashevtsi cemetery; r – Bakarena fabrika cemetery; t – City Garden; g – Geo Milev Park; z – Zoopark; f – yard of Bulgarian Academy of Sciences 7-th km; a – Sofia airport Park; p – St. St. Peter and Pavel Park; l – Soviet army monument; h – Park near hotel Hilton; e – Loven Park; y – yard of American college; q – near Passarel Village; i – near German monastery; v – near Vladaya Village.

munities in the city of Sofia and its surroundings: (1) type of habitat (open or woody) and (2) distance from the city centre. The latter is clearly demonstrated by the grouping of the meadow sites on the dendrogram (Fig 1) and is illustrated on Fig. 2. Three concentric zones exist around the city centre: central, peripheral and rural. The peripheral zone looks like a stripe of fragments within the city, situated near the ring road. The central urban zone encompasses sites situated concentrically at about 3, 5 km radius from the city centre (St. Nedelya Square).

Table 1 shows a table obtained by TWINSpan. The patterns of classification of assemblages are very similar to those revealed by the agglomerative clustering method (Fig. 1). The first division separated the ant assemblages into two groups: (1) the urban forest plots and (2) meadows and rural forest plots (Table 1). Again, the forest assemblages in Borisova gradina and Loven Park are separated from the others (North and West Park). The differences from the rural forest plots near Vladaya and German Monastery are higher, which reflects most probably the effect of

the higher altitudinal position of those sites. In contrast to forest assemblages, those from open areas do not show distinct separation in urban, suburban and rural zones, maybe due to the more even distribution of species composition in open habitats.

Indicator species for the forest areas are the following ant species: *Temnothorax nylanderi*, *Lasius platythorax* and *Myrmica ruginodis*, and for the meadows – *Formica rufibarbis* and *Tetramorium caespitum*. *Myrmica ruginodis* seems to be indicator species for the forest areas of Borisova gradina and Loven Park. For the meadow urban areas, indicator species are *Formica pratensis* and *F. cunicularia*, and for rural areas *Messor structor*, *Cataglyphis nodus*, *Camponotus aethiops* and *Plagiolepis tauricus*.

According to PÉTAL (1994), in case woody habitats are strongly disturbed, the ant communities are very similar to those in open areas. This might be the reason for close similarity of some of forest assemblages to those of meadows.

The main postulate of the concept of urban-to-rural gradient assumes that urbanization causes

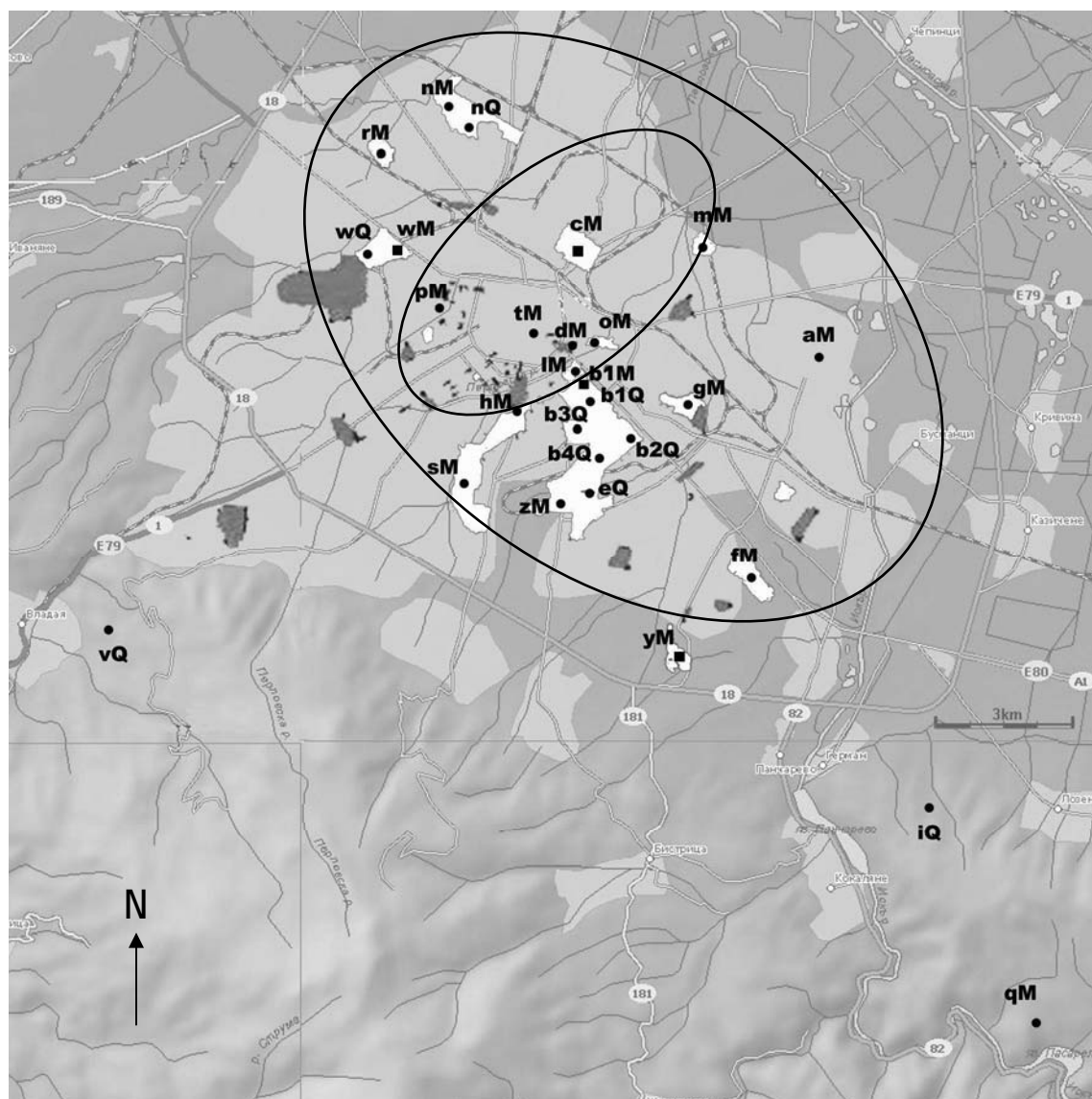


Fig. 2. Grouping of the meadows' ant communities into three main zones (central, peripheral and rural), according to the cluster analysis of faunistic similarity by qualitative data. (The communities in the plots marked with squares are grouped with the forest ones). Legend: M – meadows; Q – woods; w – West Park; b1 – Borisova gradina Park – fragment 1; b2 - Borisova gradina Park – fragment 2; b3 - Borisova gradina Park – fragment 3; b4 - Borisova gradina Park – fragment 4; s – South Park; n – North Park; d – Doktorska gradina Park; o – Oborishte Park; c – Central cemetery; m – Malashevtsi cemetery; r – Bakarena fabrika cemetery; t – City Garden; g – Geo Milev Park; z - Zoopark; f – yard of Bulgarian Academy of Sciences 7-th km; a – Sofia airport Park; p – St. St. Peter and Pavel Park; l – Soviet army monument; h – Park near hotel Hilton; e – Loven Park; y – yard of American college; q – near Passarel village; i – near German monastery; v – near Vladaya village.

gradual environmental changes (KLAUSNITZER 1990, MCDONNELL, PICKET 1990). They may be studied at different levels of biota, from the city center (urban zone) along their suburbs (suburban zone) to the natural habitats (rural zone). In the recent study we may conclude that urbanization leads to forming of specific “urban” ant assemblages within the city. The ant assemblages around the periphery of the city form a kind of transitional zone between the urban

and rural ones, which could be identified as “sub-urban” and are dominated by *Myrmica specioides*, *M. scabrinodis*, *Formica rufibarbis*, *Formica cunicularia*. The ant assemblages of the parks situated around 3, 5 km from the city centre form an “urban” group characterized by occurrence of several polytopic species: *Tetramorium caespitum*, *Lasius niger*, *Formica cinerea*, *Myrmica rugulosa* and *Solenopsis fugax*. The “rural” group of assemblages occurring

Table 1. TWINSPAN table of the ant communities by qualitative data.

SPECIES	fM	gM	qM	rM	dM	oM	tM	hM	IM	mM	pM	nM	zM	b1M	cM	sM	wM	aM	vQ	iQ	yM	b2Q	b1Q	b3Q	b4Q	eQ	nQ	wQ
<i>Temnothorax tuberum</i> (FABRICIUS, 1775)	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
<i>Temnothorax unifasciatus</i> (LATREILLE, 1798)	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	1	-	-	-	-	-	-	-	-
<i>Myrmica salina</i> RUZSKY, 1905	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-
<i>Myrmica sulcinodis</i> NYLANDER, 1846	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
<i>Camponotus vagus</i> (SCOPOLI, 1763)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
<i>Formica sanguinea</i> LATREILLE, 1798	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
<i>Formica rufa</i> LINNAEUS, 1761	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
<i>Myrmica lonae</i> FINZI, 1926	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
<i>Camponotus ligniperda</i> (LATREILLE, 1802)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
<i>Lasius citrinus</i> EMERY, 1922	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	1	1	1	1	-	-	-	-	-	-	-	-
<i>Formica gagates</i> LATREILLE, 1798	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
<i>Myrmica schencki</i> VIERECK, 1903	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	1	-	1	-	-	-	-	-	-	-	-
<i>Tapinoma erraticum</i> (LATREILLE, 1798)	-	-	-	-	-	-	-	-	-	1	-	-	1	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-
<i>Ponera coarctata</i> (LATREILLE, 1802)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Tetramorium hungaricum</i> RÖSZLER, 1935	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Tetramorium moravicum</i> KRATOCHVIL, 1941	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
<i>Camponotus truncatus</i> (SPINOLA, 1808)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Myrmica rugulosocabrinodis</i> KARAWAJEW, 1929	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Lasius psammophilus</i> SEIFERT, 1992	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Myrmica specioides</i> BONDROIT, 1918	1	1	-	1	-	-	-	1	-	-	-	1	1	1	1	1	1	1	1	-	1	-	-	-	-	-	-	1
<i>Tetramorium caespitum</i> (LINNAEUS, 1758)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>Solenopsis fugax</i> (LATREILLE, 1798)	-	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	-	-	-	-	-	-
<i>Plagiolepis pygmaea</i> (LATREILLE, 1798)	1	1	-	-	-	-	-	-	1	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Formica cinerea</i> MAYR, 1853	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>Formica rufibarbis</i> FABRICIUS, 1793	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>Plagiolepis taurica</i> SANTSCHI, 1920	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Messor structor</i> (LATREILLE, 1798)	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

in the vicinity of the city, outside the city ring road, is dominated mainly by *Messor structor* and *Formica pratensis*.

The urban ant communities are divided into two other groups. One of them includes the fragments in Borisova gradina and Loven Park, and the other - North and West Park. Probably, the division is due to the geographical closeness of the parks of the particular group, as well as the possible different sources for colonization (in the first group – Lyulin and Stara Planina mountains, and in the other Vitosha Mountain).

Our results confirm some earlier conclusions made on mollusks, which also show clearly defined

urban assemblages (DEDOV, PENEV 2004). Similarly, ground beetles demonstrated specificity of the urban sites, but did not confirm presence of transitional “suburban” area (STOYANOV, PENEV 2004). Suburban zone was proved to exist in forest ant assemblages, but not so clearly in open areas. This fact reinforces the necessity to study urbanization pattern on the basis of different taxonomic groups of various life strategies.

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Класификация на съобществата от мравки (Hymenoptera: Formicidae) в зелените площи на София

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(Резюме)

Проучена е мирмекофауната в зелените площи на град София на базата на качествени и количествени сборове. Направени са клъстерни анализи на проучваните паркови фрагменти и биотопи, за да се проследи групирането на съобществата по качествено фаунистично сходство. Става ясно, че парковите фрагменти се разделят на две главни групи при фаунистично сходство около 17% – горски и открити. Съобществата на откритите биотопи от своя страна се разделят също на две при около 38% сходство – тревни пространства и изкуствени биотопи (каменни настилки и обработваеми площи). Отчетено е групирането на по-голямата част от тревните съобщества в три главни зони в зависимост от разстоянието си до центъра: централна, периферна и извънградска.