CHANGES IN CARABID COMMUNITIES (INSECTA: COLEOPTERA) ALONG AN URBANIZATION GRADIENT IN MADRID (SPAIN)

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Abstract. The Carabids were pitfall-trapped in Madrid in 43 sites in the city interior and in its surroundings from late June to early August 1986. Altogether 78 species were recorded. They represented 6.7% of the Carabid fauna of the Iberian Peninsula. The communities consisted exclusively of small or medium sized species. There was not recorded any species of the genus *Carabus* in the city interior in spite of the fact that there exist very extensive areas of seminatural vegetation like the Casa de Campo park. However, their absence in the material from such places could result just from the fact that the sampling took place in the warmest and driest part of the year. Unlike cities in other areas, the Carabid communities of Madrid consisted of a considerable portion of West Mediterranean species or even of the Iberian endemics like *Calathus granatensis.* In contrast, in the city interior, especially in watered grassy plots, an obvious convergence to the fauna of Central European cities and, at a more general level, even to the East Asian cities was observed. The species of larger distributional areas prevailed there. The communities in the seminatural habitats showed very low diversity indices, similarly as in the analogous habitats in Central Europe. In seminatural habitats a considerable portion of highly specialized granivorous species of the genera *Ditomus, Carterus* and *Acinopus* was recorded.

Keywords: Coleoptera, Carabidae, urban fauna, Madrid, ecology, zoogeography.

Rezumat. Cenozele carabidelor (Insecta: Coleoptera) oraşului Madrid. Carabidele au fost colectate cu capcane de sol în 43 localităţi în centrul oraşului şi în zonele periurbane începând cu ultima decadă a lunii iunie până la începutul lunii august 1986. În total au fost găsite 78 de specii care reprezintă 6,7% din fauna carabidelor peninsulei Iberice. Cenozele constau exclusiv din specii de talie mică sau medie. În centrul oraşului nu au fost găsite specii ale genului *Carabus* chiar dacă acolo există mari suprafeţe de vegetaţie seminaturală precum parcul Casa de Campo. Absenţa acestor specii în materialul din acest tip de ecosisteme poate rezulta din faptul că toate colectările au avut loc în perioadă cea mai caldă şi uscată a anului. Spre deosebire de oraşele din celelalte regiuni biogeografice, fauna Madridului constă în mare parte din specii vest mediteranee şi chiar de specii iberice endemice precum *Calathus granatensis*. Spre deosebire de aceasta, în centrul oraşului, în mod special în pajiştile irigate, fauna carabidelor manifestă o convergenţă la fauna oraşelor din Europa centrală şi, la un nivel mai general, chiar la fauna oraşelor din Asia răsăriteană. În aceste localităţi au dominat speciile cu mari areale de distribuţie geografică. Cenozele din locurile seminaturale aveau valorile indicilor de diversitate scăzute, asemănător cenozelor din localităţile analoage din oraşele central europene. În localităţile seminaturale o mare parte a cenozelor a constat din specii puternic specializate granivore din genurile *Ditomus, Carterus* şi *Acinopus*.

Cuvinte cheie: coleoptere, Carabidae, faună urbană, Madrid, ecologie, zoogeografie.

INTRODUCTION

Large cities represent a highly variable mosaic of habitats ranging sometimes even from almost natural habitats to the s.c. asphalt desert, without any vegetation. In some abandoned sites, some habitats may reach a considerably advanced succession stage toward the climax state, whereas other habitats in their close vicinity are exposed to frequent destructive anthropogenic interventions. At the same time, the ecosystems in cities are continuously subjected to a climatic regime which considerably differs by higher temperatures when comparing with the surroundings (QUITT, 1983). The species composition in concrete sites depends on immigration possibilities from the city surrounding, historical development of each site, existence of biocorridors, size of the site, state of the biota in the immediate surroundings of the city. In general, the concepts of island biogeography can be applied on the rules determining the state and forming of the biocoenoses. In the recent three decades the ecology of large cities becomes an intensively studied topic with a great practical significance (NIEMELÄ *et al*., 2011).

Although the first observations on the influence of anthropogenic factors (electric illumination), on occurrence of Carabids in human settlements were published by DELAHON (1931), the animal and, in particular, the Carabid communities in urban ecosystems were systematically investigated since 1970-s, especially in West and Central Europe. There exist studies from London (DAVIS, 1978), Birmingham (SMALL *et al.*, 2003, 2006), Kiel (TOPP, 1972), West Berlin (GOSPODAR, 1981, GOSPODAR & SCHLÜTTER, 1982), Leipzig (KLAUSNITZER & RICHTER, 1980. KLAUSNITZER *et al*., 1980), Warsaw (CZECHOWSKI, 1980a, 1980b, 1981a, 1981b, 1982), Brno (ŠUSTEK, 1979, 1980, 1984, ŠUSTEK & VAŠÁTKO, 1983a, 1983b), Bratislava (ŠUSTEK, 1984, 1987, 1999a, 2002), Moscow (DUSHENKOV, 1983) and in Scandinavia (ALARUIKKA *et al*., 2002, VENN *et al*., 2003). In other parts of the world such studies are scarce and have only an orientation character (ŠUSTEK 2011).

Probably the first paper on insect fauna of Madrid, written however from purely practical viewpoint of plant protection, was published already in 1834 (SANGÜESA, 1834). But the systematic interest in the study of its fauna began as late as by the turn of the 20th and the 21th centuries, when the first ecological papers were published on the avian fauna in the parks of Madrid (FERNANDEZ-JURICIC, 2000, 2001, 2004, FERNANDEZ-JURICIC *et al*., 2001), on Hymenoptera (MARTÍNEZ *et al*., 1997, NIEVES & LOBO 2006) and Diptera (SORIANO O. & COBO 2006). Recently, a general characteristic of arthropod and beetle fauna of Madrid and its surroundings (Comunidad de Madrid) was published (GONZÁLEZ-GRANADOS *et al.*, 2012a, 2012b), which lists five endangered species occurring there. However,

a special study on Carabid fauna of Madrid does not exist, only some data were published in a more general context by ŠUSTEK (1989). The papers on Carabid communities in different ecosystems in free landscape in Spain are also scarce and were published only recently (BAEHR, 1986, MONZÓ *et al*., 2005, TABOADA *et al.,* 2004) or deal with more general problems (JIMÉNEZ-VALVERDE & ORTUÑO, 2007).

The aim of this paper is to analyse the structure of Carabid communities in different habitats in Madrid and in its surroundings and to compare it with the analogic communities in other big cities.

MATERIAL AND METHODS

The material was collected during a two-month stage to Spain undertaken on the invitation of the Institute of Edaphology and Vegetal Biology of CISC (Instituto de Edafología y Biología Vegetal). The beetles were pitfall-trapped (plastic jars of 300 ml with 75 mm opening, filled with formalin). The number of traps in each site varied from one to six, depending on the site size (Tables 3, 4) and they were exposed 16-43 days. The exposition depended on time limits to install them after finding of suitable sites and to visit the sites for the last time before the stage end. The traps were emptied at least in three-day intervals, because of the strong evaporation of the fixing solution and to minimize damaging of traps by the public.

The sites were selected so that they represent the urbanization gradient from the surroundings to the very city centre and different modes of their use and management. Their selection was strongly limited by possibilities to control them frequently by walking.

The beetles were identified using mainly the keys by DE LA FUENTE Y MORALES (1927) and JEANNEL (1941-1942). The zoogeographical typification of species was made according to BURMEISTER (1939), HŮRKA (1996), JEANNEL (1941-1942), SERRANO *et al.* (2003). The characteristic of trophic relations was made according to SHAROVA (1981). The statistical evaluation of the material was made by means of the program PAST version 2,16 (HAMMER, 2012).

Study site specification

All sites studied were situated in the Meseta Central plain, in a moderately undulated terrain at altitudes of 550 – 650 m, the highest points reaching about 1,000 – 1,100 m. The climate (Table 1) is arid with maximum precipitation in November and December and minimum precipitation from June to August. The winters are cool, but the average temperatures do not fall below 0ºC, while summers are very hot and dry, the temperature reaching 40-42ºC by day. The potential natural vegetation consists of the evergreen holm oak (*Quercus ilex*) forests – "encinars", but the actual vegetation is strongly changed. The encinars are mostly very sparse or turned into low shrub stands (matorral), replaced with small artificially planted pine forests or arable land. The smaller water streams are mostly dried in summer. The herbage and grass vegetation becomes yellow by turn of June and July.

In the selection of reference sites, the material collected in the close Sierra de Guadarrama was intentionally omitted, because the forests studied consisted of the deciduous oaks and were note comparable with the vegetation in immediate surroundings of Madrid, although some species like *Carabus quadarramus* LA FERTÉ–SÉNECTÈRE, 1847 or *Carabus lusitanicus* FABRICIUS, 1801 dominant in these forests could be also expected in Madrid and in the encinar-like vegetation.

Table 1. Climatic characteristic of Madrid.
Tabel 1. Caracteristica climatică a oraşului Madrid.

1971 – 2000	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average / sum
Maximum temperature (°C)	9.7	12	15.7	17.5	21.4	26.9	31	30.7	26	19	13.4	10.1	19.4
Minimum temperature (°C)	2.6	3.7	5.6	7.2	10.7	15.1	18	18.2	15	10.2	6	3.8	9.7
Precipitation (mm)	37	35	26	47	52	25	15	10	28	49	56	56	436

The reference localities in free landscape

All sites were situated within distance of about 80 km from Madrid. In parentheses there are given abbreviations of their names used in the tables and diagrams.

- Manzanares el Real – a large water reservoir north of Madrid, altitude about 1,000 m:
  1. a flat shore of the water reservoir overgrown with a high stand of *Juncus* sp. (MMR),
  2. a pasture margin on a low terrace at the water reservoir shore (MRC),
  3. a small ash forest on the shores of the water reservoir (MRF),
- Monte de Campo – a locality about 80 km east of Madrid
  1. a sparse seminatural encinar (MCE),
  2. riverbed of a dry creek (MCA),
- Casa de Monte – farm a locality in the surroundings of Talavera de la Reína, about 80 km west-of Madrid
  1. a sparse seminatural encinar (CMF),
- Fuente la Higuera – a locality in the surroundings of Talavera de la Reína, about 80 km west of Madrid

1. a mattoral – a low dense stand of evergreen shrubs (FHM)
2. a wheat field (FHS)

- Aranjuez – town about 60 km south of Madrid (ACM)
  1 – a maize field on a canal of the Tejo river arm terrace close to the city

Figure 1. Position of localities study sites in centre of Madrid and at its margins. / Figura 1. Poziţia localităţilor şi a staţionarelor în centrul Madridului şi pe marginea oraşului.

Localities in suburban zone and in city interior (Figs. 1, 2)

Universidad Autónoma – a locality on the margin of Madrid preserving remnants of vegetation typical for the surrounding of Madrid:

1. a sparse ecinar (UAE)
2. bottom of a deep riverbed of dried creek with dense and high shrub vegetation (UAA)
3. a small pine stand (UAP)

Casa de Campo – originally a hunting area of the Spanish kings, transformed into an enormously large seminatural park (1,722 ha) on a moderately undulated terrain, situated in the western part of the city, close to the historical centre. On its major part, it preserves sparse tree vegetation consisting predominantly of sparse encinars and pine stands, locally with undergrowth of shrubs and matorral-like vegetation. Most of the area is covered by grassy or herbage vegetation. The park is intensively used for the short-time recreation, for which various facilities are build up in its southeastern corner, including an artificial lake and creek:

1. pine stand 1 (CCP1),
2. pine stand 2 (CCP2),
3. a matorral-like stand with grass (CCPN),
4. an encinar below the funicular (CCTE),
5. an encinar in the eastern part of the park (CCE1),
6. a stand of planes bellow the lake (CCPT)
7. ash stand under the artificial lake (CCA)
8. bank of a creek running from the lake (CCL),
9. bank of a dried creek (CCD),
10. a stand of planes bellow the lake (CCPT)
11. ash stand under the artificial lake (CCA)
12. bank of a creek running from the lake (CCL),
13. bank of a dried creek (CCD).

Figure 2. Details of position of localities study sites in centre of Madrid and at its margins (Google Earth). /
Figura 2. Poziţia detaliată a localităţilor şi a staţionarelor din centrul Madridului şi din marginea oraşului.(Google Earth).

Parque de Oeste – an about 30 ha large, intensively cultivated French park of a western slope at margin of the historical centre:

1. bank of an artificial creek, shadowed by trees (POC),
2. a watered grass plot with shrubs close to the creek (POC1),
3. a watered grass plot with shrubs (POW1),
4. a watered grass plot with shrubs (POW2).

Paseo del Prado – a watered grass plot in a little part at the Museo de Prado (PPR).

Parque de Retiro – a 77 ha large park in densely built-up part of the city, the surrounding building originate mostly from the turn of the 19th – 20th century, partly has character of a French and English park:

1. a grass plot (REG),
2. a shadowed grassless plot under trees (REN),
3. an abandoned, partly shadowed plot densely overgrown by umbellate plants (REU).

Serrano, Area of Centro de Investigaciónes Científicos, a park-like area of sparsely situated building of institutes in the modern part of the city with a high portion of the greenery:

1. a dry grass plot (SEG),
2. a watered grass plot (SEW2).

Maria de Mollina – a wide street in the modern part of the city, with narrow grassy strips dividing the traffic ways:

1. a watered grass plot (MOW),
2. a grassy strip at the road margin (MOR),
3. an old abandoned garden, probably after a demolished house (MOG),
4. a watered grass plot at the intersection of the Serrano and Maria Molina streets.

Avenida Americana – a wide four-way street in the modern part of the city, with mostly small strips of dry grassy vegetation at pavement margins or watered plots at residential buildings, in centre a large free area transformed into public park:

1. a ruderal plot at pavement margin (AAR1),
2. a ruderal plot at pavement margin (AAR2),
3. a dry grass margin (AAR),
4. a watered grassy plot (AAW1),
5. a watered grassy plot (AAW2).

Calle Velázquez – a small park at the crossing of this street with Calle de Padilla street, in the densely built-up Salamanca quarter with closed house blocks, mostly built up in the early 20th century:

1. a watered grassy plot under high trees (PSA).

Museo Municipal – a small square in front of the building of the museum in the densely built up historical centre of the city on the Fuencaral street, with narrow streets and almost absolute absence of greenery:

1. a small grassy plot in front of the museum (MUM).

RESULTS

The whole material consists of 7,460 individuals belonging to78 species (Tables 2-4) representing 6.7% of 1,158 species known from the Iberian Peninsula (SERRANO, 2003). Only few of them were really abundant or found simultaneously in more sites and, in addition, the more abundant species were very unequally distributed, being concentrated in one or two sites. Almost 70% of individuals belonged to the endemic *Calathus granatensis* present in 44% of sites. The second most abundant species was the expansive and tolerant open landscape species *Pseudoophonus rufipes* (11.3% of individuals, occurrence in 11.6% of sites). Most of its individuals were found in the maize field at Aranjuez taken as one of the reference localities (Table 3), while a small number of individuals was found also in Madrid centre. The third species was *Calathus fuscipes* (4.73% of individuals) present on 32.6% of sites, exclusively in Madrid. The fourth species was *Poecilus cupreus* (3.4% of individuals) occurring in 2 (4.6%) sites out of the city, particularly in the maize field at Aranjuez (Table 3). The fifth species was *Nebria brevicolis*, a characteristic species of moderately humid floodplain forests or urban parks in Central Europe (2.4% individuals) found in 13.9% of sites, in the humid, directly or indirectly or irrigated localities in Madrid. The sixth species was *Calathus mollis* (2.1% individuals) co-occurring mostly with *Calathus granatensis* in 11.6% of sites, mostly in the reference localities out of the city. These six species represented 93.8% of the material.

They were followed by 12 species, whose share in the entire material was low (0.13-0.55%, cumulative share 3.4%), but they occurred in a relatively large number of sites. In decreasing order of presence (Table 2) they were represented by *Trechus quadristriatus* (30.2%), *Acinopus picipes* (20.9%), *Amara aenea* (16.3%), *Ditomus capito, Ophonus puncticollis, Harpalus wagneri* (each 11.6%), *Ditomus sphaerocephalus, Harpalus distinguendus, Stenolophus teutonus, Microlestes abeilli, Microlestes seladon* and *Microlestes corticinus* (3% each). These species formed two groups. The first consisting of *Trechus quadristriatus, Amara aenea, Ophonus puncticollis* and *Harpalus distinguendus* was represented by widely distributed open landscape species. The second group consisting of *Ditomus capito, Ditomus sphaerocephalus, Microlestes abeilli* and *Microlestes seladon, Microlestes corticinus* included thermoxerophilous Mediterranean species. *Stenolophus teutonus* is a hydrophilous species of water table shores overgrown by reed, cattail of sedge.

Table 2. Survey of species found in Madrid and in reference localities in its surrounding, abbreviation of their names (A), characteristics of their geographical distribution (Z) and trophic relationships (T), number of individuals (N), dominance (D) and presence (P). / Tabel 2. Lista speciilor găsite în Madrid şi în localităţile de referinţă din împrejurimile oraşului: abrevierile numelor speciilor (A), caracteristica răspândirii geografice (Z) şi a relaţiilor trofice (T), numărul indivizilor (N), dominanţa (D) şi prezenţa (P).

Species	A	Z	T	N	D [%]	P [%]
Acinopus picipes (OLIVIER, 1795)	Apic	ME	P	23	0.31	20.93
Acinopus sabulosus (FABRICIUS, 1792)	Asab	WME	P	1	0.01	2.33
Acupalpus brunipes (STURM, 1825)	Abru	WP	P	2	0.03	2.33
Acupalpus exiguus DEJEAN, 1829	Aexi	WP	P	6	0.08	4.65
Agonum marginatum (LINAEUS, 1758)	Amar	WP	C	4	0.05	2.33
Agonum muelleri (HERBST, 1784)	Amue	ES	C	1	0.01	2.33
Agonum nigrum (DEJEAN, 1828)	Anig	WME	C	5	0.07	4.65
Agonum viridicupreum (GOEZE, 1777)	Avir	WP	C	1	0.01	2.33
Amara aenea (DE GEER, 1774)	Aean	PP	P	40	0.54	16.28
Amara apricaria (PAYKUL, 1790)	Aapr	H	P	1	0.01	2.33
Amara communis (PANZER, 1797)	Acom	TP	P	2	0.03	2.33
Amara familiaris (DUFTSCHMIDT, 1812)	Afam	TP	P	6	0.08	4.65
Amara rufipes DEJEAN, 1828	Arif	WE	P	4	0.05	4.65
Anchomenus dorsalis (PONTOPPIDAN, 1763)	Ador	ES	C	11	0.15	6.98
Anisodactylus hispanus PUEL, 1931	Ahis	IB	P	8	0.11	4.65
Anisodactylus nemorivagus (DUFTSCHMIDT, 1812)	Anem	WP	P	2	0.03	2.33
Badister bulatus (SCHRANK, 1798)	Bbul	H	C	3	0.04	2.33
Bembidion aeneum GERMAR, 1824)	Baen	WME	C	1	0.01	2.33
Bembidion biguttatum (FABRICIUS, 1779)	Bbig	ES	C	1	0.01	2.33
Bembidion guttula (FABRICIUS, 1792)	Bgut	WP	C	1	0.01	2.33
Bembidion lampros (HERBST, 1784)	Blam	H	C	1	0.01	2.33
Bembidion quadrimaculatum (LINAEUS, 1761)	Bqua	H	C	1	0.01	2.33
Bembidion tetracolum SAY, 1823	Btet	H	C	3	0.04	2.33
Calathus ambiguus (PAYKULL, 1790)	Camb	WP	C	7	0.09	4.65
Calathus circumscriptus GERMAR, 1824	Ccir	ME	C	1	0.01	2.33
Calathus fuscipes (GOEZE, 1777)	Cfus	WP	C	353	4.73	32.56
Calathus granatensis VUILLEFROY, 1866	Cgra	IB	C	5186	69.52	44.19
Calathus mollis (MARSHAM, 1802)	Cmol	ME	C	158	2.12	11.63
Calathus piceus (MARSHAM, 1802)	Cpic	WE	C	1	0.01	2.33
Carabus melancholicus FABRICIUS, 1798	Cmel	WME	C	5	0.07	4.65
Carterus cephalotes (DEJEAN, 1826)	Ccep	WME	G	1	0.01	2.33
Carterus cordatus (DEJEAN, 1825)	Ccor	WME	G	3	0.04	2.33
Carterus interceptus DEJEAN et BOISDUVAL, 1829	Cint	WME	G	1	0.01	2.33
Carterus microcephalus RAMBUR, 1837	Cmic	WME	G	14	0.19	6.98
Clivina fossor (LINNAEUS, 1758)	Cfos	E	C	4	0.05	2.33
Cymindis variolosa (FABRICIUS, 1794)	Cvar	ES	C	2	0.03	4.65
Diachromus germanus (LINNAEUS, 1758)	Dger	WP	P	9	0.12	6.98
Ditomus capito SERVILLE, 1821	Dcap	ME	G	22	0.29	11.63
Ditomus clypeatus (ROSSI, 1790)	Dcly	ME	G	1	0.01	2.33
Ditomus sphaerocephalus (OLIVIER, 1795)	Dsph	WME	G	23	0.31	9.3
Dromius bifasciatus (DEJEAN, 1825)	Dbif	ME	C	3	0.04	4.65
Drypta dentata (ROSSI, 1790)	Dden	SWP	C	1	0.01	2.33
Harpalus distinguendus (DUFTSCHMIDT, 1812)	Hdist	TP	P	26	0.35	9.3
Harpalus longicollis (RAMBUR, 1838)	Hlon	WE	P	1	0.01	2.33
Harpalus rotundatus (DEJEAN, 1826)	Hrot	WE	P	5	0.07	6.98
Harpalus rubripes (DUFTSCHMIDT, 1812)	Hrub	TP	P	1	0.01	2.33
Harpalus scaritides (STUMR, 1818)	Hsca	ME	P	2	0.03	2.33

Harpalus wagneri SCHAUMERBER, 1936	Hwag	IB	P	27	0.36	11.63
Chlaenius festivus (PANZER, 1796)	Cfes	SWP	C	2	0.03	2.33
Chlaenius variegatus (FOURCROY, 1785)	Cvar	WME	C	2	0.03	2.33
Masoreus wetterhali (GYLLENHAL, 1813)	Mwet	ME	C	1	0.01	2.33
Metophonus bonvouloiri VUILLEFROY, 1866	Mbon	WE	P	6	0.08	6.98
Microlestes abeilli BRISOUT, 1885	Mabe	WME	C	10	0.13	9.3
Microlestes corticalis (DUFOUR, 1820)	Mcor	WP	C	6	0.08	9.3
Microlestes negrita WOLASTON, 1854	Mneg	SWP	C	1	0.01	2.33
Microlestes seladon HOLDHAUS, 1812	Msel	WME	C	17	0.23	9.3
Nebria brevicollis (FABRICIUS, 1792)	Nbre	E	C	180	2.41	13.95
Nebria salina FAIRMAIRE et LABOULBENE, 1854)	Nsal	WE	C	1	0.01	2.33
Ophonus puncticollis (PAYKULL, 1798)	Opun	ES	P	12	0.16	11.63
Ophonus rufibarbis (FABRICIUS, 1792)	Oruf	WP	P	2	0.03	4.65
Paranchus albipes (FABRICIUS, 1796)	Palb	WP	C	7	0.09	6.98
Parophnus hispanus (RAMBUR, 1838)	Phis	WE	P	1	0.01	2.33
Parophnus mendax (ROSSI, 1790)	Pmen	ME	P	1	0.01	2.33
Poecilus distinctus(LUCAS, 1846)	Pdis	E	C	2	0.03	2.33
Poecilus cupreus (LINAEUS, 1758)	Pcup	TP	C	256	3.43	4.65
Poecilus kugelani (PANZER, 1797)	Pkug	WE	C	4	0.05	6.98
Pseudoophonus griseus (PANZER, 1797)	Pgri	TP	P	6	0.08	2.33
Pseudoophonus rufipes (DE GEER, 1774)	Pruf	ES	P	839	11.25	11.63
Pterostichus diligens (STURM, 1824)	Pdil	ES	C	1	0.01	2.33
Pterostichus globosus (FABRICIUS, 1792)	Pglo	WME	C	10	0.13	4.65
Pterostichus nigrita (PAYKULL, 1790)	Pnig	TP	C	13	0.17	4.65
Pterostichus vernalis (PANZER, 1796)	Pver	H	C	8	0.11	4.65
Siagona europea DEJEAN, 1826	Seur	WE	C	2	0.03	2.33
Stenolophus mixtus (HERBST, 1784)	Smix	WP	P	1	0.01	2.33
Stenolophus teutonus (SCHRANK, 1781)	Steu	WP	P	41	0.55	9.3
Syntomus foveolatus (DEJEAN, 1831)	Sfov	ES	C	4	0.05	6.98
Tachys bistriatus (DUFTSCHMIDT, 1812)	Tbis	WP	C	1	0.01	2.33
Trechus quadristriatus (SCHRANK, 1781)	Tqua	WP	C	38	0.51	30.23

Legend:
Geographic distribution: H – holarctic, TP – transpalaearctic, ES – Eurosiberian, WP – west palaearctic, SWP – south-west palaearctic, E – European, ME – Mediterranean, WME – west Mediterranean, IB – Iberian.
Trophic relations: C – carnivor, O – omnivor, G – granivor.
Legendă:
Răspândirea geografică: H – holarctică, TP – transpalearctică, ES – eurosiberiană, WP – vest palearctică, SWP – sud-vest palearctică, E – europeană, ME – mediteraneană, WME – vest mediteraneană, IB – iberică.
Relaţii trofice: C – carnivor, P – omnivor, G – granivor.

Table 3. Survey of species found in reference localities in surroundings of Madrid (arranged alphabetically). / Tabel 3. Lista speciilor găsite în localităţile de referinţa din împrejurimile Madridului (aranjate în ordinea alfabetică).

Species	Locality, habitat and their abbreviation											
	Manzanares Reales			Monte de Casa			Fuente de la Higuera		Aran-juez	Unidersidad Autónoma		
	shore (*Juncus*	pasture	ahs forest	encinar	encinar	low matirral	matorral	cereal field	maize field	encinar	dry riverbed	pine forests
	MRR	MRC	MRF	MCE	MCA	CMF	FHM	FHS	ACM	UAE	UAA	UAP
Acinopus picipes							1	7				
Acinopus sabulosus								1				
Acupalpus exiguus	5		1									

Agonum marginatum	4											
Agonum muelleri	1											
Agonum nigrum	3		2									
Agonum viridicupreum	1											
Amara communis									2			
Amara rufipes	3											
Anchomenus dorsalis			1						7			
Anisodactylus hispanus	7											
Bembidion aeneum			1									
Bembidion biguttatum			1									
Bembidion guttula			1									
Bembidion lampros	1											
Bembidion quadrimaculatum			1									
Bembidion tetracolum			3									
Calathus granatensis	1	1		232	1	7	495	1		7	1	22
Calathus mollis				73	4	3	77					
Calathus piceus	1											
Carabus melancholicus	3	2										
Carterus cephalotes						1						
Carterus cordatus						3						
Carterus interceptus						1						
Carterus microcephalus								1				
Clivina fossor			4									
Diachromus germanus	1		2									
Ditomus capito				7	1							
Dromius bifasciatus					1							2
Drypta dentata	1											
Harpalus distunguendus								22	1			
Harpalus longicollis								1				
Harpalus scaritides								2				
Harpalus wagneri					2		2					1
Chlaenius festivus	2											
Chlaenius variegatus	2											
Masoreus wetterhali				1								
Microlestes abeilli								2				
Microlestes seladon	1											
Nebria salina			1									
Ophonus puncticollis	2		7									
Paranchus albipes	2		4									
Parophnus mendax								1				
Poecilus distinctus								2				
Poecilus cupreus	1								255			
Poecilus kugelani	2	1										
Pseudoophonus griseus									6			
Pseudoophonus rufipes			1						819			
Pterostichus diligens			1									
Pterostichus globosus							5	5				
Pterostichus nigrita	7											
Pterostichus vernalis	6		2									
Stenolophus mixtus		1										
Stenolophus teutonus	13		1									
Syntomus foveolatus	2	1										
Tachys bistriatus	1											
Trechus quadristriatus			1	2	1					1	8	
Number of individuals	**73**	**6**	**35**	**315**	**10**	**15**	**580**	**45**	**1090**	**8**	**9**	**25**
Number of species	**25**	**5**	**18**	**5**	**6**	**5**	**5**	**11**	**6**	**2**	**2**	**3**
Number of traps	**4**	**2**	**3**	**4**	**3**	**3**	**3**	**3**	**10**	**6**	**4**	**10**
Days of exposition	**35**	**35**	**21**	**33**	**33**	**33**	**33**	**33**	**16**	**35**	**35**	**35**

Table 4. Survey of species found localities in center of Madrid (arranged alphabetically). / Tabel 4. Lista speciilor găsite în localităţile din centrul Madridului (aranjat în ordine alfabetică).

Species	Locality, habitat and their abbreviation																															
	Casa de Campoâ										Parque de Oeste				Parque de Retiro			Serrano		Maria Molina			Avenida Americana					Isolated sites			
	pine stans	pine stand	grass + shrubs	encinar	encinar	grass + planes	ash stand	creek bank	dry creek bank	creek banks	creek bank	watered grass	waterde grass	watered grass	grassless plot	grassless plot	Umbeliferes	dry grass	watered grass	watered grass	old garden	grassy margin	ruderal plot	ruderal plot	grassy margin	grassy plot	watered grass	watered grass	watered grass	watered grass	watered grass
	CCP1	CCP2	CCPN	CCTE	CCE1	CCPT	CCA	CCL	CCC	CCCD	POC	POC1	POW1	POW2	REG	REN	REU	SEG	SEW1	MOW	MOG	MOR	AAR1	AAR2	AAW1	AAR	AAW2	PSA	PPR	MUM	SEW2
Acinopus picipes	5	1	2		4	1	1	1																							
Acupalpus brunipes									2																						
Amara aenea	12				4	1												15	6			1					1				
Amara apricaria																							1								
Amara familiaris																		5	1												
Amara rufipes									1																						
Anchomenus dorsalis									3																						
Anisodactylus hispanus									1																						
Anisodactylus nemorivagus									2																						
Badister bulatus																	3														
Calathus ambiguus																							5	2							
Calathus circumscriptus																													1		
Calathus fuscipes	1				70	162	29	21	1				7	2	1		1	28	23				2	5							
Calathus granatensis	39	7	3	4	1550	2792	5			17							1														
Calathus mollis						1																									
Carterus microcephalus																							2	11							
Cymindis variolosa				1									1																		
Diachromus germanus									6																						
Ditomus capito			1												1		12														
Ditomus clypeatus																		1													
Ditomus sphaerocephalus	17	2	3			1																									
Harpalus distunguendus							1																	2							
Harpalus rotundatus	1		1	3																											
Harpalus rubripes													1																		
Harpalus wagneri	21				1																										
Metophonus bonvouloiri					1	4	1																								
Microlestes abeilli					1														1					6							
Microlestes corticalis						2	1											2	1												
Microlestes negrita																									1						
Microlestes seladon																							1	14	1						
Nebria brevicollis								22	2	3	122	30					1														

Ophonus puncticollis						1							1					1													
Ophonus rufibarbis					1														1												
Paranchus albipes									1																						
Parophnus hispanus					1																										
Poecilus kugelani																	1														
Pseudopophonus rufipes											2		5				12														
Pterostichus nigrita									6																						
Siagona europea				2																											
Stenolophus teutonus									26		1																				
Syntomus foveolatus							1																								
Trechus quadristriatus								12	2		1	1	1		2	1	5														
Number of individuals	**96**	**10**	**10**	**10**	**1633**	**2965**	**39**	**56**	**53**	**20**	**126**	**31**	**16**	**2**	**4**	**1**	**36**	**52**	**33**			**1**	**11**	**40**	**2**		**1**		**1**		
Number of species	**7**	**3**	**5**	**4**	**9**	**9**	**7**	**4**	**12**	**2**	**4**	**2**	**6**	**1**	**3**	**1**	**8**	**6**	**6**			**1**	**5**	**6**	**2**		**1**		**1**		
Days of trap exposition	**42**	**33**	**42**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**40**	**40**	**33**	**40**	**35**	**35**	**35**	**38**	**38**	**32**	**43**	**43**	**43**	**43**	**43**	**43**	**43**	**32**	**30**	**32**	**43**
Number of traps	**4**	**4**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**2**	**3**	**3**	**3**	**2**	**3**	**3**	**4**	**8**	**1**	**1**	**3**	**2**	**3**	**1**	**2**

The representation of these 19 species in individual sites predominantly decided about the differentiation of the Carabid communities studied. These species are also responsible for the trends in structural changes along the urbanization gradient studied. Almost one half (34) of the species was represented by only 1-2 individuals (Table 2). As such they contributed to a high heterogeneity of the material, but owing to their ecologic and zoogeographic properties they enhanced the specific character of the communities that was indicated by more abundant species in individual parts of the idealized urbanization gradient. In spite of the fact that the studied communities included many strongly xerophilous species, the Carabids did not penetrate to all sites in the very city centre. With the increasing degree of urbanization and decreasing size of the sites studied, they were gradually replaced by more mobile Staphylinids or by non-flying, but more thermoxerophilous and detritophagous Tenebrionids and/or Anthicids (Figs. 3, 4). It is illustrated by a free, moderately positive to slightly negative correlation of the qualitative representation of the Carabids with these three families (Staphylinids 0.29, Tenebrionids –0.06, Anthicids 0.53), and by a moderately negative correlation of their quantitative representation with these families (Staphylinids –0.11, Tenebrionids –0.21, Anthicids –0.15).

The number of species in individual reference sites ranged from 2 to 25, while the number of individuals from 6 to 1,090 (Table 3), with an obvious dependence on only increasing humidity (discontinuous *Juncetum* on lake shores in Manzanares el Real) or density of vegetation cover and humidity (maize field at a branch of the Tajo river at Aranjuez). There was a very low positive correlation between the number of individuals and the number of traps exposed (0.05) and between the number of traps and number of species (0.12). In the city interior, (except of three sites, where Carabids were absent) the number of species ranged from 1 to 12, again with dependence on increasing humidity (sites in vicinity of the lake in Casa de Campo), while the number of individuals from 1 to even 2,965 individuals (Table 4). This extreme fluctuation was caused by the extreme variability in activity abundance of the endemic *Calathus granatensis*, especially in several similar sites in Casa de Campo (3 –2,792 individuals). The number of species in individual sites would be doubtless much larger, when the sampling could be undertaken longer. Many species found only in one or few sites would be also recorded on other sites. The relatively low number of species recorded within the investigation is documented by a considerable speedy right side part of the areal curve (Fig. 5).

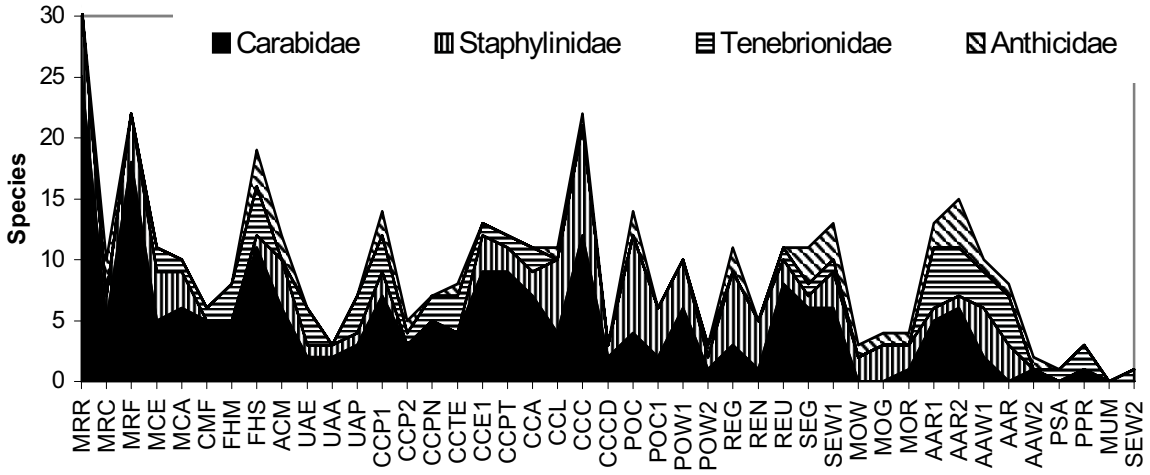

Figure 3. Relationship of number of species of Carabids, Staphylinids, Tenebrionids and Anthicids in Madrid and in references localities. / Figura 3. Relaţia numărului speciilor de Carabidae, Staphylinidae, Tenebrionidae şi Anthicidae din Madrid şi din localităţile de referinţă.

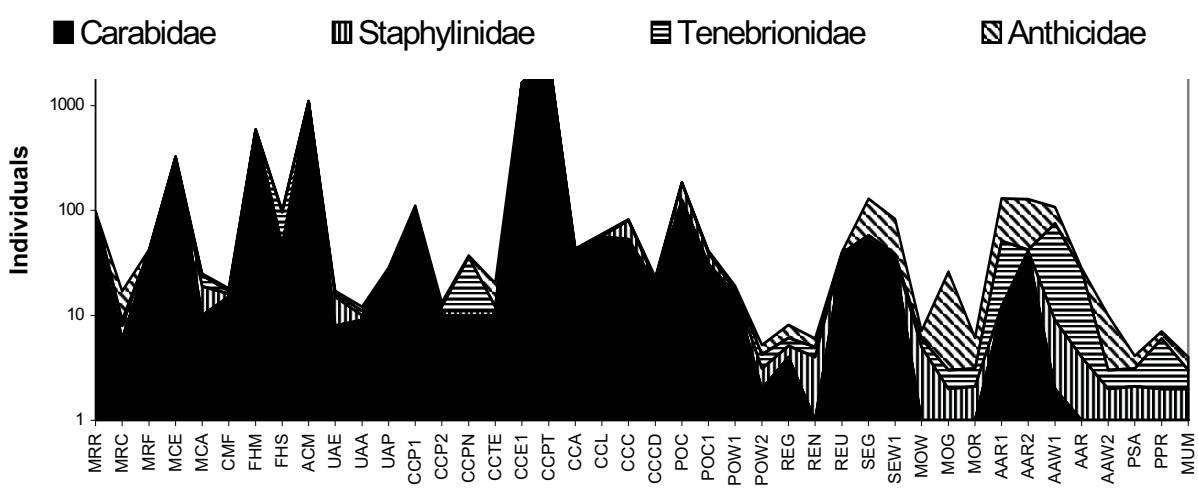

Figure 4. Relationship of number of individuals of Carabids, Staphylinids, Tenebrionids and Anthicids in Madrid and in references localities. / Figura 4. Relaţia numărului indivizilor de Carabidae, Staphylinidae, Tenebrionidae şi Anthicidae din Madrid şi din localităţile de referinţă.

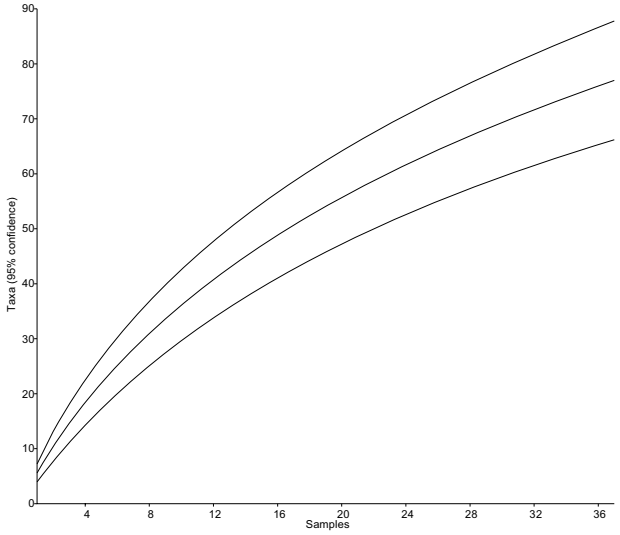

Figure 5. Areal curve of Carabids in 43 sites in Madrid and surroundings (only positive samples considered). / Figura 5. Curba de areal a carabidelor din 43 de locaţii din Madrid şi împrejurimi (luate în considerare numai probele pozitive).

The Shannon-Weawer diversity index ranged from 0.14 to 2.88 bits and equitability from 0.13 to 0.90 (Fig. 6). The highest values of the diversity index were recorded in the rich community from the *Juncetum* in Manzanares el Real. The lowest values of both parameters were observed in the sites with a strong predominance of one or two species. In the reference localities it was the maize field at Aranjuez (*Pseudoophonus rufipes* and *Poecilus cupreus*), in the centre of Madrid, the encinars and pine forests Universidad Autónoma and in Casa de Campo with predominance of *Calathus granatensis* and in Parque de Oeste with predominance of *Nebria brevicollis*. The low values of diversity index, but high values of equitability were recorded in the sites in city centre, where two species occurred in a very limited number of individuals. The high values of equitability coincided with the high values of diversity in the communities from Manzanares el Real.

The communities in the city consisted only of small or medium sized species in the length range of 2 – 18 mm. The only large species found in the reference localities was *Carabus melancholicus* in the shores of the lake in Manzanares el Real.

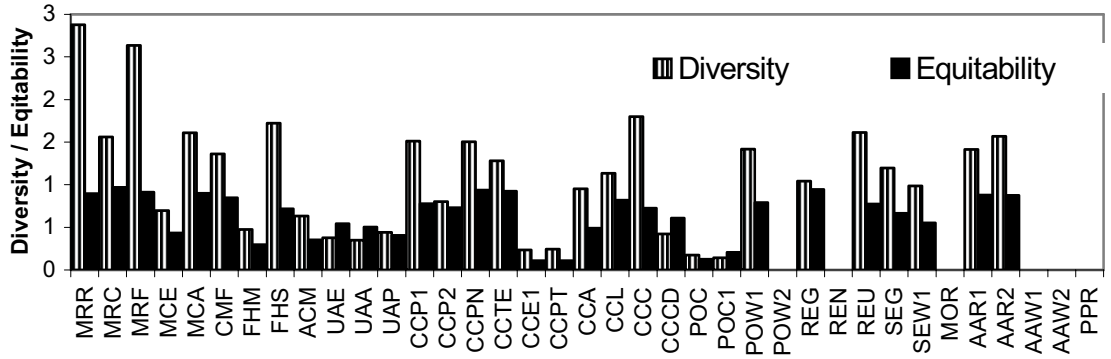

Figure 6. Diversity and equitability of 43 Carabid communities in Madrid and its surroundings (abbreviations of sites as in Tables 3 and 4). / Figura 6. Diversitatea şi echiitabilitatea celor 43 de cenoze de carabide din Madrid şi din împrejurimi (abrevierile locaţiilor ca în tabelele 3 şi 4).

Classification and ordination of communities

The hierarchical classification of the communities was made only on the base of Horn´s similarity index (Fig. 7) that reflects the proportional similarity of the communities and compensates the large difference in the catches size. In this way, it also compensated the great heterogeneity of the material. According to this index, the studied communities form five major clusters. One is characterized by co-dominance of two hydrophilous species, *Stenolophus teutonus* and *Diachromus germanus*, accompanied in individual sites by further hydrophilous species (*Agonum nigrum, Paranchus albipes).* This cluster includes communities from the reference locality Manzanares el Real and from the creek in Casa de Campo. The next four clusters arise owing to the predominance of one of the four species *Trechus quadristriatus, Calathus granatensis, Calathus fuscipes* or *Amara aenea.* With one exception (pasture margin in Manzanares el Real), they include communities from the city. In addition, there exist two outliers – the reference community from maize field with enormous predominance of *Pseudoophonus rufipes* and *Poecilus cupreus* and the community from Paseo del Prado consisting of a single individual of *Calathus fuscipes*.

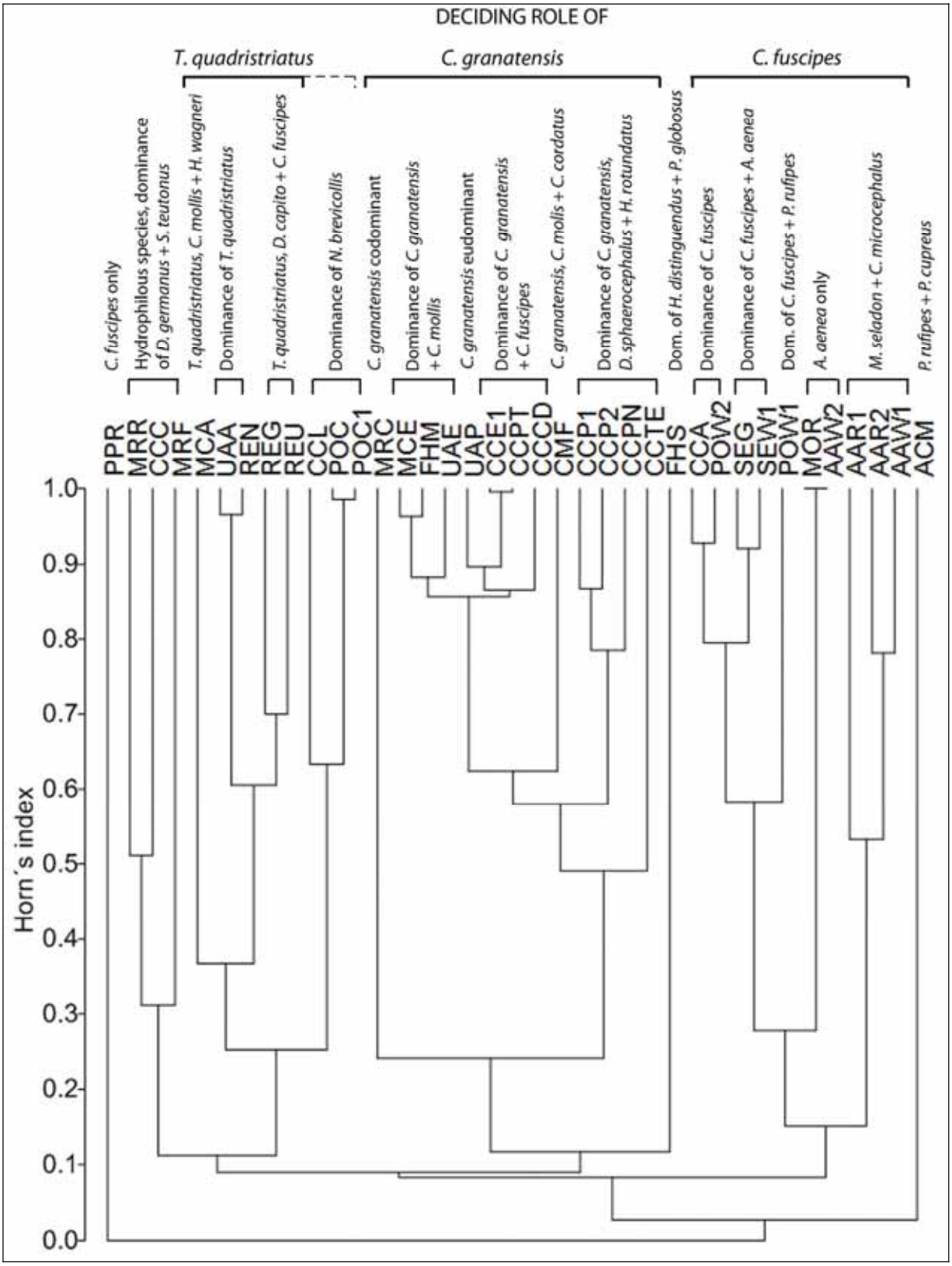

Figure 7. Hierarchical classification of Carabid communities using Horn's similarity index from Madrid and its surroundings (abbreviations of sites as in Table 3 and 4). / Figura 7. Clasificarea ierarhică a cenozelor de carabide din Madrid şi din împrejurimi după indicele lui Horn (abrevierile localţiilor ca în tabelele 3 şi 4).

The cluster with the predominance of *Trechus quadristriatus* consists of three subclusters arising due to dominance of *Trechus quadristriatu*s itself or due to its co-dominance with other species *Calathus mollis* + *Harpalus wagneri* or *Ditomus capito* + *Calathus fuscipes*. More freely these subclusters join a subcluster characterized by the predominance of the hygrophilous *Nebria brevicollis*, which also occurs as a subdominant or recedent species in other communities included in the major cluster characterized by the predominance of *Trechus quadristriatus*.

The cluster characterized by the predominance of *Calathus granatensis* consist of six subclusters of communities, in which this species is a single dominant species, or co-dominates with *Calathus mollis* or *Calathus fuscipes* or *Calathus molis* + *Carterus cordatus* or with several further species. Excepting the community from the pasture margin in Manzanares el Real, these communities are the seminatural communities from the city margin (Universidad Autónoma) or from Casa de Campo. At a very low similarity level of 0.12 this cluster joins with the community from wheat field in Fuente de Higuera with a dominance of the transpaleactical typical field species *Harpalus distinguendus* and the west Mediterranean *Pterostichus globosus* and the presence of *Calathus granatensis.*

The subcluster characterized by the predominance of *Calathus fuscipes* also consists of the communities dominated by this species itself or characterized by its co-dominance with *Pseudoophonus rufipes* or *Amara aenea* or the thermoxerophilous species *Carterus microcephalus* + *Microlestes seladon*. An isolated position is taken by a subcluster of the communities consisting of a single individual of *Amara aenea*. This subcluster joins to this cluster just due to the co-occurrence of *Amara aenea* with *Calathus fuscipes* in other communities. This cluster includes the communities from the very city centre and reflects the degree of watering of the grassy plots (co-occurrence of *Calathus fuscipes* with *Pseudophonus rufipes* or *Amara aenea*) or absence of watering (co-occurrence with *Carterus microcephalus* and *Microlestes seladon.*

It is obvious that if a longer lasting sampling can be carried out, many species would be found in more sites and the material would be more homogeneous. But the most abundant species deciding about the classification results would be probably the same and the results of classification would be similar in spite of a greater homogeneity.

The principle coordinate coordination ordination using Horn´s index (Fig. 8) shows clearly the arrangement of the communities according to the quantitative representation of the four deciding species, *Carabus granatensis, Calathus fuscipe, Trechus quadristriatus* and to certain degree also *Nebria brevicollis,* which are placed within the area of the communities dominated by *Trechus quadristriatus.* These groups correspond to the major clusters in the hierarchical classification. Between them, in the ordination space centre, the communities from the reference localities are placed. To certain degree, they take a position according to the representation of the abovementioned four species. The first axis (ordinate is interpretable as a humidity gradient increasing from left to right. The second axis has not a clear ecological interpretation.

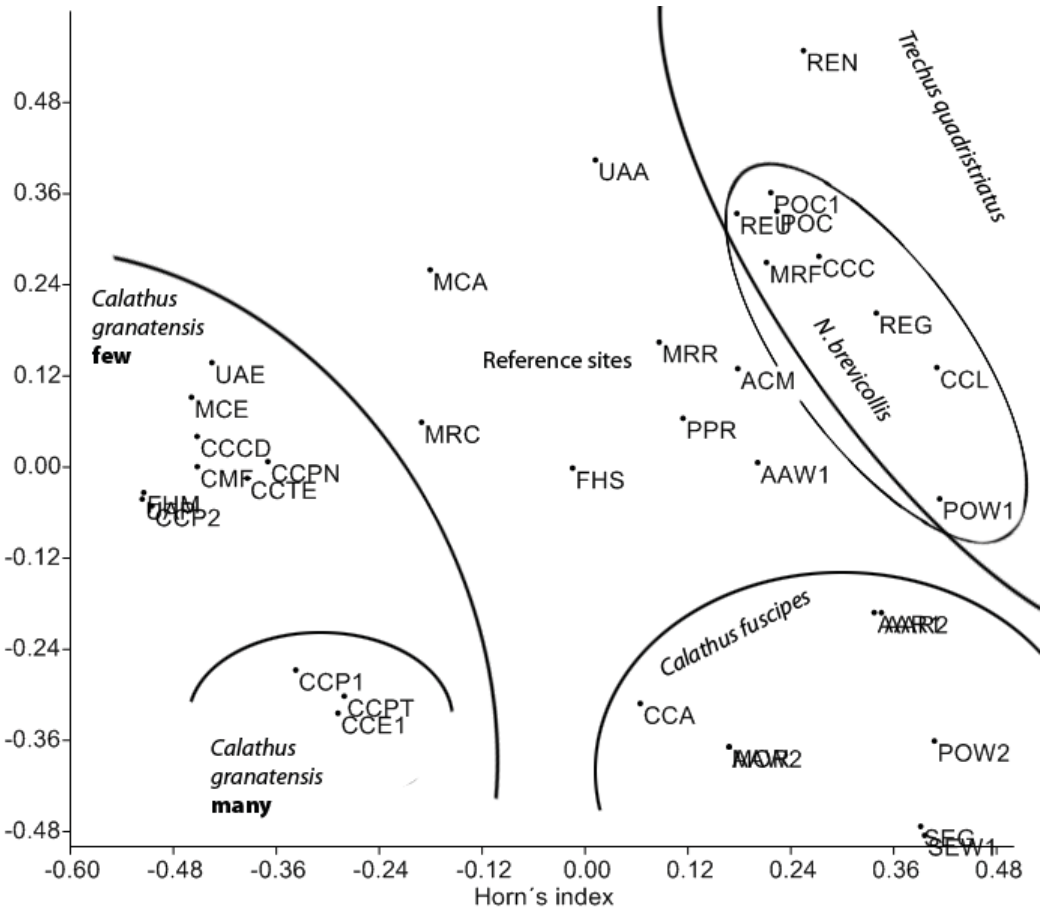

Figure 8. Principal coordinate ordination of Carabid communities from Madrid and its surroundings (abbreviations of sites as in Table 3 and 4). / Figura 8. Ordonarea după coordonata principală a cenozelor de carabide din Madrid şi din imprejurimi (abrevierile locaţiilor ca în tabelele 3 şi 4).

Basing on the above analyses, the sequence of communities along the urbanization gradient can be characterized as it follows. In the dry habitats of matorrals and encinars, the communities are characterized by the combination of predominant *Calathus granatensis* and less dominant *Calathus mollis*. The seminatural dry communities in city are characterized by the predominance of *Calathus granatensis* accompanied with gradually increasing proportion of *Calathus fuscipes*. The next stage of succession is characterized by continuing occurrence of *Calathus fuscipes* accompanied by *Trechus quadristriatus*, *Pseudoophonus rufipes*, *Amara aenea* or *Amara familiaris* and decline or absence of *Calathus granatensis.* Their absolute quantitative representation is low, but proportionally balanced. The final stages represent the sporadic occurrence of *Amara* spp. and of the xerophilous species of the genus *Microlestes* or even the absence of the Carabids. The second, but incompletely reconstructed succession series consists of the reference sites on the shores of stagnant or flowing waters with a rich species spectrum followed by the more or less naturally humid or artificially irrigated habitats with predominating *Nebria brevicollis*, accompanied by some hydrophilous, individually occurring species and *Calathus fuscipes*. These communities do not have a final stage in the most urbanized sites in the very city centre.

Trophic relations

As to the trophic relations, a tendency to decrease of the number of carnivorous species is obvious from the reference localities toward the city centre (Fig. 9). This tendency is more visible in the percentage of carnivorous, omnivorous and purely granivorous species (Fig. 10). A similar, bur not so expressive situation is the percentage of individuals belonging to one of these three trophic groups (Fig. 11). This general tendency is however not so expressive in the localities with increased humidity in the vicinity of the artificial lake in Casa de Campo and at the artificial water streams in Casa de Campo or Parque de Oeste, where *Nebria brevicollis* accompanied by some other hygrophilous species occurred (Figs. 9-11, Tables 3 -4). In the reference localities, as well as in some more xerophilous localities in the city interior (ruderal sites in Avenida Americana) an increased absolute or relative share of purely phytophagous or, more precisely said, specialized granivorous species of the genera *Ditomus, Carterus* or *Acinopus* increased. These species, however, were not found in the irrigated sites, where the species of the genus *Amara* tended to predominate or were the only Carabids found in these places (Fig. 11).

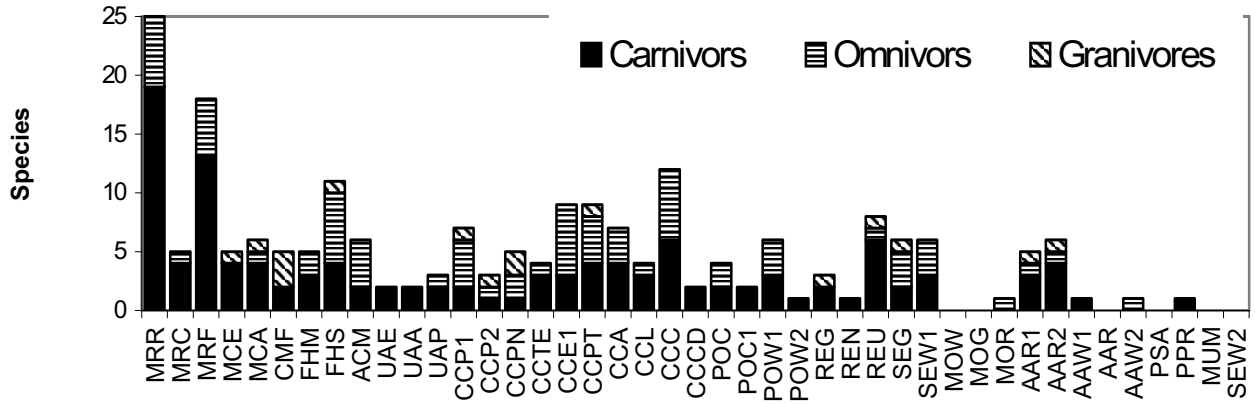

Figure 9. Number of species of three trophic groups of Carabids in Madrid and its surroundings (abbreviations of localities as in tables 3 and 4). / Figura 9. Numărul speciilor a trei grupe trofice de carabide din Madrid şi din împrejurimile lui (abrevierile localităţilor ca în tabelele 3 şi 4).

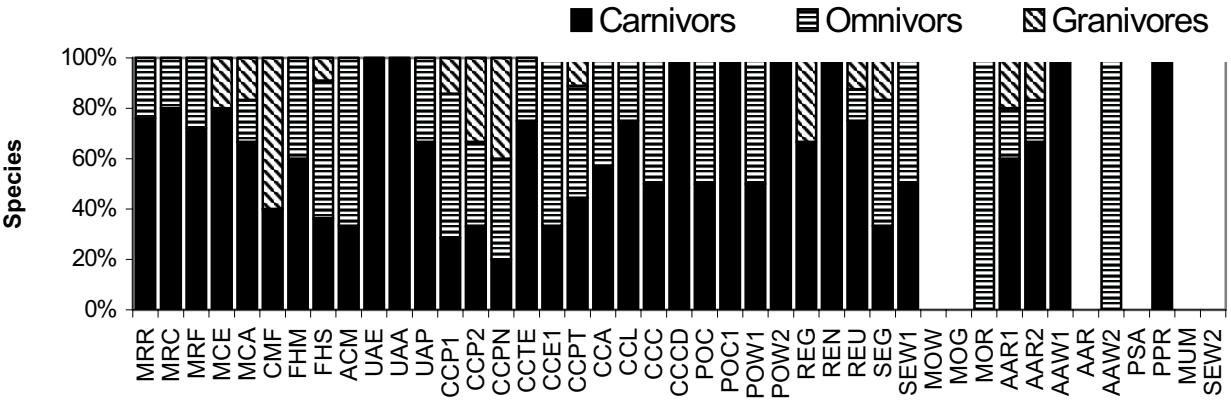

Figure 10. Relative representation (in %) of species of three trophic groups of Carabids in Madrid and its surroundings (abbreviations of localities as in tables 3 and 4). / Figura 10. Reprezentarea relativă (în%) a speciilor din trei grupe trofice de carabide din Madrid şi din împrejurimile lui (abrevierile localităţilor ca în tabelele 3 şi 4).

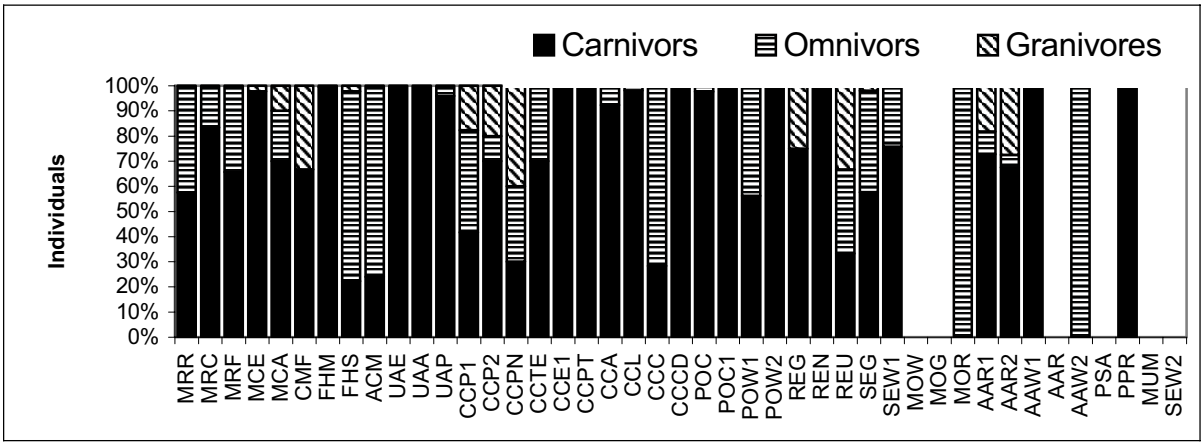

Figure 11. Relative representation (in %) of individuals of three trophic groups of Carabids in Madrid and its surroundings (abbreviations of localities as in tables 3 and 4). / Figura 11. Reprezentarea relativă (în%) a indivizilor din trei grupe trofice de carabide din Madrid şi din împrejurimile lui (abrevierile localităţilor ca în tabelele 3 şi 4).

Zoogeographical structure

In the areographic structure, a trend of decrease of the number of species with small areas of distribution (west Mediterranean, Iberian, and increase or portion of species with large area (transpalaeartic, westpalaearctic, Eurosiberian, European) is visible in the direction toward the city centre (Fig. 12). This trend is still more evident in the percentage of individuals of species belonging to these two groups of areas of geographical distribution (Fig. 13). It is particularly evident in two groups of communities. The first group includes the sites under the artificial lake in Casa de Campo and along the artificial creek in Parque de Oeste, where the succession tends to the azonal communities characteristic of water stream shores in floodplain ecosystems. Unlike the true floodplain Carabid communities there were found no holarctic or transpalaearctic species, but the European or westpalaearctic species dominate there (Table 2). A remarkable feature of these communities is a relatively high share of species with rather small areas, like the west Mediterranean *Carabus melancholicus, Agonum nigrum* and *Bembidion aeneum*.

The second group consists of the communities in city centre, which are shadowed by trees (Parque de Retiro) or in sites where the grass is watered in summer in order to maintain it green from aesthetic reasons. Also in these sites the transpalearctic (*Pseudoophonus rufipes*) or westpalaeartcic species (*Trechus quadristriatus, Calathus fuscipes*) predominate. On the other hand, the non-irrigated more or less abandoned grassy or ruderal plots in city centre are colonized by the thermoxerophilous species having differently extensive, but in general relatively small distribution areas at or around the Mediterranean Sea (genera *Ditomus, Carterus* and *Acinopus, Microlestes corticallis, Microlestes seladon*). Their survival is characteristic for the more modern residential quarters of the city. The endemic *Calathus granatensis* seems to be the most tolerant and adaptive species in the seminatural encinar- or matorral-like habitats, but does not penetrate to the city centre itself.

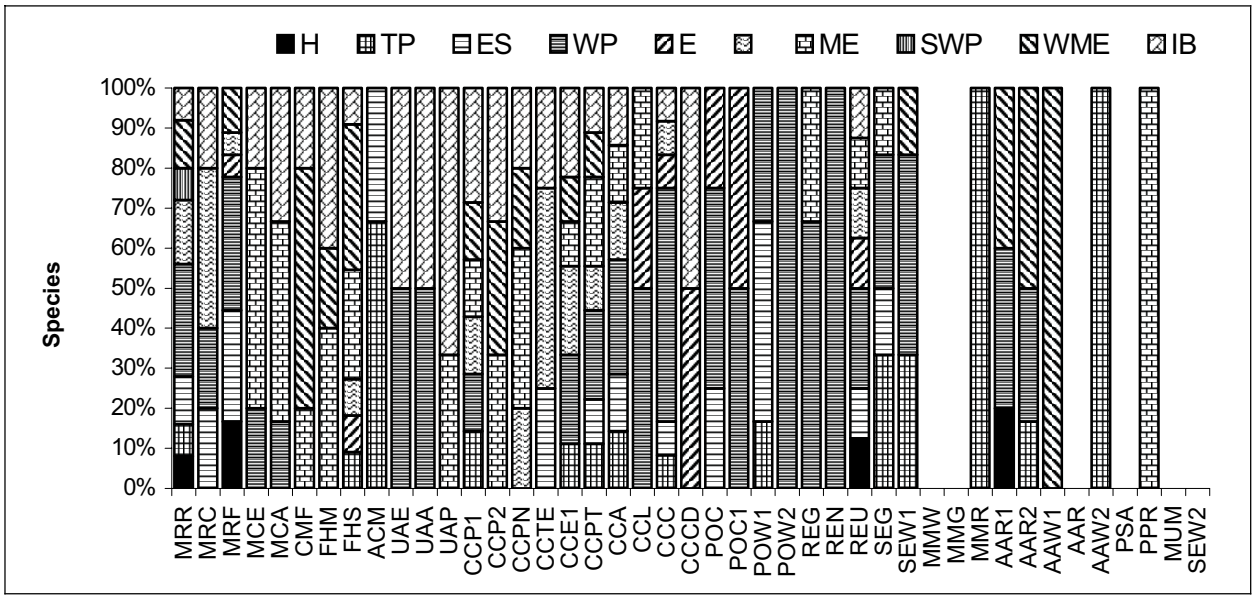

Figure 12. Number of species of 10 types of geographical distribution of Carabids in Madrid and its surroundings (abbreviations of localities as in tables 3 and 4). / Figura 12. Numărul speciilor a 10 tipuri ale răspândirii geografice ale carabidelor din Madrid şi din împrejurimile lui (abrevierile localităţilor ca în tabelele 3 şi 4).

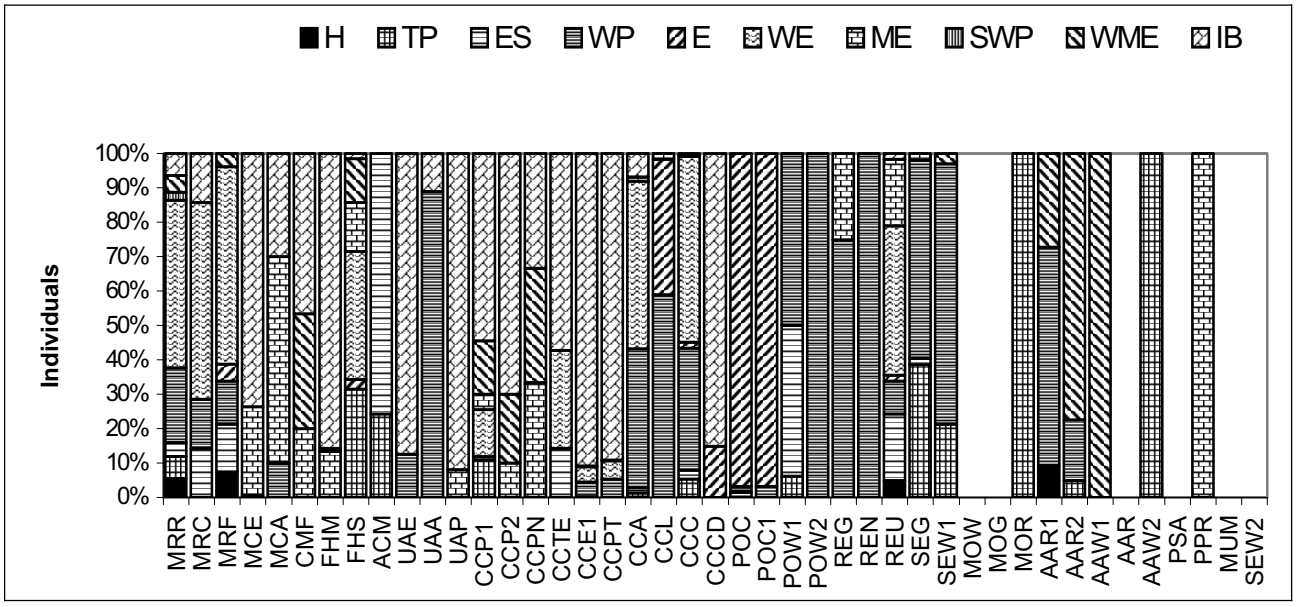

Figure 13. Relative representation of individuals of species of 10 types of geographical distribution of Carabids in Madrid and its surroundings (abbreviations of localities as in tables 3 and 4). / Figura 13. Reprezentarea relativă a indivizilor speciilor celor 10 tipuri de răspândire geografică a carabidelor din Madrid şi din împrejurimile lui (abrevierile localităţilor ca în tabelele 3 şi 4).

DISCUSSION

The constant occurrence of *Calathus granatensis* in sparse stands in reference localities and in urban parks in Madrid is in certain contradiction with the results of TABOADA *et al.* (2004). In their material it preferred the interior of the oak forests studied, while at the edges of the oak and beech stands it was replaced by *Calathus fuscipes*, which is really an open landscape species. The results from Madrid indicate that this species is more tolerant to opening of the tree canopy in the forest (forests-like) habitats than indicated by these authors.

The trends in structural changes along the urbanization gradient in Madrid and in other cities can be generally characterized by the disappearance of typical forests species and their replacement by the open landscapes species and a strong decline of diversity indices in the seminatural habitats. The enormous dominance of *Calathus granatensis* in Casa de Campo or a high dominance of hygrophilous *Nebria brevicollis* in Parque de Oeste has an analogy in the dominance of the couple of the species *Patrobus atrorufus* (STROEM, 1768) + *Platynus assimilis* (PAYKUL, 1790) and *Nebria brevicollis* + *Platynus assimilis* in the Central European cities (ŠUSTEK 1979, 1984) or of *Nebria coreica* SOLSKY, 1875 in the suburban zones of Pyongyang or *Platynus magnus* (BATES, 1873) in the alluvial park Potogang in Pyongyang (ŠUSTEK, 2011). A high dominance of *Nebria brevicollis* was also observed by TOPP (1972) in Kiel.

In spite of the limited time to collect the material in Madrid, the pattern of values of diversity index was very similar with more representative results from Brno and Bratislava (ŠUSTEK 1984), where a strong decline of diversity and equitability was observed in the medium influenced communities, whereas a low diversity but a high equitability was characteristic for the sites in the very city centre. A similar trend, in spite of the extremely limited material, was also observed in Pyongyang.

Unlike the central European cities (CZECHOWSKI, 1982, ŠUSTEK 1984), the strongly expansive species *Pseudoophonus rufipes* played only a secondary role in the Carabid communities in Madrid and did not occur in all studied sites. The less abundant congener *Pseudoophonus griseus* was found in small number of individuals only in the reference locality in maize field at Aranjuez. In Central Europe and East Asia it is one of the most characteristic species of the urban Carabid communities.

Similarly as in most places in centres of the Central European cities and in Pyongyang, no large species (*Carabus* spp.) were found in the city interior, in spite of the fact that at least *Carabus melancholicus* is probable to occur at least in some suburban parts of Madrid, especially at the river banks due to its preference of the riverine and field habitats (BURMEISTER, 1939). Thus this species could be an analogue to *Carabus intricatus* LINNAEUS, 1761, which shows a remarkable ability to penetrate in small number of individuals in urbanized habitats due to its ability to climb on vertical surfaces (BURMEISTER, 1939, ŠUSTEK 1999b). However, the absence or low representation of the large and non-flying species of the genus *Carabus* in Central European cities, in Madrid and Pyongyang is just a property of the more southern cities. In contrast, in the northeastern European cities (Moscow, Yaroslavl, Minsk, Grodno) the lower climatic gradient between the forest surrounding and city allows *Carabus nemoralis* O. F. MÜLLER, 1764 to successfully penetrate in considerable numbers in localities in the city centre, like the Leninskij prospect street in Moscow, and even mate on the street pavements in Yaroslavl (personal observations and personal communication by A. Derunkov).

Unlike other cities, two contradicting trends in the representation of species with differently large areas of the geographic distribution can be observed in Madrid. On the one hand, there is a similar trend to favouring the species with larger areas in the city centre as in East Asia and Central Europe. On the other hand, the species with small areas (west Mediterranean) or even the endemic species are remarkably successful in survival in the seminatural or strongly urbanized habitats. There is however an analogy between Madrid and Pyongyang, where the endemic species – *Calathus granatensis* in Madrid and *Nebria coreica* strongly predominated in the seminatural habitats.

Similarly as in the Central European cities (CZECHOWSKI 1980a, 1980b, 1981a, 1981b, 1982, ŠUSTEK 1979, 1984, ŠUSTEK & VAŠÁTKO 1983a, 1983b), there was a trend to decline of the carnivorous species in favour of the omnivorous ones. In both areas it is a consequence of the absence or very low representation of the omnivorous species in the fauna of forest ecosystems representing the potential natural vegetation and of a considerable share of the omnivorous species among the open landscape species, which are favoured in urban ecosystems. A specific feature of the fauna of Madrid, as a Mediterranean city, is the occurrence of the purely granivorous species typical of this biogeographical area.

The obtained results are, however, influenced by the fact that they were obtained during a relatively short time and at the beginning of the dry and hot period, which could inhibit the activity of many species whose occurrence can be limited to spring. Theoretically, there also arises the question of the winter activity of Carabids, which is know from the subtropical areas or which was observed even in Central Europe in warm winter periods (ŠUSTEK, 1979).

CONCLUSIONS

In spite of a considerable heterogeneity of the material, the character of the communities in individuals sites was predominantly determined by the occurrence and mutual relation of six species, viz. *Calathus granatensis, Calathus mollis, Calathus fuscipes, Trechus quadristriatus, Nebria brevicollis* and *Amara aenea,* accompanied in individual communities by some less abundant species. *Pseudoophonus rufipes* playing a significant role in forming of the urban communities in Central Europe plays only a secondary role in Madrid as a Mediterranean city.

According to the mutual proportion of these species, two parallel successional series can be distinguished:

A) Dry or mesohygrophilous habitats derived from holm oak forests (encinars):

1. More or less natural - combinations of predominant *Calathus granatensis* and less dominant *Calathus mollis*.
2. The seminatural communities in city predominance of *Calathus granatensis* accompanied with gradually increasing proportion of *Calathus fuscipes*.
3. Medium influenced communities – continuing occurrence of *Calathus fuscipes* accompanied by *Trechus quadristriatus*, *Pseudoophonus rufipes*, *Amara aenea* or *Amara familiaris* and decline or absence of *Calathus granatensis.* All of them were quantitatively little represented, but with a proportionally balanced share.
4. Strongly influenced sites – sporadic occurrence of *Amara* spp. and of the xerophilous species of the genus *Microlestes* or even absence of the Carabids.

B) Humid habitats on shores or banks of water bodies

1. Natural – communities rich in characteristic hydrophilous species.
2. Seminatural - more or less naturally humid or artificially irrigated habitats with predominating *Nebria brevicollis*, accompanied by some hydrophilous, individually occurring species and *Calathus fuscipes* as an open landscape species.
3. Strongly influenced – not found, probably convergent to the communities of the strongly influenced dry or mesohygrophilous habitats.

The communities show a higher portion of endemic Iberian or Mediterranean species penetrating into the very centre of the city. In spite of it, a general trend to increase of representation of species with large areas of geographical distribution, known from other cities, was confirmed.

Similarly as in other cities, the seminatural communities in the city are characterized by decline of diversity indices and by a low equitability, while the communities in the most exposed sites are characterized by low values of diversity index and by a high equitability.

In contrary to the arid and dry climate, the species composition of the communities in centre of Madrid converges to the communities known from Central Europe. This convergence is however only anthropogenic and results from the intensive care of the urban greenery.

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