Vestnik Zoologii, **53**(2): 89–106, 2019
DOI: 10.2478/vzoo-2019-0009

Fauna and Systematics

UDC 595.76: 502.7 (1-17:477)

DISTRIBUTION OF THE CARABID SPECIES (COLEOPTERA, CARABIDAE) IN WOODLANDS OF THE PROTECTED AND URBAN AREAS (NORTH OF UKRAINE)

M. B. Kirichenko-Babko[1*], L. I. Kobzar[2], J. M. Danylkiv[1], G. Łagód[3], M. Franus[4]

[1]Schmalhausen Institute of Zoology NAS of Ukraine,
vul. B. Khmelnytskogo, 15, Kyiv, 01030 Ukraine
E-mail: kirichenko@izan.kiev.ua
[2]Polisky Nature Reserve, Zhytomirska oblast, Selezivka, 11196 Ukraine
E-mail: lina_kobzar@ukr.net
[3]Lublin University of Technology, Nadbystrzycka 40B, 20-618 Lublin, Poland
E-mail: g.lagod@pollub.pl
[4]Lublin University of Technology, Nadbystrzycka 40, 20-618 Lublin, Poland
E-mail: m.franus@pollub.pl
Corresponding author

Distribution of the Carabid Species (Coleoptera, Carabidae) in Woodlands of the Protected and Urban Areas (North of Ukraine). Kirichenko-Babko, M. B., Kobzar, L. I., Danylkiv, J. M., Łagód, G., Franus, M. — The assemblages of ground beetles of forest areas of the northern part of Ukraine were studied: Polisky Nature Reserve (PNR) and urban parks of Kyiv City. In general, 88 species of carabids of 29 genera were observed in the studied areas. Thirty-one forest species were found in the studied territories, of which 22 species were registered in urban parks, and 17 species within the PNR. In all investigated areas, the number of forest species was lower, than open-habitat species and generalists species. Today, based on data on the occurrence and abundance of carabid species, forests in urban areas can be considered as refugia for many forest species, in particular, protected and endangered species — *Abax parallelus, Carabus glabratus, Carabus menetriesi* and *Cychrus caraboides*. The results of cluster analysis, non-metric multidimensional scaling and detrended correspondence analysis showed the difference between the forests of the PNR and the urban parks. In addition, the species richness of the PNR were lower than in urban parks. The results of the study showed that urban parks can be considered as important elements for the future management and conservation of landscapes.
Key words: woodland, forest carabids, occurrence, conservation.

Introduction

The development of civilization led to the replacement of primeval forests with plantings, many of which are representing by monocultures, and a significant reduction in their area (Parviainen, 2005). Nowadays, less 40 % of the land surface in Europe is forested, but natural forests account for 1.7 % of the area (Parviainen, 2005). The most forested European countries are Sweden and Finland, where the percentage reaches nearly 70 % (Magura et al., 2015). In Ukraine, the area covered by forests consists nearly 9.6 million hectares, or 15.7 % of the country's territory (Zagalna characterystyka …, 2016). The virgin forests have almost entirely disappeared due to unsustainable forestry in Europe. In Ukraine, they virgin forests are extant in the Carpathians (Chumak et al., 2005). The 30–40 years old artificial plantations prevail in Ukraine. Due to the extensive agriculture and urbanization, about 25 % of forests in Ukraine are situated near large cities and resorts. The parks and green areas in cities are usually constitute artificial woody plantations and generally are not the remains of natural forests. Urban green areas are highly fragmented and subject to intensive recreational use.

Over the last few thousand years, the agricultural intensification profoundly affected the European landscapes, leading to shifts in species areals and local extinctions including ground beetles (Matson et al., 1997; Myers, Knoll, 2001). Therefore, many scientists note the importance of studying the assemblages of beetles in various gradients, especially under the conditions of forests on the European continent. The carabid beetles have been already intensively studied in the boreal forests in Scandinavia and Canada (Spence et al., 1996; Niemelä et al., 1988; Matveinen-Huju et al., 2009) and deciduous woodlands in England, Belgium, Hungary, Germany and Mediterranean region (Terell-Nield, 1990; Assmann, 1999; Desender et al., 1999; Molnár et al., 2001; Günter, Assmann, 2004; da Silva et al., 2009). Due to the large number of studies, the effects of habitat fragmentation and habitat size at woodlands on forest carabids were shown in detail (Spence et al., 1996; Davies, Margules, 1998; Magura et al., 2001). Relationships between the age of a forest area and diversity of carabids, as well as the structure their assemblages were studied by Taboada et al. (2006) and Jelaska et al. (2011). The distribution of ground beetles in forests, its dependence on abiotic factors (temperature, moisture and edaphic conditions) were studied by Baguette (1993), Irmler (1999), Antvogel, Bonn (2001), Judas et al. (2002), and Poole et al. (2002). Fahy, Gormally (1998), Koivula et al. (2002), Karen et al. (2008), and Debnar et al. (2016) studied the influence of forestry management practices and clearcuts on carabid beetle assemblages. In the literature, there is information about the patterns of distribution of ground beetles along rural-urban gradients (Venn et al., 2003; Weller, Ganzhorn, 2004; Elek, Lovei, 2007; Niemelä, Kotze, 2009).

In this work, the carabid assemblages composition, the distributions of ground beetles in different woodland areas which are located in northern part of Ukraine were analyzed and compared. The role of forest group species as indicators for assessing the state of landscapes is discussed in the paper.

Material and methods

Study areas and sampling

The studies were conducted in Polisky Nature Reserve (PNR) and two urban parks in the city of Kyiv, belong to different geographical regions: to the forest and to the forest-steppe zones, respectively (fig. 1). The studied territories were relatively close to each other: PNR separated from city of Kyiv by a maximum of 155 km; one park in Kyiv was located at least 8 km from the next.

Polisky Nature Reserve (PNR; 51°32´04˝ N and 28°06´20˝ E) is located between the Ubort' and Bolotnytsia Rivers. It was established in 1968 for conservation of boreal flora (woods and marshes). The reserve is only a part of an immense stretch of forests that goes all the way into the neighboring state of Belarus. The area is a marshland and marshes have kept that area from being widely cultivated. In recent years, there has been a tendency for depletion of the region flora due to drainage reclamation (Bumar, 2009). The following woodland types were studied in this territory: coniferous (pine, 5 sites), mixed forests (pine-birch, 4 sites) and deciduous (birch and oak, 2 sites) which are 60–70 years old. The studies were carried out at the Polisky Nature Reserve in 2011–2012 and in 2014–2015 during of vegetation period. The 15 pitfall traps (0.3 L volume, filled with ethylene glycol) were placed on each of 11 sites; traps were installed at a distance of 10 m from each other. They were emptied at ca. 14-day intervals.

Kyiv is a highly urbanized city in Ukraine, which occupies 836 km^2 with a large population of around 2.91 million inhabitants. In this city, the selected parks, Theophania and Teremky, are forest fragments have been under government protection. They are located in the south-western part of City Kyiv. The Theophania (50°20´22˝ N and 30°29´22˝ E) is a park monument of landscape architecture of national importance. Since 1990, this forest-park is protected as a garden national natural monument, its area is approximately 150 ha. This park is located on the picturesque slopes of Theophanian brook, in the distance of 15 km from the city center. Therefore, its relief crosses ravines and several lakes. The territory of this park includes ancient deciduous forest and artificial stands (age from 60 to 180 years old) for recreational use. The forest in Teremky (area 93.8 ha; 50°21´34˝ N and 30°27´4˝ E) is surrounded by residential blocks. Its territory is a relatively flat upland area, which is covered by a hornbeam-oak forest, and since 2007 it is part of the Holosiivskyi National Nature Park. At each study park, plastic pitfall traps (0.3 l volume) were used as sampling procedure to collect the carabid beetles. Traps were partly filled with propylene-glycol solution as a killing agent and preservative. Beetles were collected over their whole activity period from April to October. At Theophania, sampling was carried out in 2007, 2009 and 2012. Ten pitfall traps were placed in a line (5 m apart) on each of five rows. Traps were checked every 10 days. In Teremky, the study was conducted in 2007–2009. Nine traps (spaced at 2 m apart) on each of three rows were established in each of the three sites, and at 3 m intervals between rows. Traps were emptied once a week.

Fig. 1. Geographic location of the investigated areas is shown in arrows (indicating the position of the Polisky Nature Reserve (PNR) and the urban parks in Kyiv City, in the Ukraine). The study area is marked by the red flags.

Data analysis

Ground beetles were identified using standard keys (Hůrka, 1996; Freude et al., 2004). The information on functional (wing morphology, mean body length) and ecological traits (habitat preferences) of carabid species was taken from the literature (Turin, Heijerman, 1988; Hůrka, 1996; Homburg, 2014). Carabid species were categorized as forest, generalist (as typical of both forest and open habitats), open-habitat species, species preferred riparian and wet habitat (table 1, Appendix, table A1). Carabid species were classified according to the wing development as macropterous (hind wings fully developed); brachypterous (hind wings reduced); and dimorphic (short-and long-winged forms) (table 1, Appendix, table A1). According to the chorological analysis of the fauna, the collected ground beetles species were divided into four main types of fauna and on zoogeographical categories (table 2) (Vigna Taglianti, 1995; Vigna Taglianti et al., 1999). A list of the species with their functional and ecological characteristics is given in the Appendix (table A1). Authors of species names and year listed here and are not repeated elsewhere in the text.

In this paper, we also consider the category of the Red List protected species and also rare forest species (Appendix, table A2) if mentioned in the Red Lists of European countries including Ukraine (The National Red List; Red Book of Ukraine, 2009).

The datasets of the studied territories were standardized for trapping effort. Species abundance has been calculated as the number of individuals collected per active trap and days during trapping period in each year, and considered as activity density (ind./trap-day). In order to make data comparable, the carabid catches from sampling periods for each territory were combined and averaged.

Rarefaction was used as a measure for alpha diversity as it takes both species richness and abundance (average density) into account. Rarefaction compensates for differences in sampling effort among habitats (Gotelli & Cotwell, 2001). Rarefaction curves were calculated in steps of 10 individuals (Cotwell, 2006). Cluster analyses was performed (with the group average the linkage algorithm and Bray-Curtis similarity metric) to explore the differences in carabid assemblages between the investigated territories. Non-metric multidimensional scaling (NMDS) using the Bray-Curtis index was applied. The carabid abundance data matrix (the dataset per territory in each of study year) was transformed by square root to give more weight to rarely collected species. Lastly,

Table 1. The number of species and their proportions of total collected species (in brackets, %) for their functional traits among the studied territories

Traits	Total species	Polisky Nature Reserve	Urban parks	Shared species
Habitat requirements:				
Forest species	31 (35.0)	17 (36.2)	22 (31.4)	8
Open habitat species	33 (38.0)	15 (32.0)	28 (40.0)	10
Generalist species	22 (25.0)	13 (28.0)	20 (28.6)	10
Wet habitat and riparian species	2 (2.0)	2 (4.3)	–	–
Wing morphology:				
Brachypterous	22 (25.0)	10 (21.3)	16 (23.0)	4
Dimorphic	13 (15.0)	9 (19.1)	11 (16.0)	7
Macropterous	53 (60.0)	28 (59.6)	43 (61.0)	17
Total species number	88	47	70	28

Appendix. Table A1. List of ground beetles species present in the forests at the Polisky Nature Reserve (PNR) and the urban parks of the Kyiv City (Ukraine)

Species	Habitat affinity	Wing state	Range	Polisky Nature Reserve	Urban parks	
					Theophania	Teremky
Abax parallelepipedus Piller et Mitterpacher, 1783	F	b	EUR	–	82.3	–
Abax parallelus Duftschmid, 1812	F	b	EUR	–	297.0	181.0
Amara aenea De Geer, 1774	O	m	PAL	0.3	–	0.6
Amara aulica Panzer, 1797	O	m	E-AS	–	0.3	0.2
Amara brunnea Gyllenhal, 1810	F	m	OLA	9.3	–	0.4
Amara communis Panzer, 1797	G	m	PAL	11.3	–	26.0
Amara consularis Duftschmid, 1812	O	m	E-CAS	1.0	–	–
Amara convexior Stephens, 1828	G	m	E-CAS	0.3	–	–
Amara eurynota Panzer, 1797	O	m	OLA		2.3	0.8
Amara famelica Zimmermann, 1832	O	m	PAL	0.3	–	–
Amara familiaris Duftschmid, 1812	O	m	OLA	0.3	–	4.0
Amara littorea Thomson, 1857	O	m	W-PAL	–	–	0.4
Amara majuscula Chaudoir, 1850	O	m	PAL	–	0.3	–
Amara ovata Fabricius, 1792	G	m	PAL	–	2.3	0.2
Amara praetermissa Sahlberg, 1827	F	m	PAL	0.3	–	–
Amara similata Gyllenhal, 1810	G	m	E-AS	–	2.0	0.6
Amara spreta Dejean, 1831	O	m	PAL	–	–	0.8
Amara tibialis Paykull, 1798	O	m	W-PAL	0.3	0.3	–
Amara tricuspidata Dejean, 1831	O	m	E-SI	–	–	0.2
Anisodactylus binotatus Fabricius, 1787	G	m	E-AS	0.3	1.0	0.8
Anisodactylus nemorivagus Duftschmid, 1812	O	m	W-PAL	–	–	0.2
Anisodactylus signatus Panzer, 1797	O	m	E-AS	–	–	0.4
Asaphidion flavipes Linnaeus, 1761	G	m	PAL	–	–	0.4
Badister bullatus Schrank, 1798	G	m	W-PAL	–	–	0.6
Bembidion lampros Herbst, 1784	O	d	OLA	–	–	1.4
Bembidion properans Stephens, 1828	O	m	E-WSI	–	–	0.8
Broscus cephalotes Linnaeus, 1758	O	m	E-AS	0.8	–	0.8
Calathus ambiguus Paykull, 1790	O	m	E-AS	1.0	–	–
Calathus erratus erratus Sahlberg, 1827	O	d	E-AS	27.0	0.3	–
Calathus fuscipes Goeze, 1777	G	d	PAL	1.8	13.0	3.0
Calathus halensis Schaller, 1783	O	m	E-AS	–	9.3	–
Calathus melanocephalus Linnaeus, 1758	G	d	PAL	18.5	–	–
Calathus micropterus Duftschmid, 1812	F	b	PAL	26	–	5.0
Calosoma inquisitor Linnaeus, 1758	F	m	PAL	–	1.0	0.2
Carabus arcensis Herbst, 1784	F	b	E-AS	50.0	–	–
Carabus cancellatus Illiger, 1798	G	b	E-SI	–	104.7	–
Carabus convexus Fabricius, 1775	F	b	E-PAS	–	72.7	–
Carabus coriaceus Linnaeus, 1758	F	b	E-PAS	–	5.3	1.0
Carabus glabratus Paykull, 1790	F	b	EUR	–	19.3	0.2
Carabus granulatus Linnaeus, 1758	F	b	E-AS	3.0	5.0	0.6
Carabus menetriesi Faldermann, 1827	F	b	EUR	0.1	0.3	–
Carabus violaceus Linnaeus, 1758	G	b	E-SI	–	–	0.2
Clivina fossor Linnaeus, 1758	O	d	PAL	–	–	0.2
Cychrus caraboides Linnaeus, 1758	F	b	EUR	–	1.7	–

Demetrias imperialis Germar, 1824	R	m	E-PAS	0.5	–	–
Epaphius secalis Paykull, 1790	F	b	PAL	8.5	–	–
Harpalus affinis Schrank,1781	O	m	PAL	–	1.0	–
Harpalus distinguendus Duftschmid, 1812	O	m	PAL	0.3	2.7	1.0
Harpalus flavicornis Dejean, 1829	O	d	CE-PAS	0.3	–	
Harpalus latus Linnaeus, 1758	G	m	E-AS	0.5	2.7	1.2
Harpalus luteicornis Duftschmid, 1812	F	m	E-SI	–	0.3	0.2
Harpalus pumilus Sturm, 1818	O	b	E-CAS	0.3	–	–
Harpalus quadripunctatus Dejean, 1829	F	m			9.0	3.8
Harpalus rubripes Duftschmid, 1812	O	m	E-SI	–	0.3	–
Harpalus serripes Quensel in Schönherr, 1806	O	m	PAL	–	2.7	–
Harpalus smaragdinus Duftschmid, 1812	O	m	W–PAL	1.5	0.3	0.2
Harpalus tardus Panzer, 1797	O	m	E-CAS	–	7.0	1.0
Harpalus xanthopus winkleri Schauberger, 1923	F	m	E-PAS	–	1.0	0.4
Leistus ferrugineus Linnaeus, 1758	F	b	EUR	–	1.0	–
Loricera pilicornis Fabricius, 1775	G	m	OLA	–	–	0.6
Miscodera arctica Paykull, 1798	F	m	PAL	0.3	–	–
Molops piceus Panzer, 1793	F	b	E-PAS	–	15.0	–
Nebria brevicollis Fabricius, 1792	F	m	E-PAS	–	31.3	81.0
Notiophilus aquaticus Linnaeus, 1758	F	b	OLA	1.0	–	–
Notiophilus biguttatus Fabricius, 1799	F	d	W-PAL	0.5	1.0	4.6
Notiophilus germinyi Fauvel in Grenier, 1863	O	b	W-PAL	–	–	1.4
Notiophilus palustris Duftschmid, 1812	G	b	E-SI	1.0	–	5.0
Ophonus nitidulus Stephens, 1828	G	d	E-SI	–	–	0.2
Ophonus shaubergerianus Puel, 1937	O	m	E-PAS	–	–	0.2
Oxypselaphus obscurus Herbst, 1784	F	b	OLA	36.8	–	–
Patrobus atrorufus Stroem, 1768	F	b	E-WSI	0.5	–	–
Platynus assimilis Paykull, 1790	F	m	PAL	–	1.0	7.8
Platynus krynickii Sperk, 1835	F	m	PAL	0.3	–	–
Poecilus cupreus Linnaeus, 1758	G	m	E-AS	0.8	0.3	5.0
Poecilus lepidus Leske, 1787	G	d	W-PAL	0.5	7.0	0.4
Poecilus versicolor Sturm, 1824	O	m	PAL	0.5	–	3.0
Pseudoophonus griseus Panzer, 1797	O	m	PAL	0.5	1.0	0.2
Pseudoophonus rufipes De Geer, 1774	O	m	PAL	1.0	84.0	3.0
Pterostichus anthracinus Illiger, 1798	G	d	E-PAS	–	0.3	0.2
Pterostichus aterrimus Herbst, 1784	W	m	W-PAL	0.3	–	–
Pterostichus diligens Sturm, 1824	G	d	E-SI	7.3	–	0.2
Pterostichus gracilis Dejean, 1828	F	m	PAL	0.8	–	–
Pterostichus melanarius Illiger, 1798	G	d	E-SI	52.0	31.0	9.6
Pterostichus niger Schaller, 1783	F	m	E-AS	46.3	11.0	3.2
Pterostichus nigrita Paykull, 1790	G	m	PAL	4.3	–	0.4
Pterostichus oblongopunctatus Fabricius, 1787	F	m	PAL	16.8	92.0	108.2
Pterostichus strenuus Panzer, 1797	G	d	E-AS	1.0	–	12.0
Stomis pumicatus Panzer, 1796	F	b	E-PAS	–	0.3	1.0
Total number of species (and genera)				47 (16)	44 (17)	56 (21)
					70 (24)	

N o t e. Life-history traits of species: habitat affinity (F — forest species, G — generalists, O — open habitat species, R — riparian species, W — wet habitat species); dispersal ability (b — brachypterous, d — dimorphic, m — macropterous); and geographical range (abbreviations see in table 2). The mean of individuals captured in all years per studied territory.

Table 2. Chorological composition of ground beetle assemblages in the studied territories. The number of species is indicated for each geographical range and each faunistic type, their ratio is given (in brackets, %).

	Faunal type	Range	Polisky Nature Reserve	Urban parks
I	Northern Holarctic and Euro-Siberian	Holarctic (OLA)	4 (9.0)	5 (7.0)
		Palearctic (PAL)	17 (36.0)	19 (27.0)
		Western Palearctic (W-PAL)	5 (11.0)	8 (12.0)
		Euro-Siberian (E-SI)	4 (9.0)	9 (13.0)
		Euro-Westsiberian (E-WSI)	1 (2.0)	1 (2.0)
		No. species (in their ratio, %)	31 (66)	42 (60)
II	European	European (EUR)	1 (2.1)	6 (9.0)
		European-Neareastern(E-PAS)	1 (2.1)	7 (10.0)
		Central European and Neareastern (CE-PAS)	1 (2.1)	1 (1.4)
		No. species (in their ratio, %)	3 (6.3)	14 (20)
III	Euroasiatic	Euroasiatic steppe complex (E-AS)	10 (21.3)	12 (17)
		European and Central Asian (E-CAS)	3 (6.4)	1 (1.4)
		No. species (in their ratio, %)	13 (27.7)	13 (18.6)
IV	Mediterranean	European-Centralasian-Mediterranean (E-CA-M)	-	1 (1.4)

detrended correspondence analysis (DCA) was performed to display the similarity forest species compositions between the studied territories. In addition, a quantitative Sørensen index was calculated in this analysis. These analyses were performed using the EstimateS 8.20 (Cotwell, 2006), PAST (Hammer et al., 2001) and Primer-E (Clark, Gorley, 2006).

Results

General aspects

A total of 88 species (29 genera) were recorded across the three territories (Appendix, table A1). The overall number of species (70 species and 24 genera) were higher in both urban parks (Theophania and Teremky) of the Kyiv City. The highest of number species (56 species and 21 genera) was found in the Teremky, and fewer in the Theophania park (44 species and 16 genera). Forty-seven species were recorded in the forests at the Polisky Nature Reserve (PNR). The follow genera were rich in species: *Amara* (17 species), *Harpalus* (12 species), *Pterostichus* (nine species) and *Carabus* (eight species).

Rarefaction curves of pitfall traps data in the studied territories are outlined in fig. 2. The observed species curves does not flatten towards the values from 15 (PNR) to 20 (Theophania park) (fig. 2). It could be hypothesized that these curves reach the plateau at 25.

The carabid assemblage structure of the deciduous forest fragments in the urban parks is clearly different from the forests of the Reserve, because these territories are located in different geographical zones. The number of exclusively collected species was higher at both urban parks (40 species, 57 % of the species captured) than in the forests of the PNR (18 species, 39 % of the captured species) (Appendix, table A1). It was observed that the urban parks and Reserve shared 27 out of 88 species. Thus, the most numerous species in the forests of PNR were *Pterostichus niger*, *Calathus micropterus* and *Carabus arcensis*, which for accounted 54 % of the total catch. On the other hand, the two species — *Abax parallelus* and *Pterostichus oblongopunctatus* were abundant in the urban parks of the Kyiv and they accounted for 57 % of the total catch. These species are strictly associated with forests (Appendix, table A2).

Structure of carabid assemblages

The cluster analysis revealed the differences in the species compositions between the studied territories (fig. 3). Hence, two distinct clusters are formed. The carabid assemblage structure in the urban parks clearly separated from the forests of PNR at about 20 % simi-

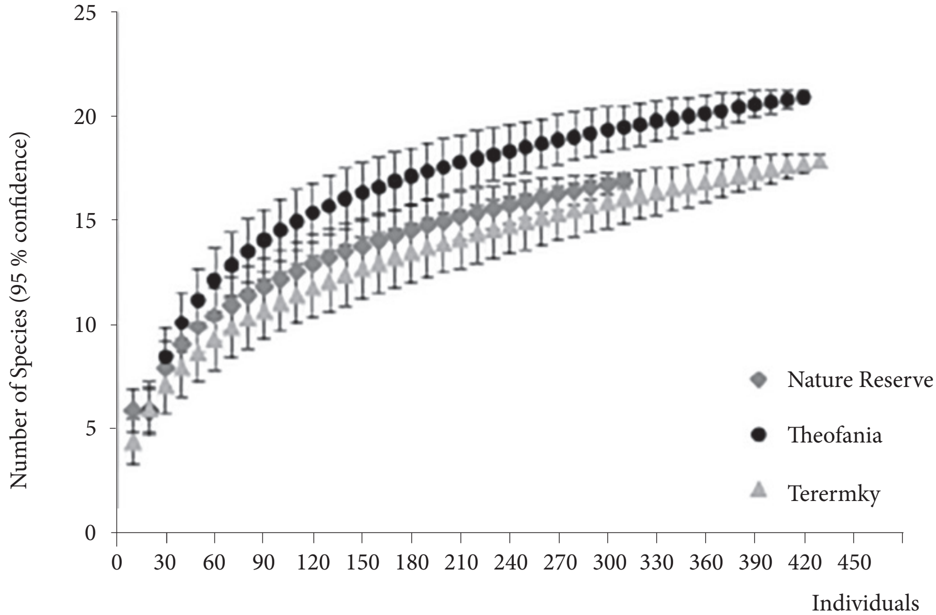

Fig. 2. Estimated species richness of carabid beetles collected in the investigated territories using rarefaction analysis (bars are 95 % CI).

larity level. The lowest similarity between assemblages of the PNR and urban parks demonstrate also Sørensen index — 48 %. The urban parks were more similar to each other (60 % Sørensen index similarity), due to the same deciduous forest type and location in conditions of urban matrix. Moreover, the similarity between the both parks (Theophania and Teremky) showed NMDs ordination because have 30 shared carabids (fig. 4). At the same time, the sites of PNR were separated from the sites of urban parks along the first axis.

All collected carabid species belong to 11 zoogeographical categories and were grouped in four major "faunal types" (table 2, Appendix, table A1). The majority of collected species

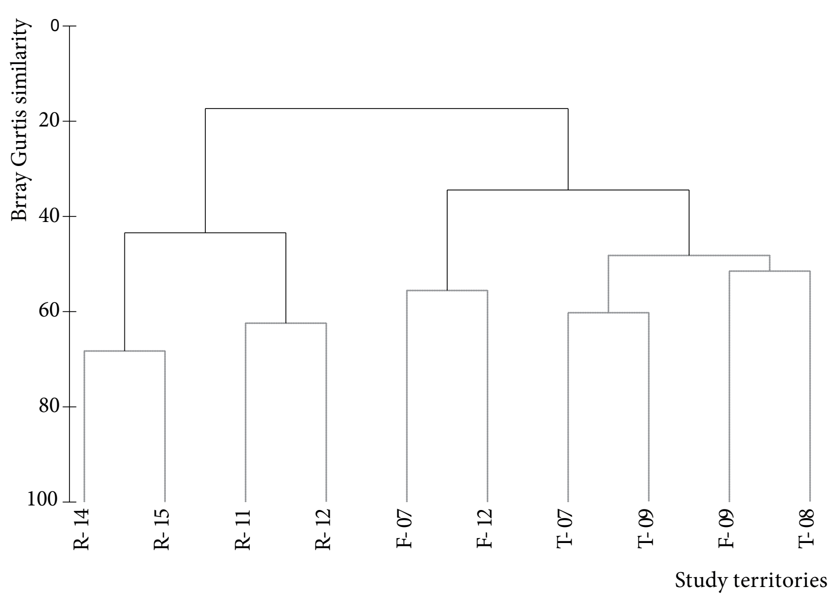

Fig. 3. Cluster analysis of Bray-Curtis similarity measure and the group average linkage method of carabid assemblages in the studied areas. Site name abbreviations: R — Polisky Nature Reserve, T — Teremky and F — Theofania urban parks; the numbers after the letter are indicate the study year.

Appendix. Table A2. List of forest carabid species recorded at investigated territories, their conservation status mentioned in the National Red Lists of European countries and Red Book of Ukraine (2009) (RL status). Species ranked by the Polisky Nature Reserve (PNR) where recorded

Species	Code[1]	PNR	Urban parks	RL status (Country[2])	Reference[3]
Amara brunnea	Am-brunn	x	x		1, 3, 4, 9
Amara praetermissa	Am-praet	x		CR(DE), rare(UK)	
Calathus micropterus	Ca-micro	x	x	Declining species (DE)	1, 3, 4, 6, 9
Carabus arcensis	Ca-arcen	x		NT(NO), Declining species (DE)	6, 9
Carabus granulatus	Ca-granu	x	x		6, 9
Carabus menetriesi	Ca-menet	x	x	EN(PL), T(DE), VU(CZ), VU(UA)	
Epaphius secalis	Ep-secal	x			9
Harpalus quadripunctatus	Ha-quadr	x	x		1, 2, 9
Miscodera arctica	Mi-arcti	x		VU(CZ), DD(PL), CR(DE)	
Notiophilus aquaticus	No-aquat	x			
Notiophilus biguttatus	No-bigut	x	x		1, 2, 5, 6, 7, 8, 9
Oxypselaphus obscurus	Ox-obscu	x			
Patrobus atrorufus	Pa-atror	x			4, 5, 8, 9
Platynus krynickii	Pl-kryni	x			
Pterostichus gracilis	Pt-graci	x			
Pterostichus niger	Pt-niger	x	x		5, 6, 7, 8, 9
Pterostichus oblongopunctatus	Pt-oblon	x	x		1, 2, 7, 8, 9,
Abax parallelepipedus	Ab-ater		x		1, 4, 5, 7, 8
Abax parallelus	Ab-para		x	Extremely rare (DE)	1, 7, 8
Calosoma inquisitor	Ca-inqui		x	NT(NO), EN(EE, DE), EX(FI), VU(AL), rare(LT)	9
Carabus convexus	Ca-conve		x	EX(NO), VU(FI, SE), NT(PL), EN(DE)	2, 6
Carabus coriaceus	Ca-coria		x	VU(AL), CR(DE)	1, 6, 7, 9
Carabus glabratus	Ca-glabr		x	Declining species (DE)	2, 7, 9
Cychrus caraboides	Cy-carab		x		1, 2, 3, 5, 6, 7, 9
Harpalus luteicornis	Ha-lutei		x	NT(NO), VU(SE), Declining species (DE)	
Harpalus xanthopus winkleri	Ha-winkl		x	DD(DE)	
Leistus ferrugineus	Le-ferru		x		5, 6
Molops piceus	Mo-piceu		x		8
Nebria brevicollis	Ne-brevi		x		1, 5, 6
Platynus assimile	Pl-assim		x		1, 4, 5, 6, 7, 8, 9
Stomis pumicatus	St-pumic		x		1, 5

[1] Code of species used in DCA ordination (see fig. 6).

[2] Abbreviations name of countries is represented by a code based on the ISO. Abbreviations of species category of the IUCN: CR — critically endangered, EN — endangered, VU — vulnerable, NT — near threatened, DD — date deficient, EX — regionally extinct, T — threatened with extinction.

[3] Reference: previous studies where these species were indicated as forest (1 — Turin, Heijerman, 1988; 2 — Assmann, 1999; 3 — Koivula et al., 2002; 4 — Gunter, Assmann, 2004; 5 — Sadler et al., 2006; 6 — Sienkiewicz, Konwerski, 2006; 7 — Sroka, Finch, 2006; 8 — Gaublomme et al., 2008; 9 — Gryuntal, 2008).

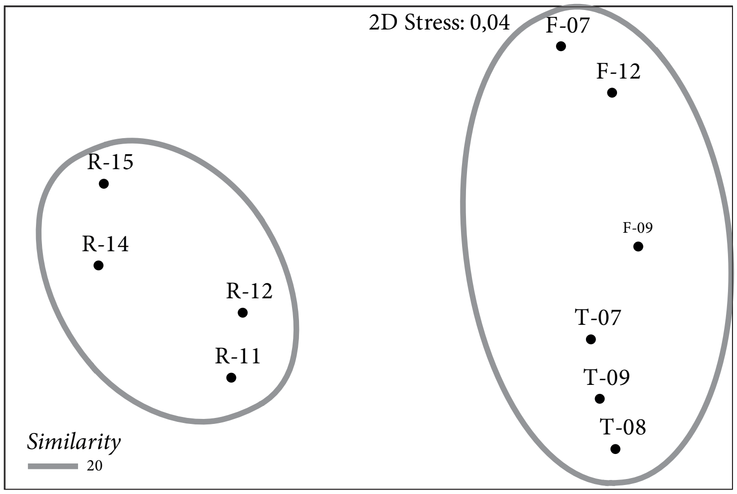

Fig. 4. The ordination (non-metric multidimensional scaling using the Bray-Curtis index similarity and the square root transform method) of the total species compositions in the forests of the Polisky Nature Reserve and the urban parks during the study years. The stress of the two-dimensional configuration is 4 %. Site name abbreviations are the same as in fig. 3.

at studied territories were wide temperate species. The species of the Holarctic and Euro-Siberian faunal type represented more than 60 % of carabid compositions at the territories (table 2). At the same time, it is important that according to zoogeographical categories, species with palearctic and euroasiatics ranges prevailed in the studied territories (table 2). The difference between the protected territory (PNR) and two urban parks by terms of the proportion of species of the European and Euroasiatic faunal types (II and III, respectively) was observed. Thus, in the parks the ratio of representatives of the European and Euroasiatic faunal types was equal, whereas in the PNR the European type was three times smaller in relation to the Euroasiatic faunal type (table 2).

According to the habitat preferences of ground beetles (table 1), the majority of species were represented by 33 open-habitat associated species (37 % of the total catch) and 31 forest species (35 % of the total catch). The generalist species were represented by 22 species (25 % of the total catch). Nevertheless, their proportions were different per each study territory. Thus, in the urban parks, by terms of species number, the open-habitat species were dominant (40 %); but in the Reserve the forest species prevailed (36 %).

The most numerous species were macropterous beetles: 58 % in PNR and 61 % in both parks (table 1). The ratios of representatives with different of dispersal ability in the each of habitat group are shown on the diagrams (fig. 5, A, B). The similarity between the structure of the assemblages of the Reserve and urban parks is clearly seen in the same ratio of species with different dispersal abilities in the forest species (fig. 5, A, B) and open habitat species (fig. 5, A). Among generalists, both in the Reserve and in parks, dimorphic species dominated on abundance (fig. 5, B). However, the dissimilarly between the protected and urban parks was observed in the predominance among the open-habitat group of abundant dimorphic species in the Nature Reserve, whereas the macropterous species were abundant in parks (fig. 5, B).

Distribution patterns of forest species

As mentioned above, 31 forest carabids species founded in the studied areas. The proportion of forest carabids (to overall total number of species) was slightly more than 30 % in the each territory (table 1). The density of forest species exceeded (> 60 % of the total density of collected carabids) in the assemblages structure at each studied territories. As mentioned above in text, the ratio of forest species with different dispersal capacity is simi-

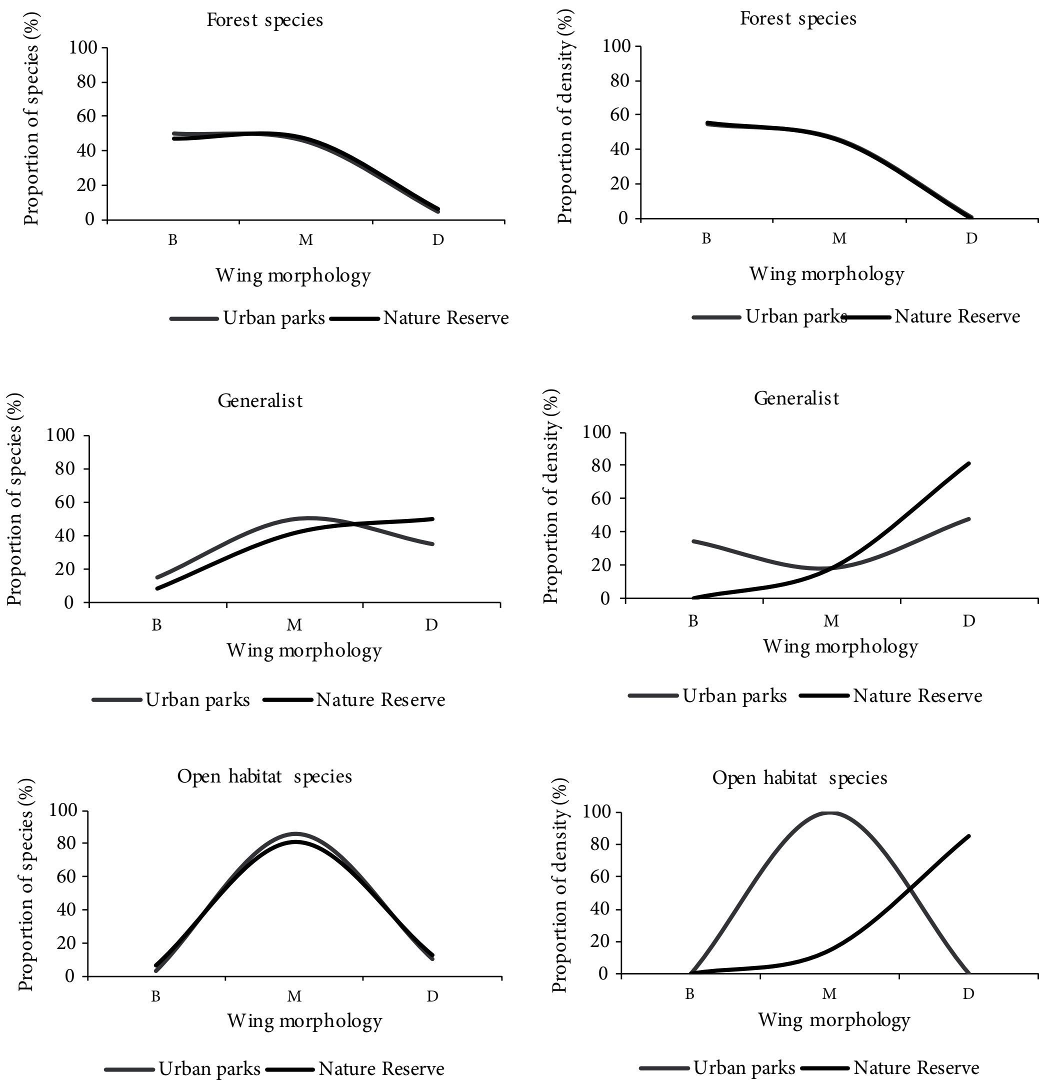

Fig. 5. Plots of the distribution of carabids species (A) and their density (B) according to dispersal ability (B — brachypterous, D — dimorphic, M — macropterous) in three habitat affinity groups in the Polisky Nature Reserve and in the urban parks.

lar at these territories, namely the brachypterous and macropterous species have predominated by terms of abundance and number of species (fig. 5, A, B).

The plot of DCA showed that 31 forest species groupings between the territories (PNR and urban parks — Theophania and Teremky), where the first two dimensions explain 66 % of the variation (fig. 6). It should be noted that nine out of 17 forest species were exclusively recorded in the PNR, and 14 forest species from 22 exclusively found in the urban parks (fig. 6, Appendix, table A2). As it was shown, eight out of 31 forest species regularly occurred in both parks and Nature Reserve: *Amara brunnea*, *C. micropterus*, *Carabus granulatus*, *Carabus menetriesi*, *Harpalus quadripunctatus*, *Notiophilus biguttatus*, *P. niger*, *P. oblongopunctatus* (Appendix, table A2). Hence, these common forest species also separated between these territories: *A. brunnea*, *C. micropterus*, *C. granulatus*, *P. niger* are clearly to the forests in the PNR, while the other species (*H. quadripunctatus*, *N. biguttatus*, *P. oblongopunctatus*) prefer conditions of the city parks (fig. 6).

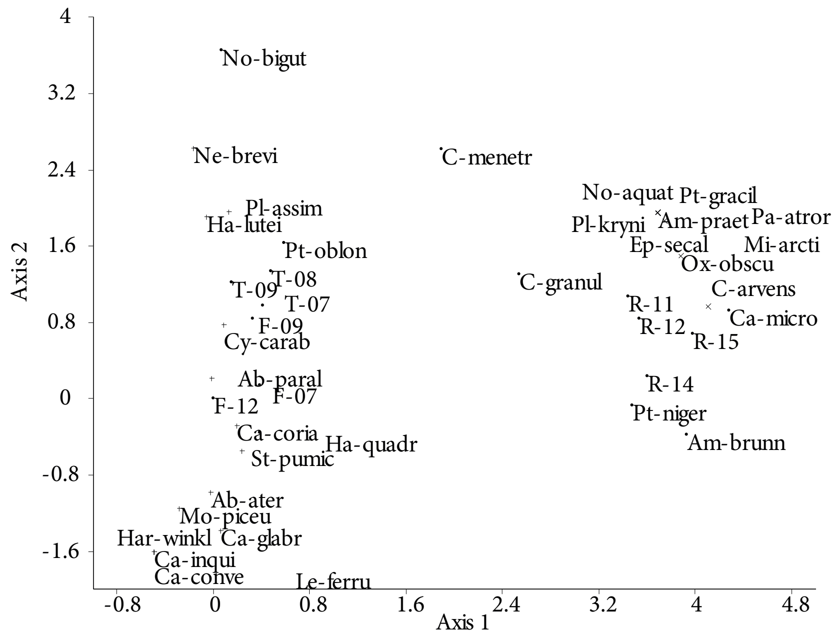

Fig. 6. Plot ordination of detrending correspondent analysis (66 % of the variance) of the forest species compositions in forests of the Nature Reserve and the urban parks during the study years. Symbols represent: plus — species which found only in parks, cross — species which found only in Reserve and column — shared species in both territories. Site name abbreviations are the same as in fig. 3.

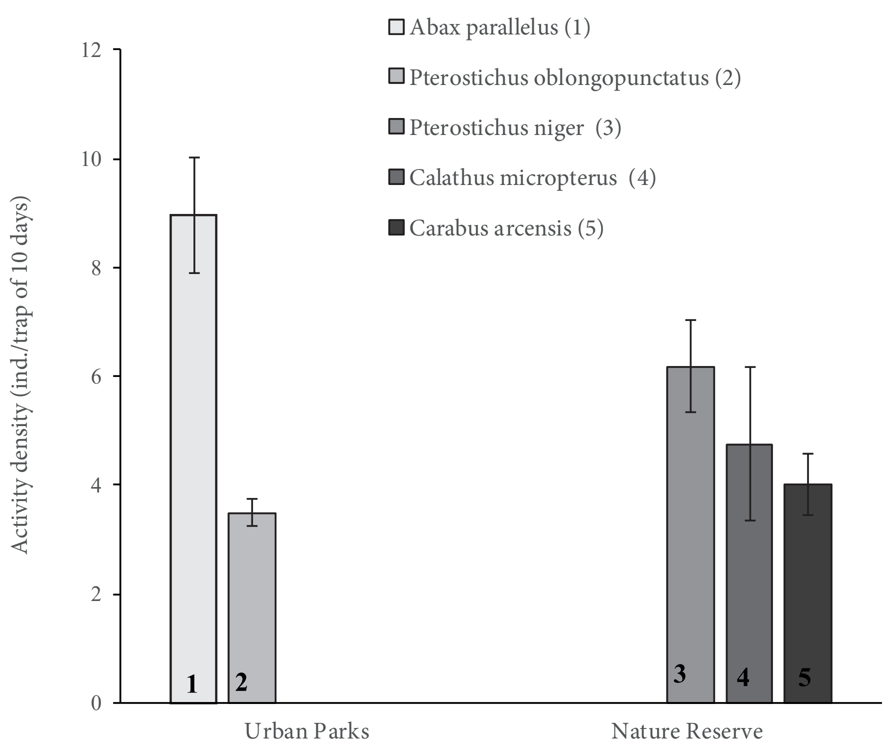

Fig. 7. Average of activity density (± 95 %CI) of the five abundant forest species in the Polisky Nature Reserve and in the urban parks.

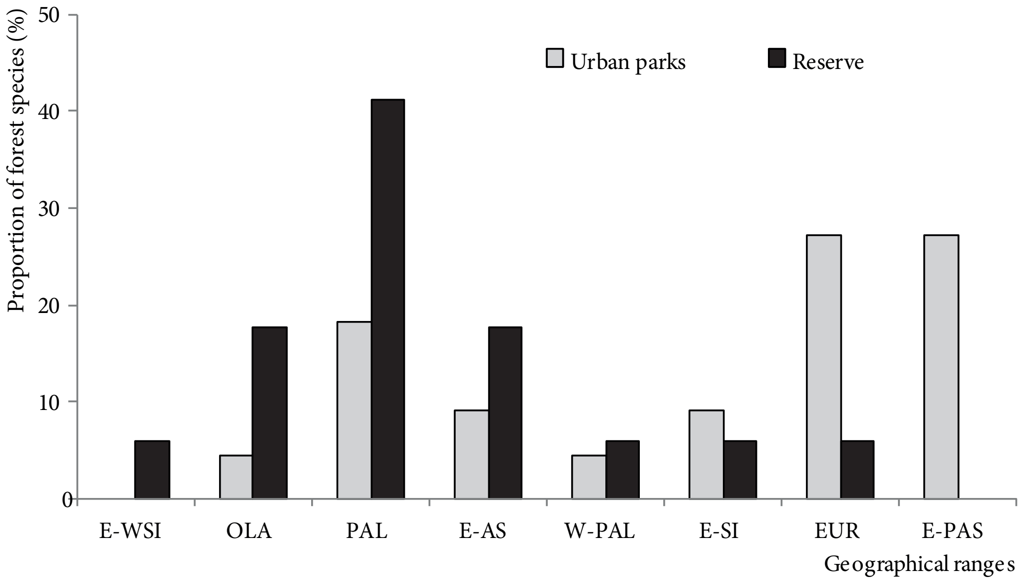

Fig. 8. The ratios of forest carabid species according to their geographical ranges in the studied territories. Codes of geographical range given in table 2.

The five populations of forest species were abundant (fig. 7). In the PNR, the populations of *P. niger, C. micropterus* and *C. arcensis* had high densities (fig. 7). Moreover, *P. niger* and *C. micropterus* were found in at urban parks but by low abundance. *Abax parallelus* and *P. oblongopunctatus* were the most abundant species in the two urban parks; whereas in the PNR the population of *A. parallelus* was not found, *P. oblongopunctatus* has minimal abundance.

The forest species with holarctic and palearctic ranges (which accounted 59 %) have been prevailed at the Nature Reserve, whereas in the two parks the representatives of european and european-neareastern ranges (54 %) dominated (fig. 8).

Discussion

Numerous researchers have shown that carabid species composition alters under the structural changes of the habitat and does not depend on specific vegetation cover (Scott, Anderson, 2003; Sadler et al., 2006). The studies aimed at investigating forests proved that in old forests the diversity of beetles is higher. This is due to the fact that forest age could affect the carabids assemblages because of the changes in habitat structure, where early and later forest successive stages differ in the vegetation structure, and in the accumulation of dead and decaying wood (Tyrell, Crow, 1994; Ings, Hartley, 1999). High diversity of beetles in middle-aged forests can be achieved due to the increasing heterogeneity of the environment and the settlement of their species, characteristic of both young and old forests.

Notwithstanding our expectations, the species richness of ground beetles in urban parks obtained in our studies was higher than in PNR, respectively total richness — 70 species (57 species n Teremky and 44 in Theophania) and 47 species. The reason for the high species richness in urban parks may be that urban environments (the woodland patches and their surroundings) are more heterogeneous in terms of habitat types, patch configuration, size and isolation, and nutrient enrichment, as compared to the environmental conditions of the Nature Reserve. Some researchers obtained similar results, where the species richness of carabid beetles in cities was significantly higher than in reserves (Żelazna, Blażejewicz-Zawadzińska, 2005, 2006; Nietupski et al., 2006; Satler et al., 2011). As shown by Sattler et al. (2011) high species richness of urban ecosystems is attributed to the constantly changing and often ephemeral habitats of cities.

At the same time, the low species richness of carabids in the Nature Reserve is conditioned by the fact that the poor soil under conifer and mixed forests, and also due to desalinating reclamation carried out in the 1960s in the Polissia that led to forest degradation in the PNR (Bumar, 2009). The results obtained by Fahy and Gormally (1998) also showed that carabid species richness was less in the conifer than in the oak forests. In addition, the dissimilarity (on the landscape-level difference) between our woodland areas due to different the environmental conditions at the two geographic zones (forest and forest-steppe).

The abiotic conditions (moisture and temperature of soil, pH of soil, litter properties) can determine the differences not only in the composition of forest species, but also in the structure assemblages of ground beetles in general. In this study, the open-habitat species and generalists species accounted for 70 % of the total number of species in the urban parks and 60 % in the PNR. Generalists are able to tolerate much higher levels of disturbance and occur in different habitats; they are expected to better resist habitat fragmentation in urban landscape than forest species. Many authors have demonstrated that the changes in species composition at the forests of urban landscape are explained by the replacement of habitat specialists with generalist species and open habitat species (Summerville & Crist, 2004; Didham et al., 2007). For example, Sroka and Finch (2006) showed similar results: in oak-beech and oak-hornbeam forests (Germany) the open-habitat species accounted for 47 % of the total number of species (total recorded species 47) and generalists accounted for 15 % of the total number of species. Thus, it is supported by observations of many open habitat species which commonly invade urban woodland fragments (Halme & Niemela, 1993; Koivula et al., 2002).

The dispersal ability has important value affecting the dispersion of species in a fragmented landscape (Halme & Niemela, 1993; Kinnunen et al., 2001). The most typical forest dwellers are large brachypteran species (Baguette, 1993), which are sensitive to forest fragmentation because have low colonising capacities. According to Ribera et al. (2001), a high proportion of brachypterous species in assemblage indicates an undisturbed habitat. In our investigations, the ratios of brachypterous carabids beetles were low in the studied territories (table 1). Kotze and O'Hara (2003) concluded that dimorphic species are more adapted to disturbed habitat, and their dominance showed that habitat is disturbed. In this study the ratios of dimorphic carabids were low than brachypteran species in the studied territories (table 1). At the same time, the wing-dimorphic species were more abundant among generalist and open-habitat species in the PNR, but only among generalist in the urban parks. With regard to the presence of macropterous species in the structure of assemblages, they prevailed by terms of the number of species and density in both studied territories and among all habitat affinity groups. The abundant macropterous beetles were represented by open-habitat species at the urban parks; they actively can disperse across urban forests with open patches and residential areas. Thus, this allows us to assume that the conditions in the Nature Reserve and in the urban parks are disturbed and unstable, and the urban parks are more fragmented.

Forest carabids species

The ground beetle assemblages in forests are represented by the species with different ecological characteristics and it is clear that the assessment of the nature of forests is most adequate on the basis of species oriented to enclosed habitats. Thus, many researchers identified a group of forest species as indicators of the forest ecosystems state (Appendix, table A2). For example, 15 carabid species were classified as stenotopic and 14 as eurytopic forest species in a region in the Netherlands by Turin and Heijerman (1988). According to Assmann (1999) these 'forest-dwelling' ground beetles were also recorded in ancient woodlands of the north-west Germany. The results of another study indicated that eight indicator species of forest carabids were recorded in the ancient oak-beech woods (Germany) (Finch, 2005); among them, six species were similar to our data (Appendix, table A2). According to Sroka and Finch (2006) the 15 forest species were found in ancient deciduous forests which are located between the two cities (Lower Saxony, Germany).

In the Protected Area of Lusowskie Lake and Sama Valley (Poland) the 18 forest species were recorded (Sienkiewicz, Konwerski, 2006). Gryuntal (2008) indicated 24 forest species for mixed forest zone and 19 forest species for forest-steppe zone in the forests of the Russian Plain. In addition, the presence of the forest species was also noted while studying the urban forest fragments along urban-rural gradient (Niemela & Kotze, 2009). Sadler et al. (2006) found five woodland specialist and 15 woodland-associated species in the urban forest areas of Birmingham (UK). Thus, along the urbanization gradient in Brussels (Belgium), the 11 forest specialists and 17 forest generalists were found in the different forest fragments (Gaublomme et al., 2008).

In this study, 31 species were identified as a forest species, the 22 species of them were indicated as forest species by other authors as well (Appendix, table A2). In addition, these species occurred in woodlands areas in Europe (including Ukraine) and in the European part of Russia. In this study, there were no significant differences in both the overall forest-carabid abundance and the number of forest-associated species among the studied territories (36 % forest species in PNR and 31 % in parks). However, the compositions of forest species group have a low similarity between PNR and urban parks (42 % Sørensen index value). This was confirmed by the results of DCA ordination revealed a clear separation between the PNR and urban parks. Perhaps, it can be explained by the fact that some forest species are limited in their distribution at the forest zone (*Amara praetermissa*, *C. arcensis*, *Miscodera arctica*), and other species do not occur in the urban green areas: *Patrobus atrorufus*, *Platynus krynickii* and *Pterostichus gracilis* (Żelazna, Blażejewicz-Zawadzińska, 2005; Nietupski et al., 2006; Putchkov et al., 2003; Kirichenko, Danylkiv, 2011; Rizun, Dedus, 2016). Thus, *Cychrus caraboides* (flightless) and *Nebria brevicollis* F. (flight) were mainly collected in urban parks of the Kyiv City, which are located in suburban zone. This was also confirmed by the findings of Sadler et al. (2006) who indicated that *N. brevicollis* was most associated with disturbed sites, but *C. caraboides* was strongly associated with larger, less disturbed rural sites.

In Ireland, *N. brevicollis* was found at the plantation conifer and as a one of the most abundant species (Karen et al., 2008). In total, *N. brevicollis* is constituted the most frequent ground species in urbanized areas in the entire Europe (Żelazna & Blażejewicz-Zawadzińska, 2005; Gaublomme et al., 2008). At the same time, many researches considered this species as generalist.

The studied territories were also distinguished by the composition of abundant species. Previous works have shown that these species have been found in urban forests and ancient woods too (Assmann, 1999; Sroka, Finch, 2006; Tóthmérész et al., 2011). As mentioned by Niemelä (1993), the boreal forests are dominated by a few species. In our case, structure of assemblage in boreal forests in PNR are prevailed the following species — *C. arcensis*, C. *micropterus*. and *P. niger*. It is mportant to underline that in boreal forests, the early successional phases can be numerically dominated by *P. niger*, while closed phases are often dominated by *C. micropterus* (Koivula et al., 2002; Niemela et al., 2007). Whereas in the parks of the Kyiv City there were *A. parallelus* Duft. and *P. oblongopunctatus* F. For example, these species also were abundant in the Vynnyky forest-park of Lviv City (Rizun, Diedus, 2016).

Conservation interest

Due to an intensive agriculture and the high degree of fragmentation of natural areas, Ukraine is one of the Eastern Europe regions that have lost a considerable part of its biodiversity. The long-term habitat degradation under the conditions of woodlands has led to: the loss of a number of forest species which have been less adapted to disturbances by management. Carabid beetles are often considered as good bioindicators for nature conservation purposes. Among carabids, the forests as vulnerable species are the most important target group for forest conservation management. According to Rassi et al. (2000) about 31 % of the red-listed species being threatened are protected in the Finland forests. For example, some of the typical forest species are severely threatened in Belgium (Desender et al., 2008). Thus, Gaublomme et al. (2008) suggested that forest species with stringent habitat requirements would disappear after destruction or impoverishment of their habitats. Jelaska et al. (2009) reported that the proportion of species and individuals belonging to the forest specialist significantly decreased with isolation of woodland areas. As mentioned by Turin and Heijerman (1988), the following species are more affected by forestry practices: *Abax paralelepipedus*, *Carabus nemoralis* and *P. oblongopunctatus*. The brachypterous beetles among forest species (e. g., *Carabus* spp. and *Abax* spp.) are highly affected by habitat fragmentation (Magura, Kodobocz, 2001; Niemela, 2001). In this study, six *Carabus* and two *Abax* species were found also. The proportion of brachypterous and macropterous species in the forest affinity group was very close in all territories (fig. 5, A, B).

For example, a decline of *Carabus glabratus* in all of north-western Europe has been reported by previous studies; because it needs a well-developed humid litter layer (e. g., Desender et al., 1989). Sroka and Finch (2006) considered this ground beetle as target species for nature conservation measures. In addition, a rare mollusk-feeding ground beetle *Cychrus caraboides* was sampled. According to Koivula et al. (2002) *C. caraboides* prefers wet habitats, but if the conditions of these habitats would become drier, it may disappear. In this study, a vulnerable carabid species *C. menetriesi* was collected in the park Theophania and in the Nature Reserve also. This species is included in Red book of Ukraine (2009).

In this study, 12 out of 31 forest ground beetle species have particular conservation interest in many of European countries (The National...) (Appendix, table A2). The following species are listed on Red List (RL) of as critically endangered and endangered species in different countries: *A. praetermissa*, *Calosoma inquisitor*, *Carabus convexus*, *C. coriaceus*, *C. menetriesi* and *M. arctica* (Appendix, table A2). *Abax parallelus* Duft. is considered as rare species in Germany and United Kingdom, but in Ukraine it is common. Among founded of 31 forest species the 6 carabid species are listed as vulnerable at other countries.

Conclusion

In our studies, 12 rare and endangered species which are protected in Europe were registered in the forests. It is important to note that the vulnerable species *Carabus menetriesi* (Red book..., 2009) was found in the Theophania Park and in the Polisky Nature Reserve. This study shows that there is no significant differences in both the overall forest species abundances and the number of forest-associated species among the Nature Reserve and the both urban parks. At the same time, closely located parks (Teremky and Theophania), which previously existed as a single forest area, today differ significantly in the qualitative and quantitative composition of species. The highest number of species was found in the urban parks and the lowest in the Nature Reserve. This can be explained by the native character of deciduous forests in parks.

Our research confirms that analysis of the structure of assemblages of ground beetles can be used to assess the quality and condition of both habitats and landscapes. Important noted that the use of forest carabids species (and especially rare or vulnerable species) can be indicated as a tool for typifying areas with high conservation potential. In conclusion, the results obtained are the basis for future projections on conservation of the diversity of ground beetles and for further protection and preservation of these territories.

We thanks the anonymous reviewers who helped make this paper a stronger contribution.

Conflicts of Interest

The authors declare no conflict of interest.

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Received 20 September 2018
Accepted 5 March 2019