ZooNotes 71: 1-12 (2015)
www.zoonotes.bio.uni-plovdiv.bg
ISSN 1313-9916

Ground beetles (Coleoptera: Carabidae) from the region of Cape Emine (central Bulgarian Black sea coast). Part II. Ecological parameters and community structure

TEODORA TEOFILOVA

Institute of Biodiversity and Ecosystem Research (IBER), Bulgarian Academy of Sciences, 1000 Sofia, 1 Tsar Osvoboditel Blvd, e-mail: oberon_zoo@abv.bg

Abstract. For the first time an ecological study of the carabid fauna of the area of Cape Emine (Bulgarian Black sea coast) was conducted. Over the period 2010 – 2011 adult carabid beetles were collected. The investigation was carried out at 7 sampling sites and pitfall traps were used. During the study altogether 6245 specimens were captured. The greatest number of both species and specimens was found in the steppe-like habitat, least – in the pine (*Pinus nigra* J. F. Arnold) plantation. Indices for α- and β-diversity were calculated. The dominant structure of the whole carabid complex showed the presence of two eudominant, three dominant, two subdominant, eleven recedent and 85 subrecedent species. The analysis of the sex structure showed the total prevalence of males over females. Cluster analysis indicated a low percentage of taxonomic similarity between the communities, which reflected the diversity of the landscape.

Keywords: Carabidae, Cape Emine, α- and β-diversity, dominance structure, sex structure, taxonomic similarity, occurrence

Introduction

Synecological studies are often used to characterize the influence of the biota on the environment and the impact of human activity on the functioning, productivity and changes in the ecosystems. In this respect, ecological parameters of the communities can be used in assessing the state of the environment and predicting the trends in the future development of the ecological systems.

Ground beetles (Coleoptera: Carabidae) are a frequent and convenient object for synecological studies. Carabids and their communities are widely used as bioindicators of terrestrial environment in the system of biological monitoring (Desender & Baert 1995; Luff 1996; Cranston & Trueman 1997; Pearsall 2007). Furthermore, they are easily trapped and their high taxonomic richness, large numbers and diverse life specializations are the reasons that they cover the entire environmental spectrum of fundamental natural gradients. Carabids have cosmopolitan distribution and decisive importance for the functioning of ecosystems (Brumwell *et al.* 1998).

So far there were no ecological studies, related to the ground beetles from the region of Cape Emine, which is with high conservation status (Teofilova *et al.* 2012). This study was the first which performed an ecological analysis of the carabid communities in some of the main types of habitats in the area. The survey aimed to contribute for the better

Accepted: 27 January 2015
Published: 12 February 2015

acquaintance and more complete biomonitoring use of this undoubtedly beneficial group of insects.

Material and Methods

In connection with the participation in a project for biological monitoring studies in the area, a series of observations and samplings were carried out in two years period during 2010 – 2011. Catches were carried out during the three vegetative periods – spring, summer and autumn – of both years. Ground beetles were collected by the approved method with terrestrial pitfall traps (Dahl 1896; Hertz 1927; Barber 1931). The traps were made of plastic bottles, buried at the level of the ground surface. As fixation fluid a 4% solution of formaldehyde was used. The investigations were performed at 7 sample sites. Specimens were identified according to: Kryzhanovskij (unpublished data), Arndt *et al.* (2011), Lindroth (1974), Hůrka (1996), Reitter (2006), Trautner & Geigenmüller (1987) and are deposited in the Carabidae collection of the Institute of Biodiversity and Ecosystem Research.

Study area

Cape Emine marks the end of the Stara planina Mts. range and conditionally separates Northern and Southern Bulgarian Black sea coast (Galabov 1956). However, it is questionable whether the Cape is also the biogeographical boundary of the coast, as claimed (Josifov 1988, etc.), because the mixing of many biogeographical elements has been found (Tzonev *et al.* 2005; Popov 2007; Teofilova 2013; Teofilova *et al.* 2015). The Cape is located 79 km south of the town of Varna and 54 km north of the town of Bourgas. Stara planina Mts. coast has a length of 52 km, of which beaches occupy over 32%. The coast is almost completely steep and rocky, and between Cape Emine and the town of Obzor is situated one of the few places in Bulgaria where the forest goes immediately to the sea shore.

The geostrategic location of the studied territory, its diverse topography, formed by the "meeting" of the mountain with the sea, and the contingent climate with influence of three climatic zones, contribute to the mixing of the representatives of various ecological and biogeographical complexes, which has led to the formation of peculiar biocoenoses.

The working sampling sites are included within the territory of the protected zones BG0001004 „Emine – Irakli" under Directive 92/43 for the protection of natural habitats and wild flora and fauna and BG0002043 „Emine" under Directive 79/409 for the protection of birds. They are representative ecosystems, characteristic for the region. A brief description of the sampling sites is given in Table 1. Further on in the text, the abbreviated expressions given in the table were used.

In all sampling areas 10 – 14 pitfall traps were set.

Data analysis

The classical four-level classification of Tischler (1949) for soil invertebrates, modified by Sharova (1981) with the initiation of a 5th category "eudominant", was used for determination of the **dominance structure** of the communities: eudominants (with degree of dominance over 10%), dominants (5 to 10%), subdominants (2 to 5%), recedents (1 to 2%), subrecedents (< 1%). The **sex structure** of the individual communities and of the carabid complex as a whole was determined.

Indices for **α-diversity** reflect the biological diversity within the community or the habitat. The following indices were used: concentration of dominance (Simpson 1949), species richness of Margalef (1958), total species diversity (Shannon 1949, 1963), evenness (Pielou 1966). The index of Hill was calculated for comparison.

The indices for **β-diversity** reflect the diversity between the individual communities or habitats and may serve as a measure of the value and the rate of change in species on a gradient from one habitat to another. For determination of the taxonomic similarity between the faunistic complexes in the different ecosystems the coefficients of Jaccard (1908) and

Sørrensen (1948) were used. Cluster analysis was performed with the program PRIMER6 (Clarke & Gorley 2005). The similarity in population density was determined by the coefficient of Jaccard-Naumov (Chernov 1975). Species **occurrence** was established according to the three-level classification of Bodenheimer (1955) and Balogh (1958).

Table 1. Abbreviation, name and description of the sampling sites.

Abbr.	Name	Description of the sampling site	Altitude	Coordinates
IrL	„Irakli, vineyard"	An abandoned vineyard with initial stages of a autochthonous forest recovering succession	26 – 34 m a. s. l.	N 42°45' E 27°53'
IrD	„Irakli, oak forest"	Mesophilous oak forest near the Irakli site	45 – 54 m a. s. l.	N 42°45' E 27°53'
IrB	„Irakli, shore ecotone"	Immediately upon the rocky edge above the sea shore, near a mixed pine-oak forest	38 – 47 m a. s. l.	N 42°45' E 27°53'
VBd	„Military base, Domuskolak gully"	On the open path from the oak forest to the beach and the mouth of a brook drying up in summer	8 – 13 m a. s. l.	N 42°47' E 27°53'
VBb	„Military base, pine forest"	Black pine plantation with accompanying bush-grass vegetation	13 – 25 m a. s. l.	N 42°47' E 27°53'
Rs	„Signal repeater, steppe"	Steppe-like habitat at the crest meadow above site Rd	114 – 117 m a. s. l.	N 42°46' E 27°53'
Rd	„Signal repeater, oak forest"	Old oak forest with dense undergrowth of spiny shrubs and moderately xerothermic conditions	112 – 121 m a. s. l.	N 42°46' E 27°53'

Results

During the study altogether 6245 specimens were captured (2163 ex. in 2010 and 4082 ex. in 2011). They belong to 103 species, 34 genera, 15 tribes, 3 subfamilies.

Carabus coriaceus Linnaeus, 1758 (with 950 indvs.) and *Chlaenius nitidulus* (Schrank, 1781) (with 1256 ex.) are the most abundant species. Thirty-one species (30%) are represented by only one individual. The largest number of such species was found in the sample sites Rs (8 species) and VBd (7 species).

For further information about species composition, taxonomic structure etc., see Teofilova (2013) and Teofilova *et al.* (2015).

The analysis of the dominance structure showed the presence of 2 eudominants (*Carabus coriaceus* and *Chlaenius nitidulus*) with total numbers of 35% of all captured specimens, 3 dominants (*Pterostichus melas* (Creutzer, 1799), *Calathus fuscipes* (Goeze, 1777) and *Brachinus crepitans* (Linnaeus, 1758), 2 subdominants (*Harpalus dimidiatus* (Rossi, 1790) and *Acinopus megacephalus* (Rossi, 1794), 11 recedents (*Calosoma sycophanta* (Linnaeus, 1758), *Carabus ullrichi* Germar, 1824, *Carabus convexus* Fabricius, 1775, *Trechus quadristriatus* (Schrank, 1781), *Myas chalybaeus* (Palliardi, 1825), *Calathus cinctus* (Motschulsky, 1850), *Laemostenus terricola* (Herbst, 1783), *Agonum (Europhilus)* sp. Chaudoir, 1859, *Harpalus flavicornis* Dejean, 1829, *Ophonus azureus* (Fabricius, 1775) and *Microlestes negrita* (Wollaston, 1854), and 85 subrecedents (Fig. 1). The number of species of various categories for the individual sampling sites is shown in Table 2.

Table 2. Categories of dominance of the Carabidae species in the sampling sites (number of species).

Category	IrL	IrD	IrB	VBd	VBb	Rs	Rd	Total
eudominants	3	2	2	2	2	1	4	2
dominants	3	1	0	2	3	3	1	3
subdominants	0	3	2	3	2	3	2	2
recedents	7	7	11	11	4	9	10	11
subrecedents	25	14	15	22	11	50	24	85

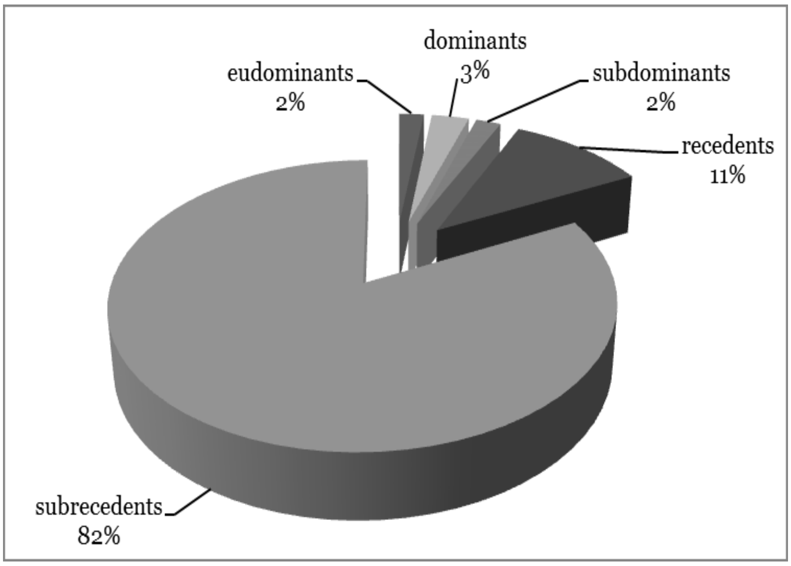


Fig. 1. Dominance structure of the entire carabid complex (number of species).

Eudominants in the individual sampling sites are between 1 and 4, and their total numbers amount to over 50% in all sampling sites with the exception of Rs, where eudominant is one species (*Chlaenius nitidulus*) with numbers of around 40%. For the whole carabid complex eudominants cover 35% of the total numbers. *Carabus coriaceus* can be determined as a permanent eudominant (i. e. established in all of the points), as it belongs to the latter category in all of the sampling sites except one (Rs), where it belongs to the category of dominants, and also is generally a characteristic representative of species with a high degree of dominance (Polak 2004; Varvara & Zugravu 2004). *Calathus fuscipes* has been also established as a dominant in an ecological study of carabid communities from Northern Poland (Aleksandrowicz *et al.* 2009).

In all sampling sites the number of the subrecedents is the highest and it represents over 50% of the number of species. In sampling site Rs they reach 76% of all species.

In relation to the distribution of the number of specimens over the categories of dominance, the biggest share of eudominants and dominants (forming together a 60% of the total population) should be highlighted (Fig. 2).

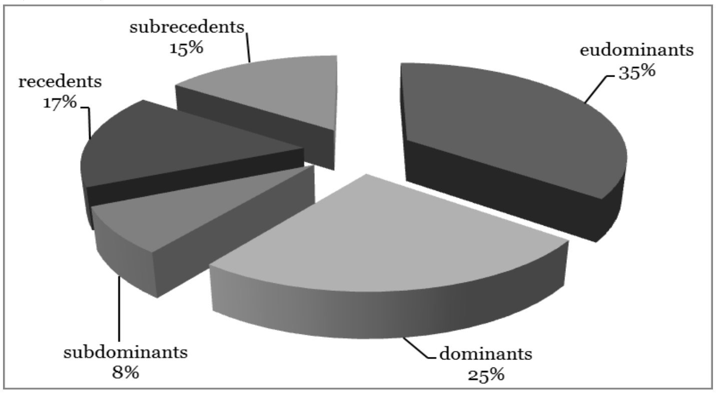
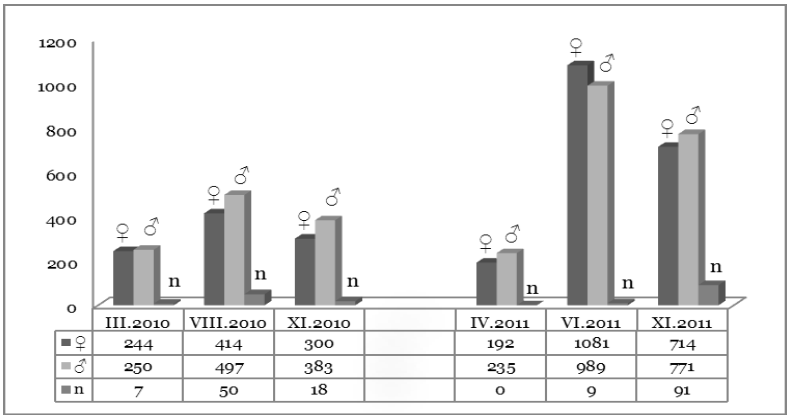


Fig. 2. Distribution of specimens of ground beetles on the levels of the dominant structure for the entire carabid complex (number of specimens).

The **sex structure** of the biocoenose reflects the ratio between individuals of different genders. The analysis of the results showed the total predominance of male over female specimens. The dominance of male beetles is expressed in all catches, with the exception of the summer collection in 2011, when the greatest total catch was also observed (Fig. 3). The least number of caught carabids of both sexes is during the spring collection of 2011, followed by the same in 2010. This pattern appears to be normal and is associated with the natural development of beetles and the absence of activity in the winter season. Distribution of carabids in the individual sampling sites is shown in Fig. 4.



	III.2010	VIII.2010	XI.2010		IV.2011	VI.2011	XI.2011
♀	244	414	300		192	1081	714
♂	250	497	383		235	989	771
n	7	50	18		0	9	91

Fig. 3. Distribution of the specimens by gender during the different seasons (♀ – female, ♂ – male, n – not determined) (number of specimens).

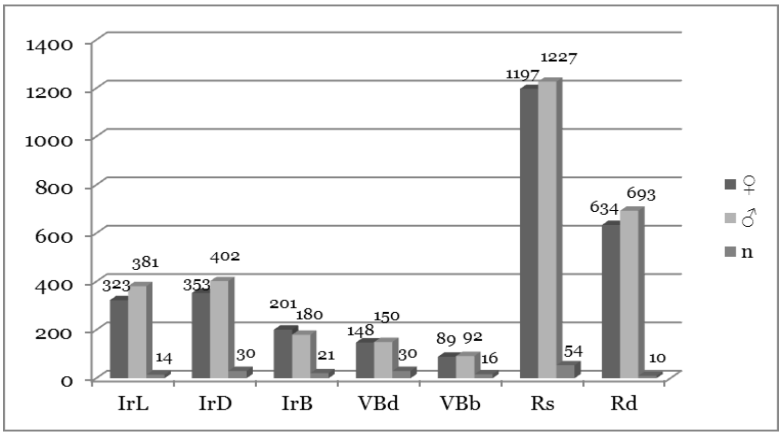


Fig. 4. Distribution of the specimens by gender in the individual sampling sites (♀ – female, ♂ – male, n – not determined) (number of specimens).

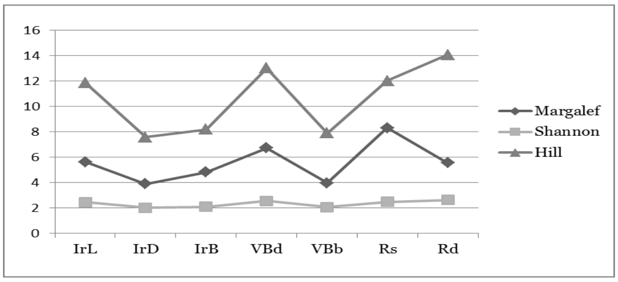
The analysis of biodiversity (Table 3) showed, that the largest number of species (S) and specimens (N) is found in the site Rs (S = 66; N = 2478), and the least – in VBb (S = 22; N = 197). Similar pattern is found for pine forest assemblages in the Carpathian Mountains (Balog *et al.* 2012).

The parameters of the **α-diversity** indicated that the seashore in Irakli site (IrB) where dominant species are missing and the category of eudominants is represented by two species, is characterized with the highest concentration of dominance of Simpson (hence, impaired dominant structure). This value is lowest in the old oak forest near signal repeaters north of Irakli site (Rd). The diversity of Margalef, the function of the Shannon and the Pielou's evenness are with the highest values in sampling sites Rd, VBd and Rs (Fig. 5).

Calculated indices of Jaccard and Sørrensen, reflecting the **β-diversity**, showed an average or low taxonomic similarity between the individual sampling sites, which indicates a significant heterogeneity of the studied communities.

Table 3. Numerical values of the ecological indices of α-diversity.

Index	IrL	IrD	IrB	VBd	VBb	Rs	Rd
number of species (S)	38	27	30	40	22	66	41
number of specimens, abundance (N)	718	785	402	329	197	2478	1336
Margalef	5,626	3,901	4,836	6,729	3,975	8,317	5,558
Pielou's Evenness	0,68	0,615	0,618	0,696	0,669	0,593	0,712
Shannon	2,474	2,025	2,104	2,566	2,067	2,486	2,644
Simpson's dominance	0,125	0,236	0,269	0,155	0,199	0,191	0,111
Simpson's diversity	0,875	0,764	0,731	0,845	0,801	0,809	0,889
Hill	11,87	7,577	8,196	13,01	7,904	12,01	14,07



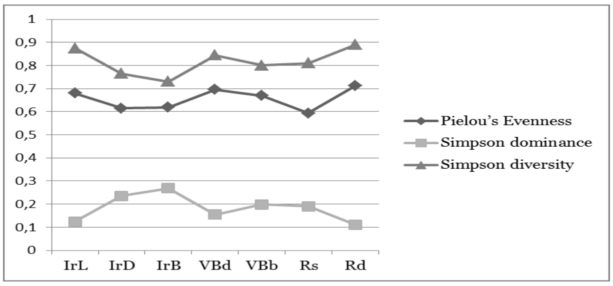


Fig. 5. Indices of α-diversity: Species diversity of Margalef, Shannon and Hill (left) and Evenness, Simpson's concentration of dominance and diversity (right).

Cluster analysis (Fig. 6) showed a lower rate of taxonomic similarity of associations, compared for example with the values obtained in agrocoenoses near the town of Sofia (Kostova 2004; Shishiniova *et al.* 2001). Higher is the similarity between the coastal habitats, as well as between the situated in close proximity to each other sampling areas Rs and Rd. Analysis demonstrated the separation of the two main groups, which might be characterized as "forest habitats" and "ecotones".

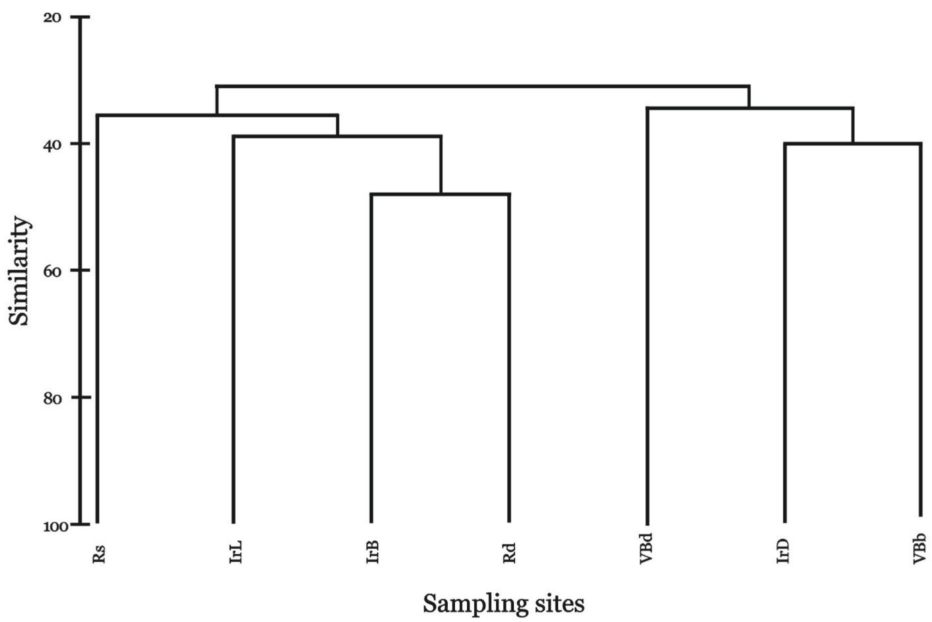


Fig. 6. Cluster analysis of the carabid assemblages of the region of Cape Emine, using the index of similarity of Jaccard.

The results of the analysis of **quantitative data** (Jaccard-Naumov index) also showed the greatest taxonomic similarity between the coastal communities. With high similarity in quantity are both sampling sites located on the territory of the military base (VBd and VBb), followed by the Rs and Rd areas. The lowest quantitative similarity is found between the pine forest (VBb) and the steppe-like habitat (Rs).

The **occurence** reflects the uniformity or the evenness of the distribution of species in space. The division of species of the entire carabid complex according to their occurrence showed the highest share of rare, random species that occur in less than 20% of the sampling sites (Table 4). Species that were found in all sampling sites and had 100% of occurrence are five: *Carabus coriaceus*, *Trechus quadristriatus*, *Calathus fuscipes*, *Laemostenus terricola* and *Harpalus dimidiatus*.

Table 4. Categories of occurrence of the ground beetles.

Bodenheimer, Balogh	Number of species	Species
permanent (> 50%)	26	*Nebria brevicollis*, *Calosoma sycophanta*, *Calosoma inquisitor*, *Carabus ullrichi*, *Carabus convexus*, *Carabus coriaceus*, *Trechus quadristriatus*, *Myas chalybaeus*, *Pterostichus melas*, *Calathus fuscipes*, *Calathus ambiguus*, *Calathus melanocephalus*, *Calathus cinctus*, *Laemostenus terricola*, *Amara aenea*, *Amara anthobia*, *Amara familiaris*, *Harpalus rubripes*, *Harpalus attenuatus*, *Harpalus tardus*, *Harpalus dimidiatus*, *Acinopus megacephalus*, *Ophonus azureus*, *Chlaenius nitidulus*, *Microlestes maurus*, *Microlestes negrita*
auxiliary (25 to 50%)	29	*Leistus rufomarginatus*, *Notiophilus rufipes*, *Carabus scabriusculus*, *Cychrus semigranosus*, *Bembidion lunulatum*, *Calathus distinguendus*, *Calathus longicollis*, *Agonum sp.*, *Amara communis*, *Parophonus mendax*, *Pseudoophonus rufipes*, *Harpalus flavicornis*, *Harpalus hospes*, *Harpalus distinguendus*, *Ophonus puncticeps*, *Ophonus similis*, *Ophonus ardosiacus*, *Ophonus sabulicola*, *Ditomus calydonius*, *Dixus obscurus*, *Dinodes decipiens*, *Microlestes fissuralis*, *Microlestes minutulus*, *Cymindis ornata*, *Brachinus berytensis*, *Brachinus brevicollis*, *Brachinus crepitans*, *Brachinus explodens*, *Brachinus psophia*
random (< 25%)	48	all the rest

Discussion

The results of the survey showed strong variation in number of species and specimens in the individual communities, and in the VBb both had lowest values. Poor species composition is typical for pine cultures (Hengeveld 1980; Niemelä 1993; Rainio 2009; Balog *et al.* 2012), while the richest species composition of the steppe-like habitat is likely due to the presence of some extrazonal (i.e. forest) and intrazonal (halophilic) and Mediterranean species (Putchkov 2011). Furthermore, it has been demonstrated, that species diversity decreases towards the affected habitats along with the gradient of urbanization (Niemelä *et al.* 2002, etc.). In addition, anthropogenic interference affects indirectly the dynamics of the ground beetles distribution, causing the homogenization of habitats and thus affecting the availability of the beetles' prey (McKinney 2006).

The large percentage of species, which were represented by a single specimen did not appear to be unusual, as it was also established by other authors (Coddington *et al.* 2009; Ferro *et al.* 2012).

The analysis of the dominance structure showed the presence of eudominant species, which is typical for anthropogenically-influenced and unsustainable ecosystems and was also established by Kodzhabashev & Mollov (2000), Kostova (2004) and Baranová *et al.* (2013). Recurring ecological model in biocoenotic researches is the presence of a few abundant species and the predominance of the variety of rare species (Preston 1962), which is confirmed by the results of this study, showing the greatest number of species from the category of the subrecedents.

In terms of the sex structure, it could be said that the predominance of males over females is completely understandable, because males are more active, and therefore are more likely to fall into the traps.

Low species diversity and high values for Simpson's concentration of dominance in IrD and IrB probably originate from the stronger anthropogenic influence in that areas, especially during the summer season when tourism pressure increases.

Analysis of β-diversity demonstrated the separation of the two main groups – "forest habitats" and "ecotones". The inclusion of Rd in the second group can be explained by its proximity with the steppe-like habitat (Rs) and the corresponding influx of open habitat dwelling forms in it. Clearly notable is the separation of the Rs site, probably originating from the highest species diversity in this biotope. The immediate statistical vicinity of the abandoned vineyard (IrL) could be resulting from a succession, taking place with similar speed in both sampling sites, despite the spatial distance.

The results of this study indicate, that the grouping of the clusters somewhat follows the humidity gradient. However, it is more likely that the determining factor in the studied case is the synanthropic effect. Similar results were obtained by Kostova (2004) and Shishiniova *et al.* (2001), where the first environmental gradient was determined by the type of cultivated vegetation (moisture, respectively), and the second reflected the degree of anthropogenic load. The low percentage of taxonomic similarity of the groups reflects the diversity of the landscape.

Conclusions

For the first time main coenotic structure parameters of the carabid communities in different types of ecosystems from the region of Cape Emine were determined and analyzed.

The dominant structure showed the presence of two eudominants, which is typical for anthropogenically-influenced and unstable ecosystems.

The analysis of biodiversity indices proved: 1) the importance of coastal habitats, associated with the primary hygromesophylic preferences of the ground beetles; 2) the role of steppe-like habitats in the maintenance of the populations of rare and stenotopic species; 3) the negative impact of anthropogenization, expressed as a direct concern of the species and as an altering or destroying of their habitats.

Cluster analysis indicated a low percentage of taxonomic similarity of the coenoses, reflecting the diversity of the biotopes, and also confirmed the importance of soil and air humidity and water balance (Thiele 1977; Fuellhaas 2000; Antvogel, Bonn 2001; Eyre *et al.* 2005), as well as the influence of various anthropogenic activities (Kostova 2004; Teofilova *et al.* 2012) as an additional environmental gradient in the distribution of ground beetles.

Although the territory has a high conservation status, the human element continues to play a negative role in the functioning of the ecosystems (Teofilova *et al.* 2012). Given its determinative importance in the distribution of ground beetles, the imposition of measures for the protection of biodiversity as a whole is needed (Teofilova 2013).

Acknowledgments. The study was carried out thanks to the financial assistance of "Litex Commerce" Ltd. (through the Project "Monitoring researches in the areas of land properties № 53045.232.11 in "Balabana" locality and № 53046.639.3 in "Ivanov dol" locality in the land of the town of Obzor, Nesebar Municipality, Bourgas Province"). The author expresses her gratitude to Dr. Svetlana Boycheva, Lyubomira Lyubomirova, Radostina Pravcheva, Yanica Ivanova, Anton Stamenov, Lado Aleksandrov and Pencho Pandakov for their help.

References

Aleksandrowicz, O., Pakula, B. & Grabiec, E. (2009) Species composition and ecological structure of carabid's assembly in a fodder's mixture field in north Poland. *Environment. Technology. Resources. Proceedings of the 7th International Scientific and Practical Conference*, 1: 147-153.

Antvogel, H. & Bonn, A. (2001) Environmental parameters and microspatial distribution of insects: case study of carabids in an alluvial forest. *Ecography*, 24 (4): 470-482.

Arndt, E., Schnitter, P., Sfenthourakis, S. & Wrase, D. W. (Eds.) (2011) *Ground Beetles (Carabidae) of Greece.* PENSOFT Publishers, Sofia-Moscow, 393 pp.

Balogh, J. (1958) *Lebensgemeinschaften der Landtiere*. Berlin, 560 pp.

Balog, A., Hartel, T, Máthé, I. & Urák, I. (2012) Carabid assemblages along a land use gradient in a Carpathian Mountain landscape. *North-Western Journal of Zoology*, 8 (2): 215-222.

Baranová, B., Fazekašová, D., Jászay, T. & Manko, P. (2013) Ground beetle (Coleoptera: Carabidae) community of arable land with different crops. *Folia faunistica Slovaca*, 18 (1): 21-29.

Barber, H. S. (1931) Traps for cave-inhabiting insects. *Journal of the Elisha Mitchel Scientific Society* (Chapel Hill, USA), 46: 259-266.

Bodenheimer, F. (1955) *Precis d'ecologie animale*. Paris, 315 pp.

Brumwell, L. J., Craig, K. G. & Scudder, G. G. E. (1998) Litter Spiders and Carabid Beetles in a Successional Douglas-fir Forest in British Columbia. *Northwest Science*, 72: 94-95.

Chernov, Y. I. (1975) Main synecological characteristics of soil invertebrates and methods for their analysis. *In*: *Methods of soil-zoological investigations*. Nauka, Moscow, pp. 198-216 (in Russian).

Clarke, K. R. & Gorley, R. N. (2005) PRIMER 6 (Plymouth Routines In Multivariate Ecological Research). Lutton, Ivybridge, PRIMER-E Ltd.

Coddington, J. A., Agnarsson, I., Miller, J. A., Kuntner, M. & Hormiga, G. (2009) Undersampling bias: the null hypothesis for singleton species in tropical arthropod surveys. *Journal of Animal Ecology*, 78: 573-584.

Cranston, P. S. & Trueman, J. W. H. (1997) "Indicator" taxa in invertebrate biodiversity assessment. *Memoirs of the Museum of Victoria*, 56 (2): 267-274.

Dahl, E. (1896) Vergleichende Untersuchungen über die Lebensweise wirbelloser Aasfresser. *Sitzungsberichte Königlichen Preußiche Akademie*, Wissenbach, 1: 11-24.

Desender, K. & Baert, L. (1995) Carabid beetles as bio-indicators in Belgian coastal dunes: a long term monitoring project. *Bulletin de L'Institut Royal de Belgique Entomologie*, 65: 35-54.

Eyre, M. D., Rushton, S. P., Luff, M. L. & Telfer, M. G. (2005) Investigating the relationships between the distribution of British ground beetle species (Coleoptera, Carabidae) and temperature, precipitation and altitude. *Journal of Biogeography*, 32: 973-983.

Ferro, M. L., Gimmel, M. L., Harms, K. E. & Carlton, C. E. (2012) Comparison of the Coleoptera communities in leaf litter and rotten wood in Great Smoky Mountains National Park, USA. *Insecta Mundi*, 0259: 1-58.

Fuellhaas, U. (2000) Restoration of degraded fen grassland-effects of long-term inundation and water logging on ground beetle populations (Coleoptera, Carabidae). *In*: Brandmayr, P., Lövei, G., Zetto Brandmayr, T., Casale, A., Vigna Taglianti, A. (Eds.), *Natural History and Applied Ecology of Carabid Beetles*. Proceedings of the IX European Carabidologists' Meeting (26-31 July 1998, Camigliatello, Cosenza, Italy), PENSOFT Publishers, Sofia–Moscow, pp. 251-263.

Galabov, Zh. (1956) Black sea coast. *In*: Galabov Zh. (Ed.), Physical geography of Bulgaria. BAS, Sofia, pp. 317-333 (in Bulgarian).

Hengeveld, R. (1980) Polyphagy, oligophagy and food specialization in ground beetles (Coleoptera, Carabidae). *Netherlands Journal of Zoology*, 30: 564-584.

Hertz, M. (1927) Huomiota petokuorianisten olinpaikoista. *Luonnon Ystävä*, 31: 218-222.

Hůrka, K. (1996) *Carabidae of the Czech and Slovak Republics.* Kabourek, Zlin, 565 pp.

Jaccard, P. (1908) Nouvelles Recherches sur la Distribution Florale. *Société Vaudoise des Sciences Naturelles*, 44: 223-270.

Josifov, M. (1988) Über den zoogeographischen Charakter der Südeuropäischen Insektenfauna unter besonderer Berücksichtigung der Heteropteren. *Berichte des Naturwissenschaftlichen-medizinischen Vereins Insbruck*, 75: 177-184.

Kodzhabashev, N. D. & Mollov, K. B. (2000) Faunistic and ecological studies on the carabid fauna of the open territories in the vicinity of city of Sofia. *Jubilee Book of Scientific Papers*, Forestry University, Sofia, pp. 291-302. (in Bulgarian, English Summary).

Kostova, R. (2004) *Faunistichni i ekologichni izsledvaniya na saobshtestva ot brambari begachi ot agrotsenozi okolo Sofia (Faunistic and ecological studies on ground beetles communities from agrocoenoses near Sofia).* PhD Dissertation, Sofia University, Sofia, 118 pp. (in Bulgarian).

Kryzhanovskij, O. L. Unpublished data. *Fauna Bulgarica, Carabidae.* Manuscript (in Russian).

Lindroth, C. H. (1974) Coleoptera, Carabidae. *In: Handbooks for the Identification of British Insects, Vol. IV, Part 2.* Royal Entomological Society of London, 154 pp.

Luff, M. L. (1996) Use of Carabids as environmental indicators in grasslands and cereals. *Annales Zoologici Fennici*, 33: 185-195.

Margaleff, D. (1958) Information Theory in Ecology. *Yearbook of the Society for General Systems Research*, 3: 36-71.

McKinney, M. L. (2006) Urbanization as a major cause of biotic homogenization. *Biological Conservation*, 127: 246-260.

Niemelä, J. (1993) Mystery of the missing species: species-abundance distribution of boreal ground-beetles. *Annales Zoologici Fennici*, 30: 169-172.

Niemelä, J., Kotze, J., Venn, S., Penev, L., Stoyanov, I., Spence, J., Hardley, D. & Montes De Oca, H. (2002) Carabid beetle assemblages (Coleoptera, Carabidae) across urban-rural gradients: an international comparison. *Landscape ecology*, 17 (5): 387-401.

Pearsall, I. A. (2007) Carabid beetles as ecological indicators. *In*: "*Monitoring the Effectiveness of Biological Conservation*". Proceeding of conference, 2-4 November 2004, Richmond, BC, pp. 389–399.

Pielou, E. (1966) Species diversity and pattern diversity in the study of ecological successions. *Journal of Theoretical Biology*, 10: 370-383.

Polak, S. (2004) Cenoses and species phenology of carabid beetles (Coleoptera: Carabidae) in three stages of vegetational succession in upper Pivka karst (SW Slovenia). *Acta entomologica slovenica*, 12 (1): 57-72.

Popov, V. (2007) Zoogeografski osobenosti (Zoogeographical peculiarities). *In:* Popov, V., Spasov, N., Ivanova, T., Mihaylova, B. & Georgiev, K., *Redki i zastrasheni bozainitsi v Balgariya (Rare and endangered mammals in Bulgaria).* Dutch Mammal Society VZZ, Holland and National Museum of Natural History, Sofia, pp. 55-77 (in Bulgarian).

Preston, F. W. (1962) The canonical distribution of commonness and rarity. *Ecology*, 43: 185-215, 410-432.

Putchkov, A. (2011): Ground beetles of the Ukraine (Coleoptera, Carabidae). *In*: Kotze D. J., T. Assmann, J. Noordijk, H. Turin, R. Vermeulen (Eds), *Carabid Beetles as Bioindicators: Biogeographical, Ecological and Environmental Studies*. ZooKeys, 100: 503-515.

Rainio, J. (2009) *Carabid beetles (Coleoptera, Carabidae) as indicators of environmental change in Ranomafana National Park, Madagascar.* Academic Dissertation, Department of Biological and Environmental Sciences, Faculty of Biosciences, University of Helsinki, 33 pp.

Reitter, E. (2006) *Fauna Germanica – Die Käfer des Deutschen Reiches.* Digitale Bibliothek Band 134, Directmnedia Publishing GmbH, Berlin, ISBN 3-89853-534-7.

Shannon, C. E. & Weaver, W. (1949, 1963) *The Mathematical Theory of Communication.* University of Illinois Press, Urbana, Chicago, 132 pp.

Sharova, I. (1981) *Zhiznenye formyj zhuzhelits (Life forms of Carabids).* Nauka (Science), Moskow, 360 pp. (in Russian).

Shishiniova, M., Kostova, R. & Kodzhabashev, N. (2001) A study of carabid beetle (Coleoptera: Carabidae) communities in three types of agrocenoses. *Archives of Biological Sciences*, 53 (3-4): 123-128.

Simpson, E. H. (1949) Measurement of diversity. *Nature*, 163: 688.

Sørrensen, K. (1948) A method of establishing groups of equal amplitude in plant society based on similarity of species content and its application to analyses of the vegetation on Danish commons. *Det Kongelige Danske Videnskap Selskap Biol. Skr.*, 5: 1-34.

Teofilova, T. M. (2013) *Sastav I struktura na carabidnite (Coleoptera: Carabidae) saobshtestva v razlichni tipove mestoobitaniya ot rayona na nos Emine (Composition and structure of the carabid (Coleoptera: Carabidae) communities in different types of ecosystems of the region of Cape Emine).* PhD Thesis, Sofia University, Sofia, 234 pp. (in Bulgarian)

Teofilova, T. M., Markova, E. P. & Kodzhabashev, N. D. (2012) Negative anthropogenic activities and threats to the biodiversity in the area of Cape Emine. *Science & Technologies, Section "Nautical & Environmental studies"*, II (2): 13-18.

Teofilova, T. M., Markova, E. P. & Kodzhabashev, N. D. (2015) Ground beetles (Coleoptera: Carabidae) from the region of Cape Emine (Central Bulgarian Black sea coast). Part I. Taxonomic and zoogeographic structure, life forms, habitat and humidity preferences. *ZooNotes*, 68: 1-18.

Thiele, H. U. (1977) *Carabid beetles and their environments: a study on habitat selection by adaptations in physiology and behaviour.* Springer-Verlag, Berlin, Heidelberg, New York, 369 pp.

Tischler, W. (1949) *Grundzüge der terrestrischen Tierökologie.* Friedrich Vieweg und Sohn, Braunschweig, 219 pp.

Trautner, J. & Geigenmüller, K. (1987) *Tiger beetles, Ground beetles. Illustrated Key to the Cicindelidae and Carabidae of Europe.* Josef Margraf Publisher, Aichtal/Germany, 488 pp.

Tzonev, R, Dimitrov, M. & Roussakova, V. (2005) Dune vegetation of the Bulgarian Black Sea coast. *Hacquetia*, 4 (1): 7-32.

Varvara, M. & Zugravu, F. (2004) Contributions to the study of carabids (Coleoptera, Carabidae) from the Gadinti forest, Neamt County. *Analele Stiintifice ale Universitatii „Al.I.Cuza" Iasi, s. Biologie animala*, Tom L, 157-172 pp.