ECOLOGIA BALKANICA
2021, Special Edition 4 pp. 29-47

Ecological Structure of the Carabidae complex (Coleoptera) from the Sarnena Sredna Gora Mts., Bulgaria

Teodora M. Teofilova[1*], Nikolay D. Kodzhabashev[2]

1 - Institute of Biodiversity and Ecosystem Research (IBER), Bulgarian Academy of Sciences (BAS), 1 Tsar Osvoboditel Blvd., 1000 Sofia, BULGARIA
2 - University of Forestry, Faculty of Forestry, Department of Hunting and Game Management, 10 Kliment Ohridski Blvd., 1756 Sofia, BULGARIA
[*]Corresponding author: oberon_zoo@abv.bg

Abstract. On the basis of material collected during field trips in the Sarnena Sredna Gora Mts. in 2018–2020, and the available bibliographic data, we completed a list of 175 species of ground beetles (Coleoptera: Carabidae), belonging to 59 genera and 21 tribes. During the field work we collected 7961 specimens from 164 species. This study aimed at analyzing the ecological structure of the carabid fauna. The dominant structure was characteristic with the presence of 1 eudominant numbering 11% of all specimens (*Laemostenus cimmerius*), 5 dominants (32%), 6 subdominants (22%), 12 recedents (23%) and 82 subrecedents (12%). Analysis of the life forms showed a predominance of the zoophages (107 species, 61%) over the mixophytophages (68 species, 39%). Similar ratio (65: 35%) is mostly approaching to the typical for the forest-steppe zones of Eurasia. Humidity preferences analysis showed the larger share of the mesophilous and mesoxerophilous carabids. The macropterous carabids were 57% of all species. All dominant mountain forest species are wingless. The results suggest a well-differentiated and preserved forest carabid fauna and carabid coenosis, with a typical mountain zoning, consisting in distinguishing between typical montane forest carabids and species characteristic of all types of deciduous forests. Established forest species have a relatively high density and a high level of evenness, characteristics of the climax or near-climax forest communities.

Key words: carabids, ecological structure, Sarnena Gora, life forms, wing morphology.

Introduction

The Sarnena Sredna Gora Mts. (Sarnena Gora) is the easternmost part of the Sredna Gora Mts. It falls on the border of two biogeographical regions and three subregions (Gruev, 1988; Teofilova & Kodzhabashev, 2020a). Geographical location, relief, edaphic conditions and specific climatic factors in the Sarnena Sredna Gora Mts. suggest an exceptional variety of habitats (oak forests, beech forests, coniferous plantations, broadleaf plantations, bushes, riparian woods and bushes, dry, mesophilous and hygrophilous grasslands, pastures, inland standing and running surface waters, as well as some artificial landscapes – villages, chalets, agrocoenoses, etc. All this suggests a diverse fauna with variety of forms and complexes.

During the research of the animal diversity of the Sarnena Gora, two very rare species of Coleopterans characteristic of old climax forests from the beech mountain belt

http://eb.bio.uni-plovdiv.bg
Union of Scientists in Bulgaria – Plovdiv
University of Plovdiv Publishing House

were found (Teofilova et al., 2021a, 2021b). A similar pattern has also been established about earthworm (Lumbricidae) species characteristic of territories with typical mountain climate (Zdravkova et al., 2020). Despite the relatively small altitude of the Sarnena Gora, the established fauna indicates the presence of a well-structured and differentiated vertical distribution, characteristic of the middle and low mountain belts of other Bulgarian mountains.

This paper represents the second part of the first purposive study on the ground beetles (Coleoptera: Carabidae) from Sarnena Gora Mts. So far, 175 species (23% of all Bulgarian Carabidae species) are to be found there (Teofilova & Kodzhabashev, 2020a). Ground beetles represent one of the largest beetle families with cosmopolitan distribution and with decisive importance for the functioning of ecosystems. Their high taxonomic richness, the large numbers and the diverse life specializations are the reasons they cover the entire environmental spectrum of fundamental natural gradients.

Ecological classifications of carabids are numerous and various, but for their practical application in assessing the condition of the faunas and coenoses and the degree of anthropogenic influence, as main factors determining their presence and distribution the feeding, the diet and the mode of movement (respectively life forms), as well as the hydrothermal regime and the state of the soil, the type of plant cover, climatic and geographical features, are used (Kotze et al., 2011; Kryzhanovskij, 1983; Sharova, 1981).

The present study aimed at analyzing the ecological structure of the carabid complex in Sarnena Gora in relation to main ecological parameters, e.g. dominance structure, life form categorization, wing development, humidity and habitat preferences, with a subsequent assessment of the environmental trends and anthropogenic impact in the studied area.

Material and Methods

The species list is completed on the basis of the available bibliographic data and material collected during field trips carried out in 2017–2020. Ground beetles were collected with pitfall traps, hand picking and light attraction, and different types of habitats were sampled (see Teofilova & Kodzhabashev, 2020a). Main sampling sites were: 1) Svezhen Region – I. Pasture with single bushes and trees; II. Coniferous pine-spruce plantation; III. Mesophilous ridge beech forest; IV. Old beech forest; V. Mesoxerothermic oak forest; VI. Ridge beech forest with many old trees; VII. Ridge coniferous pine-spruce-Douglas fir plantation; VIII. Ridge pasture, surrounded by forests; IX. Mixed oak-beech-hornbeam forest; X. River bank with oak, cornel and white willow; XI. Oak forest with *Ruscus aculeatus*; 2) Chirpan Heights Region – XII. Black locust plantation; XIII. Pasture with *Paliurus spina-christi* and *Opuntia* sp.; XIV. Mixed riverine forest; XV. Linden forest with *Ruscus aculeatus;* XVI. Mixed oak-linden-maple forest with *Ruscus*; XVII. Dry oak-Oriental hornbeam forest on shallow and stony soil; XVIII. Abandoned pasture with single bushes and trees; XIX. Edge of alfalfa field; XX. Wheat field and small river ecotone with walnuts; 3) Bratan Region – XXI. Scots pine plantation near walnut and linden plantations; XXII. Riverine forest with beech, alder, hazel and hornbeam. They are presented on Fig. 1.

The analysis of the specific community ecology included only the material from the 141 pitfall traps set in the main 22 sampling sites in the period 22 March 2019 – 9 May 2020, when 5948 specimens and 106 species were collected. In order to determine the dominance structure, the relative abundance (or degree of dominance) was used: $D = (n_i/N).100$, where n_i is the number of individual representatives of each species, and N – their total number. The classical four-level classification of Tischler (1949) for invertebrates, modified by Sharova (1981), was adopted: eudominants (> 10% of all individuals); dominants (5 to 10%); subdominants (3 to 5%); recedents (1 to 3%); subrecedents (< 1%). Frequency of occurrence was calculated and species were divided to constant ($F > 50\%$), auxiliary ($F = 25–50\%$), and accompanying ($F < 25\%$).

Main ecological analysis included all collected data about the species composition (both from the literature and the field work). The total number of all collected beetles was 7961, belonging to 164 species, and 11 species were known from the literature.

Categorization of the species in respect of their life forms followed the classification of Sharova (1981). Species were also classified into three groups according to their hind wing development: macropterous (always possessing wings), wing dimorphic/polymorphic (only part of the population being fully winged), and brachypterous (wingless), according to Den Boer et al. (1980). According to their ecological requirements in terms of humidity, the established carabid species were divided into six categories (Teofilova, 2018): hygrophilous, mesohygrophilous, mesophilous, mesoxerophilous, xerobionts, and eurybionts.

Captured animals are deposited in the first author's collection in the Institute of Biodiversity and Ecosystem Research (Bulgarian Academy of Sciences, Sofia).

Results

The results from the study revealed that in the Sarnena Sredna Gora Mts. 175 species of ground beetles occur, belonging to 59 genera and 21 tribes. For details about the sampling sites and collecting methods for each species, see Teofilova & Kodzhabashev (2020a). The complete check-list of the established species with their full name, author and year of description, information about their wing morphology, humidity and habitat preferences, life form, dominance degree and occurrence (the last two parameters calculated only on the basis of the data from the pitfall traps sampling in 2019–2020) is given in the Appendix 1.

Dominance structure

The dominance structure of the entire carabid complex was characterised by the presence of only one eudominant (with a total number of 11% of all caught specimens), five dominants (32%), six subdominants (22%), 12 recedents (23%) and 82 subrecedents (12%). The eudominant species was *Laemostenus cimmerius*, dominants were *Aptinus bombarda*, *Carabus montivagus*, *C. convexus*, *Molops piceus*, *Pterostichus oblongopunctatus*, and the subdominant species were *Abax carinatus*, *Calathus distinguendus*, *C. fuscipes*, *Carabus hortensis*, *Harpalus tardus*, *Myas chalybaeus* (Table 1). *Carabus intricatus* , *Limodromus assimilis*, and *Xenion ignitum* had degree of dominance close to 3% (see Appendix 1), but they were considered recedent.

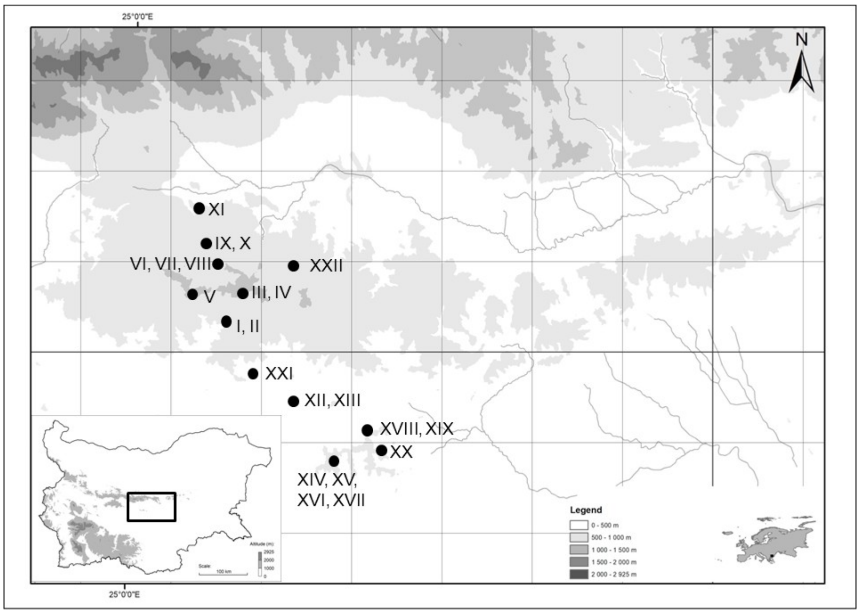

Fig. 1. Indicative map of the study area.

Table 1. Dominance structure of the carabid complex in Sarnena Gora during the whole-year research in 2019–2020**.**

Category	Species	No
Eudominant	*Laemostenus cimmerius*	1
Dominant	*Aptinus bombarda*, *Carabus montivagus*, *C. convexus*, *Molops piceus*, *Pterostichus oblongopunctatus*	5
Subdominant	*Abax carinatus*, *Calathus distinguendus*, *C. fuscipes*, *Carabus hortensis*, [*C. intricatus*], *Harpalus tardus*, [*Limodromus assimilis*], *Myas chalybaeus*, [*Xenion ignitum*]	6
Recedent	*Abax ovalis*, *A. parallelus*, *Brachinus crepitans*, *Br. explodens*, *Calosoma inquisitor*, *Carabus intricatus*, *C. coriaceus*, *Limodromus assimilis*, *Notiophilus rufipes*, *Pterostichus niger*, *Trechus quadristriatus*, *Xenion ignitum*	12
Subrecedent	all the rest	82

Frequency of occurrence

The occurrence reflects the uniformity or the evenness of the distribution of species in space. In whole-year catches in Sarnena Gora we found the highest share of auxiliary species occurring in less than 25% of the sampling sites – 81 species (76.4% of all). Only in one sampling site (F = 5%) occurred 44 (41%) of the species. The accompanying species occurring in 25–50% of the sampling sites were 14 (13.2%). As constant (F > 50%) we found 11 species (10.4%), and euconstant species (F = 100%) were missing (Table 2). *Laemostenus cimmerius* was not found only in sites III and XIX.

Richest in rare species occurring in only one of the studied habitats were sampling sites XIX (alfalfa field edge) (10 species), followed by sites X (river bank) and XX (river-field ecotone) with 6 rare species each, and site XXII (riverine forest) with 5 species. This fact points the peculiarity of these habitats. In site XIII we found 4 species, which were not found in the remaining sites; in sites I, VIII, XII and XIV – 2 such species; in III, V, XVI and XVIII – only 1 species. No "unique" species were found in sites II, IV, VI, VII, IX, XI, XV, XVII and XXI).

Life forms

The 175 ground beetle species belonged to two classes and 22 life form groups proposed by Sharova (1981) – 16 zoophagous and 6 mixophytophagous. The life forms of each species were given in the Appendix 1. The analysis of the life forms showed a predominance of the zoophages (107 species, 61%) over mixophytophages (68 species, 39%) (Table 3). The most numerous life form groups were the harpaloid geohortobionts from class Mixophytophaga (33 species), and the litter & soil-dwelling digging stratobionts (21 species) and the surface & litter-dwelling stratobionts (19 species) from class Zoophaga (Table 3). The significant percentage of the mixophytophagous harpaloid geohortobionts was mainly resulting from the increased presence of species from the genus *Harpalus*.

Wing morphology

The degree of hind wing development allowed distinguishing of three groups of carabids: brachypterous (hind wings shorter than elytra or missing), macropterous (winged), and dimorphic (some individuals have fully developed wings, others have only vestigial ones). Macropterous beetles represented 57% (101 species) of all collected carabid species. Pteridimorphic species were 22% of all (39 species), and brachypterous were 16% (30 species). For five species in our study (5%) there were no data about their wing morphology (Fig. 1).

Humidity and habitat preferences

The analysis of the humidity preferences (Fig. 2) of the ground beetles from Sarnena Gora showed the prevalence of the mesoxerophilous (59 species, 34% of all established species) and mesophilous carabids (50 species, 27%). Mesohygrophilous were 29 species (17%). Less represented were strictly hygrophilous (14 species, 9%) and xerophilous (11 species, 6%) carabids, as well as eurybionts (12 species, 7%). The habitat-preferential structure showed a strong dispersion in the distribution of the carabid complex in the region of Sredna Gora. The inhabitants of the dry oak forests are less than 5%. The majority of the xerophiles (about 30% of all species) were open-habitat forms, and many of them are broad-spectrum thermophiles able to inhabit both natural or semi-natural habitats and agrocoenoses. The mesophilic complex included mainly forest mesophiles (about 15% of all) found in the beech (*Fagus sylvatica* L.) mountain belt, with lesser share in the north-facing pre-mountain mixed forests with linden as co-edificator. One third of the hygrophilic carabid fauna were coastal extra- or intrazotal species, and the rest of it inhabited biotopes with a high degree of moisture regardless the vegetation type. Relatively small shares had eurybionts, which are usually very common among the main entomofauna of agrocoenoses and are also among the dominant component of the whole carabid complex, as well as the specific groups of stenobionts, such as halophiles and bothrobionts (about 1% each). Specific group were the inhabitants of the ecotones, which in Sarnena Gora were about 10% of all species.

Table 2. Frequency of occurrence in the carabid complex from the Sarnena Gora.

F	*Species*	*No*
> 50%	91%: *Laemostenus cimmerius*; 82%: *Carabus convexus, Myas chalybaeus*; 68%: *Abax carinatus, Carabus montivagus*; 64%: *Carabus coriaceus, Trechus quadristriatus*; 55%: *Calathus fuscipes, Calosoma inquisitor, Harpalus tardus, Pterostichus oblongopunctatus*	11
25–50%	45%: *Carabus intricatus, Molops piceus, Notiophilus rufipes*; 36%: *Calathus distinguendus, Carabus hortensis, Xenion ignitum*; 32%: *Cychrus semigranosus, Pterostichus niger*; 27%: *Abax ovalis, Aptinus bombarda, Brachinus explodens, Carabus scabrosus, Laemostenus venustus, Molops alpestris*	14
< 25%	all other	81

Table 3. Life forms of the ground beetles from the Sarnena Sredna Gora Mts. The first figure in the index shows the class of life form, the second shows the subclass, and the third indicates the life form group; the figure in brackets after the subclass shows the series, if any.

	Life forms	**No sp.**	%
	Class: Zoophagous		
	Life form subclass: 1.1 – Phytobios		
1.1.2	Stem-dwelling hortobionts	1	0.6
1.1.3	Leaf-dwelling dendrohortobionts	3	1.7
	Life form subclass: 1.2 – Epigeobios		
1.2.2	Large walking epigeobionts	12	6.9
1.2.2(1)	Dendroepigeobionts	1	0.6
1.2.3	Running epigeobionts	3	1.7
1.2.4	Flying epigeobionts	3	1.7
	Life form subclass: 1.3 – Stratobios		
	Series: 1.3(1) – crevice-dwelling stratobionts		
1.3(1).1	Surface & litter-dwelling	19	10.6
1.3(1).2	Litter-dwelling	16	9.1

1.3(1).3	Litter & crevice-dwelling	18	10.3
1.3(1).4	Endogeobionts	2	1.1
1.3(1).5	Litter & bark-dwelling	2	1.1
1.3(1).6	Bothrobionts	3	1.7
	Series: 1.3(2) – digging stratobionts		
1.3(2).1	Litter & soil-dwelling	21	12.0
1.3(2).2	Litter & crevice-dwelling	1	0.6
1.3(2).3	Bothrobionts	1	0.6
	Life form subclass: 1.4 – Geobionts		
1.4.1(1)	Narrow-headed running & digging geobionts	1	0.6
	Zoophagous total:	***107***	***61.0***
	Class Mixophytophagous		
	Life form subclass: 2.1 – Stratobios		
2.1.1	Crevice-dwelling stratobionts	9	5.1
	Life form subclass: 2.2 – Stratohortobios		
2.2.1	Stratohortobionts	16	9.1
	Life form subclass: 2.3 – Geohortobios		
2.3.1	Harpaloid geohortobionts	33	18.9
2.3.1(1)	Crevice-dwelling harpaloid geohortobionts	2	1.1
2.3.2	Zabroid geohortobionts	5	2.6
2.3.3	Dytomeoid geohortobionts	3	1.7
	Mixophytophagous total:	***68***	***39.0***

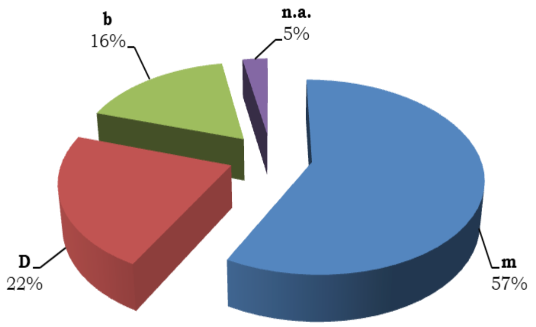

Fig. 1. Wing morphology of carabid species in Sarnena Gora: m – macropterous, D – wing di(poly)morphic, b – brachypterous, n.a. – no data.

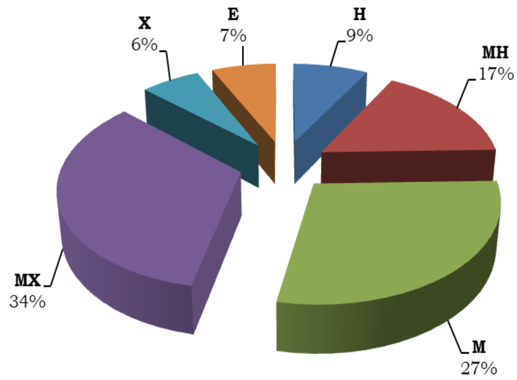

Fig. 2. Humidity preferences (number of species) of the carabids: H – hygrophilous, MH – mesohygrophilous, M – mesophilous, MX – mesoxerophilous, X – xerobiont, E – eurybiont.

Discussion

The results of the present study show that the region of the Sarnena Sredna Gora Mts. keeps a very rich, diverse and heterogeneous ground beetle fauna.

The dominance structure demonstrates the quantitative significance of the species and provides information on their quantitative share, which is a way of establishing the ecological situation and condition in the particular habitat or region. In Sarnena Gora it has a less concentrated dominance with more salient evenness between the dominant and recedent categories, unlikely the more anthropogenically loaded regions near Sofia (Kodzhabashev & Mollov, 2000), on Cape Emine (Teofilova, 2015), and in Zlatiya Plateau (Teofilova & Kodzhabashev, 2020c). Foreign authors studying the anthropogenic impacts on carabids are many, and works dealing with agrocoenoses (e.g. Batáry et al., 2012; Mast et al., 2012; Meissle et al., 2012; Pizzolotto et al., 2018; Porhajašová et al., 2008) and forests (e.g. Cobb et al., 2007; de Warnaffe & Leburn, 2004; Koivula & Niemelä, 2002; Lange et al., 2014; Magura et al., 2002; Skłodowski, 2014) are especially numerous. In Bulgaria, however these aspects are relatively rarely concerned (Popov & Krusteva, 1999; Teofilova et al., 2012; Teofilova, 2016, 2017). Main anthropogenic impacts in the studied region are agriculture, livestock farming and logging.

We found 12 species in the dominant component, and 8 of them are typical forest species. Characteristic of mountain mesophilic forests are *Molops piceus*, *Carabus hortensis*, *C. intricatus* and *Xenion ignitum*, and typical for all old deciduous forests are *Laemostenus cimmerius*, *Aptinus bombarda*, *C. convexus*, *C. montivagus*, *Abax carinatus*, *Harpalus tardus*, *Pterostichus oblongopunctatus* and *Myas chalybaeus*. The recedent component of the dominant structure without exceptions includes mesophiles and mesohygrophiles, which clearly confirms the mountainous mesophilic appearance of the region as a whole. The established subrecedent component includes 77% of the species and 23% of the specimens caught, which is closer to the normal distribution for natural ecosystems with a low degree of anthropogenic influence. All xerophilous open-habitat species are in the subrecedent category, which confirms the presence of mesophilic montane appearance of the area as a whole. In particular, many xerophilous species, all of which have very low abundance, are established in the Chirpan Heights area, where many of the open habitats have been dried and steppificated as a result of forest felling and cultivation of the soil for agricultural purposes and pastures (habitats XII, XIII, XVII, XVIII, XIX, XX).

In relation to the frequency of occurrence, it is notable the absence of euconstant species (*F* = 100%). It seems that such common species are more often in areas with higher anthropogenic load, as the region of Cape Emine (Teofilova, 2015), where five euconstant species were found in various types of ecosystems, and the Zlatiya Plateau, where three species of *Harpalus* were found in all sampling sites (Teofilova & Kodzhabashev, unpublished results).

All species having a frequency of occurrence > 25% are forest mesophiles (20 species) or eurybionts (5 species), which confirms the middle-montane character and mesophilic forest appearance of the area, despite large anthropogenic transformations occurred in the last 80–100 years. This group of species, in addition to relatively high occurrence, also has a relatively high degree of dominance, and most species are represented in the dominant component of the dominance structure. Of all 25 species, 13 are representatives of the nemoral European carabid fauna, and another 8 are forest species characteristic of the southeastern parts of Europe.

Relatively low frequency of occurrence have all intra- and extrazonal species, such as coastal hygrophiles (*Elaphrus aureus*, *Perileptus areolatus*, *Pterostichus vernalis*, *Pt. anthracinus*, *Tachyura haemoroidalis*), certain halobionts (*Apotomus clypionitens*, *Bembidion subfasciatum*, *Carterus dama*, *Harpalus hospes*, *Microlestes corticalis*, *M. fulvibasis*) and synanthropic xerobionts (*Brachinus alexadri*, *Dixus obscurus*, *Licinus cassideus*, *Microlestes lactuosis*, *Harpalus albanicus*, *H. angulatus*, *H. smaragdinus*, H. *subcylindricus*). Their specific ecological requirements are the cause of their local habitation, low frequency of occurrence and, usually, density.

The morphological structure of the life forms of carabids shows the overall adaptability of the group to the complex of all environmental factors, i.e. the “life form” can be accepted as a specific ecological adaptation (specialization) or as a measurement of a specific “ecological niche”. The life forms’ spectra of a region or habitat may provide information on the ecological structure, environmental conditions and regularities in the distribution along ecological gradients (Sharova, 1981). The share of the two main classes of Zoophages: Mixophytophages established in Sarnena Gora (61%: 39%), is characteristic of wooded areas with wide open spaces among or around them. Zoophagous life form groups are normally more numerous, especially in stable ecosystems (Sharova, 1981) and in forest regions, as it was found in 'Leshnitsa' Reserve (Teofilova, 2016), Vrachanska Planina Mts. (Teofilova, 2019b), and in the Western Rhodope Mts. (Teofilova, 2018). According to Sharova (1981), the normal ratio between the two classes is 60%: 40% for the forest-steppe areas, and 70%: 30% for the nemoral forest zone. Close to the normal ratio between the classes values were established in the Srebarna Reserve – 60%: 40% (Kodzhabashev, 2016, PhD thesis, unpublished results), the region of Cape Emine and Eastern Rhodope Mts. – 57%: 43% (Teofilova et al., 2015; Teofilova & Kodzhabashev, 2020b), and the Lower Tundzha Valley – 62.5%: 37.5% (Teofilova, 2017). Close to the normal for the nemoral zone was the ratio in the Western Rhodopes Mts. – 67%: 33% (Teofilova, 2018). The proximity of the Upper Thracian Lowland and the substantial transformation of much of the territory of Sarnena Gora into agricultural land and pastures are the reason for the significant preponderance of life forms specializing in living in open, secondary stepped spaces. In forest habitats, the percentage of the two classes is 70%: 30%, which is due to the high density of zoophages of the subclasses of Stratobios (46%) and Epigeobios (11%).

The increased share of mixophytophages indicates that the area is anthropogenically influenced, which is characteristic of the vast open territories occupied mainly by arable agricultural lands, pastures and sparsely vegetated old clearings on shallow soils. In arable lands, mainly representatives of the geohortobionts occur, which use the crumbly surface layer as shelter, but feed upon herbaceous plants. This group is very often ephemeral in nature, predetermined by the technical activities of the management of agricultural lands. Many of the species are steppic or thermophilic xerobionts adapted to live in conditions of prolonged droughts. Stratohorobionts and stratobionts include species that mainly inhabit pastures and degraded open habitats, grassed and shrubbed with xero- and mesoxerophytic vegetation. Increased number of mixophytophages is been found in xerophytic pseudomaquis communities in SW Bulgaria (Teofilova, 2020). It seems that fossorial mixophytophagous harpaloid geohortobionts are the dominating life form not only in this study but also in many other regions of Bulgaria (e.g. Kodzhabashev & Penev, 2006; Teofilova, 2017, 2018, 2019a, 2019b; Teofilova & Kodzhabashev 2020b, 2020c).

The analysis of the established results about the development of the carabids' wings shows a ratio between the three main types characteristic of areas with wide forest massifs located among plain open areas. All dominant mountain forest species are wingless, and some of the recedent species are di(poly)morphic. Similar results found Brandmyr (1983) in a study of the mountain carabid fauna of the Alps. According to Darlington (1943), Brandmayr (1983) and Desender (1989, 2000), wingless carabid assemblages are characteristic of ecologically homogeneous and stable environments, where resources are sufficient for beetles' entire life cycle. These theories explain the presence of the specific wingless carabid fauna in mountain forest habitats. According to Desender (2000), Kotze et al. (2011) and Venn (2007, 2016), the proportions in the ecological groups can be successfully used to register changes in environmental conditions, i.e. for bioindication and monitoring purposes. The increase in winged forms among dimorphic species and the appearance of winged males in species for which it is characteristic to have mainly winged females, is a signal of changes requiring migration or resettlement for colonization. Unfortunately, despite all summaries on this ecological aspect (e.g. Den Boer et al., 1980; Desender, 1989, 2000; Venn, 2016), many of the regularities are still at the level of a scientific hypothesis, or apply to a particular geographic region, a particular species or taxonomic group, making it difficult to fully discuss the topic. In Bulgaria, such researches are still beginning to develop (Teofilova & Kodzhabashev, 2020c; Teofilova, 2021). Here, we have a ratio between the winged, dimorphic and wingless species of 57%, 22% and 16%, respectively. As a comparison, that ratio is, respectively, 69%, 22% and 8% in Zlatiya Plateau (Teofilova & Kodzhabashev, 2020c), and 73%, 17% and 10% in Bulgarian rapeseed (*Brassica napus* L.) fields (Teofilova, 2021). An increased presence of winged forms is recorded in all arable agricultural and degraded lands in our study, as well as in many agrocoenoses in Europe (e.g. Pizzolotto et al., 2018; Teofilova, 2021). If we follow Gray's hypothesis, that the proportion of flight capable pioneer species should increase with increasing disturbance, and the proportion of flightless species should decrease (Gray, 1989), we can conclude that the environment in Sarnena Gora is more stable and determines carabids' wing morphology structure with a lesser share of winged beetles, in comparison with other regions in Bulgaria.

According to a number of carabidologists (Eyre et al., 2005; Kryzhanovskij, 1983; Lindroth, 1992; Thiele, 1977), the main factors of the environment of particular importance for the distribution of ground beetles are the type and hydrothermal regime of the soils. They, in turn, determine the plant cover and many other dependent factors important for the carabids. Changes in these conditions are usually the result of human activities related to destruction or transformation of the vegetation and, respectively, of all conditions determining the normal gradient distribution of ground beetles.

Our results about the humidity preferences of beetles show that mesoxerophiles predominate in Sarnena Gora. They are mostly inhabitants of open areas, such as arable lands, pastures, hay meadows and clearings, and of natural origin are probably the dry grassland communities in the Chirpan Heights and the easternmost regions of the mountain. Carabid fauna of open territories is a mix of naturally occurring and some ecologically plastic species, some of which in process of initial invasive expansion. This effect is particularly pronounced in intensive agricultural lands. A number of xerobionts specific to Eurasian steppes and Mediterranean succulent communities are also found among this fauna (*Acinopus megacephalus*, *Carterus dama*, *Dixus obscurus*, *Harpalus angulatus*, *H. smaragdinus*). Xerophilous and mesoxerophilous carabid fauna (about 40% of the species) is disjunct, with low occurrence and low relative density, but with an extreme variety of species. Perhaps the proximity of the Upper Thracian Lowland to the south and the Sub-Balkan Valleys to the north, which have been converted into large agricultural areas for intensive farming, have had a strong impact on the modern state of the carabid coenoses found near them. Most of the xerobionts are registered in pastures, alfalfa fields and degraded due soil erosion sloping pre-mountainous terrains. Increased number of xerophiles and mesoxerophiles (over 60%) is found in xerophytic pseudomaquis communities in SW Bulgaria (Teofilova, 2020). Arable lands and pastures serve as peculiar corridors and refugia for xerophilous carabid fauna; annual agricultural and livestock activities, combined with prolonged periods of drought and geographical location, favour its invasive expansion.

In synanthropic habitats, there is also an increased percentage of eurybionts, which are mostly ecologically plastic species, tolerant to a wide range of environmental conditions and their frequent changes, with extensive Palaearctic or Eurasian ranges (Kryzhanovskij, 1983). The share of eurytopic species in the region of Cape Emine is 9% (Teofilova et al., 2015), and in Zlatiya Plateau it is 11% (Teofilova & Kodzhabashev, 2020c), pointing the more stable conditions in Sarnena Gora, where only 7% of all species are eurybionts.

A significant share of the species composition of the carabids from the Sarnena Gora is occupied by the mesophilous and mesohygrophilous carabid fauna – 79 species, representing 44% of all established species. This fauna mainly includes forest species characteristic of the middle beech mountain belt of the Sarnena Gora. Characteristic species for montane forest carabid fauna are *Carabus hortensis*, *Cychrus semigranosus*, *Molops* spp., *Pterostichus merklii*, *Pt. vecors*, *Tapinopterus cognatus*, *Xenion ignitum*. The distribution of these species coincides with the distribution limits of the beech. Widespread mesophilous forest species in all height belts are *Abax carinatus*, *A. ovalis*, *A. parallelus*, *Aptinus bombarda*, *Calosoma inquisitor*, *Carabus scabrosus*, *Myas chalybaeus*, *Pterostichus oblongopunctatus*, etc. As a comparison, the share of mesophilous and mesohygrophilous carabids was 38% in the Eastern Rhodope Mts. (Teofilova & Kodzhabashev, 2020b), 32% in Zlatiya Plateau (Teofilova & Kodzhabashev, 2020c), and under 25% in pseudomaquises in SW Bulgaria (Teofilova, 2020).

Hygrophilous carabid fauna is mainly concentrated around montane rivers and includes 15 species (9%), some of which are found in only one of the four riparian habitats. Such stenotopic riparian species are *Bembidion dalmatinum, B. deletum*, *Chlaenius nitidulus, Elaphrus aureus, Drypta dentata, Perileptus areolatus*, *Pterostichus vernalis.*

The results of this work demonstrate the predominantly mesophilic nature of Sarnena Gora as a whole, similar to that in the western part of the Rhodope Mts. (Teofilova, 2018) and Vrachanska Planina Mts. (Teofilova, 2019b), and contrasting with the predominantly mesoxerophilic conditions in the Eastern Rhodope Mts. (Teofilova & Kodzhabashev, 2020b) and pseudomaquises in SW Bulgaria (Teofilova, 2020).

Conclusions

The present study proves that the region of the Sarnena Sredna Gora Mts. keeps a very rich, diverse and heterogeneous ground beetle fauna, and has a significant conservation value. The insufficient research in the area and the large carabid species richness suggest that future targeted studies would contribute to the enrichment of the species list presented here.

The results of our research and analysis suggest a well-differentiated and preserved forest carabid fauna and carabid coenose, with a typical mountain zoning, consisting in distinguishing between species characteristic of all types of old mesophilic deciduous forests, and montane forest carabids typical for the beech mountain belt. Established forest coenoses have a relatively small number of species with high density and high level of evenness, characteristics of the climax or close to climax state forest ecosystems. All established forest species are wingless, mesophilous or mesohygrophilous stratobionts and epigeobionts, which confirms the naturalness and autochtonity of the ground beetle communities and their habitats. The established in the dominant component of the dominant structure species can be used as indicators of mountain forest mesophilic fauna. Such are also some typical forest species from the recedent category, which are being represented by a relatively large number of specimens only in mountain forest ecosystems.

Despite the large and drastic changes in the environment, there is an exceptional variety of preserved habitats of carabids in the Sarnena Gora, which is confirmed by the great species richness, the high density of species specific to natural habitats and their stable carabid coenoses.

A significant problem for natural ground beetle communities is the rapid human intervention associated with the felling of old, diverse in age forests and their transformation into even-age forests, as well as the conversion of natural forests into coniferous or exotic plantations. Another significant problem is the intensive agriculture, which destroys soil structure annually, and pesticides and mineral fertilizers destroy soil organisms and lead to irreversible degradation.

In order to assure the preservation of the natural habitats and significant species, a proclamation of some protected areas and/or zones is recommendable.

Acknowledgements

This study was funded by the National Science Fund via the Project № КП-06-М21/2 (Н-18-ТТЕО-010) "Study of the faunistic diversity and assessment of the condition and ecosystems services in different types of model ecosystems in the Sarnena Sredna Gora Mts". Part of the material was collected with the aid of the Project BiodivERsA-FACCE2014-47 "SusTaining AgriCultural ChAnge Through ecological engineering and Optimal use of natural resources (STACCATO)". Authors thank Elena Zdravkova, Kalina Miteva, Georgi Boevski, Stilian Stefanov, and Dr. Ivaylo Todorov for their help with the field work, and Dr. Dilian Georgiev, Dr. Denis Gradinarov and Dr. Yana Petrova for providing material.

References

Batáry, P., Holzschuh, A., Márk Orci, K., Samu, F. & Tscharntke, T. (2012). Responses of plant, insect and spider biodiversity to local and landscape scale management intensity in cereal crops and grasslands. *Agriculture, Ecosystems and Environment, 146*, 130-136. doi: 10.1016/j.agee.2011.10.018.

Brandmayer, P. (1983). The main axes of the coenoclinal continuum from macroptery to brachyptery in Carabid communities of the temperate zone. In P. Brandmayer, P. J. Den Boer & F. Weber (Eds.). *Ecology of Carabids: The synthesis of field study and laboratory experiment*. (pp. 147-169). Wageningen, Netherlands: Centre for Agriculture Publishing and Documentation.

Cobb, T. P., Langor, D. W. & Spence, J. R. (2007). Biodiversity and multiple disturbances: boreal forest ground beetles (Coleoptera: Carabidae) responses to wildfire, harvesting and herbicide. (Coleoptera: Carabidae). *Canadian Journal of Forest Research, 37*, 1310-1323. doi: 10.1139/X06-310.

Darlington, P. J. (1943). Carabidae of mountains and islands: data on the evolution of isolated faunas, and on atrophy of wings. *Ecological Monographs, 13*, 39-61. doi: 10.2307/1943589.

Den Boer, P. J., Van Huizen, T. H. P., Den Boer-Daanje, W., Aukema, B. & Den Bieman, C. F. M. (1980). Wing polymorphism and dimorphism in ground beetles as a stage in an evolutionary process (Coleoptera: Carabidae). *Entomologia Generalis, 6*(2/4), 107-134.

Desender, K. (1989). Dispersal forms in the ecology of carabid beetles (Coleoptera, Carabidae). *Documents de Travail de l'Institut Royal des Sciences naturelles de Belge, Gent, 54*, 1-136.

Desender, K. (2000). Flight muscle development and dispersal in the life cycle of carabid beetles: patterns and processes. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Entomologie, 70*, 13-31.

de Warnaffe, G. & Leburn, P. (2004). Effects of forest management on carabid beetles in Belgium: implications for biodiversity conservation. *Biological Conservation, 118*, 219-234. doi: 10.1016/j.biocon.2003.08.015.

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.

Gray, J. S. (1989). Effects of environmental stress on species rich assemblages. *Biological Journal of the Linnean Society,* *37*, 19-32. doi: 10.1111/j.1095-8312.1989.tb02003.x.

Gruev, B. (1988). *Obshta biogeografiya* (*General biogeography*). Sofia, Bulgaria: Nauka i Izkustvo (Science and Art), 396 p. (In Bulgarian).

Kodzhabashev, N. D. & Mollov, K. B. (2000). Faunistic and ecological studies on the carabid fauna of the open areas in the vicinity of Sofia. *Jubilee Compendium of Scientific Reports, University of Forestry, Sofia*: 291-302 (In Bulgarian).

Kodzhabashev, N. D. & Penev, L. D. (2006). The ground beetles (Coleoptera: Carabidae) of South Dobrudzha, Bulgaria. *Acta Zoologica Bulgarica, 58*(2), 147-180.

Koivula, M. & Niemelä, J. (2002). Boreal carabid beetles (Coleoptera: Carabidae) in managed spruce forests – a summary of Finnish case studies. *Silva Fennica, 36*(1), 423-436.

Kotze, J. D., Brandmayr, P., Casale, A., Dauffy-Richard, E., Dekoninck, W., Koivula, M. J., Lövei, G. L., Mossakowski, D., Noordijk, J., Paarmann, W., Pizzolotto, R., Saska, P., Schwerk, A., Serrano, J., Szyszko, J., Taboada, A., Turin, H., Venn, S., Vermeulen, R. & Zetto, T. (2011). Forty years of carabid beetle research in Europe – from taxonomy, biology, ecology and population studies to bioindication, habitat assessment and conservation. *Zookeys, 100*, 55-148. doi: 10.3897/zookeys.100.1523.

Kryzhanovskij, O. L. (1983). *Fauna of the USSR. Coleoptera, Vol. 1, iss. 2. The Ground-beetles of suborder Adephaga: families Rhysodidae, Trachypachidae; family Carabidae (introduction, overview of the fauna of the USSR)*. Leningrad, USSR: Nauka (Science). 341 p. (In Russian).

Lange, M., Türke, M., Pašalić, E., Boch, S., Hessenmöller, D., Müller, J., Prati, D., Socher, S. A., Fischer, M., Weisser, W. W. & Gossner, M. M. (2014). Effects of forest management on ground-dwelling beetles (Coleoptera; Carabidae, Staphylinidae) in Central Europe are mainly mediated by changes in forest structure. *Forest Ecology and Management, 329*, 166-176. doi: 10.1016/j.foreco.2014.06.012.

Lindroth, C.H. (1992). *The ground-beetles (Carabidae) of Fennoscandia. A zoogeographic study. Part I. Specific knowledge regarding the species*. New Delhi, India: Amerind Publishing Ltd. 630 p.

Magura, T., Elek, Z. & Tóthmérész, B. (2002). Impacts of non-native spruce reforestation on ground beetles. *European Journal of Soil Biology, 38*, 291-295.

Mast, B., Graeff Hönninger, S. & Claupein, W. (2012). Evaluation of carabid beetle diversity in different bioenergy cropping systems. *Sustainable Agriculture Research, 1*(2), 127-140. doi: 10.5539/sar.v1n2p127.

Meissle, M., Álvarez-Alfageme, F., Malone, L. A. & Romeis, J. (2012).Establishing a database of bio-ecological information on non-target arthropod species to support the environmental risk assessment of genetically modified crops in the EU. *Supporting Publications*, EN-334. Parma, Italy: European Food Safety Authority (EFSA). 170 p.

Pizzolotto, R., Mazzei, A., Bonacci, T., Scalercio, S., Iannotta, N. & Brandmayr, P. (2018). Ground beetles in Mediterranean olive agroecosystems: Their significance and functional role as bioindicators (Coleoptera, Carabidae). *PLoS ONE, 13*(3): e0194551. doi: 10.1371/journal.pone.0194551.

Popov, V. V. & Krusteva, I. A. (1999). Epigeobiont animal assemblages from two landscapes of the Bulgarian Black Sea Coast: relationship to environmental gradients, assemblage structure and biodiversity. Part I: Ground beetles. *Acta Zoologica Bulgarica*, *51*(1), 81-114.

Porhajašová, J., Petřvalský, V., Šustek, Z., Urminská, J., Ondrišík, P. & Noskovič, J. (2008). Long-termed changes in ground beetle (Coleoptera: Carabidae) assemblages in a field treated by organic fertilizers. *Biologia, 63*(6), 1184-1195. doi: 10.2478/s11756-008-0179-8.

Sharova, I. (1981). *Life forms of carabids*. Moskow, USSR: Nauka (Science). 360 p. (In Russian).

Skłodowski, J. (2014). Consequence of the transformation of a primeval forest into a managed forest for carabid beetles (Coleoptera: Carabidae) – a case study from Białowieża (Poland). *European Journal of Entomology, 111*(5): 639-648. doi: 10.14411/eje.2014.088.

Teofilova, T. (2015). Ground beetles (Coleoptera: Carabidae) from the region of Cape Emine (Central Bulgarian Black sea coast). Part II. Ecological parameters and community structure. *ZooNotes, 71*, 1-12.

Teofilova, T. (2016). Initial study of the ground beetles (Coleoptera: Carabidae) and other Invertebrates from "Leshnitsa" nature reserve (Central Stara Planina Mountains, Bulgaria). *Ecologia Balkanica, 8*(1): 79-87.

Teofilova, T. M. (2017). Ground beetles (Coleoptera: Carabidae) and some other invertebrates from the managed nature reserves "Dolna Topchiya" and "Balabana" (Lower valley of the river of Tundzha, Bulgaria). *Ecologia Balkanica 9*(1): 63-77.

Teofilova, T. M. (2018). A contribution to the study of ground beetles (Coleoptera: Carabidae) in the Western Rhodope Mts. (Bulgaria). *Journal of BioScience and Biotechnology, 6*(3), 203-209.

Teofilova, T. M. (2019a). Ground beetles (Coleoptera: Carabidae) from sparsely vegetated lands in Bulgaria. *NorthWestern Journal of Zoology (2018), 15*(1), 30-41.

Teofilova, T. M. (2019b). Ground beetles (Coleoptera: Carabidae) from the region of Vrachanska Planina Mts. In Bechev, D. & Georgiev, D. (Eds.). *Faunistic diversity of Vrachanski Balkan Nature Park. Part 2* (pp. 39-58). *ZooNotes, Supplement 7*, Plovdiv University Press.

Teofilova, T. M. (2020). Pseudomaquises in SW Bulgaria as a habitat for the ground beetles (Coleoptera: Carabidae). *Zoology and Ecology, 30*(1): 27-36.

Teofilova, T. M. (2021). Macropterous ground beetles (Coleoptera: Carabidae) prevail in European oilseed rape fields. *Ecologia Balkanica, Special Edition 3 (2020)*, 211-225.

Teofilova, T. & Kodzhabashev, N. (2020a). Ground beetles (Coleoptera: Carabidae) from the Sarnena Sredna Gora Mts. In Georgiev D., Bechev D. & Yancheva V. (Eds.). *Fauna of Sarnena Sredna Gora Mts, Part 1* (pp. 95-114). *ZooNotes, Supplement 9*, Plovdiv University Press.

Teofilova, T. M. & Kodzhabashev, N. D. (2020b). Ecological, faunistic and zoogeographical notes on the ground beetles (Coleoptera: Carabidae) from the Eastern Rhodope Mts. of Bulgaria. *Forestry Ideas, 26*(1), 77-96.

Teofilova, T. M. & Kodzhabashev, N. D. (2020c). The ground beetles (Coleoptera: Carabidae) from a significant, but poorly studied region in NW Bulgaria. Part 2: Ecology. *Forestry Ideas, 26*(2), 435-451.

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

Teofilova, T., Markova, E., & Kodzhabashev, N. (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.

Teofilova, T. M., Gradinarov, D. & Kodzhabashev, N. D. (2021a). *Phosphaenus hemipterus* (Goeze, 1777) (Coleoptera: Lampyridae) in Bulgaria – new species and new genus with some ecological data. *Acta Zoologica Bulgarica*, *73*(1), 59-64.

Teofilova, T. M., Gradinarov, D. & Kodzhabashev, N. D. (2021b). The first record of the family Cerophytidae (Coleoptera) from Bulgaria: the rare saproxylic beetle *Cerophytum elateroides* (Latreille, 1804) in beech woodland in Sarnena Sredna Gora Mts. *Acta Zoologica Bulgarica*, online first 002499.

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

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

Venn, S. (2007). Morphological responses to disturbance in wing-polymorphic carabid species (Coleoptera: Carabidae) of managed urban grasslands. *Baltic Journal of Coleopterology, 7*(1), 51-59.

Venn, S. (2016). To fly or not to fly: Factors influencing the flight capacity of carabid beetles (Coleoptera: Carabidae). *European Journal of Entomology, 113*, 587-600. doi: 10.14411/eje.2016.079.

Zdravkova, E., Teofilova, T. & Kodzhabashev, N. (2020). Faunistic study on the earthworms (Annelida: Oligochaeta: Lumbricidae) from the Sarnena Sredna Gora Mts. In Georgiev D., Bechev D. & Yancheva V. (Eds.). *Fauna of Sarnena Sredna Gora Mts, Part 1* (pp. 122-141). *ZooNotes, Supplement 9,* Plovdiv University Press.

Received: 31.03.2021
Accepted: 30.05.2021

Appendix 1. Species list and ecological characteristics of carabids from Sarnena Sredna Gora Mts. WM – Wing morphology (m – macropterous, D – wing di(poly)morphic, b – brachypterous, n.a. – no data); HP - Humidity preferences (H – hygrophilous, MH – mesohygrophilous; M – mesophilous, MX – mesoxerophilous, X – xerophilous, E – eurybiont); HT - Habitat type (1 – inhabitants of dry open habitats; 2 – inhabitants of humid open habitats; 3 – inhabitants of dry forest habitats; 4 – inhabitants of humid forest habitats; 5 – inhabitants of open, sunny coasts; 6 – inhabitants of canopy, shady shores; 7 – halobionts; 8 – bothrobionts; 9 – eurybionts, 10 – species of ecotones); LF – Life forms (descriptions of life forms codes are given in Table 4); *D* – Dominance degree; *F* – Occurrence. *only data from the pitfall traps sampling in 2019 – 2020.

Species	WM	HP	HT	LF	*D*%*	Sampling site [*F*%]*
Abax (Abax) carinatus carinatus (Duftschmid, 1812)	b	M	4	1.3(2).1	3.04	all without IV, VI, XII, XIII, XVIII, XIX, XX [*68*]
Abax (Abax) ovalis (Duftschmid, 1812)	b	MH	4	1.3(2).1	1.34	III, IV, VI, VII, IX, XXII [*27*]
Abax (Abax) parallelus parallelus (Duftschmid, 1812)	b	M	4	1.3(2).1	2.00	XXI, XXII [*9*]
Acinopus (Acinopus) picipes (Olivier, 1795)	D	MX	1	2.3.2.	0.02	III [*5*]
Acinopus (Oedematicus) megacephalus (P. Rossi, 1794)	m	MX	1	2.3.2.		
Acupalpus (Acupalpus) dubius Schilsky, 1888	m	H	2,6	2.1.1.		
Acupalpus (Acupalpus) meridianus (Linnaeus, 1760)	m	MH	2,5	2.1.1.		
Amara (Amara) aenea (De Geer, 1774)	m	E	9	2.3.1.	0.08	X, XVIII, XIX, XX [*18*]
Amara (Amara) anthobia A. Villa et G. B. Villa, 1833	m	MX	1	2.1.1.	0.18	X, XII, XVIII [*14*]
Amara (Amara) communis (Panzer, 1797)	m	M	2,3,10	2.3.1.		
Amara (Amara) convexior Stephens, 1828	m	MX	1	2.3.1.	0.62	XX, XXI, XXII [*14*]
Amara (Amara) eurynota (Panzer, 1796)	m	M	1,2	2.3.1.	0.03	VIII [*5*]
Amara (Amara) familiaris (Duftschmid, 1812)	m	MX	1,2	2.1.1.		
Amara (Amara) lucida (Duftschmid, 1812)	m	M	1,2	2.3.1.	0.02	XVIII [*5*]
Amara (Amara) montivaga Sturm, 1825	m	M	2	2.3.1.		
Amara (Amara) ovata (Fabricius, 1792)	m	E	1,2	2.3.1.	0.02	XI [*5*]
Amara (Amara) saphyrea Dejean, 1828	m	M	3,4	2.3.1.	0.59	X, XI, XII, XX, XXI [*23*]
Amara (Amara) similata (Gyllenhal, 1810)	m	MX	1,2	2.3.1.		
Amara (Bradytus) consularis (Duftschmid, 1812)	m	MX	1,10	2.3.1(1)		
Amara (Percosia) equestris equestris (Duftschmid, 1812)	m	MX	1	2.3.2.	0.02	XX [*5*]
Amara (Xenocelia) municipalis (Duftschmid, 1812)	m	MX	1,10	2.3.1.		
Amara (Zezea) chaudoiri incognita Fassati,1946	m	M	2	2.2.1.		
Amara (Zezea) fulvipes (Audinet-Serville, 1821)	m	MX	1	2.2.1.		
Amblystomus metallescens (Dejean, 1829)	m	MH	2,5	2.1.1.		
Amblystomus rectangulus Reitter, 1883	m	MH	2	2.1.1.		
Anchomenus (Anchomenus) dorsalis dorsalis (Pontoppidan, 1763)	m	MX	1,2,10	1.3(1).1	0.29	XVIII, XIX, XX, XXI [*18*]
Anisodactylus (Anisodactylus) binotatus (Fabricius, 1787)	m	MH	2,10	2.3.1.	0.02	I [*5*]
Apotomus clypeonitens adanensis Jedlička, 1961	m	MH	5,7	1.4.1(1)		
Aptinus (Aptinus) bombarda (Illiger, 1800)	b	M	4	1.3(1).3	7.8	III, IV, V, VII, IX, XXII [*27*]
Asaphidion flavicorne (Solsky, 1874)	m	MH	6	1.2.3.	0.02	X [*5*]
Asaphidion flavipes (Linnaeus, 1760)	m	MH	2,5,10	1.2.3.	0.02	XX [*5*]
Bembidion (Metallina) lampros (Herbst, 1784)	D	M	1,2,10	1.3(1).2	0.08	X, XX [*9*]
Bembidion (Metallina) properans (Stephens, 1828)	D	MH	2,5	1.3(1).2	0.02	XX [*5*]
Bembidion (Ocyturanes) balcanicum Apfelbeck, 1899	n.a.	MH	2	1.3(1).1		
Bembidion (Peryphanes) castaneipenne Jacquelin du Val, 1852	m	H	6	1.3(1).1		

Bembidion (Peryphanes) dalmatinum dalmatinum Dejean, 1831	m	H	2,6	1.3(1).1	0.02	XIV [*5*]
Bembidion (Peryphanes) deletum deletum Audinet-Serville, 1821	m	H	6	1.3(1).1		
Bembidion (Peryphus) femoratum Sturm, 1825	m	MH	2,5	1.3(1).1		
Bembidion (Talanes) subfasciatum Chaudoir, 1850	m	H	7	1.3(1).1		
Brachinus (Brachinus) alexandri F. Battoni, 1984	m	X	1	1.3(1).3		
Brachinus (Brachinus) crepitans (Linnaeus, 1758)	D	MX	1,10	1.3(1).3	2.10	XII, XVII, XIX, XX, XXI [*23*]
Brachinus (Brachinus) psophia Audinet-Serville, 1821	m	MX	1	1.3(1).3		
Brachinus (Brachynidius) brevicollis Motschulsky, 1844	n.a.	MX	3	1.3(1).3	0.02	XX [*5*]
Brachinus (Brachynidius) explodens Duftschmid, 1812	m	MX	1	1.3(1).3	1.63	XII, XVIII, XIX, XX, XXI, XXII [*27*]
Calathus (Calathus) distinguendus Chaudoir, 1846	D	MX	1	1.3(1).2	4.00	IV, V, VIII, XI, XVII, XVIII, XIX, XX [*36*]
Calathus (Calathus) fuscipes fuscipes Goeze, 1777	D	E	9	1.3(1).2	4.00	I, II, IV, V, VIII, IX, X, XI, XII, XVI, XIX, XX [*55*]
Calathus (Calathus) longicollis Motschulsky, 1865	D	MX	1	1.3(1).2	0.03	XII [*5*]
Calathus (Neocalathus) cinctus Motschulsky, 1850	D	MX	1	1.3(1).2	0.05	XIII [*5*]
Calathus (Neocalathus) melanocephalus (Linnaeus, 1758)	D	M	1,2,10	1.3(1).2	0.07	I, VIII, X, XX [*18*]
Calosoma (Calosoma) inquisitor inquisitor (Linnaeus, 1758)	m	MX	3	1.2.2(1)	1.51	II, IV, V, VII, IX, XI, XII, XVI, XVII, XVIII, XXI, XXII [*55*]
Calosoma (Campatita) auropunctatum auropunctatum (Herbst, 1784)	m	MX	1	1.2.2.		
Carabus (Archicarabus) montivagus montivagus Palliardi, 1825	b	M	3,10	1.2.2.	6.20	I, V, VII, VIII, IX, X, XI, XII, XIII, XV, XVII, XIX, XXI, XXII [*68*]
Carabus (Carabus) granulatus granulatus Linnaeus, 1758	D	MH	4,6	1.2.2.		
Carabus (Chaetocarabus) intricatus intricatus Linnaeus, 1760	b	MH	4,6	1.2.2.	2.76	III, IV, VI, VII, VIII, IX, XIV, XV, XVI, XXII [*45*]
Carabus (Eucarabus) ulrichii rhilensis Kraatz, 1876	b	M	2,4	1.2.2.		
Carabus (Megodontus) violaceus azuresens Dejean, 1826	b	M	2,4	1.2.2.	0.54	III, IV, VI, VIII, XXII [*23*]
Carabus (Pachystus) hortensis hortensis Linnaeus, 1758	b	M	3,4,10	1.2.2.	3.26	II, III, IV, VI, VII, VIII, IX, XXII [*36*]
Carabus (Procerus) scabrosus scabrosus Olivier, 1790	b	M	4	1.2.2.	0.29	XII, XIV, XV, XVI, XX, XXI [*27*]
Carabus (Procrustes) coriaceus cerisyi Dejean, 1826	b	E	9	1.2.2.	1.66	I, VII, VIII, XI, XII, XIII, XIV, XV, XVI, XVII, XVIII, XIX, XX, XXI [*64*]
Carabus (Tachypus) cancellatus Illiger, 1798	b	MH	2,4,6	1.2.2.		
Carabus (Tomocarabus) convexus dilatatus Dejean, 1826	b	MX	1,3,10	1.2.2.	5.63	all without III, VI, XIV, XX [*82*]
Carterus (Carterus) dama (P. Rossi, 1792)	n.a.	X	1,7	2.3.3.		
Chlaenius (Chlaeniellus) nitidulus (Schrank, 1781)	m	H	2,6,10	1.3(1).1	0.03	X [*5*]
Chlaenius (Chlaeniellus) vestitus (Paykull, 1790)	m	H	2,5	1.3(1).1		
Chlaenius (Dinodes) decipiens (L. Dufour, 1820)	m	MX	1,7	1.3(1).1	0.13	XIX [*5*]
Chlaenius (Trichochlaenius) aeneocephalus aeneocephalus Dejean, 1826	m	M	1,5	1.3(1).1	0.02	XIX [*5*]
Cicindela (Cicindela) campestris campestris Linnaeus, 1758	m	MX	1	1.2.4.		
Cicindela (Cicindela) sylvicola Dejean, 1822	m	MX	1	1.2.4.		
Cychrus semigranosus balcanicus Hopffgarten, 1881	b	M	4	1.2.2.	0.50	II, III, IV, VI, VII, XXI, XXII [*32*]
Cylindera (Cylindera) germanica germanica (Linnaeus, 1758)	m	M	2,5,7	1.2.4.		
Cymindis (Cymindis) axillaris axillaris (Fabricius, 1794)	D	MX	1,2	1.3(1).3	0.02	XIII [*5*]
Diachromus germanus (Linnaeus, 1758)	m	MH	2	2.2.1.		
Dicheirotrichus (*Trichocellus) discicollis* (Dejean, 1829)	m	MH	6	2.1.1.	0.02	XII [*5*]
Ditomus calydonius calydonius (P. Rossi, 1790)	m	MX	1	2.3.3.		
Dixus obscurus (Dejean, 1825)	m	X	1	2.3.3.	0.02	XIII [*5*]
Dromius (Dromius) quadrimaculatus (Linnaeus, 1758)	m	M	4	1.3(1).5		
Drypta (Drypta) dentata (P. Rossi, 1790)	m	H	2,6	1.1.2.		
Elaphrus (Elaphroterus) aureus aureus P. W. J. Müller, 1821	m	H	6	1.2.3.	0.03	XXII [*5*]
Gynandromorphus etruscus (Quensel en Schönherr, 1806)	m	MX	1	2.2.1.		

Harpalus (Harpalus) affinis (Schrank, 1781)	m	MX	1,9	2.3.1.		
Harpalus (Harpalus) albanicus Reitter, 1900	m	X	1	2.3.1.	0.17	XVIII, XIX, XX [*14*]
Harpalus (Harpalus) angulatus scytha Tschitschérine, 1899	n.a.	X	1	2.3.1.		
Harpalus (Harpalus) atratus Latreille, 1804	D	MX	1,3	2.3.1.	0.10	X, XV, XVII, XXI [*18*]
Harpalus (Harpalus) attenuatus Stephens, 1828	m	MX	1,3	2.3.1.	0.05	XVIII, XIX [*9*]
Harpalus (Harpalus) caspius (Steven, 1806)	m	X	1	2.3.1.	0.32	XVII, XVIII, XIX, XX [*18*]
Harpalus (Harpalus) cupreus fastuosus Faldermann, 1836	m	MX	1,10	2.3.1.		
Harpalus (Harpalus) dimidiatus (P. Rossi, 1790)	m	MX	1,3	2.3.1.		
Harpalus (Harpalus) distinguendus (Duftschmid, 1812)	m	E	9	2.3.1.	0.15	IV, V, X, XIX, XX [*23*]
Harpalus (Harpalus) flavescens (Piller et Mitterpacher, 1783)	m	MX	5	2.3.1(1)		
Harpalus (Harpalus) flavicornis flavicornis Dejean, 1829	D	MX	1,3	2.3.1.	0.47	XIII, XVIII, XIX, XXI [*18*]
Harpalus (Harpalus) honestus (Duftschmid, 1812)	D	MX	1	2.3.1.	0.05	VII, XIX [*9*]
Harpalus (Harpalus) hospes hospes Sturm, 1818	m	X	1,7	2.3.1.	0.74	XIX [*5*]
Harpalus (Harpalus) picipennis (Duftschmid, 1812)	D	MX	1	2.3.1.	0.02	XIX [*5*]
Harpalus (Harpalus) pumilus Sturm, 1818	D	MX	1	2.3.1.		
Harpalus (Harpalus) pygmaeus Dejean, 1829	m	MX	1,3	2.3.1.		
Harpalus (Harpalus) rubripes (Duftschmid, 1812)	m	E	1,9	2.3.1.	0.20	V, X, XII, XVIII, XIX [*23*]
Harpalus (Harpalus) rufipalpis rufipalpis Sturm, 1818	m	MX	1	2.3.1.	0.03	VIII [*5*]
Harpalus (Harpalus) saxicola Dejean, 1829	m	MX	1	2.3.1.		
Harpalus (Harpalus) serripes serripes (Quensel, 1806)	m	MX	1,3	2.3.1.	0.1	XII, XIII [*9*]
Harpalus (Harpalus) smaragdinus (Duftschmid, 1812)	m	X	1,3	2.3.1.		
Harpalus (Harpalus) subcylindricus Dejean, 1829	m	X	9	2.3.1.	0.05	XVIII, XX [*9*]
Harpalus (Harpalus) tardus (Panzer, 1796)	m	E	9	2.3.1.	3.08	V, X, XI, XII, XIII, XIV, XV, XVI, XVIII, XIX, XX, XXI [*55*]
Harpalus (Pseudoophonus) griseus (Panzer, 1796)	m	MX	1	2.2.1.		
Harpalus (Pseudophonus) rufipes (De Geer, 1774)	m	E	9	2.2.1.	0.18	XIX, XX [*9*]
Harpalus (Semiophonus) signaticornis (Duftschmid, 1812)	m	MX	1	2.2.1.	0.07	XIII, XVIII, XIX [*14*]
Laemostenus (Laemostenus) venustus (Dejean, 1828)	m	M	4	1.3(1).6	0.22	IV, VI, IX, XV, XVI, XXI [*27*]
Laemostenus (Pristonychus) cimmerius weiratheri J. Müller, 1932	b	M	8	1.3(1).6	11.25	all without III, XIX [*91*]
Laemostenus (Pristonychus) terricola punctatus (Dejean, 1828)	D	M	8	1.3(1).6	0.12	V, XVI, XVII, XXII [*18*]
Lebia (Lebia) cruxminor cruxminor (Linnaeus, 1758)	m	M	2,10	1.1.3.		
Lebia (Lebia) humeralis Dejean, 1825	m	M	1,10	1.1.3.		
Lebia (Lebia) scapularis scapularis (Geoffroy, 1785)	m	MX	3	1.1.3.		
Leistus (Pogonophorus) rufomarginatus (Duftschmid, 1812)	D	M	4	1.3(1).1	0.32	II, V, VIII, X, XI [*23*]
Licinus (Licinus) cassideus cassideus (Fabricius, 1792)	b	X	1,3	1.3(1).1	0.03	XIX [*5*]
Licinus (Licinus) depressus (Paykull, 1790)	D	M	2,4,10	1.3(1).1		
Limodromus assimilis (Paykull, 1790)	m	MH	4,6,10	1.3(1).2	2.96	IX, X, XI, XVIII, XXII [*23*]
Microlestes corticalis (L. Dufour, 1820)	m	M	1,7	1.3(1).3		
Microlestes fissuralis (Reitter, 1901)	D	M	1,3	1.3(1).3	0.05	XIX [*5*]
Microlestes fulvibasis (Reitter, 1901)	b	M	1,7	1.3(1).3		
Microlestes luctuosus luctuosus Holdhaus, 1904	m	X	1	1.3(1).3	0.03	XIX [*5*]
Microlestes maurus maurus (Sturm, 1827)	D	MX	1,3	1.3(1).3	0.17	XIX [*5*]
Microlestes minutulus (Goeze, 1777)	D	MX	1,3	1.3(1).3	0.17	I, XVIII, XIX [*14*]
Microlestes negrita negrita (Wollaston, 1854)	D	MX	1	1.3(1).3		
Molops (Molops) alpestris kalofericus Mlynář, 1977	b	M	4	1.3(2).1	0.64	III, V, VI, IX, XXI, XXII [*27*]
Molops (Molops) dilatatus angulicollis J. Müller, 1936	b	M	4	1.3(2).1	0.40	III, V, X, XI, XXII [*23*]
Molops (Molops) piceus bulgaricus Mařan, 1938	b	M	4	1.3(2).1	6.42	II, III, IV, V, VI, VII, VIII, IX,

						XIX, XXII [*45*]
Myas (Myas) chalybaeus (Palliardi, 1825)	b	M	3,4	1.3(2).1	4.14	all without I, XII, XIII, XIV [*82*]
Nebria (Nebria) brevicollis brevicollis (Fabricius, 1792)	D	MH	2,4	1.3(1).1	0.10	X [*5*]
Notiophilus aestuans Dejean, 1826	D	M	1,4	1.3(1).1		
Notiophilus biguttatus (Fabricius, 1779)	D	MH	2,4	1.3(1).1	0.17	VII, XI [*9*]
Notiophilus rufipes Curtis, 1829	m	M	3,4	1.3(1).1	1.03	II, III, V, VII, VIII, IX, X, XI, XX, XXI [*45*]
Ophonus (Hesperophonus) azureus (Fabricius, 1775)	D	MX	1	2.2.1.	0.12	XVIII, XIX [*9*]
Ophonus (Hesperophonus) cribricollis (Dejean, 1829)	m	MX	1	2.2.1.		
Ophonus (Metophonus) brevicollis (Audinet-Serville, 1821)	m	MX	1	2.2.1.	0.03	XIX [*5*]
Ophonus (Metophonus) laticollis Mannerheim, 1825	D	MX	1,3,10	2.2.1.	0.59	XX, XXI, XXII [*14*]
Ophonus (Metophonus) parallelus (Dejean, 1829)	m	MX	1,10	2.2.1.	0.02	XIX [*5*]
Ophonus (Ophonus) sabulicola (Panzer, 1796)	m	MX	1	2.2.1.	0.34	XIX, XX [*9*]
Parophonus (Parophonus) laeviceps (Ménétriés, 1832)	m	M	1	2.2.1.		
Parophonus (Parophonus) maculicornis (Duftschmid, 1812)	m	M	2	2.2.1.	0.03	X, XII [*9*]
Parophonus (Parophonus) mendax (P. Rossi, 1790)	m	MH	2,4	2.2.1.	0.02	XIII [*5*]
Pedius inquinatus (Sturm, 1824)	D	MX	1,3	1.3(2).1		
Perileptus (Perileptus) areolatus (Creutzer, 1799)	m	H	5	1.3(1).2		
Philorhizus notatus (Stephens, 1827)	D	MX	1,10	1.3(1).3	0.07	I, X, XIII [*14*]
Platyderus (Platyderus) rufus rufus (Duftschmid, 1812)	b	M	4	1.3(1).2	0.02	V [*5*]
Poecilus (Poecilus) cupreus cupreus (Linnaeus, 1758)	m	E	9	1.3(2).1	0.05	XX [*5*]
Poecilus (Poecilus) cursorius cursorius (Dejean, 1828)	m	MH	2,6	1.3(2).1		
Poecilus (Poecilus) versicolor (Sturm, 1824)	m	M	1,2	1.3(2).1	0.03	I [*5*]
Polystichus connexus (Geoffroy in Fourcroy, 1785)	m	MH	2	1.3(1).3		
Pterostichus (Argutor) vernalis (Panzer, 1796)	D	H	2,6	1.3(1).2	0.02	X [*5*]
Pterostichus (Bothriopterus) oblongopunctatus oblongopunctatus (Fabricius, 1787)	D	MH	4,10	1.3(2).1	6.24	I, II, III, IV, V, VI, VII, IX, X, XI, XXI, XXII [*55*]
Pterostichus (Bothriopterus) quadrifoveolatus Letzner, 1852	m	MH	4,6	1.3(2).1	0.02	XVI [*5*]
Pterostichus (Feronidius) incommodus Schaum, 1858	b	MX	3	1.3(2).1	0.02	XVII [*5*]
Pterostichus (Feronidius) melas depressus (Dejean, 1828)	b	E	9	1.3(2).1	0.76	VIII, XIV, XV, XVI, XVII [*23*]
Pterostichus (Parahaptoderus) vecors (Tschitschérine, 1897)	b	M	4	1.3(2).1	0.03	XXII [*5*]
Pterostichus (Petrophilus) melanarius (Illiger, 1798)	D	E	9	1.3(2).1		
Pterostichus (Phonias) strenuus (Panzer, 1796)	D	MH	2,4,6	1.3(1).2	0.03	X [*5*]
Pterostichus (Platysma) niger niger (Schaller, 1783)	D	MH	2,4,10	1.3(2).1	1.01	III, IV, VII, VIII, X, XIV, XXII [*32*]
Pterostichus (Pseudomaseus) anthracinus anthracinus (Illiger, 1798)	D	H	2,4,6	1.3(2).1		
Pterostichus (Pseudomaseus) nigrita nigrita (Paykull, 1790)	D	MH	2,4,6	1.3(2).1	0.03	XXII [*5*]
Pterostichus (Pterostichus) merklii J. Frivaldszky, 1879	b	M	4	1.3(2).1	0.12	XXII [*5*]
Sphodrus leucophthalmus (Linnaeus,1758)	m	M	8	1.3(2).3		
Stenolophus (Stenolophus) abdominalis persicus Mannerheim, 1844	m	H	5,6	2.1.1.		
Stenolophus (Stenolophus) teutonus (Schrank, 1781)	m	MH	2,5,10	2.1.1.		
Syntomus obscuroguttatus (Duftschmid, 1812)	m	M	1	1.3(1).3	0.03	XX [*5*]
Syntomus pallipes (Dejean, 1825)	D	MX	1	1.3(1).3	0.05	XII, XXI [*9*]
Synuchus (Synuchus) vivalis vivalis (Illiger, 1798)	D	M	2,4	1.3(1).2	0.03	X [*5*]
Tachys (Paratachys) bistriatus bistriatus (Duftschmid, 1812)	m	MH	2,6	1.3(1).4		
Tachyta (Tachyta) nana (Gyllenhall, 1810)	m	M	4	1.3(1).5		
Tachyura (Sphaerotachys) hoemorroidalis (Ponza, 1805)	m	H	2,5	1.3(1).1		
Tapinopterus (Tapinopterus) cognatus kalofirensis Mařan, 1933	b	M	4	1.3(2).2	0.49	III, VI, VII, VIII, XXII [*23*]
Trechus (Trechus) crucifer Piochard de la Brûlerie, 1876	m	M	4	1.3(1).2	0.07	II, VII [*9*]

Trechus (Trechus) irenis Csiki, 1912	n.a.	M	4	1.3(1).2	0.02	XXII [*5*]
Trechus (Trechus) quadristriatus (Schrank, 1781)	m	E	9	1.3(1).2	2.13	I, III, VI, VII, VIII, X, XI, XIV, XVII, XVIII, XIX, XX, XXI, XXII [*64*]
Xenion ignitum (Kraatz, 1875)	b	M	4	1.3(1).4	2.84	II, III, IV, V, VI, VII, IX, XXII [*36*]
Zabrus (Zabrus) tenebrioides (Goeze, 1777)	m	MX	1	2.3.2.		
Zabrus (Pelor) spinipes spinipes (Fabricius, 1798)	b	MX	1	2.3.2.		