Biodiversity Journal, 2015, 6 (1): 341–352 **MONOGRAPH**

Ground beetles (Coleoptera Carabidae) diversity patterns in forest habitats of high conservation value, Southern Bulgaria

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ABSTRACT The study presents a comparison between the diversity of the carabid beetles taxocoenoses and their spatial distribution in different forest types of high conservation value in Strandzha (8 sites), the Rhodopes (4 sites) and Belasitsa (6 sites) mountains. The diversity indices have demonstrated the highest species richness and the highest diversity values in the riverside sites of Strandzha Mountain. The lowest species richness has been found in the tertiary relict forest of oriental beech with undergrowth of rhododendron (Strandzha Mountain) and in the century-old sweet chestnut forest (Belasitsa Mountain). The lowest values of diversity and evenness have been found in the beech forest sites in Strandzha and the Rhodopes due to the prevalence of the *Aptinus* species. This low diversity is a natural condition for the studied sites. The classification of the ground beetles complexes from the studied sites by similarity indices and TWINSPAN has been made. A high level of dissimilarity among the sites has been found, showing unique species composition and abundance models in each site. Carabid beetles taxocoenoses in the forests of Strandzha Mountain have shown a low similarity level by species composition and abundance even in the range of the same mountain. Indicator species have been shown. The ordination of the carabid complexes has showed that the sites have been distributed continuously along two significant gradients. The first gradient has been found to be the altitude (probably due to the temperature conditions) in a combination with the hydrological regime. The second significant gradient probably has been under the complex influence of the climate conditions and vegetation type.

KEY WORDS Carabidae; diversity; conservation; Bulgaria.

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INTRODUCTION

The present study is a part of the pilot studies of some indicator species groups as a basis for a long term monitoring in different forest types of high conservation value (Natura 2000 sites) in the Rhodopes, Belasitsa and Strandzha Mountains.

In order to assess the ecosystems before taking some management decisions there is a need of basic knowledge of the species compositions and successional processes of the species assemblages occupying the habitats (Szyszko et al., 2000).

Ground beetles could be a very useful group as an indicator of the habitat disturbance as well: they are abundant in most ecosystems; some species possess strong habitat preferences; most of the ground beetle species are associated with specific landscapes and microclimate conditions; they show rapid response to environmental changes (Pearsal, 2007). Until this study there was scarce information about carabid beetles' fauna of Strandzha and Belasitsa Mountains (Gueorguiev & Gueorguiev, 1995). The diversity patterns and spatial structure of the ground beetles communities from these habitats have been unknown as well.

MATERIAL AND METHODS

Study area and sampling methods

The studied sites have been chosen in order to be representative habitat types for the Rhodopes, Belasitsa and Strandzha Mountains. The total number of the studied sites has been eighteen (Table 1, Fig.1). The description of the sample sites and their code according to Habitats Directive (Directive 92/43 EEC, EC, 1992) are given in Table 1.

At each site10 pitfall traps (diameter = 80 mm, length = 110 mm) were set in a line. The conserving fluid in the traps was propylene glycol. The material was collected from May to October in the corresponding years shown in Table 2.

Data Analysis

The species richness-number of collected species in each sample site (S); Shanon's (H) and Evenness indexes have been calculated to compare alfa-diversity. Chao 1 procedure has been applied to calculate the expected species richness in the studied sites (Chao, 2005).

The dominance of the species has been determined using Pesenco's logarithmic scale (Pesenko, 1982) and the categories names have been adapted to Tischler's dominance categories, (1949): eudominants (very hight abundance), dominants (high abundance), subdominants (average abundance), recedents (low abundance) and subrecedents (single individuals) (Kostova, 2009). Multidimensional non-parametric scaling (MDS) has been applied to visualize is similarity distances between the dominance curves of the studied taxocoenoses (Clarke, 1993). Chi-square test has been used to test the goodness of fit of the studied taxoconoses' abundance models to the theoretical ones.

Czekanowski–Sörensen and Bray-Curtis similarity coefficients have been used to calculate similarity between carabid taxocoenoses, by species composition and by relative abundance of the species respectively. UPGMA method for clustering has been applied for constructing the dendrograms (Krebs, 1999). Two way indicator species analysis (TWINSPAN) for classification of the carabid beetle complexes has also been performed.

Figure 1. A map of the location of the study sites, S-Bulgaria (Source: Google Earth, 2014).

Mountain	Site	Altitude	Characteristic trees	Code HD92/43
Belasitsa	B_Pl	450	*Platanus orientalis* Linnaeus	92C0 - *Platanus orientalis* and *Liquidambar orientalis* woods
	B_Pl_Cast	400	*Platanus orientalis* Linnaeus, *Castanea sativa* Miller	92C0 - *Platanus orientalis* and *Liquidambar orientalis* woods
	B_Cast_Pl	400	*Platanus orientalis* Linnaeus, *Castanea sativa* Miller	92C0 - *Platanus orientalis* and *Liquidambar orientalis* woods
	B_Cast	750	*Castanea sativa* Miller, *Fagus sylvatica* Linnaeus	9260 *Castanea sativa* woods
	B_F	700	*Fagus sylvatica* Linnaeus (along waterfall)	9110 *Luzulo-Fagetum* beech forests
	B_F2	1500	*Fagus sylvatica* Linnaeus	9110 *Luzulo-Fagetum* beech forests
Rhodopes	Rh_Q	1054	*Quercus dalechampii* Tenore	91M0 Pannonian-Balkanic turkey oak-sessile oak forests
	Rh_F	1133	*Fagus sylvatica* Linnaeus	9130 *Asperulo-Fagetum* beech forests
	Rh_F_Ab	1401	*Fagus sylvatica* Linnaeus, single trees *Picea abies* Karsten, *Abies alba* Miller	9130 *Asperulo-Fagetum* beech forests
	Rh_Pic_Ab	1596	*Picea abies* Karsten, *Abies alba* Miller	9410 Acidophilous *Picea* forests of the montane to alpine levels
Strandzha	S_Q	324	*Quercus hartwissiana* Steven, *Quercus cerris* Linnaeus	91M0 *Pannonian-Balkanic turkey oak-sessile oak forests
	S_Q2	15	*Quercus frainetto* Tenore, *Quercus cerris* Linnaeus	91M0 *Pannonian-Balkanic turkey oak-sessile oak forests
	S_Q_F	271	*Quercus polycarpa* Schur, single trees *Fagus orinetalis* Lipsky	91M0 *Pannonian-Balkanic turkey oak-sessile oak forests
	S_F	401	*Fagus orientalis* Lipsky	91S0 *Western Pontic beech forests
	S_F_Rhod	183	*Fagus orientalis* Lipsky, udergrowth *Rhododendron ponticum* Linnaeus	91S0 *Western Pontic beech forests
	S_Rip	224	*Alnus glutinosa* Gaertn., *Quercus cerris* Linnaeus	91E0 *Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*
	S_Rip2	35	meadow with single trees *Alnus glutinosa* Gaertn., *Salix sp., Uglans regia* Linnaeus, *Rubus sp.* near *Quercus sp.* forest	91E0 *Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*
	S_Longoz	6	*Fraxinus angustifolia* subsp. *oxycarpa* (M.Bieb. ex Willd.), *Alnus glutinosa* Gaertn.	91F0 Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers

Table 1. Description of the sample sites, S-Bulgaria.

This method makes classification of the samples, and then uses this classification to obtain a classification of the species according to their ecological preferences. It also makes a dichotomy based on ordination identifying the direction of variation. It gives an indicator pseudospecies, i.e. transforms abundance into pseudospecies (Hill & Šmilauer, 2005).

Detrended correspondence analysis (DCA) has been applied for ordination of the beetle complexes by sample sites. Data standardization has been applied for the analysis due to the different duration of the collecting time. The relative abundance (proportion of the total number of caught individuals) of the species from a given sample site has been used to calculate alfa-diversity indices, two way indicator species analysis and dominant structure analysis. Mean number of caught individuals per 100 trap/days has been used for cluster and ordination analysis. The following statistical softwares were used: Microsoft Excel (Office 2010), Past 3.01 (Hammer & Harper, 2001), Estimate S9.1.0 (Colwell, 2013), Primer 6 (Clarke & Gorley, 2006), WinTWINS 2.3 (Hill & Šmilauer, 2005).

Mountain	Year of study	N_exemplars	N_Species
Rhodopes	2006, 2007	5062	29
Belasitsa	2008, 2009	1810	46
Strandzha	2009	5004	92
Total	-	11876	128

Table 2. A summary table of the collected material, S-Bulgaria.

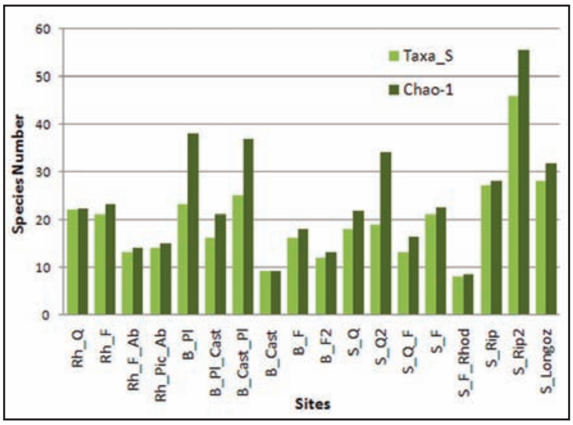

Figure 2. Species richness (empirical and estimated by Chao 1 procedure) of the ground beetle complexes in the studied sites.

RESULTS

Eleven thousand eight hundred and seventy-six individuals belonging to one hundred twenty-eight species have been collected (Tables 2, 3). Only six species have been common to the three mountains: *Calosoma sycophanta*, *Carabus convexus*, *C. intricatus*, *C. coriaceus*, *Pterostichus niger* and *Myas chalybaeus* (Fig. 2).

The highest species richness of ground beetles has been shown in the riparian site with meadow and single trees (Strandzha)- 45 species. Relatively high species richness has also been demonstrated in the riparian sites of Strandzha with rich herbaceous undergrowth. The lowest species number has been found in the tertiary relict forest of *Fagus orientalis* with undergrowth of *Rhododendron ponticum* (Strandzha), 8 species and in the centuries-old forest of *Castanea sativa* (Belasitsa), 9 species. Relatively low species richness has also been found in the carabid taxocoenoses from the sample sites with altitude above 1400 m (the Rhodopes and Belasitsa Mountains) (Fig. 3). The species number of the ground beetles at each site has been actually greater, because there have been species that do not fall into the traps. The estimated species number by Chao1 procedure has been almost the same only for four of the carabid taxocoenoses with relatively low species richness. The highest species number has been estimated for the riparian sites,the oak forests at the seashore in Strandzha and for the oriental plane forests in Belasitsa (Fig. 3).

Shanon's diversity index, fairly sensitive to actual site differences (Krebs, 1999), has demonstrated relatively high ground beetles diversity for all of the studied sites (Figs. 4, 5). An exception has been the beech forests of the Rhodopes and Strandzha Mountains due to the prevalence of one species: *Aptinus bombarda* and *A. cordicollis* respectively. The carabid taxocoenose of the century-old sweet chestnut forest in Belasitsa has shown the highest value of evenness -0.8. The lowest evenness has been estimated for the carabid taxocoenoses from the beech forest of Strandzha and the Rhodopes due to the above mentioned prevalence of the *Aptinus* species (Fig. 6).

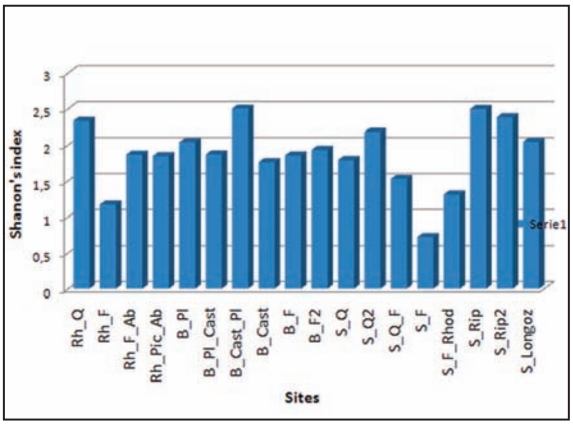

Figure 3. Diversity of the ground beetle complexes in the studied sites,estimated by Shanon's index.

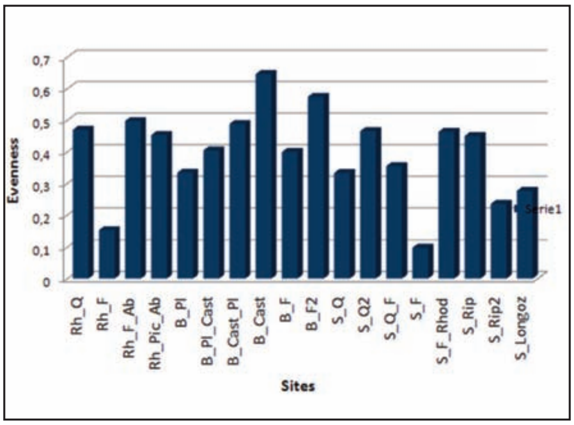

Figure 4. Evenness of the ground beetle complexes in the studied sites.

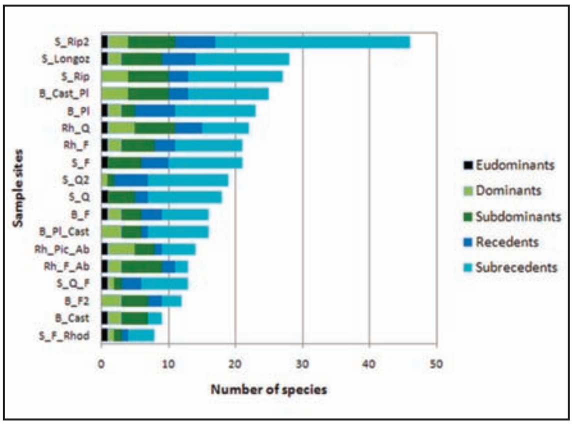

Figure 5. Dominance structure of the ground beetle complexes, based on Pesenko's logarithmic scale.

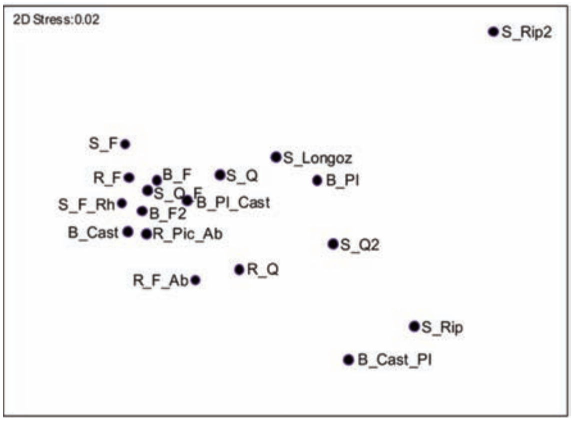

Figure 6. Dissimilarity distances between the dominance curves of the studied taxocoenoses, an MDS method.

The dominance structure of the riparian site with meadow in Strandzha has differed strongly from all the other with many species represented by single individuals (Figs. 7, 8). The riparian forest of Strandzha (S_Rip) has showed a dominance structure close to the chestnut with oriental plane trees in Belasitsa (B_Cast_Pl) without eudominants and more species as dominants and subdominants. These two sites have one thing in common- through both of them pass eco-trails. They have demonstrated Log-series model of the abundance, characteristic for disturbed habitats (B_Cast_Pl: Chi square = 0.97, p = 0.94; S_Rip: Chi square = 0.98, p = 0.91). The beech woods with prevalence of the *Aptinus* species have also represented a close dominant structure, so as the century-old and the tertiary relict forests with a small number of species and high evenness. The classification of the carabid beetles'taxocoenoses by qualitative and quantitative similarity coefficients has demonstrated low levels of similarity for the mountains in general. Four main clusters have been formed by species composition (Fig. 9). The similarity by species composition has been relatively high for the studied carabid assemblages from the Rhodopes where they have formed a separate cluster. A separate cluster, although with low similarity, has been formed by the periodically flooded riparian sites of Strandzha with thick herbaceous undergrowth (S_Rip; S_Longoz).

The beech and the chestnut forests of Belasitsa have also represented a separate cluster. The rest of the studied ground beetle assemblages have formed a cluster with low to average similarity between them. The picture of the clustering based on Bray-Curtis coefficient has shown more differences between the studied carabid assemblages.

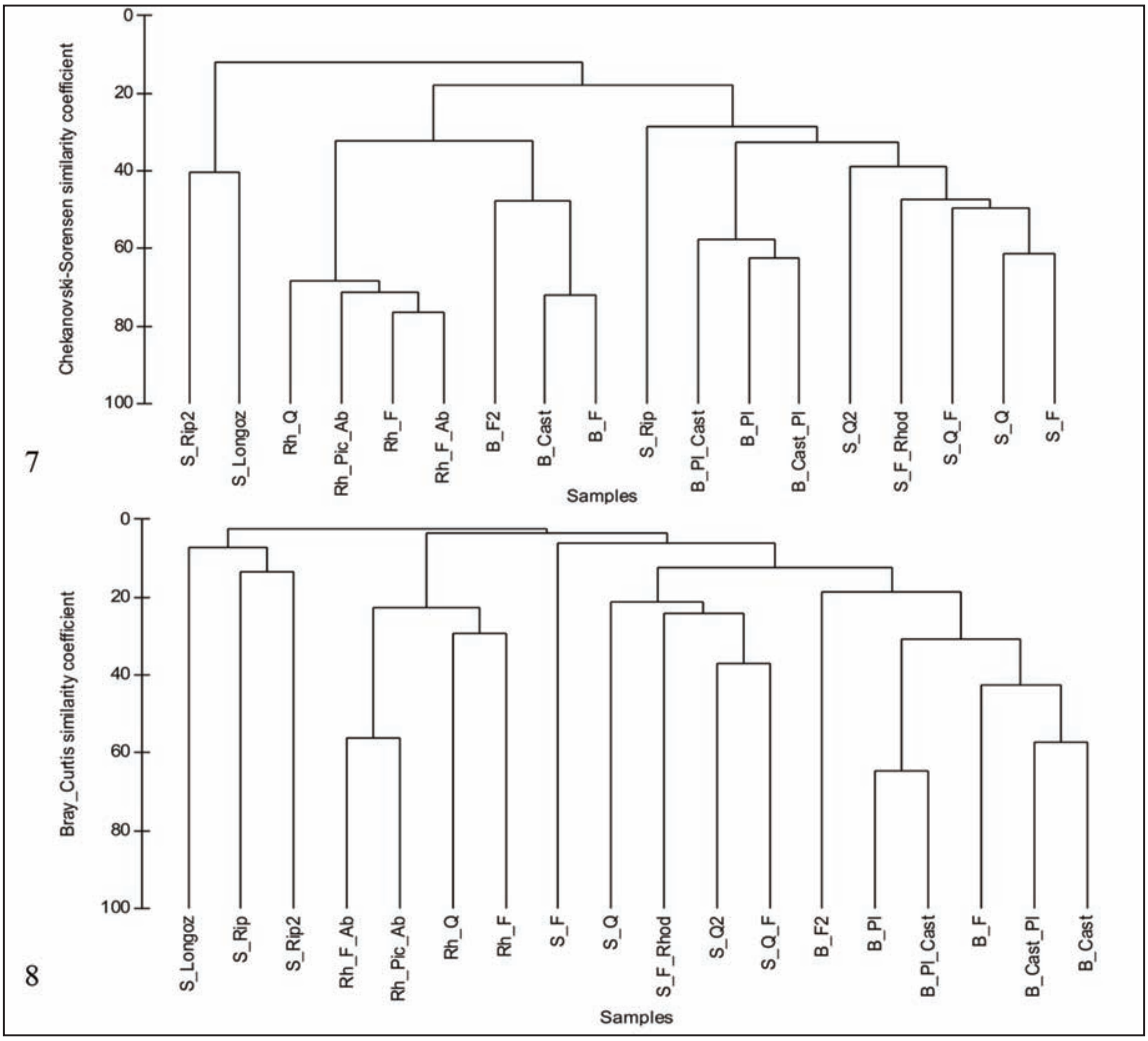

Figure 7. A dendrogram for hierarchical clustering of the similarity by species composition of the carabid beetles' complexes, an UPGMA method, based on Chekanovski- Sörensen coefficient of similarity. Figure 8. A dendrogram for hierarchical clustering of the similarity by species abundance of the carabid beetles' complexes, an UPGMA method, based on Bray-Curtis coefficient of similarity.

The levels of similarity have been much lower than by species composition only. There have been three main clusters: one of the riparian sites of Strandzha; one of the sites of the Rhodopes and one of all the other sites. At first level of division TWINSPAN analysis of the ground beetles'taxocoenoses by sample sites has shown separation of the Strandzha and Belasitsa low altitude sites from the other sample sites. The following groups of sites have been formed at second level of division: 1.the Rhodopes sites with altitude above 1000 m and Belasitsa sites above 700 m; 2. Belasitsa and Strandzha forest sites up to 450m; 3. the periodically flooded riparian sites of Strandzha. The classification of the species based on their habitat preferences has also been obtained (Table 3).

The ordination of the carabid assemblages by DCA has demonstrated two significant gradients (Eigenvalues: first axis = 0.97, second axis = 0.63, third axis = 0.34, fourth axis = 0.15). The sample sites have been arranged along the first axis as follows: the sites from the Rhodopes (above 1000 m) have been followed by the sites from Belasitsa in direction higher to lower altitude sites, then the forest sites from Strandzha and the riparian sites from the same mountain ending with the periodically flooded forest along the estuary of Veleka river with altitude almost at the sea level. The arrangement along the second axis (gradient) has separated the Norway spruce forests with altitude above 1400 meters from all the other sites (Fig. 11).

DISCUSSION

The studied carabid beetles' taxocoenoses have demonstrated high species richness and diversity as a whole. There have been some exceptions like the low species richness of ground beetles in the old stable forest ecosystems, which is a natural condition. The higher species number of carabids in the open area habitats and cleared forests than in the old forests is typical for the temperate zone (Kryzhanovsky, 1983). The low values of diversity indices and evenness of the beech forests of the Rhodopes and Strandzha Mountains have been due to the prevalence of one species: *Aptinus bombarda* and *A. cordicollis*, respectively. This natural condition had also been found for the beech forests in Vitosha Mountain, Bulgaria (Popov et al., 1998).

The dominance structure and the abundance models of the carabid beetles' associations could be important indicators for the statement of succession and disturbance (Hill & Hamer, 1998). Only two of the studied habitats have shown disturbance by this estimators, probably due to an anthropogenic disturbance of the often visited by tourists eco-trails in them. However, the use of the abundance models for assessment of the ground beetles status, respectively habitat status, is controversial. One of the reasons is that there are taxocoenoses with natural conditions differing from log-normal abundance model, which is an indicator of natural undisturbed communities.

When chi-square test is used for estimating goodness of fit to the theoretical models, there appears another problem. This test has low power and cannot be used for small samples (for example sites with low species number cannot be tested), so as for the different abundance models it has a different power, and the results of p - value should not be used for comparisons between the goodness of fit to the different models (Hammer et al., 2001). Then Kolmogorov-Smirnov one sample test could also be used. The classification of the studied sites has shown unique species composition and abundance of the ground beetle assemblages even within the range of one mountain. The unique indicator carabid species and pseudospecies (with transformed abundance) for the studied sites have been estimated by TWINSPAN analysis. An indicator pseudospecies could be those with category above 2 (abundance above 5 %), they have to be abundant enough to be easily found and collected.

As a result, the following indicator species could be used for the studied taxocoenoses: *Cychrus semigranosus balcanicus* and *Carabus hortensis* have been found as indicators for the high altitude beech and Norway spruce forests, *Calathus metal-*

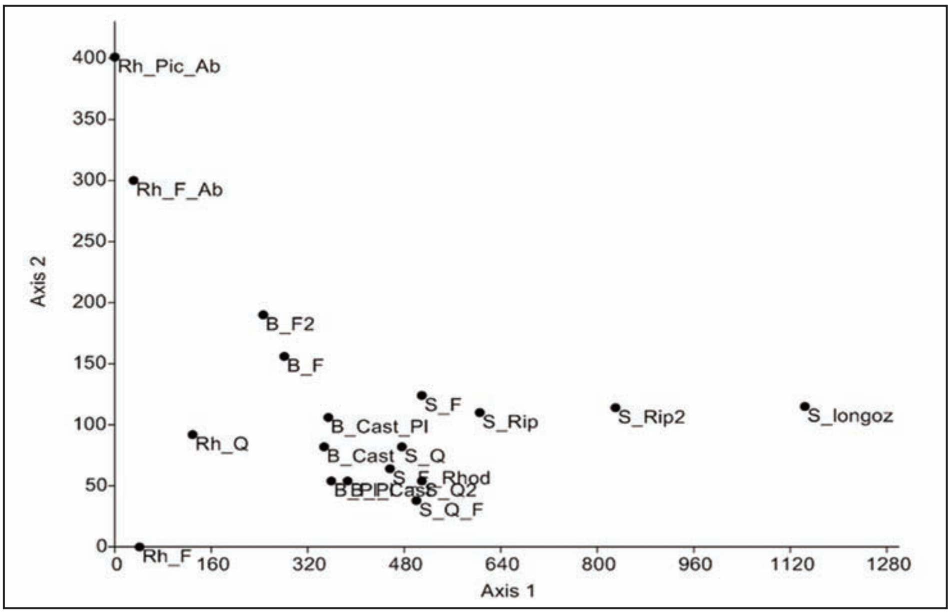

Figure 9. Detrended correspondence analysis (DCA) ordination diagram of the carabid beetles' complexes.

Species	Sample sites																		Species division levels
	Rh_Q	Rh_F	Rh_F_Ab	Rh_Pic_Ab	B_Cast_Pl	B_Cast	B_F	B_F2	B_Pl	B_Pl_Cast	S_Q	S_Q_F	S_F	S_F_Rhod	S_Q2	S_Rip	S_Rip2	S_Longoz	
Platyderus rufus Duftschmid, 1812	-	-	-	-	4	-	-	-	1	3	-	-	-	-	-	-	-	-	*11
Ophonus laticollis Mannerheim, 1825	-	-	-	-	4	-	-	-	2	-	-	-	-	-	-	-	-	-	*11
Carabus intricatus Linnaeus, 1761	3	1	1	-	4	5	4	-	4	5	2	-	2	-	-	-	-	-	*11
*Tapinopterus balcanicus belasicensis*Maran, 1933	-	-	-	-	5	4	5	5	3	2	-	-	-	-	-	-	-	-	*10111
Laemostenus terricola punctatus Dejean, 1828	-	-	-	-	3	-	-	-	1	-	-	-	-	-	-	-	-	-	*10111
Pterostichus vecors (Tschitscherine, 1897)	-	-	-	-	-	-	4	1	-	-	-	-	-	-	-	-	-	-	*10110
Pterostichus brucki Schaum, 1859	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	*10110
Pterostichus brevis (Duftschmid, 1812)	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	*10110
Platynus scrobiculatus (Fabricius, 1801)	-	-	-	-	5	4	5	-	2	-	-	-	-	-	-	-	-	-	*10110
Ophonus schaubergerianus (Puel, 1937)	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	*10110
Molops rufipes belasicensis Mlynar, 1977	-	-	-	-	5	5	5	5	3	-	-	-	-	-	-	-	-	-	*10110
Leistus magnicollis Motschulsky, 1866	-	-	-	-	-	-	1	3	-	-	-	-	-	-	-	-	-	-	*10110
Lebia cyanocephala (Linnaeus, 1758)	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	*10110
Harpalus triseriatus Fliescher, 1897	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	*10110
Harpalus griseus (Panzer, 1797)	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	*10110
Synuchus vivalis (Illiger, 1798)	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	*101011
Cychrus semigranosus balcanicus Hopffgarten, 1881	4	5	5	5	2	1	2	5	-	-	-	-	-	-	-	-	-	-	*101011
Pterostichus oblongopunctatus (Fabricius, 1787)	-	2	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	*101010
Carabus violaceus azurescens Dejean, 1826	2	4	5	5	-	2	4	2	-	-	-	-	-	-	-	-	-	-	*101010
*Carabus hortensis*Linnaeus, 1758	5	5	5	5	-	-	1	5	-	-	-	-	-	-	-	-	-	-	*101010
Xenion ignitum (Kraatz, 1875)	5	5	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001
Apinopterus balcanicus Ganglbauer, 1891	4	5	5	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001
Notiophilus biguttatus (Fabricius, 1779)	4	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001
Molops rhodopensis Apfelbeck, 1904	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001
Molops dilatatus Chaudoir, 1868	5	5	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001
Molops alpestris (Dejean, 1828)	4	5	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001
Microlestes minutulus (Goeze, 1777)	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001
Laemostenus terricola Herbst, 1784	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001
Clivina fossor (Linnaeus, 1758)	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001
Carabus montivagus bulgaricus Csiki, 1927	5	2	4	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	*101001
Calathus mollis (Marsham, 1802)	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001
Calathus metallicus Dejean, 1828	-	2	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001
Aptinus bombarda (Illiger, 1800)	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001
Abax ovalis (Duftschmid, 1812)	2	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001

Table 3.TWINSPAN analysis' table of the studied ground beetles'taxocoenoses.Species abundance has been represented by pseudospecies. Doubled line has shown the first level of division, dotted line has shown the second level of division (continued).

Species	Sample sites																		Species division levels
	Rh_Q	Rh_F	Rh_F_Ab	Rh_Pic_Ab	B_Cast_Pl	B_Cast	B_F	B_F2	B_Pl	B_Pl_Cast	S_Q	S_Q_F	S_F	S_F_Rhod	S_Q2	S_Rip	S_Rip2	S_Longoz	
Pterostichus niger (Schaller, 1930)	2	2	5	5	1	-	-	-	1	-	-	-	2	-	-	-	-	1	*101000
Amara communis (Panzer, 1797)	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	*101000
Harpalus rufipes (De Geer 1774)	4	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	3	1	*100
Calathus fuscipes (Goeze, 1777)	2	-	-	1	1	-	-	-	-	-	-	-	-	-	3	2	5	-	*011
Anisodactilus binotatus (Fabricius, 1787)	-	-	-	-	2	-	-	-	-	1	-	-	-	-	-	-	-	4	*011
Amara aenea (De Geer, 1774)	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	*011
Trechus quadristriatus (Schrank, 1781)	-	-	-	-	1	-	2	5	-	-	3	-	3	-	1	2	2	-	*0101
Myas chalybaeus (Palliardi, 1825)	4	-	-	-	5	5	3	-	5	5	4	3	4	4	3	-	-	-	*0101
Carabus convexus Fabricius, 1775	5	3	-	-	5	5	2	-	5	5	5	2	5	2	2	3	2	-	*0101
Abax carinatus (Duftschmid, 1812)	-	-	-	-	5	-	-	-	4	4	2	-	-	-	-	-	-	-	*0101
Notiophilus rufipes Curtis, 1829	-	-	-	-	4	-	-	-	2	1	4	1	-	-	-	5	-	-	*0100
Carabus coriaceus Linnaeus, 1758	3	4	3	1	-	5	3	-	2	4	3	5	5	4	5	-	2	2	*0100
Calosoma sycophanta (Linnaeus, 1758)	1	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	*0100
Harpalus atratus Latreille, 1804	-	-	-	-	5	-	-	-	3	4	1	4	4	-	-	4	-	-	*0011
Amara saphyrea Dejean, 1828	-	-	-	-	1	-	-	-	1	2	-	-	-	-	-	-	-	-	*0011
Amara convexior Stephens, 1828	-	-	-	-	1	-	1	-	-	-	-	-	2	-	-	5	-	-	*0011
Trechus crucifer Brulerie, 1875	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	*001011
Pterostichus properans (Chaudoir, 1868)	-	-	-	-	-	-	-	-	-	-	2	-	3	2	-	2	-	-	*001011
Harpalus calceatus (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	*001011
Molops piceus byzantinus Apfelbeck, 1902	-	-	-	-	-	-	-	-	-	-	-	-	5	-	2	2	-	-	*001011
Licinus cassideus (Fabricius, 1792)	-	-	-	-	-	-	-	-	-	-	1	1	-	-	1	-	-	-	*001011
Laemostenus venustus (Dejean, 1828)	-	-	-	-	-	-	-	-	-	-	2	-	3	-	-	-	1	-	*001011
Laemostenus cimmerius (Fischer-Waldheim, 1823)	-	-	-	-	-	-	-	-	-	-	5	1	5	-	4	-	-	-	*001011
Harpalus sulphuripes Germar, 1824	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	*001011
Harpalus smaragdinus (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	*001011
Harpalus honestus (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	*001011
Harpalus froelichi Sturm, 1818	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	*001011
Chlaenius aenocephalus Dejean, 1826	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	*001011
Carabus marietti Cristofori et Jan, 1837	-	-	-	-	-	-	-	-	-	-	2	3	5	5	-	-	-	-	*001011
Carabus scabrosus Olivier, 1795	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	*001011
Calosoma inquisitor (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	*001011
*Calathus longicollis*Motschulsky, 1864	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	*001011
Amara tricuspidata tricuspidata Dejean, 1831	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	*001011
Pterostichus nigrita (Paykull, 1790)	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	*001010
Harpalus tardus (Panzer, 1797)	-	-	-	-	1	-	-	-	5	2	1	5	2	2	3	4	3	-	*001010
Dromius quadrimaculatus (Linnaeus, 1758)	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	*001010

Table 3. TWINSPAN analysis' table of the studied ground beetles'taxocoenoses. Species abundance has been represented by pseudospecies. Doubled line has shown the first level of division, dotted line has shown the second level of division (continued).

Species	Rh_Q	Rh_F	Rh_F_Ab	Rh_Pic_Ab	B_Cast_Pl	B_Cast	B_F	B_F2	B_Pl	B_Pl_Cast	S_Q	S_Q_F	S_F	S_F_Rhod	S_Q2	S_Rip	S_Rip2	S_Longoz	Species division levels
	Sample sites																		
Acupalpus suturalis Dejean, 1829	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	*001010
Trechus sp. (*subnotatus* group)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	*001001
Parophonus maculicornis (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	*001001
Ophonus similis (Dejean, 1829)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	*001001
*Ophonus nitidulus*Stephens, 1828	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-	*001001
Notiophilus palustris (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	*001001
Leistus rufomarginatus Duftschmid, 1812	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	*001001
Harpalus flavicornis Dejean, 1829	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	*001001
Aptinus cordicollis Chaudoir, 1843	-	-	-	-	-	-	-	-	-	-	1	-	5	-	1	5	1	-	*001001
Amara anthobia Villa, 1833	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	2	-	-	*001001
Harpalus rubripes (Duftschmid, 1812	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	1	-	*001000
Nebria brevicollis (Fabricius, 1792)	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	5	5	3	*0001
Carabus wiedemanni Ménétriés, 1836	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	3	-	*0001
Amara ovata (Fabricius, 1792)	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	2	-	*0001
Harpalus serripes (Quensel, 1806)	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-	*000011
Harpalus dimidiatus (Rossi, 1790)	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	4	-	*000011
Syntomus pallipes (Dejean, 1825)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	*000010
Harpalus albanicus Reitter, 1900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	*000010
Bembidion lampros (Herbst, 1784)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	2	*000010
Agonum assimile (Paykull, 1790)	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	2	5	*000010
Asaphidion flavipes (Linnaeus, 1761)	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	4	5	4	*000001
Agonum dorsalis (Pontopippidian, 1763)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	4	*000001
Trechus obtusus thracicus Pawlowski, 1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	*000000
Tachys bistriatus (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	*000000
Syntomus obscuroguttatus (Duftshmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	*000000
Stenolophu smixtus(Herbst., 1784)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	*000000
Pterostichus strenuus (Panzer, 1797)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	*000000
Pterostichus melas(Creutzer, 1799)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	5	1	*000000
Pterostichus melanarius bulgaricus Lutshnik, 1915	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	*000000
Pterostichus leonisi Apfelbeck, 1904	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	*000000
Pterostichus anthracinus (Illiger, 1798)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5	*000000
Poecilus cupreus (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	*000000
Parophonus complanatus (Dejean, 1829)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	*000000
Panagaeus cruxmajor (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	*000000
Ophonus sabulicola (Panzer, 1796)	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	5	-	*000000
Ophonus melleti (Heer, 1837)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	*000000
Oodes gracilis Villa, 1833	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	*000000
Harpalus tenebrosus Dejean, 1829	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000

Table 3. TWINSPAN analysis' table of the studied ground beetles'taxocoenoses. Species abundance has been represented by pseudospecies. Doubled line has shown the first level of division, dotted line has shown the second level of division (continued).

Species	Sample sites																		Species division levels
	Rh_Q	Rh_F	Rh_F_Ab	Rh_Pic_Ab	B_Cast_Pl	B_Cast	B_F	B_F2	B_Pl	B_Pl_Cast	S_Q	S_Q_F	S_F	S_F_Rhod	S_Q2	S_Rip	S_Rip2	S_Longoz	
Harpalus cupreus Dejean, 1829	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	*000000
Harpalus autumnalis (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000
Harpalus affinis (Schrank, 1781)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000
Gynandromorphus etruscus (Quensel, 1806)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000
Dyschirius globosus (Herbst, 1783)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	*000000
Diachromus germanus (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	*000000
Chlaenius nigricornis (Fabricius, 1787)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	*000000
Carabus granulatus Linnaeus,1758	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	*000000
Calathus melanocephalus (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	*000000
Brachinus elegans Chaudoir, 1842	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	*000000
Brachinus crepitans (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	*000000
Bembidion inoptatum Schaum, 1857	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	*000000
Bembidion elongatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000
Bembidion andreae (Fabricius 1787)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	*000000
Bembidion tethys Netolitzky 1926	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000
Badister bipustulatus (Fabricius, 1792)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	*000000
Anisodactilus signatus (Panzer, 1797)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000
Agonum viduum (Panzer, 1797)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	*000000
Agonum nigrum Dejean, 1828	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	*000000
Agonum mulleri Herbst, 1785	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	*000000
Division levels of the sites	*00	*00	*00	*00	*01	*01	*01	*01	*1000	*1000	*10010	*10010	*10010	*10010	*10011	*101	*11	*11	

Table 3. TWINSPAN analysis' table of the studied ground beetles'taxocoenoses. Species abundance has been represented by pseudospecies. Doubled line has shown the first level of division, dotted line has shown the second level of division.

licus has been an indicator for the Norway spruce forest above 1500 m, *Molops rhodopensis* has been found as an indicator species onlyfor the high altitude Norway spruce forest of the Rhodopes, *Pterostichus brucki,* for the high altitude beech forest of Belasitsa, *Platyderus rufus* has been unique for the low altitude oriental plane woods, *Pterostichus melanarius bulgaricus*, *Bembidion andreae*, *Calathus melanocephalus*, *Harpalus cupreus* and *Ophonus sabulicola* have been an indicator species for the open area grassy habitats (S_Rip2), *Bembidion andreae* has also been an indicator species only for the riparian meadow, *Poecilus cupreus* has also been found as an indicator species for wet grassy habitats like the periodically flooded riparian sites of Strandzha, *Leistus rufomarginatus* and *Trechus* sp. (*subnotatus* group) have been indicator species for the riparian forest of Strandzha (S_Rip), *Carabus granulatus*, *Chlaenius nigricornis*, *Dyschirius globosus* and *Oodes gracilis* have been found as indicator species for the periodically flooded estuary forest of Strandzha (S_Longoz), *Calathus longicollis* has been an indicator species for the Black sea coastal oak forest, *Carabus scabrosus*, for the oriental beech woods of Strandzha.

The ordination of the carabid beetles' taxocoenoses has demonstrated continuous arrangement of the sites along the first axis (the first gradient). The first gradient has been found to be the altitude (probably due to the temperature conditions) in combination with the hydrological regime (for example, the periodically flooding of the last two sites). On this gradient, probably there is a complex influence of the climate conditions and the vegetation type. Continuous arrangement according the temperature conditions had also been found for the carabid associations of different altitude in Vitosha Mountain by Popov et al. (1998).

The high conservation value of the studied sites in the Rhodopes, Belasitsa and Strandzha Mountains has also to be concerned due to the great diversity of the ground beetles that should be preserved and monitored. Only the Rhodopes sites have been under high level of protection as a part of natural reserves, so as two of the sites in Strandzha as a part of protected localities. The rest of the studied habitats from Strandzha and Belasitsa Mountains have been with low protection status and therefore threatened by logging.

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