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Ground beetles in Bulgarian oilseed rape fields and adjacent actively grazed pastures (Coleoptera: Carabidae)

Teodora Marius Teofilova

Bulgarian Academy of Sciences, Institute of Biodiversity and Ecosystem Research (IBER), 1000 Sofia, Bulgaria
E-mail: oberon_zoo@abv.bg; https://orcid.org/0000-0003-0111-1573

Abstract

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This is the first study of the carabid fauna in oilseed rape fields in Bulgaria. It aimed at clarifying the species composition and ecological structure of the carabids associated with the oilseed rape during its flowering, ripening and after the harvest. The research was also encompassing the adjacent pastures. Field work was carried out in 2018, and partly in 2017. Pitfall traps (5 in each site) were set in 10 sampling sites in Thracian Lowland and Sarnena Sredna Gora Mts. A total of 6914 specimens were collected (463 in 2017 and 6451 in 2018). Collected beetles belonged to 138 species from 45 genera, representing 18.5% of all Bulgarian carabid species and 36% of the genera. The richest tribes were Harpalini (57 species), Amarini (15 species), and Lebiini (13 species). The most species-rich were the genera *Harpalus* (26 species) and *Amara* (14 species). The most abundant species in the rape fields were *Harpalus distinguendus* (714 ex.) and *Calosoma auropunctatum* (692 ex.). The most abundant in the pastures were *Harpalus flavicornis* (168 ex.) and *Microlestes fissuralis* (110 ex.). Thirty-eight species were ascertained to be new for the fauna of the Thracian Lowland and 51 species were new for the Sarnena Gora Mts.

Keywords: agrocoenoses; carabids; Bulgaria; new records; diversity

Introduction

The diversity and abundance of insect predators in agricultural areas are affected by the type of agriculture and by the presence of natural habitats (Kromp, 1989, 1999; Pfiffner & Luka, 2000). Natural habitat patches are important for agroecosystems because they encourage insect predators' dispersal (Thomas et al., 1991), an important component of sustainable agriculture (Altieri et al., 2003). In oilseed rape, the impact of ground-based natural enemies is poorly understood for most pests (Büchs & Alford, 2003).

Ground beetles are thought to be an important group of beneficial insects contributing to restricting pest activity (Symondsen et al., 2002). They are among the most important elements of the natural environment's resistance in arable fields and natural habitats. Majority of carabid species found in oilseed rape fields are known to be important polyphagous predators within arable cropping systems (Kromp, 1999) and are amongst the most abundant invertebrate predators of economically important oilseed rape pests in Europe (Williams, 2010; Gotlin Čuljak et al., 2016). Their prey includes insects feeding on both the aerial and the subterranean parts of the plants (Kalushkov et al., 2009). The provision of ecosystem services by ground beetles has become one of the potential advantages of agri-environment schemes (Alexandrovitch, 1979; Luff, 1987; Kröber & Carl, 1991; Kromp, 1999; Holland & Oakley, 2007; Horne, 2007; Whittingham, 2011; Gotlin Čuljak et al., 2016).

Faunistic researches of ground beetles in Bulgarian agroecosystems are scarce. Ground beetles were studied in typical agrocoenoses in two regions in Bulgaria (Popov & Krusteva, 1988), and only 55 species were found, with peaks in the activity density in May and June and in the end of the summer. Spatial distribution of carabid beetles in three types of agrocoenoses near Sofia was estimated, and 64 species were found (Shishiniova et al., 2001). In another study of wheat fields near Sofia, 70 species were found (Kostova, 2004). Kalushkov et al. (2009) found 59 species in potato fields, of which four species dominated (*Poecilus cupreus*, *P. versicolor*, *Harpalus rufipes* and *H. distinguendus*).

This is the first study of the carabid fauna in oilseed rape fields in Bulgaria. The aim of this research is to determine species composition of ground beetles associated with the oilseed rape during its flowering, ripening and after the harvest, and the adjacent actively grazed pastures in Upper Thracian Lowland and foots of the Sarnena Sredna Gora Mts.

Material and Methods

Field work was carried out in 2017 and 2018, in parallel with the implementation of the Project "SusTaining Agri-Cultural ChAnge Through ecological engineering and optimal use of natural resources (STACCATO)". In 2018, pitfall traps (5 in each site) were set in 10 sampling sites in Thracian Lowland (8 sites) and foots of the Sarnena Sredna Gora Mts. (2 sites near Zelenikovo vill.). The traps were made of 500 ml. beakers, buried at the level of the substrate and filled with salt and 6% acetic acid saturated solution (with small amount of dishwasher detergent). Sampling periods were three for both the rape fields and pastures. These periods corresponded with the following stages – oilseed rape's flowering [1], ripening [2] and after the harvest [3]. The sampling sites are presented at Table 1 and on Figure 1. Additional data were collected in the periods: 14.V–2.VI.2017 [1] and 2.VI–22.VI.2017 [2], with the same method, from the vicinity of the village of Kostievo (Thracian Lowland).

In each region the maximum distance between the grassland and the oilseed rape field was 500 m and the minimum distance was 100 m. The 10 sites were situated along a gradient from low (0%) to high (~20%) presence of semi-natural habitats (pastures) in the surrounding landscape. Two of the rape fields were fully encompassed in agrolandscapes and one of the pastures (G10) was considered isolated from the neighboring agrolandscapes. The respective percentages are given in Table 1.

The content of the humus and the pH (in H_2O) of the soils from each of the sampling sites in 2018 were measured and calculated according to measurement protocols in the Forest Research Institute of the Bulgarian Academy of Sciences, Sofia.

Species richness in both studied habitats was calculated using the Menhinick's species richness index (Menhinick, 1964) [$D_{Mn} = S/\sqrt{N}$]. For the mathematical processing of the data MS Excel and the software products CANOCO 4.5 (Ter

Table 1. List of the sampling sites and sampling periods. The letter in the sampling sites codes is, respectively: R – oilseed rape field, G – grassland/pasture

Site code	%	Locality	Coordinates	Altitude a.s.l.	Soil pH	Humus content	Sampling period 2018		
							[1]	[2]	[3]
R01	*100*	E Malak Chardak vill.	N 42°16′45″ E 24°38′47″	198 m	5.20	2.408	22.IV–16.V	16.V–12.VI	27.VII–26.VIII
G02	*10*	W Zelenikovo vill.	N 42°23′49″ E 25°03′09″	290 m	5.03	4.640	19.IV–15.V	15.V–11.VI	26.VII–25.VIII
R02		W Zelenikovo vill.	N 42°23′47″ E 25°02′57″	280 m	4.92	4.370	19.IV–15.V	15.V–11.VI	26.VII–25.VIII
G03	*5*	S Zelenikovo vill.	N 42°22′50″ E 25°04′43″	290 m	5.83	4.815	19.IV–15.V	15.V–11.VI	26.VII–25.VIII
R03		S Zelenikovo vill.	N 42°22′45″ E 25°04′48″	288 m	4.87	2.943	19.IV–15.V	15.V–11.VI	26.VII–25.VIII
G04	*20*	S Stalevo vill.	N 42°03′23″ E 25°23′25″	170 m	5.44	6.866	20.IV–14.V	14.V–13.VI	25.VII–24.VIII
R04		S Stalevo vill.	N 42°03′15″ E 25°23′29″	172 m	4.95	4.191	20.IV–14.V	14.V–13.VI	25.VII–24.VIII
G05	*5*	SE Dobrich vill.	N 42°01′09″ E 25°32′08″	120 m	6.53	6.955	20.IV–14.V	14.V–13.VI	25.VII–24.VIII
R05		E Dobrich vill.	N 42°01′24″ E 25°32′08″	129 m	5.99	5.439	20.IV–14.V	14.V–13.VI	25.VII–24.VIII
G06	*20*	S Momino Selo vill.	N 42°17′40″ E 24°52′59″	175 m	6.04	6.240	21.IV–15.V	15.V–12.VI	26.VII–25.VIII
R06		S Momino Selo vill.	N 42°17′31″ E 24°52′51″	175 m	5.20	3.478	21.IV–15.V	15.V–12.VI	26.VII–25.VIII
G07	*10*	W Stryama	N 42°14′57″ E 24°51′02″	174 m	6.27	5.970	21.IV–15.V	15.V–11.VI	26.VII–25.VIII
R07		SW Stryama	N 42°15′15″ E 24°50′53″	174 m	5.73	2.943	21.IV–15.V	15.V–11.VI	26.VII–25.VIII
G08	*20*	SW Malak Chardak vill.	N 42°16′53″ E 24°37′53″	204 m	5.97	7.490	21.IV–16.V	16.V–12.VI	27.VII–26.VIII
R08		SW Malak Chardak vill.	N 42°16′47″ E 24°37′32″	202 m	5.04	3.299	21.IV–16.V	16.V–12.VI	27.VII–26.VIII
G09	*5*	W Kostievo vill.	N 42°10′29″ E 24°36′50″	177 m	6.28	8.738	22.IV–16.V	16.V–12.VI	27.VII–24.VIII
R09		W Kostievo vill.	N 42°10′19″ E 24°36′48″	175 m	5.70	3.121	22.IV–16.V	16.V–12.VI	27.VII–24.VIII
G10	*100*	SW Radinovo vill.	N 42°11′13″ E 24°38′22″	180 m	6.76	7.220	22.IV–16.V	16.V–12.VI	27.VII–24.VIII
R10	*100*	S Kostievo vill.	N 42°09′34″ E 24°37′46″	178 m	5.36	2.229	22.IV–16.V	16.V–12.VI	27.VII–24.VIII

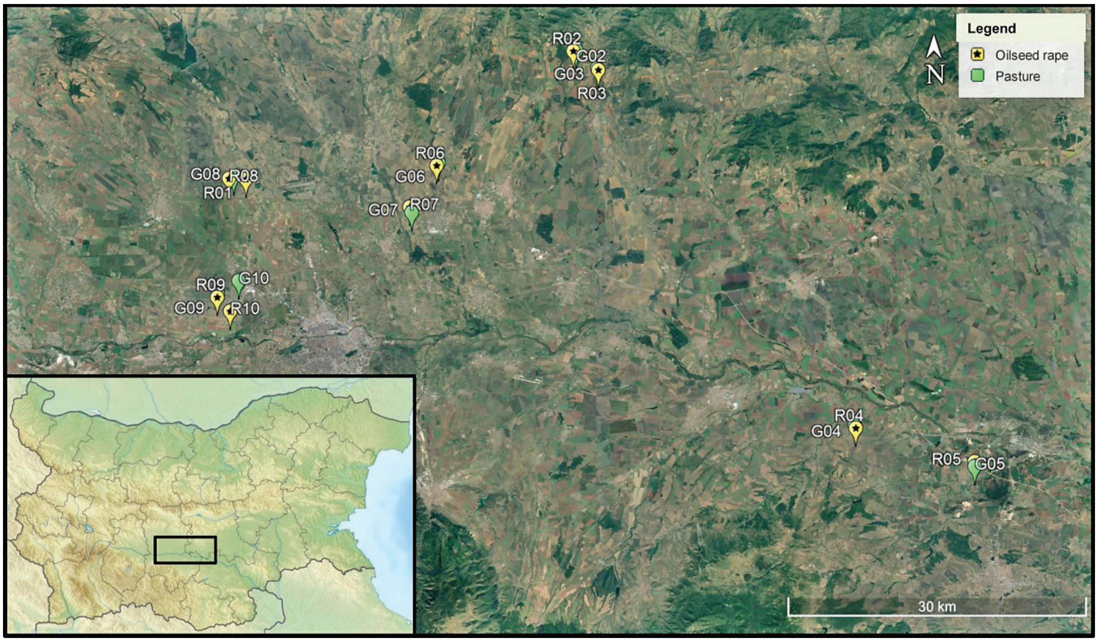

Fig. 1. Map of the STACCATO sampling sites in 2018

Braak & Šmilauer, 2002), and PRIMER 6 (Clarke & Gorley, 2005) were used. For the assessment of the taxonomic similarity, the classification of Zlotin (1975) was used.

In the ecological analysis only data from 2018 were included.

Captured animals were determined with the help of several literary sources, e.g. Hůrka (1996), Arndt et al. (2011), Kryzhanovskij (unpublished data), and are deposited in the author's collection in the Institute of Biodiversity and Ecosystem Research (BAS).

Results

A total of 6914 specimens were collected (463 in 2017, and 6451 in 2018). Collected beetles belonged to 138 species from 45 genera and 19 tribes. In 2018, when the complete sampling was conducted, we collected 5018 specimens, 109 species (15% of all Bulgarian carabids) and 40 genera (32% of all Bulgarian genera) in the oilseed rape fields, and 1433 specimens, 87 species (12%) and 33 genera (26%) in the pastures (Table 2). Four species were added to the list of Carabidae with the sampling in 2017. Only in the rape fields 48 species were established, and 28 species were unique for the pastures. Sixty two species were common for both types of habitats.

The complete check list of the established species with their full name, author and year of description, and abundance in the sampling sites, is presented in the Appendix.

Table 2. Number of taxa collected in both studied habitats during the three sampling periods of the study in 2018: oilseed rape's flowering [1], ripening [2], and after the harvest [3]

Taxa/Period	Oilseed rape fields				Pastures			
	[1]	[2]	[3]	Total	[1]	[2]	[3]	Total
Genera	25	34	24	40	25	27	21	33
Species	59	83	66	109	62	63	47	87
Specimens	1238	3102	678	5018	376	646	412	1433

The taxonomic structure of the whole carabid complex showed a clear predominance of the open habitats species from the tribes Harpalini (57 species, 41% of all species), Amarini (15 species, 11%), and Lebiini (13 species, 9%) (in total, almost 62% of all species) over the predominantly forest or extrazonal coastal species from the tribes Agonini, Pterostichini, Nebriini, and Carabini. The most species-rich was the genus *Harpalus* (26 species, 19%), followed by the genera *Amara* (14 species, 10%), *Microlestes* (9 species, 6.5%), and *Brachinus* (8 species, 6%). In the oilseed rape fields, the most species-rich were the genera *Harpalus* (18 species, 16.5% of the species in rape fields), *Amara* (13 species, 12%), *Microlestes* (8 species, 7%), *Brachinus* (7 species, 6%), and *Parophonus* (5 species, 5%). In the pastures, such genera were *Harpalus* (22 species, 25% of the species in pastures), *Amara* (7 species, 8%), *Microlestes* (6 species, 7%), and *Ophonus* (5 species, 5%).

The most abundant genera in the oilseed rape fields were: *Harpalus* (993 ex., 20% of the specimens in rape fields), *Poecilus* (753 ex., 15%), *Brachinus* and *Microlestes* (417 ex. each, 8%), and *Amara* (344 ex., 7%). In the pastures, such genera were *Harpalus* (515 ex., 36% of the specimens in pastures), *Microlestes* (283 ex., 20%), *Calathus* (91 ex., 6%), *Amara* (86 ex., 6%), and *Ophonus* (85 ex., 6%).

The most abundant species in the oilseed rape fields were *Harpalus distinguendus* (714 ex., 14% of the specimens in rape fields), *Calosoma auropunctatum* (692 ex., 14%), *Poecilus cupreus* (543 ex., 11%), *Chlaenius aeneocephalus* (498 ex., 10%), *Anchomenus dorsalis* (297 ex., 6%), *Amara aenea* (292 ex., 6%), and *Microlestes minutulus* (215 ex., 4%). The most abundant species in the pastures were: *Harpalus flavicornis* (168 ex., 12% of the specimens in pastures), *Microlestes fissuralis* (110 ex., 8%), *Calathus fuscipes* (89 ex., 6%), *M. minutulus* (89 ex., 6%), *Amara aenea* (69 ex., 5%), and *Acinopus megacephalus* (54 ex., 4%). The dominance structures of the rape field and pasture carabid complexes are presented at Table 3.

Thirty two species (29%) from the rape fields and 18 species (20%) from the pastures were represented by a single specimen.

Captured during the flowering stage of the rape beetles belonged to 59 species and 25 genera (Table 2), representing 8% of the species and 20% of the ground beetle genera occurring in Bulgaria, and being also 45% of all species found in the rape fields. The most diverse was genus *Harpalus* (10 species), followed by the genera *Amara* (8 species), *Microlestes* (6 species) and *Brachinus* (5 species). Constant species occurring in all sampling sites was only *Microlestes minutulus*. *Poecilus cupreus* was not found in only one of the sampling sites (R07).

During the ripening stage of the rape, 83 species and 34 genera were found (Table 2), representing 11% of the species and 27% of the ground beetle genera occurring in Bulgaria, and being also 76% of all species found in the rape fields. The most diverse were the same genera, represented with the same number of species. There were no constant species occurring in all sampling sites. *Poecilus cupreus* and *Microlestes minutulus* were not found in only one of the sampling sites (R08). Thirty eight species appeared during the ripening (they were absent during flowering), and 14 species disappeared (they were present during flowering). Forty five species were present both during flowering and ripening.

Captured in the harvested rape fields beetles belonged to 66 species and 24 genera (Table 2), representing 9% of the species and 19% of the ground beetle genera occurring in Bulgaria, and being also 60% of all species found in the rape fields. The most diverse was genus *Harpalus* (15 species), followed by the genera *Amara* (7 species), *Microlestes* (6 species) and *Parophonus* (5 species). There were no constant species occurring in all sampling sites (with 100% occurrence). Thirteen species appeared after the harvest (they were absent during the flowering and ripening of the rape), 44 species disappeared (they were present during flowering and ripening), and 29 species were present in all stages.

From the pastures adjacent to the rape fields, in all three sampling periods we collected ground beetles belonging to 87 species and 33 genera (Table 2), representing 12% of the species and 26% of the ground beetle genera occurring in Bulgaria. The most diverse was genus *Harpalus* (22 species), followed by the genera *Amara* (7 species), *Microlestes* (6 species), *Ophonus* (6 species) and *Parophonus* (5 species). *Microlestes minutulus* was a constant species occurring in all sampling sites.

The highest species richness and carabid abundance, both in rape fields and pastures, were found during the second sampling (Table 2), corresponding with the ripening of

Table 3. Dominance structure of the ground beetles found in both types of habitats. Only data from 2018 are included

D = (n_i/N).100%	Oilseed rape fields		Pastures	
	Species	No	Species	No
Eudominant > 10%	*Calosoma auropunctatum*, *Harpalus distinguendus*, *Poecilus cupreus*	3	*Harpalus flavicornis*	1
Dominant 5–10%	*Amara aenea*, *Anchomenus dorsalis*, *Chlaenius aeneocephalus*	3	*Calathus fuscipes*, *Microlestes fissuralis*, *M. minutulus*	3
Subdominant 3–5%	*Brachinus explodens*, *Microlestes minutulus*, *Poecilus cursorius*	3	*Acinopus megacephalus*, *Amara aenea*, *Harpalus dimidiatus*, *H. distinguendus*, *Microlestes maurus*, *Ophonus cribricollis*, *Zabrus tenebrioides*	7
Recedent 1–3%	*Acinopus megacephalus*, *Brachinus ejaculans*, *Br. psophia*, *Chlaenius decipiens*, *Microlestes fissuralis*, *Harpalus flavicornis*, *H. serripes*	7	*Acinopus picipes*, *Brachinus explodens*, *Carabus coriaceus*, *Chlaenius decipiens*, *Dixus obscurus*, *Harpalus attenuatus*, *H. rubripes*, *H. serripes*, *H. subcylindricus*, *H. tardus*, *Microlestes fulvibasis*, *Ophonus sabulicola*, *Parophonus hirsutulus*	13
Subrecedent	all the rest		all the rest	

the rapeseed in May–June, and with the findings of Popov & Krusteva (1988) and Aleksandrowicz & Bagińska (2009) about greater activity density in these months in agrocoenoses and pastures, respectively.

The investigation presents some new data about carabid diversity in Bulgaria. Remarkably, 38 species were ascertained to be new for the fauna of the Thracian Lowland and 51 species were new for the Sarnena Sredna Gora Mts. (calculations are according to the catalogue of Bulgarian carabids – Teofilova & Guéorguiev *in prep.*).

New species for the region of the Thracian Lowland were: collected during the flowering of the rape – *Amara eurynota*, *Brachinus elegans*, *Gynandromorphus etruscus*, *Harpalus xanthopus*, *Microlestes corticalis*, *M. fulvibasis*, *M. minutulus, M. plagiatus*, *Parophonus laeviceps*, *Poecilus anatolicus*, *P. puncticollis*, and *Polystichus connexus*; collected during the ripening of the rape – *Brachinus alexandri*, *Br. berytensis*, *Br. nigricornis*, *Calathus cinctus*, *Carterus dama, Harpalus fuscicornis*, *H. subcylindricus*, *Microlestes maurus*, *M. schroederi*, *Parophonus planicollis*, *Scybalicus oblongiusculus*, and *Trechus irenis*; collected after the harvest of the rape – *Amara consularis*, *Harpalus caspius*, *H. calceatus*, *Microlestes negrita*, and *Tachyura parvula*; collected only in the pastures – *Amara fulvipes*, *Anisodactylus binotatus*, *A. intermedius*, *Apotomus clypeonitens*, *Carterus gilvipes*, *Microlestes apterus*, *Notiophilus laticollis*, *Pangus scaritides*, and *Pterostichus strenuus*.

New species for the region of the whole Sredna Gora Mts. were 41: collected during the flowering of the rape – *Amara similata*, *Anchomenus dorsalis*, *Brachinus psophia*, *Calosoma auropunctatum*, *Chlaenius aeneocephalus*, *Harpalus cupreus*, *H. hospes*, *H. signaticornis*, *H. tardus*, *Microlestes fissuralis*, *M. minutulus, M. negrita*, *Notiophilus aestuans*, *Parophonus laeviceps*, *Pedius inquinatus*, and *Polystichus connexus*; collected during the ripening of the rape – *Acupalpus meridianus*, *Amblystomus metallescens*, *Apotomus clypeonitens*, *Brachinus alexandri*, *Carabus granulatus*, *Ophonus sabulicola*, and *Stenolophus abdomialis*; collected after the harvest of the rape – *Acinopus picipes*, *A. megacephalus*, *Carterus dama*, *Harpalus flavicornis*, *H. griseus*, *Licinus depressus*, and *Microlestes maurus*; collected only in the pastures – *Amara anthobia*, *Ditomus calydonius*, *Harpalus albanicus*, *H. angulatus*, *H. attenuatus*, *H. dimidiatus*, *H. pumilus*, *H. pygmaeus*, *H. subcylindricus*, *Lebia scapularis*, and *Microlestes fulvibasis*.

New for the Sarnena Sredna Gora Mts. fauna were 51 species: collected during the flowering of the rape – 16 species; collected during the ripening of the rape – 2 species; collected after the harvest of the rape – 3 species; collected only in the pastures – 30 species (Teofilova & Kodzhabashev, 2020*b*).

Genera *Apotomus*, *Gynandromorphus*, *Pangus*, *Scybalicus* and *Polystichus* were new geographic records for the Thracian Lowland. Genera *Acinopus*, *Amblystomus*, *Anchomenus*, *Apotomus*, *Carterus*, *Ditomus*, *Licinus*, *Microlestes*, *Pedius* and *Polystichus* were new geographic records for the whole Sredna Gora Mts. Genera *Brachinus*, *Harpalus*, *Chlaenius*, *Parophonus* and *Poecilus* were new reports for the Sarnena Sredna Gora Mts.

New highest altitudes were established in the distribution of 6 species in Bulgaria: *Amblystomus metallescens*, *Apotomus clypeonitens*, *Brachinus berytensis*, *Parophonus laeviceps*, *Poecilus cursorius*, and *Scybalicus oblongiusculus*.

According to the taxonomic structure and species abundance in the sampling sites in both types of habitats (only data from 2018 are included in this analysis), the similarity dendrogram showed that, although the studied habitats were resembling in appearance, their similarity was not very high, according to Zlotin (1975) (Figure 2). Sampling site G07 significantly distinguished from the other sites and separated from them on a very low level of similarity. This might be resulting from the fact that all traps there were destroyed during the second period of collection, and thus the data were not quite comparable. Similarly, the G10 site separated, probably because actually being the single 100% pasture.

It can be argued that there was some grouping of the sampling sites according to their habitat type, as the bulk of the grasslands was concentrated in the middle of the dendropgram. Only R08 fell into the same cluster, getting closest to G08. This grouping of the two sites is understandable, since the one was bordering on the other, and it is highly likely

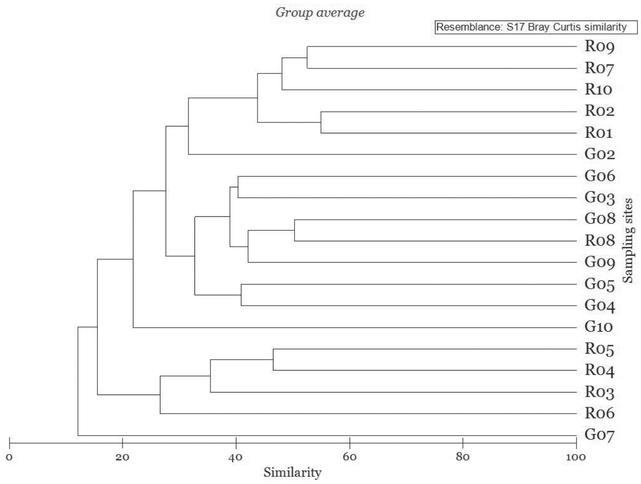

Fig. 2. Group average dendrogram of the similarity between the sampling sites, calculated on the basis of the taxonomic structure and species abundance

a mixing of their species composition to occur. In a group with the highest similarity were separated the rape fields in the most intensively cultivated areas – the two sites of 100% agrolandscapes (R01 and R10), the two fields in regions with 10% semi-natural habitats (R02 and R07), and one of the sites in region with 5% pasture (R09). In one group were separated the two rape fields located in areas with 20% pastures (R04 and R06). Two of the rape fields located in areas with 5% pasture, were also approached. The explanation for this is probably in the fact that both fields (R03 and R05) were relatively smaller in size than the others and bordered the adjacent landscapes by means of well-separated hedgerows and patches with lush vegetation.

Species richness of the carabid communities calculated with Menhinick's index showed that, regardless the lower number of species and the lower abundance, the semi-natural grasslands were somewhat more diverse than the rape fields (Table 4, Figure 3).

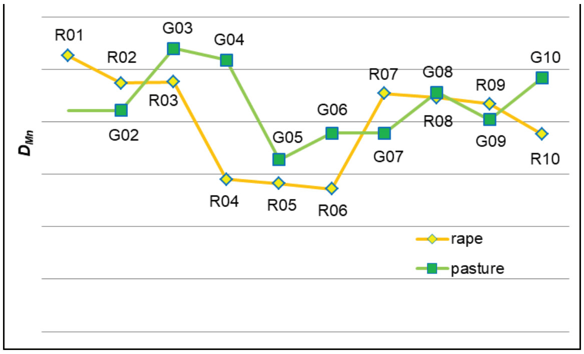

Fig. 3. Species richness in both studied habitats (D_{Mn} – Menhinick's species richness index)

The results from the soil analysis explained that fact to some extent. There was a predominantly increased content of humus in grasslands samples. Soil samples under the rape were slightly more acidic, i.e. the pH values were lower than in the samples from the pastures. These results suggest that the higher values of D_{Mn} were reflecting in the greater humus content and the higher pH of the soils (Figure 4). The only exceptions from that regularity were the sampling sites G02, R07 and G09, and this might be resulting from many different factors.

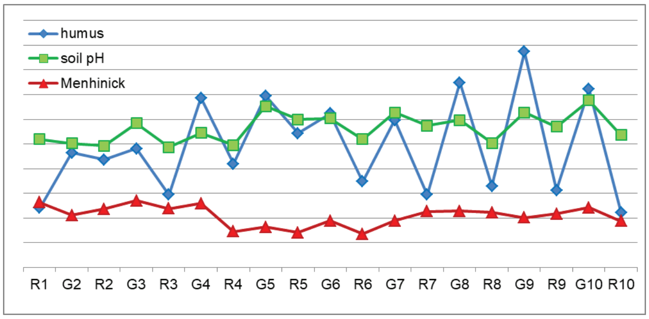

Fig. 4. Comparison between species richness (D_{Mn}), humus content and pH of the soils in the different sampling sites

The sample ordination graph (Figure 5) showed a clear separation of the two types of habitats (as it was also suggested by the dendrogram classification), with the rape fields moved closer to the Y-axis, and semi-natural grasslands grouped at higher values on the X-axis. Probably this distribution coincides with the pattern shown by the species richness and soil characteristics.

Table 4. Species richness in both studied habitats during the three sampling periods of the study in 2018. N – Number of specimens; S – Number of species; D_{Mn} – Menhinick's index

	Oilseed rape fields										
	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R-complex
N	139	218	406	763	849	1409	358	206	217	453	5018
N, %	2.1	3.4	6.3	11.8	13.2	21.8	5.5	3.2	3.4	7.0	78 of all
S	31	35	48	40	41	51	43	32	32	40	109
S, %	23.1	26.1	35.8	29.8	30.6	38.1	32.1	23.9	23.9	29.8	81 of all
D_{Mn}	2.63	2.37	2.38	1.45	1.41	1.36	2.27	2.23	2.17	1.88	1.54
	Pastures										
	–	G02	G03	G04	G05	G06	G07	G08	G09	G10	G-complex
N	–	109	132	162	181	205	148	184	178	134	1433
N, %	–	1.7	2.0	2.5	2.8	3.2	2.3	2.8	2.7	2.1	22 of all
S	–	22	31	33	22	27	23	31	27	28	87
S, %	–	16.4	23.1	24.6	16.4	20.1	17.2	23.1	20.1	20.9	65 of all
D_{Mn}		2.11	2.70	2.59	1.64	1.89	1.89	2.28	2.02	2.42	2.30

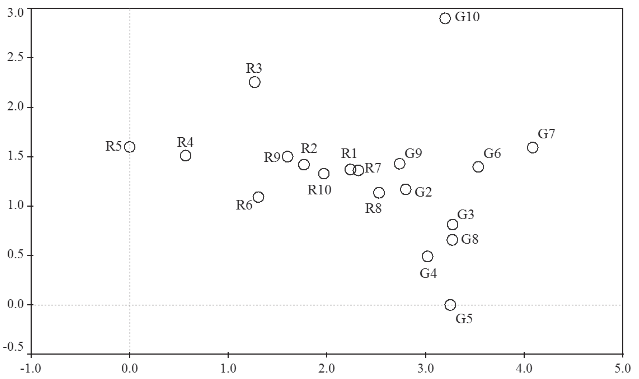

Fig. 5. DCA ordination plot of the sampling sites

The species and samples ordination graph (Figure 6) also showed a separation of the two types of habitats, the pastures being altogether aggregated, and the rape field being more unequally spread. Many *Harpalus* spp. seem more attached to the semi-natural grasslands, along with *Dixus clypeatus*, *Microlestes maurus*, *Ophonus sabulicola*, and *Parophonus hirsutulus*. Among the 48 species established only in the rape fields, more numerous were *Amara similata*, *Anchomenus dorsalis*, *Brachinus ejaculans*, *Poecilus cursorius*, and *Zuphium olens*. Some of the common for both types of habitats species were also much more numerous in the rape fields, e.g. *Calosoma auropunctatum*, *Chlaenius aeneocephalus*, *Harpalus distinguendus*, *Microlestes minutulus*, *Poecilus cupreus*, *Syntomus obscuroguttatus*, *Trechus quadristriatus*.

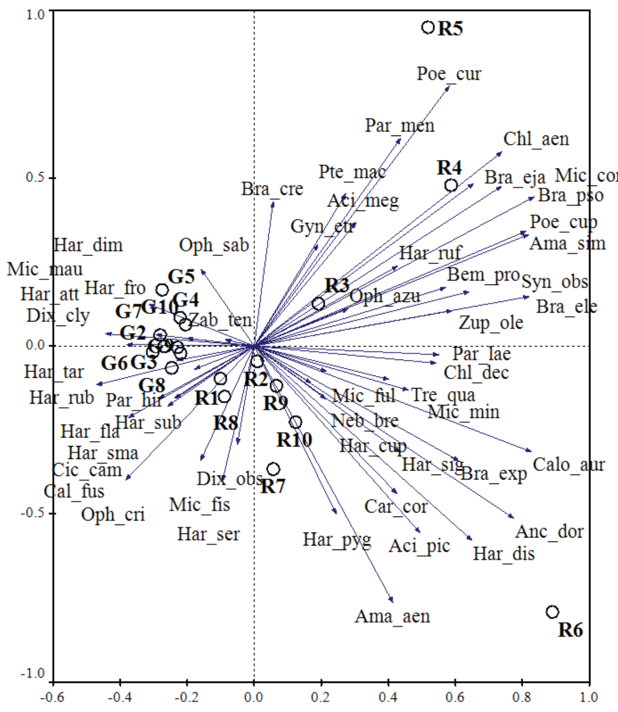

Fig. 6. PCA ordination plot of the sampling sites and the species represented with more than 10 specimens

Discussion

Collected 138 species, 45 genera and 19 tribes represented 18.5% of all Bulgarian carabid species, 36% of the genera and 51% of the tribes (Teofilova & Guéorguiev *in prep*.). In contrast to the poor species composition of agrocoenoses in Bulgaria (Popov & Krusteva, 1988; Shishiniova et al., 2001; Kostova, 2004; Kalushkov et al., 2009), and similarly to the present research, 123 carabid species were found in agrocoenoses in NW Russia (Guseva, 2014). Similar results about the taxonomic structure demonstrating the prevalence of the openly living species from the tribes Harpalini, Amarini, and Sphodrini (totally over 60% of all species, such as in our results) were obtained for the carabid complex of the Zlatiya Plateau in NW Bulgaria, where different types of habitats were studied, but the "steppe effect" was very strong (Teofilova & Kodzhabashev, 2020c). Harpalini were also predominating in Southern Dobrudzha (Kodzhabashev & Penev, 2006), Bulgarian Black Sea coast (Teofilova et al., 2015) and Eastern Rhodope Mts. (Teofilova & Kodzhabashev, 2020a). Such taxonomic structure is typical for the forest-steppe zone in northern Bulgaria (Kodzhabashev & Penev, 2006), where the natural forest-steppe landscape has gradually merged into a landscape of the open agricultural territories – fields and pastures. Colonizing such newly deforested open spaces, many xero-thermophilic species have expanded their ranges from south to north, as a consequence of global climatic and landscape changes. Probably due to their initial stage of colonization, these newly established species are rare, being recorded with single findings. Similar observations were discussed in a study of steppe carabids in Belarus (Aleksandrowicz, 2011). Probably, such was the case with the newly established for Bulgaria *Amblystomus rectangulus*, already reported for Bulgaria (Teofilova & Kodzhabashev 2020b), and collected during the present research.

Similar to our results, the most species rich were genera *Harpalus* and *Amara* in Zlatiya Plateau too (Teofilova & Kodzhabashev, 2020c), and in rape and wheat fields in NW Croatia (Gotlin Čuljak et al., 2016). These were also the most diverse genera in studied during STACCATO oilseed rape fields in Germany, Romania and Switzerland.

Based on the climatic, microclimatic and other factors existing in the crop, which affect the composition, abundance and time distribution of the Carabidae, it can be argued that the basis of the fauna in crops are xeromesophilous and mesophilous forms which prefer open biotopes, such as: *Agonum muelleri*, *Amara aenea*, *A. bifrons*, *A. similata*, *Anchomenus dorsalis*, *Anisodactylus signatus*, *Bembidion properans*, *Brachinus crepitans*, *Br. explodens*, *Calathus fuscipes*, *Calosoma auropunctatum*, *Harpalus affinis*, *H. distinguendus*, *H. rufipes*, *Poecilus cupreus*, *Pterostichus melanarius*, and others (Sharova & Lapshin, 1971; Kostova, 2004; Sumarokov, 2004; Porhajašová et al., 2008; Anjum, 2009; Popović & Štrbac, 2010; Haschek et al., 2011; Vician et al., 2011; Baranová et al., 2013; Guseva, 2014; Gotlin Čuljak et al., 2016; Kosewska, 2016; Sivčev et al., 2018).

In a complex study of the composition of carabid assemblages in Denmark, Lövei et al. (2005) found that the dominant species in the two studied areas were *Pterostichus melanarius, Anchomenus dorsalis, Harpalus rufipes* and *Calathus fuscipes* in the first, and *Poecilus versicolor, Pterostichus melanarius, Anchomenus dorsalis* and *Nebria brevicollis* in the second. The ten most common species, representing 91% of the total number of specimens in oilseed rape in N Serbia, were *Amara aenea*, *A. similata*, *Harpalus distinguendus*, *Brachinus explodens*, *Poecilus cupreus*, *Calathus fuscipes*, *C. ambiguus*, *Poecilus punctulatus*, *P. sericeus*, and *Anchomenus dorsalis* (Sivčev et al., 2018). Nine ground beetle species (including *Amara aenea*, *A. familiaris*, *Pterostichus melanarius*, *Agonum muelleri*) represented 80% of all carabids in heterogenous, but heavily grazed pastures (Byers et al., 2000).

Drmić et al. (2016) studied the endogaeic ground beetle fauna in oilseed rape field in Croatia. Species caught in endogaeic traps were smaller in size, varying from 2 mm to 8 mm. The most abundant species was *Brachinus psophia*, followed by *Anchomenus dorsalis*. These species were classified as eudominant, and had the highest frequency and only they were classified as constant species (species frequency 50–75%). *Brachinus explodens* was dominant. Subdominant species were *Brachinus crepitans*, *Clivina fossor*, *Stenolophus teutonus*. *Trechus quadristriatus* and *Asaphidion curtum* were subrecedent.

In agrocoenoses in Zlatiya Plateau, mainly ecologically plastic eurytoptic species were found, similar to those found during this research (*Harpalus rufipes*, *H. rubripes*, *H. caspius*) (Teofilova & Kodzhabashev, 2020*c*). The specific microclimate shaped by the land use regime, monocultures and constant tempering also supported some stenotopic thermophilic xerobionts, mostly steppic elements, some of which represented by a very small number of specimens (*Chlaenuis decipiens*, *H. fuscicornis*, *H. pygmaeus*, *H. hospes*, *Ophonus diffinis*).

The large percentage of species represented by a single specimen doesn't seem unusual, as it was also established in other studies (e.g. Coddington et al., 2009; Ferro et al., 2012). In Zlatiya Plateau, these species were 17% of all (Teofilova & Kodzhabashev, 2020c). Explanations of the presence of species represented by single specimens may be different – an insufficient number of samples or inappropriate collecting methods, as well as peculiarities in phenology or actual rarity of the species concerned (Novotný & Basset, 2000; Coddington et al., 2009). Many species were found rare in agrocoenoses in Ukraine (Sumarokov, 2004), and some of them were rare in this study too: *Acupalpus meridianus*, *Amara communis*, *A. lucida*, *A. fulva*, *Anisodactylus binotatus*, *Carabus convexus*, *Drypta dentata*, *Harpalus caspius*, *H. froelichi*, *H. saxicola*, *Licinus depressus*, *Pterostichus anthracinus*.

The dominance structure of the ground beetles found in pastures was similar to the established in Polish pastures, having one eudominant and three dominant species (Aleksandrowicz & Bagińska, 2009). In fact, in that study *Poecilus versicolor* was a superdominant with 52% of all specimens collected, showing the greater disturbance of the habitat. In the present study the eudominant *Harpalus flavicornis* had only 12% of the specimens, thus probably reflecting a better environmental condition, maybe resulting from the lesser extend of grazing in Bulgarian pastures.

It is known that cultivated land contains a typical ground beetle fauna, despite the regular implementation of cultivation measures on arable land (Kromp, 1999), but carabid community in arable land coenoses can be characterized as having low diversity and equitability, dominated by very eurytopic, nonspecific species of open habitats. We also found a lower species richness (D_{Mn}) in the oilseed rape fields than in the pastures. On the other hand, oilseed rape creates cooler and more shaded conditions and consequently attracts or deters some species (Holland & Oakley, 2007). Ground beetles prefer crop-shaded ground due to microclimatic differences caused by presence and density of crop cover (Honěk & Jarošík, 2000), which corresponds with the greater number of species and specimens found in rape fields. The rape seeds attract granivorous species and the presence of these seeds on the ground surface may influence the distribution of the beetles in the field (Honěk & Jarošík, 2000). This corresponds with the greatest number of species and carabid abundance during the second sampling (rapeseed ripening). It was also found that large, medium-sized, herbivorous and Collembola feeding carabids all have considerable activity in oilseed rape, and among other crops, oilseed rape was proved to keep the greatest species richness of ground beetles (Eyre et al., 2013), and the presence of aphids was associated with the abundance of aphid predators, such as *Bembidion lampros* and *Trechus quadristriatus* (Honěk & Jarošík, 2000).

In natural ecosystems, the absolute numbers of ground beetles are usually lower than in anthropogenic, but their species diversity is significantly greater. Their distribution is uneven, with areas of high concentration and significant numbers of different species formed under favorable conditions (Kryzhanovskij, 1983). Poor species richness seems normal for actively grazed pastures, since it was found in many studies (e.g. Popov & Krusteva, 1988; Aleksandrowicz & Bagińska, 2009; Teofilova & Kodzhabashev, 2020b, 2020c). Soil structure in pastures might be deteriorated from the intense trampling by the grazing animals, as it was found that the number of invertebrates in grassland litter declined with increased trampling (Duffey, 1975) or grazing (Aleksandrowicz & Bagińska, 2009). Other important factors are the plant species diversity (Byers et al., 2000), and dry matter density (Toupet et al., 2020). Heterogeneous pastures provide additional resources which can support a rich assemblage of beetles (Byers et al., 2000), and the older permanent pastures with a higher dry matter density and less disturbance due to lack of cultivation and more diverse plant species, support higher numbers of carabids (Toupet et al., 2020). Probably the state of the pastures in our case was not that poor, as it seemed in the first place. The lower number of species could be a result of the significant number of traps destroyed from humans' and animals' activities, although the pitfall traps were located mainly in the margins of the pastures.

The analysis of the soil pH and humus content showed that there was a relation between soil characteristics and carabid species richness, proving once more their importance for the ground beetle communities. Given carabids' high sensitivity to changes in abiotic factors and, in particular – soil acidity, it is known that carabids can be successfully used to establish the degree of anthropogenic impact and pollution in a given area (Kryzhanovskij, 1984; Avgin & Luff, 2010; Langraf et al., 2016). The attachment of ground beetles to a certain soil type makes them convenient for zoological diagnosis of the soils (Kryzhanovskij, 1983; Schwerk & Szyszko, 2006). Unfortunately, the presence of various pesticides and certain artificial fertilizers leads to carabids' mass extinction (Kryzhanovskij, 1983; Van Toor, 2006). In parallel with the constant impact of chemicals, carabid species composition sharply impoverishes, with species of the genera *Carabus* and *Calosoma* – the effective natural enemies of many agricultural and forestry pests, disappearing first (Kryzhanovskij, 1983).

Conclusions

Due to various preconditions the oilseed rape seems to attract both grani- and herbivorous (*Amara similata*, *Harpalus affinis*, *H. distinguendus*, *H. rufipes*, *H. serripes*), and carnivorous species (*Anchomenus dorsalis*, *Calosoma auropunctatum*, *Chlaenius aeneocephalus*, *Poecilus cupreus*, *Pterostichus melanarius*), in some cases in extremely high abundances, while in the pastures carabids are less numerous. In the same time, it seems that the catastrophic effect in agrolandscapes, according to their species richness, was more acute than initially evidenced by the greater number of species found in the rape fields.

The fact that even mixophagous carabids are at least partly carnivores, and the large number of ground beetles species recorded in the rape fields within this research present carabids' great potential in reduction of pests. Their use in the biological control could improve ecosystem conservation and sustainable development.

The analysis of the soil pH and humus content proved once more the importance of the soil composition for the ground beetle communities.

Further studies including analysis of factors as temperature and humidity of soil and air, precipitation, etc., or exploring the effect of insecticides and management practices on carabid assemblages, both in agroecosystems and grasslands, would provide valuable information about the connections and coexistence of ground beetles under different environmental conditions.

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Appendix. Species list, abundance and degree of dominance (D) of the ground beetles found in oilseed rape fields and grasslands. Species collected only in 2017 are put in square brackets

Species list [only in 2017]	R (oilseed rape fields)												G (grasslands)										
	01	02	03	04	05	06	07	08	09	10	total	D%	02	03	04	05	06	07	08	09	10	total	D%
Acinopus (s.str.) *picipes* (Olivier, 1795)	3	3		8		18	5	1	2	9	49	0.98	2		6		2	1	3	1		15	1.05
A. (Oedematicus) megacephalus (P. Rossi, 1794)		3		23	15	5	1	5		2	54	1.08		1	2	19			5	25	2	54	3.77
Acupalpus (s.str.) *meridianus* (Linnaeus, 1760)			1						2		3	0.06											
A. (Ancylostria) interstitialis Reitter, 1884	1				2	2					5	0.10											
Agonum (Olisares) viridicupreum (Goeze, 1777)				1							1	0.02											
Amara (s.str.) *aenea* (De Geer, 1774)	20	17	17	4		107	39	16	6	66	292	5.82		8	5	1	7	5	16	26	1	69	4.81
A. (s.str.) *anthobia* A. Villa et G. B. Villa, 1833	1								1		2	0.04		1				2				3	0.21
A. (s.str.) *communis* (Panzer, 1797)			1			2					3	0.06											
A. (s.str.) *eurynota* (Panzer, 1796)	1										1	0.02											
A. (s.str.) *familiaris* (Duftschmid, 1812)		1			1						2	0.04			1							1	0.07
A. (s.str.) *lucida* (Duftschmid, 1812)														2								2	0.14
A. (s.str.) *ovata* (Fabricius, 1792)	1		3		2	2				1	9	0.18		1								1	0.07
A. (s.str.) *saphyrea* Dejean, 1828			1								1	0.02		1								1	0.07
A. (s.str.) *similata* (Gyllenhal, 1810)	1	1	2	3	12	4				4	27	0.54											
A. (Bradytus) apricaria (Paykull, 1790)								1			1	0.02											
A. (Bradytus) consularis (Duftschmid, 1812)				1							1	0.02											
A. (Bradytus) fulva (O. F. Müller, 1776)						1					1	0.02											
A. (Zezea) fulvipes (Audinet-Serville, 1821)			1								1	0.02	1		1						7	9	0.63
A. (Zezea) chaudoiri incognita Fassati,1946			3								3	0.06											
Amblystomus metallescens (Dejean, 1829)		1									1	0.02											
Amblystomus rectangulus Reitter, 1883			1								1	0.02											
Anchomenus (s.str.) *dorsalis* (Pontoppidan, 1763)	3	3	10	1	6	257	4		4	9	297	5.92											
Anisodactylus (s.str.) *binotatus* (Fabricius, 1787)																					3	3	0.21
[*A. (Pseudodichirius) intermedius* Dejean, 1829]																							
Apotomus clypeonitens adanensis Jedlička, 1961			1								1	0.02				3						3	0.21
Asaphidion flavipes (Linnaeus, 1760)										6	6	0.12											
Bembidion (Metallina) properans (Stephens, 1828)	1	1	1	2	6	2	5			2	20	0.40			2			3				5	0.35
[*Bembidion (Philochthus) guttula* (Fabricius, 1792)]																							
Brachinus (s.str.) *alexandri* F. Battoni, 1984			1		1						2	0.04											
[*Br.* (s.str.) *berytensis* Reiche et Saulcy, 1855]																							
Br. (s.str.) *crepitans* (Linnaeus, 1758)				1	1				1		3	0.06				7					1	8	0.56
Br. (s.str.) *ejaculans* Fischer von Waldheim, 1828				5	41	3			9	5	63	1 25											
Br. (s.str.) *elegans* Chaudoir, 1842				1	4	4			2		11	0.22											
Br. (s.str.) *psophia* Audinet-Serville, 1821	2	7	15	54	43	12		2	2	11	148	2.95									1	1	0.07
Br. (Brachynidius) explodens Duftschmid, 1812	6	42	34	19	1	61	3	13	6	4	189	3.77		12	5				2	11		30	2.09
Br. [sp. incertae sedis] *nigricornis* Gebler, 1830				1							1	0.02											

Calathus (s.str.) *fuscipes fuscipes* Goeze, 1777	4		2			1	2	10	2	2	23	0.46		1			48	3	9	9	19	89	6.21
C. (Neocalathus) ambiguus ambiguus (Paykull, 1790)						3	1				4	0.08											
C. (Neocalathus) cinctus Motschulsky, 1850	1					2	1	1		1	6	0.12					1	1				2	0.14
C. (Neocalathus) melanocephalus melanocephalus (Linnaeus, 1758)										1	1	0.02											
Calosoma (s.str.) *sycophanta sycophanta* (Linnaeus, 1758)				1		1					2	0.04											
Calosoma (Campatita) auropunctatum auropunctatum (Herbst, 1784)			4	210	3	400	46	11	18		692	13.79							1		1	2	0.14
Carabus (Archicarabus) wiedemanni wiedemanni Ménétriés, 1836					1						1	0.02				4						4	0.28
C. (Archicarabus) montivagus montivagus Palliardi, 1825			2								2	0.04	1									1	0.07
C. (s.str.) *granulatus granulatus* Linnaeus, 1758			2								2	0.04											
C. (Procrustes) coriaceus Linnaeus, 1758	3	4		3	1	16	7	2	4	5	45	0.90	1	2	1	12	1			1	2	20	1.39
C. (Tomocarabus) convexus dilatatus Dejean, 1826		1									1	0.02											
Carterus (s.str.) *dama* (P. Rossi, 1792)		1								1	2	0.04											
C. (s.str.) *gilvipes* (Piochard de la Brûlerie, 1873)																				1		1	0.07
C. (Pristocarterus) angustipennis lutshniki Zamotajlov, 1988																1						1	0.07
Cicindela (s.str.) *campestris campestris* Linnaeus, 1758							4				4	0.08			4		1		3			8	0.56
Chlaenius (Chlaeniellus) vestitus (Paykull, 1790)				1							1	0.02											
Chl. (Dinodes) decipiens (L. Dufour, 1820)	6	1		34	1	17	1	7	3		70	1.39		1	17				3			21	1.46
Chl. (Trichochlaenius) aeneocephalus Dejean, 1826		2	5	74	363	49				5	498	9.92			2	1						3	0.21
Diachromus germanus (Linnaeus, 1758)			1								1	0.02											
Ditomus calydonius calydonius (P. Rossi, 1790)														1								1	0.07
Dixus clypeatus (P. Rossi, 1790)															8		2		1			11	0.77
Dixus eremita (Dejean, 1825)															2					2		4	0.28
Dixus obscurus (Dejean, 1825)						3	2				5	0.1			4		9	4				17	1.18
Drypta (s.str.) *dentata* (P. Rossi, 1790)							1				1	0.02											
Gynandromorphus etruscus (Quensel en Schönherr, 1806)			14		4	1					19	0.38			6	1					6	13	0.91
Harpalus (s.str.) *affinis* (Schrank, 1781)		2				1		1			4	0.08											
Harpalus (s.str.) *albanicus* Reitter, 1900													2					1	1	1	1	6	0.42
H. (s.str.) *angulatus scytha* Tschitschérine, 1899													3						1			4	0.28
Harpalus (s.str.) *attenuatus* Stephens, 1828													8	1	3				2	1		15	1.05
Harpalus (s.str.) *caspius* (Steven, 1806)							1				1	0.02		5								5	0.35
H. (s.str.) *cupreus fastuosus* Faldermann, 1836			16			2		1	1	5	25	0.50									11	11	0.77
Harpalus (s.str.) *dimidiatus* (P. Rossi, 1790)														5	24	18						47	3.28
H. (s.str.) *distinguendus* (Duftschmid, 1812)	29	39	21	2	29	281	68	32	63	150	714	14.2	28	1	1		1	2	4	3	9	49	3.42

H. (s.str.) *flavicornis flavicornis* Dejean, 1829	3	4		2	1	11		9	1	21	52	1.04	3	3	28	28	36		57	8	5	168	11.7
Harpalus (s.str.) *froelichi* Sturm, 1818																		13				13	0.91
Harpalus (s.str.) *fuscicornis* Ménétriés, 1832							2				2	0.04			2		3					5	0.35
Harpalus (s.str.) *hospes* Sturm, 1818		1	3		1						5	0.10											
Harpalus (s.str.) *pumilus* Sturm, 1818														2				2		6		10	0.70
Harpalus (s.str.) *punctatostriatus* Dejean, 1829																				5		5	0.35
Harpalus (s.str.) *pygmaeus* Dejean, 1829						13				1	14	0.28	1	1			2		10			14	0.98
Harpalus (s.str.) *rubripes* (Duftschmid, 1812)	1		1				6				8	0.16	1	11			13	9	7		2	43	2.99
Harpalus (s.str.) *saxicola* Dejean, 1829													5									5	0.35
H. (s.str.) *serripes serripes* (Quensel, 1806)	15					3	52	2		10	82	1.63		3		2	4	22			1	32	2.23
H. (s.str.) *smaragdinus* (Duftschmid, 1812)							1	8		2	11	0.22					1	11	2			14	0.98
Harpalus (s.str.) *subcylindricus* Dejean, 1829							1	12			13	0.26		4					14			18	1.25
Harpalus (s.str.) *tardus* (Panzer, 1796)	1		5				2		2		10	0.20		13				14			1	28	1.95
H. (s.str.) *xanthopus winkleri* Schauberger, 1923						1					1	0.02											
H. (Pseudoophonus) calceatus (Duftschmid, 1812)							1				1	0.02											
Harpalus (Pseudoophonus) griseus (Panzer, 1796)			1								1	0.02						7				7	0.49
Harpalus (Pseudophonus) rufipes (De Geer, 1774)	2	2	7	4	10	2	5	6		1	39	0.78						13			2	15	1.05
H. (Semiophonus) signaticornis (Duftschmid, 1812)		4		1		2	1		2		10	0.20		1								1	0.07
Laemostenus (Pristonychus) cimmerius (Fischer von Waldheim, 1823)							1				1	0.02											
Lebia (s.str.) *humeralis* Dejean, 1825													6									6	0.42
L. (s.str.) *scapularis scapularis* (Geoffroy, 1785)													2						1			3	0.21
Licinus (s.str.) *depressus* (Paykull, 1790)		2									2	0.04											
Microlestes apterus Holdhaus, 1904																1						1	0.07
Microlestes corticalis (L. Dufour, 1820)			1	10	11	3				1	26	0.59					3					3	0.21
Microlestes fissuralis (Reitter, 1901)	7	12	1	3	4	13	6	35	7	26	114	2.27	13	21	2	19	13		22	16	4	110	7.67
Microlestes fulvibasis (Reitter, 1901)	1	1	1	7	1	2	5		3	12	33	0.66	15		8				1	6	1	31	2.16
Microlestes maurus maurus (Sturm, 1827)		1		2				2	1	7	13	0.26	4	9	4	13	12		1	6		49	3.42
Microlestes minutulus (Goeze, 1777)	2	13	56	17	15	26	41	7	19	19	215	4 28	5	7	9	11	21	1	4	27	4	89	6.21
Microlestes negrita negrita (Wollaston, 1854)		3					6				9	0.18											
Microlestes plagiatus (Duftschmid, 1812)					1						1	0.02											
Microlestes schroederi Holdhaus, 1912						2	4				6	0.12											
Myas (s.str.) *chalybaeus* (Palliardi, 1825)														1								1	0.07
Nebria (s.str.) *brevicollis brevicollis* (Fabricius, 1792)			7			1					8	0.16	2							2		4	0.28
Notiophilus aestuans Dejean, 1826			1								1	0.02											
Notiophilus biguttatus (Fabricius, 1779)										1	1	0.02											
Notiophilus laticollis Chaudoir, 1850															1							1	0.07
Notiophilus substriatus G. R. Waterhouse, 1833															2							2	0.14
Ophonus (Hesperophonus) azureus (Fabricius, 1775)	1	2	1		4	2			4		14	0.28		3	1		1		1			6	0.42

O. (Hesperophonus) cribricollis (Dejean, 1829)	8	3	1		1	2	12	1	5	5	38	0.76	4	8	6		15	2	5	3	3	46	3.21
[*O. (Hesperophonus) subquadratus* (Dejean, 1829)]																							
O. (Metophonus) parallelus (Dejean, 1829)																1	1					2	0.14
Ophonus (s.str.) *diffinis* (Dejean, 1829)				1							1	0.02							1			1	0.07
Ophonus (s.str.) *sabulicola* (Panzer, 1796)			1		1					1	3	0.06		1		28	1					30	2.09
Pangus scaritides (Sturm, 1818)																		1				1	0.07
Parophonus (Ophonomimus) hirsutulus (Dejean, 1829)							3				3	0.06						23				23	1.60
Parophonus (s.str.) *laeviceps* (Ménétriés, 1832)	1	19	2	1	4	5	1			3	36	0.72			1							1	0.07
Parophonus (s.str.) *mendax* (P. Rossi, 1790)	3	1	2	4	12	1				3	26	0.52	1		1	4	1			1	1	9	0.63
P. (s.str.) *maculicornis* (Duftschmid, 1812)							1				1	0.02					2	7				9	0.63
P. (s.str.) *planicollis* (Dejean, 1829)						2		1	3		6	0.12											
Pedius inquinatus (Sturm, 1824)			1	2		1		1	1		6	0.12			1				1	2		4	0.28
Poecilus (Ancholeus) puncticollis (Dejean, 1828)				4	4						8	0.16											
Poecilus (s.str.) *anatolicus* (Chaudoir, 1850)						3		1	5		9	0.18											
P. (s.str.) *cupreus cupreus* (Linnaeus, 1758)	9	18	147	168	96	44	5	1	29	26	543	10.8									3	3	0.21
P. (s.str.) *cursorius cursorius* (Dejean, 1828)			1	77	115						193	3.85											
Polystichus connexus (Geoffroy in Fourcroy, 1785)	1	1									2	0.04							1			1	0.07
Pterostichus (Adelosia) macer macer (Marsham, 1802)				2	5			3	1	1	12	0.24							3		2	5	0.35
Pterostichus (Phonias) strenuus (Panzer, 1796)																					1	1	0.07
Pterostichus (Pseudomaseus) anthracinus anthracinus (Illiger, 1798)			1								1	0.02											
Scybalicus oblongiusculus (Dejean, 1829)							1				1	0.02									6	6	0.42
Stenolophus (s.str.) *abdomialis persicus* Mannerheim, 1844			1								1	0.02											
Syntomus obscuroguttatus (Duftschmid, 1812)	1	1	2		20	7	1		2	9	43	0.86			1	1						2	0.14
Syntomus pallipes (Dejean, 1825)							1			1	2	0.04					3			2		5	0.35
Tachys (Paratachys) bistriatus (Duftschmid, 1812)			1	1			1				3	0.06								1		1	0.07
Tachyura (Sphaerotachys) hoemorroidalis (Ponza, 1805)																				6		6	0.42
Tachyura (s.str.) *parvula* (Dejean, 1831)								1			1	0.02											
Trechus (s.str.) *irenis* Csiki, 1912										1	1	0.02											
Trechus (s.str.) *quadristriatus* (Schrank, 1781)		1	2	6	2	2	6	11	6	6	42	0.84	1	1		2	1		1	1		7	0.49
Zabrus (s.str.) *tenebrioides* (Goeze, 1777)					2	3	1	1			7	0.14			1	4		1	1	5	34	46	3.21
Zuphium olens (Rossi, 1790)				2	2	1		1		7	13	0.26											