HISTORIA NATURALIS BULGARICA

ISSN 2603-3186 (online) · ISSN 0205-3640 (print)

Volume **45** · Issue **7**

NATURA
ET SCIENTIA

Contents

Sándor Ötvös, János Varga
On the *Theodoxus prevostianus* (C. Pfeiffer, 1828) population of the Tükör Spring in Kács (Hungary) 169

Borislav Guéorguiev, Gergana Zaemdzhikova, Plamen Glogov, Alexandar Guéorguiev
New and rare species of Cryptophagidae, Latridiidae and Mycetophagidae (Insecta: Coleoptera) for the fauna of Bulgaria 179

Rumyana Kostova, Rostislav Bekchiev
Ground beetle (Coleoptera: Carabidae) taxocoenoses from high-altitude *Pinus peuce* and *Pinus heldreichii* forests in Bulgaria 187

National Museum of Natural History — Bulgarian Academy of Sciences
Sofia · 2023

Published online **3 July 2023** by:
National Museum of Natural History, Bulgarian Academy of Sciences
1 Tsar Osvoboditel Blvd, 1000 Sofia, Bulgaria
https://www.nmnhs.com/historia-naturalis-bulgarica/

Editorial board

Editor-in-chief: Stanislav Abadjiev
Subject editors: Ilya Fabian Acosta, Christo Deltshev, Richard Gemel, Snejana Grozeva, Václav Gvoždík, Peter Huemer, Kal Ivanov, Peter Jäger, Fedor V. Konstantinov, Mario Langourov, Patrick Lemell, Georgi N. Markov, Peter Shurulinkov, Teddy German Angarita Sierra, Nikolay Simov, Giancarlo Statti, Ljiljana Tomović, Rossen Tzonev, Dimitar Uzunov, Vladislav Vergilov, Boyan Zlatkov

OPEN ACCESS

Distributed under the Creative Commons Attribution 4.0 International License (CC BY 4.0)

Historia naturalis bulgarica 45 (7): 169–177
ISSN 2603-3186 (online) | ISSN 0205-3640 (print) · nmnhs.com/historia-naturalis-bulgarica
https://doi.org/10.48027/hnb.45.071
Publication date [online]: 3 July 2023

Research article

On the *Theodoxus prevostianus* (C. Pfeiffer, 1828) population of the Tükör Spring in Kács (Hungary)

Sándor Ötvös[1], János Varga[2]

(1) [Corresponding author] University of Debrecen, Faculty of Natural Sciences, Doctoral School of Earth Science, 98 Szent István király Street, 3421 Mezőnyárád, Hungary, sandorotvos79@gmail.com
(2) Eszterházy Károly Catholic University, 6 Leányka Street, Bldg D, Faculty of Natural Sciences, Institute of Biology, Department of Zoology, 3300 Eger, Hungary, varga.janos@uni-eszterhazy.hu

Abstract: For the past nearly 15 years, we have been conducting freshwater malacological studies in the Kács spring area, a wetland of great importance in the South-Eastern Bükk (Hungary). The focus of our research is the species *Theodoxus prevostianus* (C. Pfeiffer, 1828). In the present study, population density records from the direct outlet of the tepidwater Tükör Spring are presented and compared. At the study site, the number of individuals of the accompanying malacofauna of the species under study was also recorded (*Microcolpia daudebartii* (Prevost, 1821), *Bythinella thermophila* Glöer, Varga et Mrkvicka, 2015, *Bythinella pannonica* (Frauenfeld, 1865). The data were recorded in 2006 (general survey), 2010 (drastic reduction) and 2021 (relocation). On the stone slab squares used to record individual counts, we detected a high-density population in 2006, a drastically reduced population in 2010 and a high-density population again in 2021.

Keywords: freshwater snails, highly protected species, Mollusca, monitoring

Introduction

The *Theodoxus prevostianus* (C. Pfeiffer, 1828) (Gastropoda: Neritidae) is a rare, relict, endemic, highly protected freshwater snail species of the Pannonian biogeographical region (European Habitat Directive, Annex IV). Ovoid-hemispherical in shape, 6–9 mm wide by 2–6 mm high, with a shell of three convolutions, twisted to the right, bright black in colour (Fig. 1a), sometimes with dark purple hues providing a unique colouration (Fig. 1b). The last convolution becomes wider, and the aperture takes the shape of a crescent (Richnovszky & Pintér, 1979).

The few references in professional literature associate the species mainly with the direct outlet of tepid water (20–24ºC) karst springs. Earlier observations (Soós, 1943; Lukács, 1959) show that at lower water temperature ranges (min. 15.5ºC), the *T. prevostianus* is viable and able to reproduce.

They are typically found in the zones filled with solid bed material in the headwaters. They are present in high densities on the surface of the stones (Fig. 1c). They are a dioecious species and they lay their eggs on the undersurface of stones or on the shells of other snails in the vicinity.

Now only four natural populations are left in the world. In recent decades, its habitat has declined mainly due to human interventions (dredging, construction). On the IUCN Red List, the species is classified as "endangered".

The only habitat in Hungary where the *T. prevostianus* has survived in its natural state is in the Bükk, in the Kács spring group in the Bükkalja region. In 2010, Hungarian malacologists successfully translocated the species to an old and previously extinct habitat, the Sályi Spring (Fehér et al., 2011, 2017). Outside Hungary, Neritidae are recorded in the malacological literature in the hypothermal springs of Bad Vöslau and Bad Fischau in Austria and Bušeča Vas in Slovenia.

List of current and previously known and extinct Pannonian basin habitats (Fig. 2): Hungary: [1] Kácsi springs (Kács), [2] Sályi Spring (Sály Lator-Vízfő), [3] Hejő Stream (Miskolc–Dudujka), [4] Springs of

Received: 21 March 2023; accepted: 9 June 2023 · Editor: Nikolay Simov

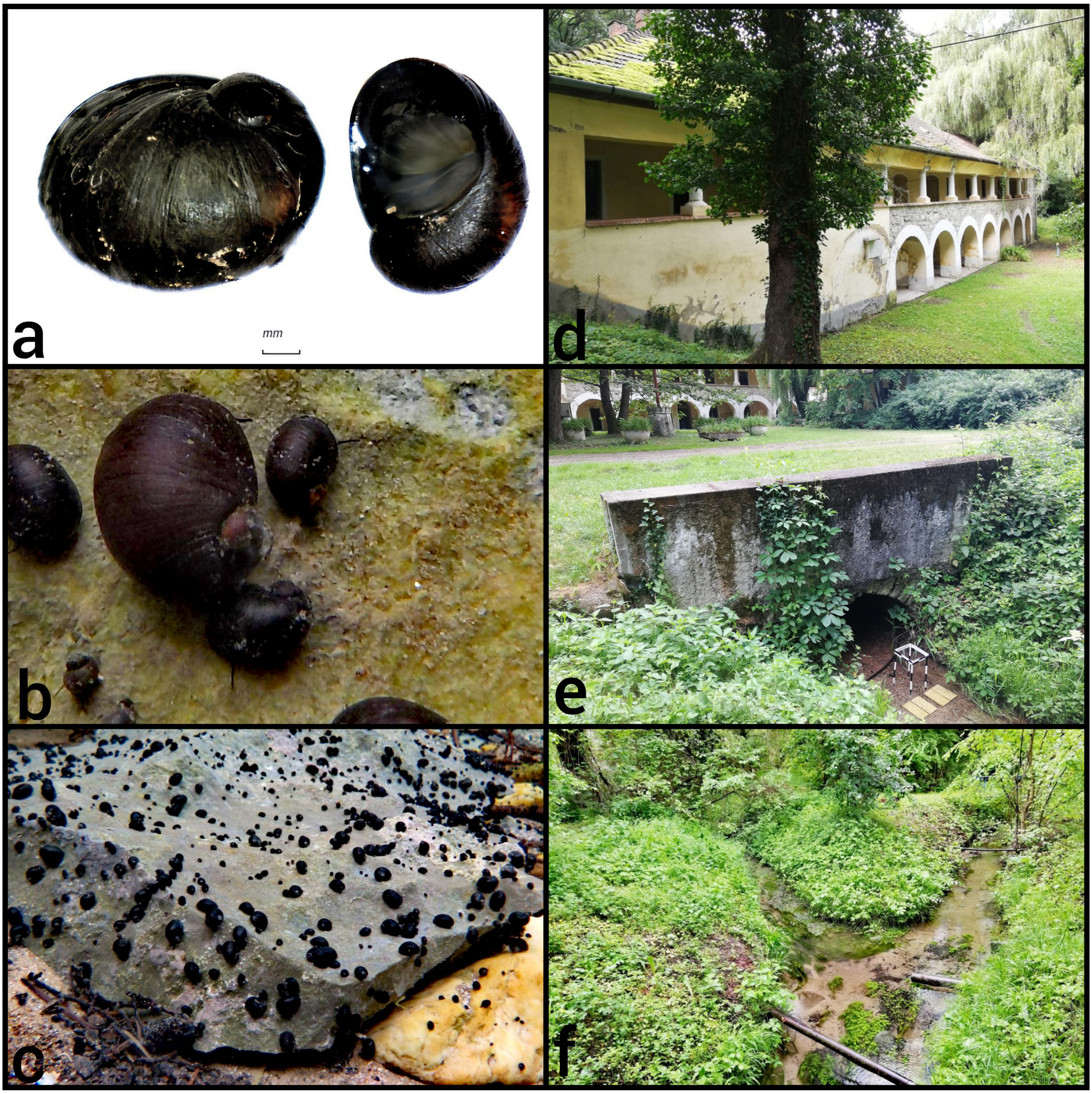

Fig. 1. (a) *Theodoxus prevostianus* (C. Pfeiffer, 1828); (b) *T. prevostianus* with dark purple hues; (c) mass occurrence of *T. prevostianus* on the surface of the stones; (d) Benedictine monastery; (e) Tükör Spring; (f) tepid spring stream (left), cold spring stream (right).

Csónakázó Lake (Miskolctapolca), [5] Tapolca Stream (Miskolc–Diósgyőr), [6] Király-kút Spring (Forrás-völgy, Bükk), [7] Tapolca Stream (Miskolc–Diósgyőr), [8] Roman Baths (Budapest), [9] English Garden (Tata), [10] Tóváros (Tata), [11] Fényes springs (Tata); Austria: [12] Bad Vöslau, [13] Bad Fischau; Slovenia: [14] Bušeča Vas; Croatia: [15] Ivanec Bistranski, [16] Podsused, [17] Velika; Romania: [18] Răbăgani, [19] Püspökfürdő (Fehér et al., 2007; Kormos, 1905b; Soós, 1927; Sümegi, 1999; Varga, 1980, 2009; Wagner, 1937).

In the Hungarian malacological bibliography from 1727 (Varga et al., 2005) onwards there have been several references to the population of *T. pre-*

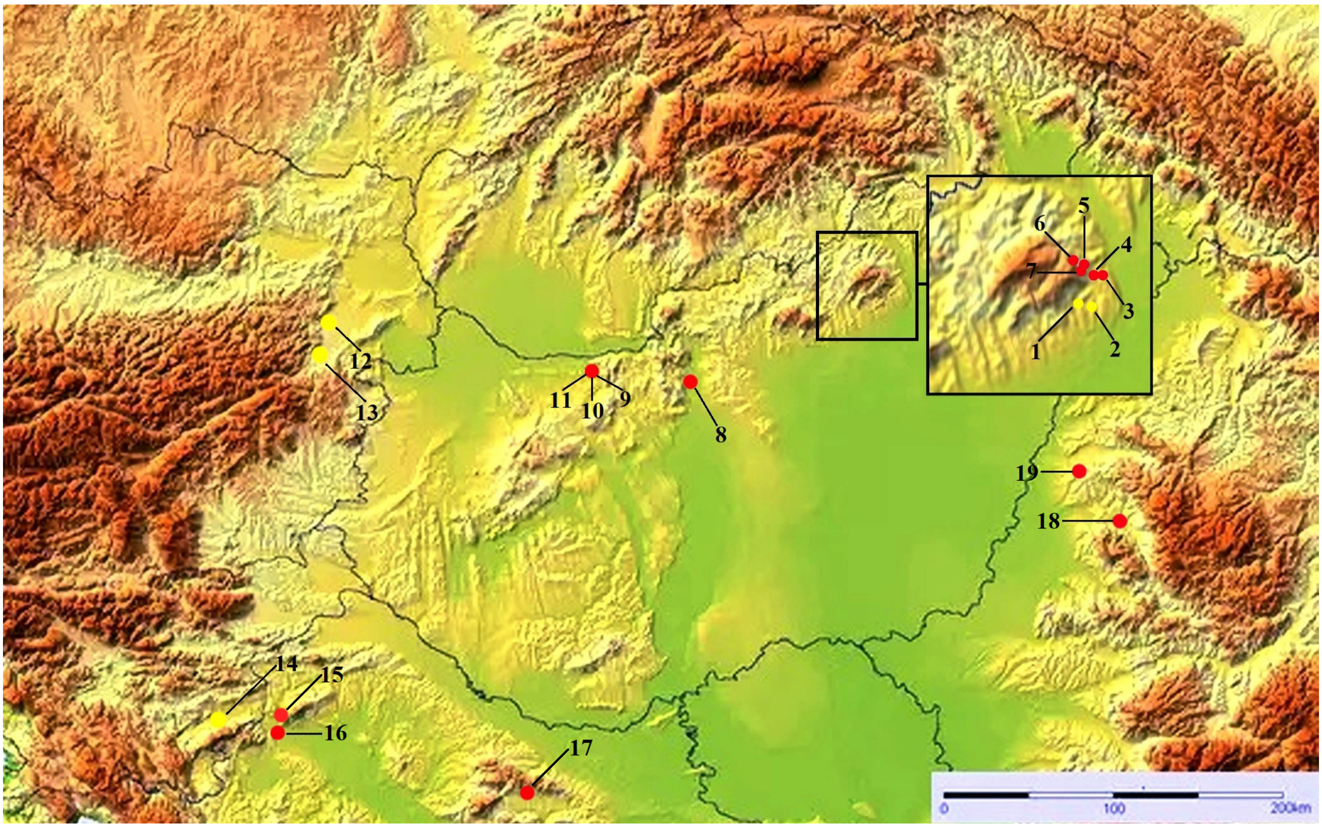

Fig. 2. Habitats of *Theodoxus prevostianus* (C. Pfeiffer, 1828) (yellow – current habitat; red – extinct habitat; base map: pinterest.com).

vostianus in Kács (Kormos, 1905a, 1905b; Schréter, 1915; Wagner, 1927; Wagner, 1937; Vásárhelyi, 1956; Lukács, 1959; Varga, 1976). Apart from the data on presence, specific test results are reported in only a very limited number of publications. Such is the work of Lajos Soós, who introduced the species in the drainage ditch of the Roman Baths in Budapest in 1909, but unfortunately his initial success did not lead to lasting results (Soós, 1927). In 1955, Dezső Lukács and Imre Vajon moved some *T. prevostianus* individuals from Miskolctapolca to a "hot-water spring" in Eger. Unfortunately, the population did not survive (Lukács & Vajon, 1955). Zoltán Fehér et al. have enriched the understanding of the species with important phylogenetic research results (Fehér et al., 2007). A 2009 paper by Ioan Sîrbu and Anna Maria Benedek provided valuable information about the disappearance of the Răbăgani habitat (Sîrbu & Benedek, 2009).

Detailed information on the hydrogeological characteristics of the Kács spring group is available in Hungarian scientific literature (Schulhoff, 1957; Almássy & Scheuer, 1967; Savanyú et al., 1986; Lénárt, 2000).

The 10–12 springs of the spring group represent a range of water temperatures between 14 and 24°C, with significantly different water yields. Of these, the tepid water Tükör Spring (44 l/s) and the cold water spring of the Northern Regional Waterworks (80 l/s) have a more significant volume of water.

The Tükör Spring has its source in the side wall of a long tunnel under a Benedictine monastery built here hundreds of years ago (Fig. 1d, e). No longer in operation, the Benedictine monks established a significant spa culture in Kács.

In 1972, the cold spring was tapped. Unused water emerging from the spring house forms the cold water tributary After a distance of 100 m from their source, the two tributaries converge and continue their course under the name of Kács Stream (Fig. 1f).

The habitat of the *T. prevostianus* covers the tepid water tributary of the Tükör Spring and the first 800 m of the Kács Stream. Here, the spreading of the snails is physically hindered by a 3 m high waterfall. Note:

recently the species has also been found in cold water springs, but the causal relationship is not addressed in this paper.

It is important to note that the tepid water spring is also home to the protected *Microcolpia daudebartii* (Prevost, 1821), and the recently described, new-to-science snail species *Bythinella thermophila* Glöer, Varga & Mrkvicka, 2015 (Glöer et al., 2015). The Kács Spring waters are also inhabited by the protected *Bythinella pannonica* (Frauenfeld, 1865).

For the last 15 years we have been studying the distribution of the *T. prevostianus* population in the Kács springs. In 2010, we tried to establish a stable population of the species through habitat reconstruction.

In the study presented in this paper, we sought to answer the question of how many individuals of the *T. prevostianus* can populate (colonise) an area of a quadrate. This study is specifically designed to analyse the spring outlet of the Tükör Spring only. From the available results, it is not appropriate to draw general conclusions for the other sections of the tepid water tributary. Due to lack of space, it was not possible to set up more quadrates in the sample area, so no statistical analysis was performed. Our aim is to obtain informative data for habitat reconstruction studies of the tepid water spring.

Material and methods

At the exit of the tunnel, stone slab quadrates were placed perpendicular to the riverbed. For data collection, 2 observation sites were placed at the Tükör Spring on each test date (2006, 2010, 2021). Density counts were recorded by census from the surface of the 25×25 cm quadrates. The unevenness of the water surface and the sunlight that is refracted on it result in significant distortions and difficult calculability. To eliminate this problem, an empty aquarium was lowered 2 cm below the surface of the water above the snails to create a transparent mirror surface. In 2006, in the absence of suitable digital technology, the density counts were recorded on the spot. In 2010 and 2021, we were able to take underwater digital photos. The photos were overlaid with a spatial grid during computer processing to facilitate counting by individual censusing. Although the focus of our studies is on the *T. prevostianus,* we also recorded the density of the accompanying species at the sampling sites. Data were collected on a weekly to fortnightly basis for 3 months.

Results and discussion

By week 4 of our 2006 survey, approximately 300 *T. prevostianus* had colonised both quadrats (Table 1). In the 5–6th week of the tests, the snow started to melt in the mountains. Due to local orographic conditions, the meltwater is drained in a dry basin, which feeds into the bed of the Tükör Spring. The temperature of the 22°C spring water dropped by 6°C and the volume of water grew eightfold. The meltwater did not bring sediment with it. The snails partly drifted off the surface of the quadrates and partly sought shelter on the back walls of the quadrates, which were more protected from the current. From week 7, the bed was again filled only with tepid water from the Tükör Spring. From week 10 onwards, apart from fluctuations in density, no further increase was recorded. The surface of the quadrates provided a favourable habitat for 400–600 *T. prevostianus*.

In 2010, we were able to directly experience the habitat-destroying effects of the surplus water mentioned earlier, bringing with it a large mass of sediment. In this case, it was not meltwater, but a significant amount of precipitation that fell on the surrounding mountains and the spring area. The original volume of water in the Tükör Spring bed was increased by 15–20 times by the sudden downpour of rainwater. At the Tükör Spring and in the tepid water tributary draining its waters, 30–50 cm thick fine sediment was deposited. The deposition of sediment had an extremely negative impact on the entire habitat of the *T. prevostianus*. At the outlet of the Tükör Spring and its tepid water tributary, the solid, rocky substrate essential for the habitat needs of the *T. prevostianus* had completely disappeared. Even by our most conservative estimates, 95–99% of the snails had died.

At the Tükör Spring, the quadrate stones were placed in the muddy bed in early April, but no Neritidae appeared on the surface. On 25 April, the observation sites were moved closer to the shore of the riverbed, where we found *T. prevostianus* clinging to the overhanging riparian foliage and an artificial structure (a drinking water pipe in the riverbed) (Fig. 3a).

On average, only 15–30 individuals settled on the quadrates in 2010. From the second week onwards,

Table 1. The malacofauna of the Tükör Spring in Kács (2006).

Test dates	Number of individuals					
	Test point 1			Test point 2		
	Theodoxus prevostianus	*Microcolpia daudebartii*	*Bythinella* sp.	*Theodoxus prevostianus*	*Microcolpia daudebartii*	*Bythinella* sp.
05/2/2006	—	—	—	—	—	—
12/2/2006	1	1	—	3	—	—
19/2/2006	19	1	—	28	2	—
26/2/2006	64	16	—	166	2	—
05/3/2006	346	12	—	297	8	—
12/3/2006	—	—	—	—	—	—
19/3/2006	—	—	—	—	—	—
26/3/2006	141	—	—	110	—	—
02/4/2006	362	2	—	224	3	—
09/4/2006	556	2	—	430	—	—
16/4/2006	593	1	—	462	3	—
23/4/2006	603	1	—	472	—	—
30/4/2006	502	—	—	444	—	—
07/5/2006	453	1	—	547	2	—
14/5/2006	591	—	—	491	2	—

Table 2. The malacofauna of the Tükör Spring in Kács (2010).

Test dates	Number of individuals					
	Test point 1			Test point 2		
	Theodoxus prevostianus	*Microcolpia daudebartii*	*Bythinella* sp.	*Theodoxus prevostianus*	*Microcolpia daudebartii*	*Bythinella* sp.
25/4/2010	—	—	—	—	—	—
01/5/2010	8	3	—	41	4	—
08/5/2010	32	64	—	38	10	—
15/5/2010	27	109	—	44	26	—
22/5/2010	24	87	—	28	44	—
29/5/2010	26	53	—	21	41	—
12/6/2010	29	17	—	14	18	—
26/6/2010	16	9	—	17	3	—
03/7/2010	14	2	—	18	7	—
17/7/2010	18	—	—	20	1	—
31/7/2010	19	—	—	25	—	—
14/8/2010	19	4	—	24	5	—
21/8/2010	22	1	—	25	—	—
04/9/2010	32	—	—	21	2	—
17/9/2010	40	1	—	32	1	—

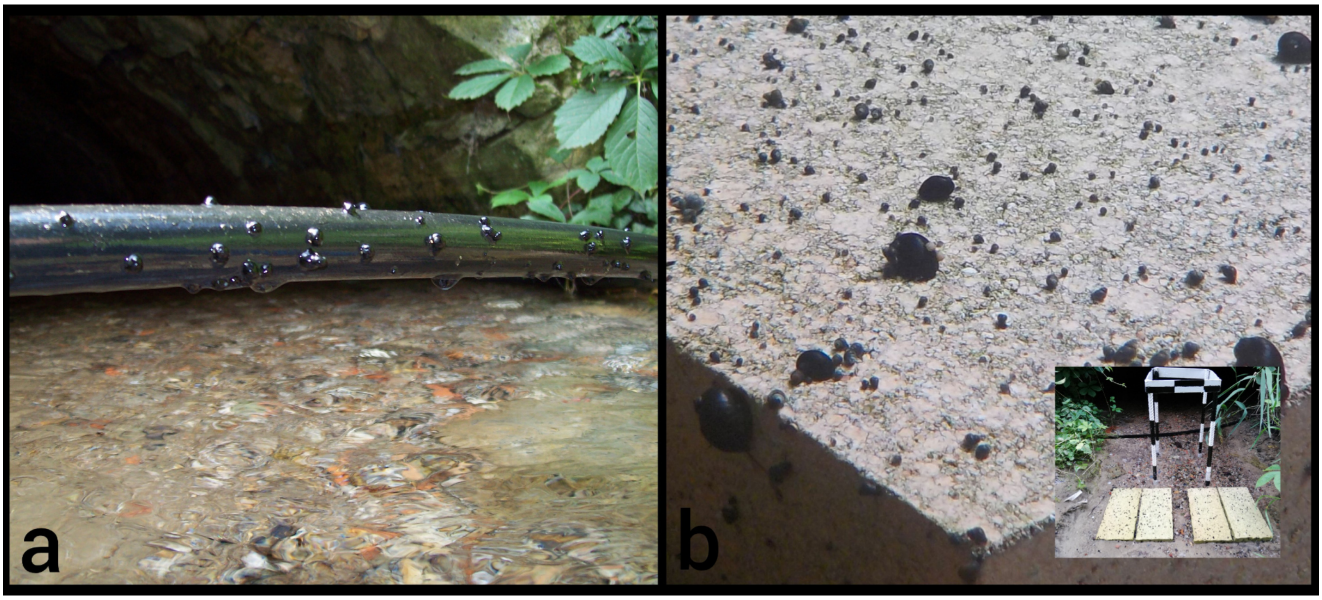

Fig. 3. (a) *Theodoxus prevostianus* clinging to an artificial surface; (b) *Theodoxus prevostianus* and *Bythinella* sp. at the Tükör Spring.

Table 3. The malacofauna of the Tükör Spring in Kács (2021).

Test dates	Number of individuals					
	Test point 1			Test point 2		
	Theodoxus prevostianus	*Microcolpia daudebartii*	*Bythinella* sp.	*Theodoxus prevostianus*	*Microcolpia daudebartii*	*Bythinella* sp.
21/3/2021	—	—	—	—	—	—
28/3/2021	3	—	12	9	—	21
04/4/2021	23	8	50	9	13	31
11/4/2021	49	53	177	60	16	68
18/4/2021	104	20	621	156	49	570
25/4/2021	170	11	389	197	25	280
02/5/2021	206	29	151	177	22	215
09/5/2021	141	17	127	179	12	185
16/5/2021	284	—	256	237	1	287
23/5/2021	318	2	253	308	2	281
30/5/2021	306	2	246	335	2	261
06/6/2021	254	—	243	179	—	209
13/6/2021	454	—	388	435	—	406
20/6/2021	445	—	283	411	2	286
27/6/2021	447	1	279	409	—	268

the number of individuals did not change, apart from minor fluctuations, and the steady upward trend of the previous period was not observed (Table 2).

By 2021, the fine sediment in the bed of the Tükör Spring had been completely washed away, and the bed is now covered by a stony substrate. Note: only

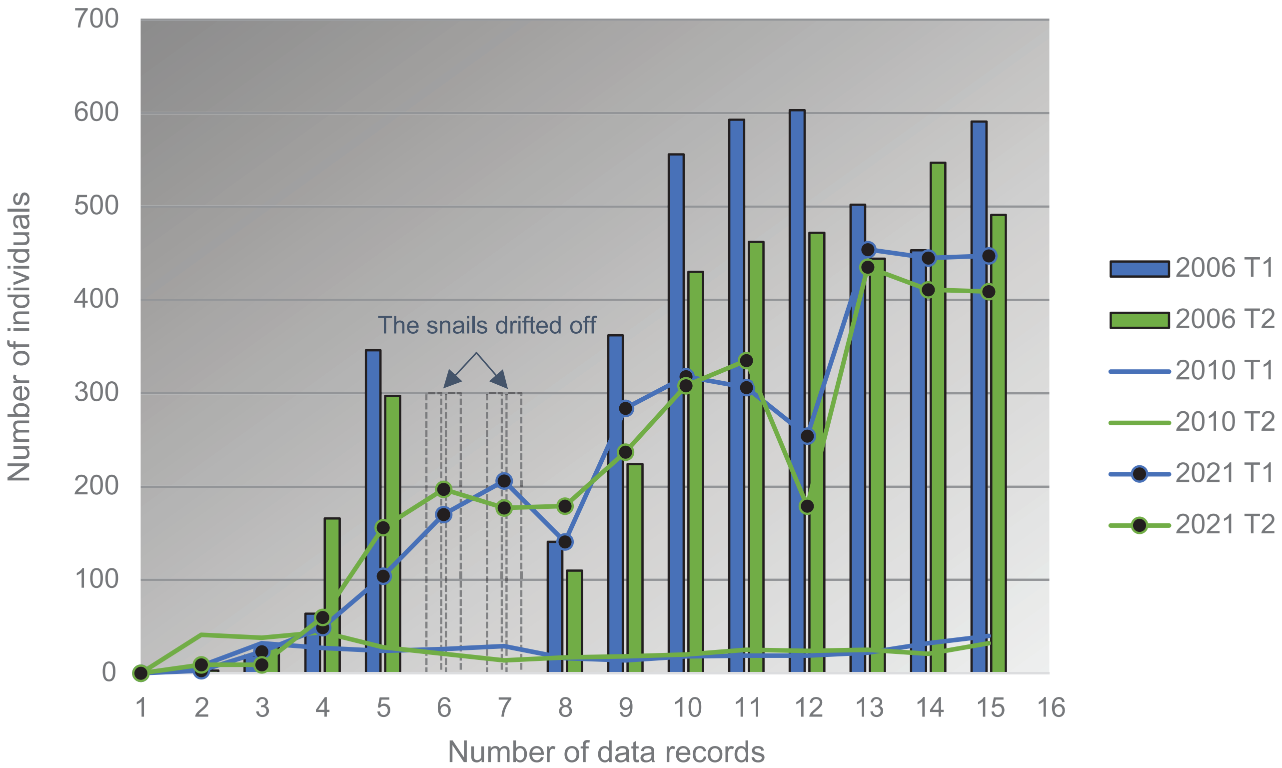

Fig. 4. Changes in the number of the individuals of *Theodoxus prevostianus* (C. Pfeiffer, 1828) at the Tükör Spring (2006, 2010, 2021). T1 – test point 1, T2 – test point 2.

partial washout was observed in the tepid water tributary. The colonisation of the quadrates was continuous and uninterrupted. Maximum densities were recorded at the survey sites in week 12. With minor fluctuations, 300–400 *T. prevostianus* settled on the quadrate surfaces during this test cycle (Table 3).

The changes in the number of the individuals of *T. prevostianus,* based on the tables and explanations presented above, are also represented with a summary diagram (Fig. 4).

Although the analysis of the accompanying fauna is not the subject of this article, we cannot but note some findings.

Microcolpia daudebartii is found in abundance at the Tükör Spring and in the entire Kács habitat, mainly in the fine sediment zones. However, on all three study dates, active presence was observed for the first 4–5 weeks on all quadrates set out, followed by a steady decline in numbers and then total disappearance from the test sites. Particularly high densities of this species were recorded during the 2010 study. Whether this is due to the absence of the *T. prevostianus,* requires further analysis. In any case, we are experiencing a similar phenomenon in our current ongoing studies.

Bythinella thermophila and *Bythinella pannonica* as *Bythinella* sp. are listed in the recorded data. The differentiation between the two species is extremely difficult from a shell morphological point of view, and impossible without manual handling of the individuals.

The *B. thermophila* was described only in 2015, from this very branch of the tepid water spring of the Kács Tükör Spring (Glöer et al., 2015). No studies have been carried out so far and we have no factual data on the species. It is important to clarify whether the *Bythinella* population here is exclusively, or to a lesser or greater extent, *thermophila* or *pannonica*. One wonders, if it is a newly described species, how it could have spread in such a short time. It also makes one wonder if *B. pannonica* is also present in the snail population of the Tükör Spring, as it has only been known in the literature to occur in colder spring waters.

In 2006 and 2010, no *Bythinella* species were detected at the Tükör Spring during the data collection. In 2021, we recorded surprisingly large numbers, sometimes exceeding those of the *T. prevostianus* (Fig. 3b). Their study is extremely important because it represents a new element in the direct outlet of the Kács Tükör Spring. Note: Until 2010, we had only observed *Bythinella* in the immediate vicinity of the mouths of a few subaqueous creek springs in the tepid water tributaries, which we then assumed to be *B. pannonica*. Dezső Lukács had already issued a publication about it in the late 1950s under the species designation "*Bythinella austriaca*" (Lukács, 1959). The snail prefers the surface of stones as its habitat, so it may have a significant impact on the population of the *T. prevostianus* here. With regard to *Bythinella,* we will carry out further investigations in cooperation with a researcher specialised in Hydrobiidae.

Conclusion

The *Theodoxus prevostianus* (C. Pfeiffer, 1828) form a stable population at the outlet of the Tükör Spring under undisturbed hydroecological conditions. Meteorological and orographic factors in the Kács spring area can adversely affect this stability. After the solid surfaces important for the *T. prevostianus* were cleared, the relocation processes were activated. Since 2010, no episodes of rainwater runoff and sedimentation have been observed, but the risk remains. The results of the study will certainly provide useful guidance for our further explorations. The study of the rare snail fauna of the Kács spring area requires very complex planning and implementation, which we are striving to achieve.

Acknowledgements

We would like to thank László Végh, the former owner of the Kács spring area, and the Bükk National Park Directorate as the new owner, for agreeing to allow us access to the area.

References

Almássy B., Scheuer Gy. 1967 A Kács-Sályi források vízföldtani viszonyai. Hidrológiai Tájékoztató 7 (1): 72–76.

Fehér Z., Majoros G., Ötvös S., Bajomi B., Sólymos P. 2017 Successful reintroduction of the endangered black nerite, *Theodoxus prevostianus* (Pfeiffer, 1828) (Gastropoda: Neritidae) in Hungary. Journal of Molluscan Studies 83 (2): 240–242. https://doi.org/10.1093/mollus/eyx007

Fehér Z., Majoros G., Ötvös S., Sólymos P. 2011 Proposed re-introduction of the endangered black nerite (*Theodoxus prevostianus*, Mollusca, Neritidae) in Hungary. Tentacle 19: 36–39.

Fehér Z., Varga A., Deli T., Domokos T., Szabó K., Bozsó M., Pénzes Zs. 2007 Filogenetikai vizsgálatok védett puhatestűeken. In: Forró L. (szerk.): A Kárpát-medence állatvilágának kialakulása: A Kárpát-medence állattani értékei és faunájának kialakulása. Magyar Természettudományi Múzeum, pp. 183–200.

Glöer P., Varga A., Mrkvicka A.C. 2015 Enigmatic *Bythinella* species in Bükk Mountains with the description of *Bythinella thermophila* n. sp. (Gastropoda: Amnicolidae). Ecologica Montenegrina 3: 40–45. https://doi.org/10.37828/em.2015.3.6

Kormos T. 1905a A Püspökfürdő hévízi faunájának eredete (Über den Ursprung der Thermenfauna von Püspökfürdő). Földtani Közlöny 35: 375–402.

Kormos T. 1905b A püspökfürdői és tatai Neritinák kérdéséhez. Állattani Közlemények 4: 39–44.

Lénárt L. 2000 A kácsi Tükör-fürdő forrásának és környezetének hidrogeológiai vizsgálata. Karsztvízgazda BT, pp. 1–25.

Lukács D. 1959 A Bükk-hegységi langyosvizek állatainak ökológiai viszonyai (Kács-fürdő vizeinek rheobiológiai vizsgálata). Akadémiai mf. 125–126.

Lukács D., Vajon I. 1955 Jegyzetek a Bükk vizeinek állatökológiai és állatföldrajzi viszonyaihoz: Közlemény az Egri Pedagógiai Főiskola Állattani Tanszékétől. Az Egri Pedagógiai Főiskola évkönyve (1. köt.) [Acta Academiae Paedagogicae Agriensis (Tom. 1.)], pp. 445–460.

Richnovszky A., Pintér L. 1979 A vízicsigák és kagylók (Mollusca) kishatározója. Vízügyi Dokumentációs és Továbbképző Intézet, Budapest. Vízügyi Hidrobiológia 6: 1–205.

Savanyú K., Juhász J., Lénárt L. 1986 Déli-bükki karsztforrások védõidom vizsgálata. NME

Közleményei, Miskolc, 1. sorozat, Bányászat 33, 1–4 füzet, 15–23.

Schréter Z. 1915 Neue Fundorte zweier relikten Gastropoden-Artenaus Ungarn. Állattani Közlemények 14: 262–265.

Schulhoff Ö. 1957 Magyarország ásvány- és gyógyvizei. Akadémiai Kiadó, Bp., 269.

Sîrbu I., Benedek A.M. 2009 The extinction of *Theodoxus prevostianus* (C. Pfeiffer, 1828) (Mollusca: Gastropoda: Neritidae) in Romania. Tentacle 17: 19–21.

Soós L. 1927 A *Theodoxus* (*Neritina*) *Prevostianus* C. Pfr. előfordulása a Rómaifürdőben. Természettudományi Közlöny, Budapest, Pótfüzetek 59: 100.

Soós L. 1943 A Kárpát-medence Mollusca-faunája. Hungarian Academy of Sciences, Budapest, pp. 1–478.

Sümegi P. 1999 Jelentés a püspökfürdőn végzett geológiai és őslénytani munka eredményeiről. OTKA beszámoló, Debreceni Egyetem, Földtani és Őslénytani Tanszék.

Varga A. 1976–1977 A Bükk-hegység Mollusca-faunája. Folia historico-naturalia Musei Matraensis 4: 37–62.

Varga A. 1980 Vásárhelyi István gyűjteménye a Herman Ottó Múzeumban I. A Herman Ottó Múzeum Évkönyve 19: 375–390.

Varga A. 2009 Régi anyagok a Mátra Múzeum (Gyöngyös) Mollusca-gyűjteményében. Folia historico-naturalia Musei Matraensis 33: 25–51.

Varga A., Fűköh L., Krolopp E. 2005 Magyar Malakológiai Bibliográfia (1727–2004). Malakológiai Tájékoztató 23: 5–129.

Vásárhelyi I. 1956 Két relictum csigáról. Miskolci Hermann Ottó Múzeum Közleményei 4: 47–48.

Wagner J. 1927 A Római-fürdőkörnyékének puhatestűfaunája. Természettudományi Közlöny (supplementum) 59: 99–101.

Wagner J. 1937 Újabb adatok a Bükk-hegység Mollusca-faunájának ismeretéhez. Állattani Közlemények 36: 59–65.

Historia naturalis bulgarica 45 (7): 179–186
ISSN 2603-3186 (online) | ISSN 0205-3640 (print) · nmnhs.com/historia-naturalis-bulgarica
https://doi.org/10.48027/hnb.45.072
Publication date [online]: 3 July 2023

Research article

New and rare species of Cryptophagidae, Latridiidae and Mycetophagidae (Insecta: Coleoptera) for the fauna of Bulgaria

Borislav Guéorguiev[1], Gergana Zaemdzhikova[2], Plamen Glogov[3], Alexandar Guéorguiev[4]

(1) National Museum of Natural History, Bulgarian Academy of Sciences, 1 Tsar Osvoboditel Blvd, 1000 Sofia, Bulgaria, gueorguiev@nmnhs.com; https://orcid.org/0000-0002-8532-0657
(2) Forest Research Institute, Bulgarian Academy of Sciences, 132 St. Kliment Ohridski Blvd, 1756 Sofia, Bulgaria, zaem.bg@abv.bg; https://orcid.org/0000-0002-0694-4331
(3) Forest Research Institute, Bulgarian Academy of Sciences, 132 St. Kliment Ohridski Blvd, 1756 Sofia, Bulgaria, plglogov@abv.bg; https://orcid.org/0000-0003-2913-3379
(4) Krasna polyana-1 Residential Quarter, Rumyana Street, Building 24, Sofia, Bulgaria

Abstract: *Cryptophagus intermedius* Bruce, *Dienerella filiformis* (Gyllenhal) and *Melanophthalma rhenana* Rücker et Johnson, 2007 are first time recorded for the fauna of Bulgaria as the first and third species are also first noted from the Balkan Peninsula. Left unmentioned for the country in the latest catalogues, but earlier noted in other announcements, other two species, *Berginus tamarisci* Wollaston and *Melanophthalma taurica* (Mannerheim) are confirmed for Bulgaria, with first detailed data reported. All the aforementioned species (except *C. intermedius*) have been reared and thus first time reported from the European mistletoe (*Viscum album* Linnaeus). A checklist of the Bulgarian hairy fungus beetles including new and republished data is presented too.

Keywords: beetles, Bulgaria, European mistletoe, first and new country records

Introduction

European mistletoe, *Viscum album* L., is an evergreen hemiparasitic shrub, growing on different woody hosts (Kahle-Zuber, 2008). In Bulgaria, the species is found all over the country from sea level to 2000 m.a.s.l. (Assyov et al., 2012). Three subspecies of European mistletoe are known to parasitise different hosts: *V. album* ssp. *album* L. (mostly on deciduous trees), *V. album* ssp. *austriacum* (Wiesb.) Vollm. (on representatives of genus *Pinus*), *V. album* ssp. *abietis* (Wiesb.) Abrom. (parasitic principally on *Abies*). Comparatively few insects have been recorded on all the European subspecies of mistletoe. In the continental Europe are recorded 81 insect species – Hemiptera (34), Coleoptera (27), the rest being mainly Diptera (5), Hymenoptera (8) and Lepidoptera (7). Of these 34 were recorded on European mistletoe in Britain (Thomas et al., 2023). Until now, the insects on the fruits of *V. album* have not been the subject of research purposes in the country.

On the other hand, still there are poorly known and little investigated groups of beetle in Bulgaria. Among them are the representatives of families Cryptophagidae and Latridiidae, which recent acquisitions initiated this study.

Material and methods

The object of study are populations of European mistletoe (*Viscum album* ssp. *album*) in pure and mixed 25-year-old artificial plantations of black locust (*Robinia pseudoacacia* L.) on the territory occupied by sand dunes close to Nesebar Town, the Black Sea Region (Fig. 1). The study area is part of the protected area BG0000574 Aheloy – Ravda – Nesebar from the NATURA 2000 ecological network.

Received: 1 June 2023; accepted: 9 June 2023 · Editor: Stanislav Abadjiev

Fig. 1. New habitat of *Dienerella filiformis, Melanophthalma rhenana, M. taurica* and *Berginus tamarisci* – fruits of European mistletoe (top left) on plantations of black locust near Nesebar Town, Bulgaria.

Fig. 2. Habitat of *Cryptophagus reflexicollis,* spruce forest above Osogovo Hut, Bulgaria.

The samples – 123 fruits of *V. album* ssp. *album,* were collected of 9.04.2023 from 10 black locust trees in a sample area 50×50m in size. The collected fruits were transported to the laboratory of the Forest Research Institute at the Bulgarian Academy of Sciences, where they were placed in plastic box with ventilation holes. The samples were stored at room temperature between 18–20°C and natural light. They were checked daily for the emergence of insect adults. All emergence adults of beetles – 5 specimens were put individually in the tubs with 95% ethanol and handed over for identification to the first author.

The material collected at the Osogovo Mts was caught in a predetermined monitoring plot for collecting live beetles (see also Bekchiev et al., 2022). Performing the procedure, 12 soil traps arranged in a rectangle-shape (3×4) were exposed for 24 hours in a spruce forest (*Picea abies* (L.) H. Karsten) (Fig. 2).

All the material of Coleoptera included in the study has been determined by the first author and preserved in the entomological collection of the National Museum of Natural History in Sofia.

Results and discussion

Coleoptera Linnaeus, 1758

Cryptophagidae Kirby, 1837

Cryptophagus Herbst, 1792

Cryptophagus intermedius Bruce, 1934

Locality: Osogovo Mts, above Osogovo Hut, N42.19811° E22.62251°, 1650 m.a.s.l., pitfall traps, 14–15.09.2022, 1 specimen, leg. B. Guéorguiev, A. Guéorguiev.

Notes: Specimen with length of body 2.05 mm and a convex pronotum having proportion width/length =1.63 (Fig. 3). Other external characters well-coincides with the species re-description (Otero & Johnson, 2013).

Distribution: According to Otero (2013) and Otero & Johnson (2013), *C. intermedius* occurs in Europe (Austria, Denmark, Estonia, France, Great

Fig. 3. *Cryptophagus intermedius* – specimen from Osogovo Mts, Bulgaria. Scale bar 0.5 mm.

Fig. 4. *Dienerella filiformis* – specimen reared from fruits of *V. album* ssp. *album*. Scale bar 0.5 mm.

Britain, Germany, Italy, Norway, Poland, Romania, Slovakia, South of Russia, Spain, Sweden, Switzerland), Caucasus (Azerbaijan, Armenia, Georgia) and Iran. The record from the Osogovo Mts is the first species mention from Bulgaria and the Balkan Peninsula.

Latridiidae Erichson, 1842

Dienerella Reitter, 1911

Notes: For the time being, 3 species of the genus are noted from Bulgaria – *D. anatoliaca* (Mannerheim, 1844), *D. clathrata* (Mannerheim, 1844) and *D. ruficollis* (Marsham, 1802) (Johnson, 2007; Rücker, 2013). Below down a fourth species is first reporting for the country.

Dienerella filiformis (Gyllenhal, 1827)

Locality: Nesebar Town, N42.64979° E27.70904°, 16 m.a.s.l., reared from fruits of *V. album* ssp. *album,* collected fruits 9.04.2023, adult emergence 30.04.2023, 1 specimen (Fig. 4), leg. G. Zaemdzhikova, P. Glogov.

Melanophthalma Motschulsky, 1866

Notes: In the recent catalogues and databases (Johnson, 2007; Rücker, 2013; Rücker & Johnson, 2013; Rücker, 2020), four species of the genus have been noted from Bulgaria – *M. extensa* Rey, 1889, *M. pallens* (Mannerheim, 1844), *M. sericea* (Mannerheim, 1844), and *M. transversalis* (Gyllenhal, 1827). A fifth species, *M. taurica* (Mannerheim, 1844) was also cited but without concrete data (Rücker, 1982). In spite of that notice, the last species has not been mentioned for the country in the latest catalogue of Latridiidae (Rücker, 2020).

Melanophthalma rhenana Rücker & Johnson, 2007

Locality: Same data as for *Dienerella filiformis*. One male specimen collected.

Notes: Male specimen of the "*taurica*" species groups (Rücker & Johnson, 2013), with length of

Fig. 5. *Melanophthalma rhenana* – male specimen reared from fruits of *V. album* ssp. *album*. Scale bar 0.5 mm.

Fig. 6. *Melanophthalma rhenana* – median lobe of aedeagus: left lateral view (left), ventral view (right). Scale bar 0.1 mm.

Fig. 7. *Melanophthalma taurica* – female specimen reared from fruits of *V. album* ssp. *album*. Scale bar 0.5 mm.

Fig. 8. *Melanophthalma taurica* – median lobe of aedeagus: left lateral view (left), ventral view (right). Scale bar 0.1 mm.

body 1.6 mm, antenna with 3-lobed club, first abdominal ventrite with lateral lines, front tibia without tooth and segment 3 of the fore tarsi with a pointed tooth bent forward (Fig. 5). Median lobe of aedeagus with a long conspicuous flagellum protruding from the basal orifice (Fig. 6).

Distribution: Until presently the species was known from Germany, Austria, Czech Republic, Slovakia, Turkey and Iran (Míka, 2023). The record near the Nesebar Town is the first one from Bulgaria and from the Balkan Peninsula.

Melanophthalma taurica (Mannerheim, 1844)

References: Rücker (1982: 80).

Locality: Same data as for *Dienerella filiformis*. One male and one female collected.

Notes: Larvae of the two species of the genus were found to live in sympatry in fruits of *V. album* ssp. *album*. Their imagoes are easily recognised one from another after a careful examination – this of *M. taurica* have lighter coloured, laterally more rounded elytra (Fig. 7) whereas that of *M. rhenana* have darker elytra with sides more parallel (Fig. 5). As well, the median lobe of aedeagus of the former species is less bent ventrally and without flagellum (Fig. 8). Except the above two characters, the male sex of *M. taurica* has the same combination of principal morphological features as that of *M. rhenana* (see "Notes" under *M. rhenana*).

Distribution: According to Rücker (2013) and Rücker & Johnson (2013), it occurs in Ukraine, South European Russia (Caucasus), Azerbaijan, Asiatic Turkey, Iran, Tajikistan, and Afghanistan, but absent from the Balkan Peninsula and Central Europe. The species is here noted with first detailed record from Bulgaria.

Mycetophagidae Leach, 1815

Notes: A checklist of the hairy fungus beetles from Bulgaria is prepared.

Mycetophaginae Leach, 1815

Litargus Erichson, 1846

Litargus (*Litargus*) *connexus* (Geoffroy, 1785)

References: Markovich (1909: 8); Guéorguiev & Ljubomirov (2009: 254); Háva (2021: 12); Háva (2022: 300).

Republished data by Guéorguiev & Ljubomirov (2009): Maleshevska Planina Mt, west of Gorna Breznitsa Village, 600–800 m.a.s.l., 1.05.2003, shifting litter, 1 specimen, leg. B. Guéorguiev.

Mycetophagus Fabricius, 1792

Mycetophagus (*Ilendus*) *multipunctatus* Fabricius, 1792

References: Joakimov (1904: 17); Háva (2022: 305).

Mycetophagus (*Mycetophagus*) *quadripustulatus* (Linnaeus, 1760)

References: Joakimov (1904: 38 sub *Tritoma quadripunctata* sic!); Netolitzky (1912: 160); Guéorguiev & Ljubomirov (2009: 254); Guéorguiev (2011: 13); Háva (2022: 307).

New data: Lyulin Mt, Karlezha Place, 6.10.1946, 1 specimen, leg. S. Bocharov; Sredna Gora Mts, Buzovgrad Village, 8.06.1948, 3 specimens, leg. S. Bocharov; Konyavska Planina Mt, Zemen Railway Station – Zemen Monastery, 6.06.1954, 3 specimens, leg. S. Bocharov; Belasitsa Mt, near Samuilovo Village, 450–500 m.a.s.l., 5.12.2009, *Platanus orientalis* L. forest, 2 specimens, leg. B. Guéorguiev.

Republished data by Guéorguiev & Ljubomirov (2009) and Guéorguiev (2011): Maleshevska Planina Mt, SW Sedelets Village, 680 m.a.s.l., 16.04–4.05.2003, *Quercus pubescens* Will. forest, soil traps, 1 specimen, leg. B. Guéorguiev; Belasitsa Mt, *Castanea sativa* Mill. forest, plot No. 13 (N41.37469204 E23.20656203, 500 m.a.s.l.), 29.03–19.05.2010, soil traps, 1 specimen, leg. B. Guéorguiev & C. Deltshev.

Mycetophagus (*Mycetoxides*) *fulvicollis* Fabricius, 1792

References: Anonymous (1907: 301); Háva (2021: 13); Háva (2022: 308).

Mycetophagus (*Parilendus*) *quadriguttatus* P. W. J. Müller, 1821

References: Guéorguiev & Ljubomirov (2009: 254); Guéorguiev (2011: 13); Nikitsky 2013 (Fauna Europaea); Háva (2021: 13).

Republished data by Guéorguiev & Ljubomirov (2009) and Guéorguiev (2011): Maleshevska Planina Mt, 3 km east of Nikudin Village, 600 m.a.s.l., 16.04–4.05.2003, soil traps in deciduous forest, 1 specimen, leg. S. Lazarov; Belasitsa Mt, *Castanea sativa* forest, plot No. 11 (N41.37234656 E23.20370984, 600 m.a.s.l.), 27.03–17.05.2010, soil traps, 2 specimens, leg. B. Guéorguiev & C. Deltshev.

Mycetophagus (*Ulolendus*) *atomarius* (Fabricius, 1787)

References: Joakimov (1904: 38 sub *Tritoma atomaria*); Roubal (1931: 453); Háva (2022: 310).

Mycetophagus (*Ulolendus*) *decempunctatus decempunctatus* Fabricius, 1801

References: Nikitsky 2013 (Fauna Europaea); Háva (2022: 311).

New data: Veliko Tarnovo Region, BG0000275 Natura 2000 Protected Area Yazovir Stamboliyski, 19.VI.2012, light trap, 1 specimen, leg. B. Guéorguiev & E. Chehlarov.

Mycetophagus (*Ulolendus*) *piceus* (Fabricius, 1777)

References: Nikitsky 2013 (Fauna Europaea); Háva (2021: 13); Háva (2022: 312).

New data: Konyavska Planina Mt, Zemen Railway Station – Zemen Monastery, 6.06.1954, 1 specimen, leg. S. Bocharov.

Pseudotriphyllus Reitter, 1880

Pseudotriphyllus suturalis (Fabricius, 1801)

References: Nikitsky 2013 (Fauna Europaea); Háva (2022: 314).

Triphyllus Dejean, 1821

Triphyllus bicolor (Fabricius, 1777)

References: Nikitsky 2013 (Fauna Europaea); Guéorguiev (2011: 13); Háva (2021: 14); Háva (2022: 315).

Republished data by Guéorguiev (2011): Belasitsa Mt, *Castanea sativa* forest, plot No. 3 N41.36326015 E23.20125052, 800 m.a.s.l.), 18.05–4.07.2010, soil traps, 2 specimens, leg. B. Guéorguiev & C. Deltshev.

Typhaea Stephens, 1829

Typhaea stercorea (Linnaeus, 1758) [= *fumata* (Linnaeus, 1767)]

References: Joakimov (1904: 17 sub *T. fumata*); Markovich (1909: 8 sub *T. fumata*); Palm (1966: 21); Háva (2021: 14).

Bergininae Lend, 1920

Berginus Erichson, 1846

Notes: Genus readily distinguished from the other West Palaearctic genera of the family by its narrow pronotum and antenna with 2-segmented club.

Berginus tamarisci Wollaston, 1854

References: Nikitsky 2013 (Fauna Europaea).

Locality: Nesebar Town, N42.64979° E27.70904°, 16 m.a.s.l., reared from fruits of *V. album* ssp. *album,* collected fruits 9.04.2023, adult emergence 30.04.2023, 1 specimen, leg. G. Zaemdzhikova, P. Glogov.

Notes: Specimen with length of body 1.9 mm, pronotum almost parallel-sided, scarcely broader than long (width/length =1.11) and much narrower than elytra (Fig. 9). Head large, with eyes nearly as wide as pronotum (head width/pronotum width = 0.89), with clypeus separated from forehead by an incised furrow. Completely pitch brown coloured.

Distribution: According to Háva (2022), the species has been established in Europe (Austria, Belgium, Bosna-Herzegovina, Croatia, Czech Republic, England, France, Germany, Georgia, Greece, Hungary, Italy, Malta, Poland, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey), Africa (Algeria, Egypt, Madeira, Morocco, Tunisia, Nigeria) and Israel. An earlier species indication exists for Bulgaria in Fauna Europaea (Nikitsky, 2013) despite no specific data has been provided there. That is why the record near

Fig. 9. *Berginus tamarisci* – specimen reared from European mistletoe, near Nesebar Town. Scale bar 0.5 mm.

Nesebar appears the first detailed species datum from the country.

Bionomics: According to Leschen (2000) [in Lawrence et al., 2014], species of *Berginus* Erichson feed on pollen or attack lac scale insects (Hemiptera: Coccoidea).

Discussion

In this study, four species – *Dienerella filiformis, Melanophthalma rhenana, M. taurica* (Latridiidae) and *Berginus tamarisci* (Mycetophagidae) are reported for the first time on *Viscum album*. The list of insects on *V. album* in Great Britain and continental Europe does not include these coleopteran species, or other species of these two families (Thomas et al., 2023). Until now, the coleopteran fauna associated with European mistletoe belongs to the following families – Anobiidae (4 species), Anthribidae (2), Apionidae (1), Buprestidae (4), Cantharidae (1), Cerambycidae (6), Corylophidae (2), Curculionidae (1), Laemophloeidae (3), Melyridae (2) and Scolytidae (1).

In addition, the species *Cryptophagus intermedius, Dienerella filiformis* and *Melanophthalma rhenana* are here first time recorded for the fauna of Bulgaria. The first and the third species are noted first time from the Balkan Peninsula, as well. *Melanophthalma taurica* and *Berginus tamarisci* are two species that have been left unmentioned for the country in the latest catalogues about families Latridiidae and Mycetophagidae, in spite of both were earlier noted in other announcements. In this study the two species are confirmed for Bulgaria, with their first detailed data reported. The opportunity to deals with *B. tamarisci* incited us to make a checklist of the Bulgarian hairy fungus beetles which includes new and some re-published data.

Acknowledgements

The first author is thankful to Wolfgang Rücker (Neuwied, Germany) and Hans-Peter Reike (Moritzburg, OT Boxdorf, Germany) for the given literature and useful communication regarding the representatives of family Latridiidae.

References

Anonymous 1907 Collections du Musée d'Histoire Naturelle de Son Altesse Royale Ferdinand I Prince de Bulgarie. Sofia, xiv + 484 pp.

Assyov B., Petrova A., Dimitrov D., Vassilev R. 2012 Conspectus of the Bulgarian vascular flora. Bulgarian Biodiversity Foundation, 489 pp. (In Bulgarian)

Bekchiev R., Antov M., Boyadzhiev P., Zaemdzhikova G., Kostova R., Guéorguiev B. 2022 *Carabus variolosus* (Fabricius, 1787) (Coleoptera: Carabidae) in Bulgaria: rediscovered after 111 years. Historia naturalis bulgarica 44 (10): 119–123. https://doi.org/10.48027/hnb.44.103

Guéorguiev B. 2011 Biodiversity of beetles (Insecta: Coleoptera) in chestnut forests, Belasitsa Mountain. In: Zlatanov T., Velichkov I., Nikolov B. (eds) State and prospects of the *Castanea sativa* population in Belasitsa mountain: climate change adaptation; maintenance of biodiversity and sustainable ecosystem management. Project BG 0031 EEA report: 1–17.

Guéorguiev B., Ljubomirov T. 2009 Coleoptera and Hymenoptera (Insecta) from Bulgarian Section of the Maleshevska Planina Mountain: Study of an

Until Recently Unknown Biodiversity. Acta zoologica bulgarica 61 (3): 235–276.

Háva J. 2021 Additions and corrections of the family Mycetophagidae (Insecta: Coleoptera) from the Catalogue of Palaearctic Coleoptera, Volume 5 – Tenebrionoidea, 2020. Natura Somogyiensis 36: 11–14.

Háva J. 2022 World Catalogue of Mycetophagidae (Coleoptera: Tenebrionoidea). Studies and Reports Taxonomical Series 18 (2): 287–331.

Joakimov D. 1904 Prinos kam Balgarskata fauna na nasekomite – Insecta. I. Coleoptera. Tvardokrili. Brambari. Sbornik za umotvorenia, nauka i knizhnina, Sofia 20 (9): 1–43. (In Bulgarian)

Johnson C. 2007 Latridiidae. In Löbl I., Smetana A. (eds) Catalogue of Palaearctic Coleoptera, vol. 4. Apollo Books, Stenstrup, pp. 74–80, 635–648.

Kahle-Zuber D. 2008 Biology and evolution of the European mistletoe (*Viscum album*). Doctoral Thesis, 112 pp.
https://doi.org/10.3929/ethz-a-005728816

Lawrence J.F., Escalona H.E., Leschen R.A.B., Ślipiński A. 2014 Review of the genera of Mycetophagidae (Coleoptera: Tenebrionoidea) with descriptions of new genera and a world generic key. Zootaxa 3826 (1): 195–229.

Leschen R.A.B. 2000 Beetles feeding on bugs (Coleoptera, Hemiptera): repeated shifts from mycophagous ancestors. Invertebrate Taxonomy 14: 917–929.

Markovich A. 1909 Prinos za nasekomnata fauna v razgradskata okolnost. Sbornik za umotvorenia, nauka i knizhnina, Sofia 25 (7): 3–20. (In Bulgarian)

Míka P. 2023 *Melanophthalma rhenana* Rücker & Johnson, 2007 from the Czech Republic (Coleoptera: Latridiidae). Studies and Reports Taxonomical Series 19 (1): 199.

Netolitzky F. 1912 Eine Sammelreise nach Bulgarien. Koleopterologische Rundschau 1: 137–143, 156–163.

Nikitsky N. 2013 Mycetophagidae. In: Audisio P. Fauna Europaea: Coleoptera 1, Beetles. Fauna Europaea version 2017.06.
https://fauna-eu.org

Otero J.C., Johnson C. 2013 Species of *Cryptophagus* Herbst, 1792, belonging to the “*dentatus* group” (Coleopera: Cryptophagidae) from the Western Palearctic region. Entomolologia Fennica 24: 81–93.

Palm T. 1966 På koleopterologiska excursioner vid Bulgariens Svarta havskust. Entomologisk Tidskrift 87: 5–22.

Roubal J. 1931 Fragmente zur Koleopterfaunistik des balkanischen Festlands. Entomologischer Anzeiger 11: 437-438, 453-454.

Rücker W.H. 1982 Zur Verwandtschaft von *Melanophthalma distinguenda* (Comolli). Entomologische Blätter 78 (2–3): 79–80.

Rücker W.H. 2013 Latridiidae. In: Audisio P. Fauna Europaea: Coleoptera 1, Beetles. Fauna Europaea version 2017.06.
https://fauna-eu.org

Rücker W.H. 2020 Latridiidae und Merophysiidae der West-Paläarktis. 2. Auflage. Selbstverlag Wolfgang H. Rücker, Neuwied, 748 pp.

Rücker W.H., Johnson C. 2013 Revision of *Melanophthalma taurica* (Mannerheim, 1844) species-group and description of three new species (Coleoptera: Latridiidae). Lartidiidae 5: 11–24.

Thomas P.A., Dering M., Giertych M.J., Iszkuło G., Tomaszewski D., Briggs J. 2023 Biological Flora of Britain and Ireland: *Viscum album*. Journal of Ecology 111 (3): 701–739.
https://doi.org/10.1111/1365-2745.14036

Historia naturalis bulgarica 45 (7): 187–196
ISSN 2603-3186 (online) | ISSN 0205-3640 (print) · nmnhs.com/historia-naturalis-bulgarica
https://doi.org/10.48027/hnb.45.073
Publication date [online]: 3 July 2023

Research article

Ground beetle (Coleoptera: Carabidae) taxocoenoses from high-altitude *Pinus peuce* and *Pinus heldreichii* forests in Bulgaria

Rumyana Kostova[1], Rostislav Bekchiev[2]

(1) Department of Zoology and Anthropology, Faculty of Biology, Sofia University, 8 Dragan Tsankov Bvld, 1000 Sofia, Bulgaria, rkostova@biofac.uni-sofia.bg; https://orcid.org/0000-0002-8119-3275
(2) National Museum of Natural History, Bulgarian Academy of Sciences, 1 Tsar Osvoboditel Blvd, 1000 Sofia, Bulgaria, bekchiev@nmnhs.com; https://orcid.org/0000-0001-6143-0184

Abstract: The sensitivity of ground beetles to changing habitat conditions makes them a good indicator of environmental change. The shift in their distribution could be used as an early warning signal for natural disturbances due to climate change. To reflect and monitor these changes, initial information is needed on carabid taxa in different high-altitude habitats, including the endemic and climate-sensitive tertiary relict coniferous forests of *Pinus peuce* (Macedonian pine) and *Pinus heldreichii* (Bosnian pine). Data on the carabid beetles in the different coniferous habitats in Bulgaria are scattered in various faunistic or taxonomic publications, and there is no exact information about their taxocoenoses in the Macedonian and Bosnian pine habitats. The present study aims to clarify the species composition and diversity patterns of ground beetles in these habitats in Bulgaria. Six sample sites were selected: five natural forest stands in the Rila Mts and Pirin Mts and one forest plantation in the Vitosha Mts. A total of 18 species and subspecies typical of forest habitats were recorded. Five of them were endemic to Bulgaria and five to the Balkan Peninsula. The most common species and the eudominant in the majority of the sample sites was *Calathus metallicus aeneus*. The exception was one of the Bosnian pine sample sites. Here, the dominant species was *Xenion ignitum*. The ground beetle species found in the studied forests were mostly zoophagous, mainly crevice or burrowing stratobionts in leaf litter, rocks and soil, a few epigeobionts, one botrobiont and one mixophytophagous geohrotobiont. The classification of the carabid taxocoenoses according to their qualitative composition showed two main clusters: the first being the carabids from the studied sites of the Vitosha and Rila Mts, and the second being the taxocoenoses from the Pirin Mts. The Bosnian pine habitats provide more favourable conditions for the high-altitude ground beetles, where they are in a state of equilibrium with higher species richness and evenness compared to those inhabiting the Macedonian pine forests. The forest communities of *Pinus peuce* and *Pinus heldreichii* in Bulgaria are of high conservation importance for the ground beetle and an even higher level of protection of these habitats is required.

Keywords: Balkan Peninsula, biodiversity, Bosnian pine, Bulgaria, endemics, ground beetles, Macedonian pine, relicts

Introduction

Carabid beetles are highly sensitive to changing habitat conditions and are good indicators of the ecosystem state (Niemelä, 2000; Rainio & Niemelä, 2003; Avgin & Luff, 2010; Koivula, 2011; Kotze et al., 2011). The species distribution of ground beetles at high altitudes depends mostly on the climate and soil conditions, as they respond to variations in temperature and moisture (Thiele, 1977; Fuller et al., 2008). In this context, the shifts in their distribution could be used as an early warning signal for natural disturbances due to climate change (Koivula, 2011; Zou Yu et al., 2014). To reflect on and monitor these changes, initial information on carabid species composition in different high-altitude habitats is needed. Such habitats of biogeographical and conservation importance are the coniferous forests dominated by tertiary relict Macedonian pine *Pinus peuce* (Balkan endemic) and Bosnian pine *Pinus heldreichii* (Balkan-Apennine endemic) in Bulgaria. Both species form specific monodominant or mixed (mainly the Macedonian pine, very limited the Bosnian pine) forest phytocoenoses (EUNIS code T39) between 1400–2200 m a.s.l., often at the timberline in the highest mountains in Bulgaria (Rusakova, 2015; Rusakova & Valchev, 2015). *P.*

Received: 22 May 2023; accepted: 16 June 2023 · Editor: Nikolay Simov

peuce forests are distributed mainly in the Rila and Pirin mountain ranges and in a very limited area in the Stara Planina Mountains, while the *P. heldreichii* forests are distributed in the Pirin and Slavyanka Mountains. These habitats are sensitive and under threat from climate change, logging and other anthropogenic pressures. In the Red Data Book of the Republic of Bulgaria, their status was assessed as 'Endangered' (for the Macedonian pine forests) and 'Vulnerable' (for the Bosnian pine forests) (Rusakova, 2015; Valchev & Rusakova, 2015). *P. peuce* and *P. heldreichii* forests in Bulgaria are protected by Bulgarian biodiversity law and are listed in Annex I of Habitat Directive 92/43/EEC (Code 95A0). A large territory of the forests in Bulgaria is situated in protected areas: Rila, Pirin and Central Balkan National Parks, including some Natural Reserves (Rila: Skakavitsa, Central Rila Reserve, Ibar; Pirin: Bayuvi Dupki-Dzhindzhiritsa, Yulen; Slavyanka: Ali Botush) and NATURA 2000 sites. Attempts have been made in the past to reforest deforested parts of various mountains with these tree species to protect them against erosion and snow drifts on high-altitude mountain roads. One of the oldest and largest forest plantations of *Pinus peuce* is located in Vitosha Mts, a natural park. The mountain was almost completely deforested by the beginning of the 20th century. The natural Macedonian pine forests in Vitosha were completely destroyed and reduced to only 30 trees (Penev, 1942). Then a large-scale afforestation was carried out (Biolchev, 1941). The planting of *P. peuce* was a successful attempt to reintroduce the species to the region.

The information on the carabid beetle taxocoenoses in the Macedonian and Bosnian pine coniferous habitats in Bulgaria is scattered in various faunistic or taxonomic publications, often giving notes only about the altitude or forest belt of the three mountains. The known number of species of ground beetles that reach 1800–2000 m above sea level in the three mountains is as follows: 122 from Rila Mts, 97 from Pirin Mts, and 95 from Vitosha Mts (Guéorguiev & Guéorguiev, 1995). Sakalian and Guéorguiev (1997) listed the endemic species of the Pirin but did not specify the exact type of their habitat. The most recent information on high-altitude endemic carabids in the Rila and Pirin Mts was published by Donabauer (2020), but the material was collected mainly from the rocky part and *Pinus mugo* forests of the subalpine zone, and from one locality with *Picea abies* forest. A few studies provide characteristics of ground beetle assemblages in coniferous forests dominated by *Picea abies* and *Pinus silvestris*. Krusteva et al. (1995), using gradient analysis, determined the direct negative effect on carabids of lowering the temperature and decreasing the productivity of the near-ground vegetation layer under a dense spruce canopy in Vitosha Mts. A total of 20 species were found in the old spruce forest of the Mantaritsa Nature Reserve (Rhodope Mts) (Kostova, 2009; Teofilova, 2017). The eudominant species were *Molops dilatatus* Chaudoir, 1868, *Calathus metallicus aeneus* Putzeys, 1873, *Carabus violaceus azurescens* Dejean, 1826, and *Cychrus semigranosus balcanicus* Hopffgarten, 1881 (Kostova, 2009). From the *Pinus sylvestris*-dominated forest near the Trite Buki Hut, Osogovo Mts, Guéorguiev (1996, 1999) reported a low taxon diversity of six species. Guéorguiev et al. (2003) reported *Dromius agilis* (Fabricius, 1787) as a new species for Vitosha Mts, collected from *Picea abies* forest in the Bistrishko Branishte Nature Reserve. The present study aims to clarify the species composition and diversity patterns of carabid beetles in the old growth forests of endemic and relict *Pinus peuce* and *Pinus heldreichii* in Bulgaria.

Material and methods

The following representative sample sites for the study were chosen: in Rila Mts: under Malyovitsa Hut (northern slope) and above Treshtenik Hut (southern slope); in Pirin Mts: near Banderitsa Hut, under Vihren Hut (Northern Pirin: eastern slope of Vihren Peak) and near Yavorov Hut (Northern Pirin: western slope of the circus Razlozhki Suhodol); in Vitosha: under Aleko Hut (north slope) (Figs 1 and 2, Table 1). The material was collected monthly during the period of July–September 2020 and May–July 2021 in the selected sites by pitfall traps: 500 ml containers filled up to 1/3 with propylene glycol as a conservant, set in a line by 10 at each site. The traps were set deep in the forests at least 50 m from the borders with other types of forest, semi-open or open habitats to avoid the edge effect. To standardise the data, the number of ground beetles captured, reflecting the ground beetle activity density, was converted into abundance: the number of individuals captured per 100 nights of trapping. The collected material was deposited at Sofia University Zoological Collection (BFUS).

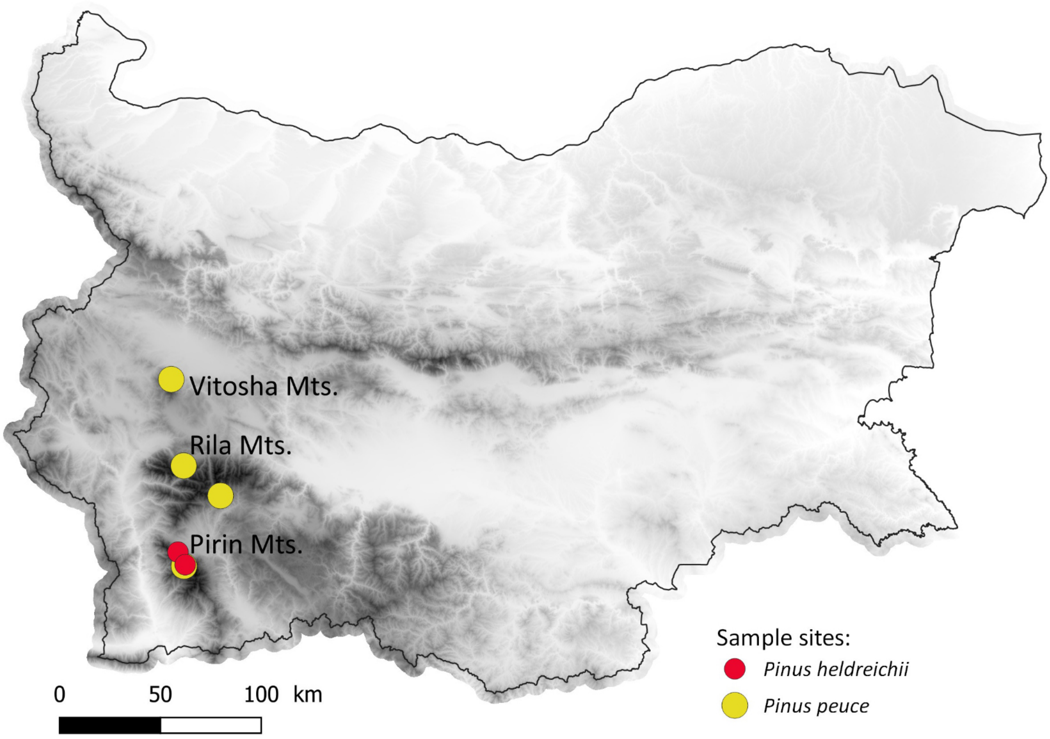

Fig. 1. Map of the studied sample sites with *Pinus peuce* and *Pinus heldreichii* forest stands in Bulgaria.

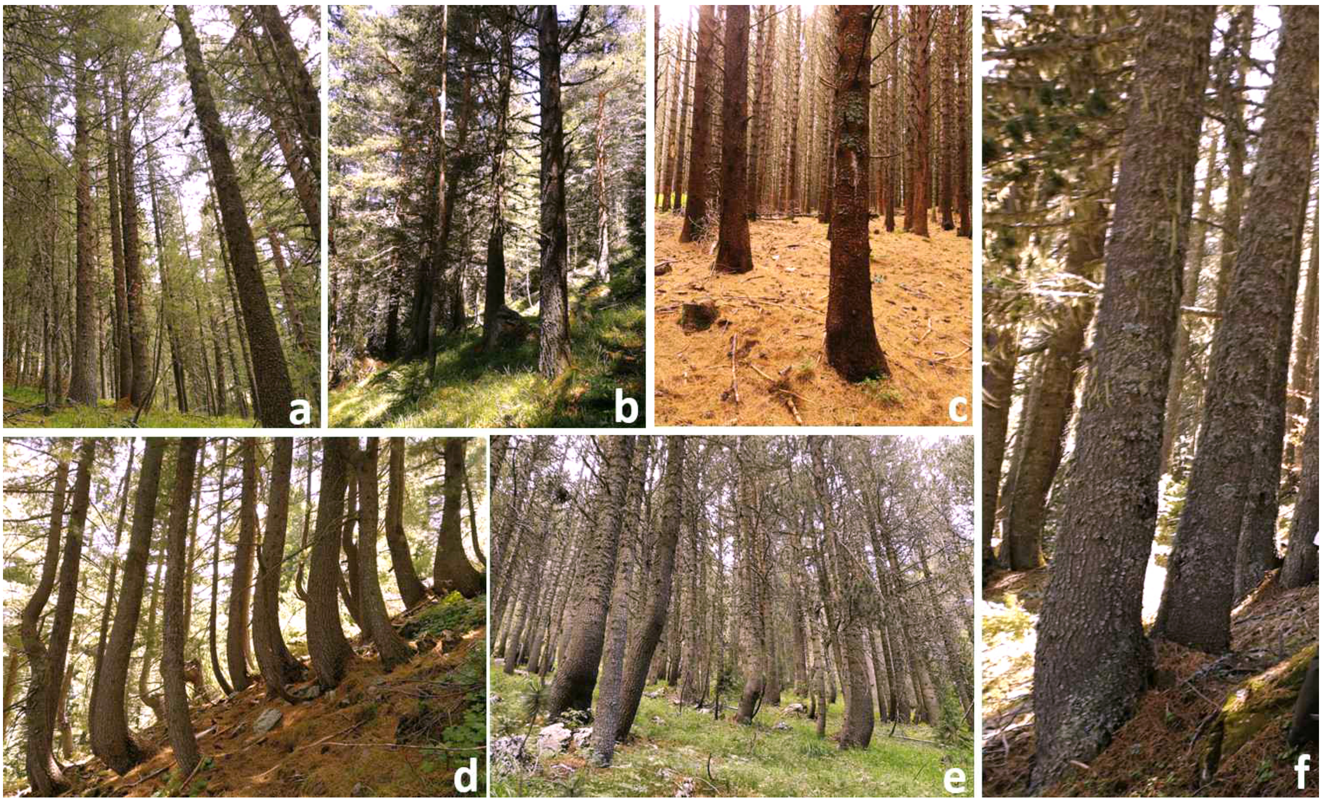

Fig. 2. Sample sites: *Pinus peuce* forests – (a) Treshtenik Hut, Rila Mts; (b) Malyovitsa Hut, Rila Mts; (c) Aleko Hut, Vitosha Mts; (d) Vihren Hut, Pirin Mts; *Pinus heldreichii* forests – (e) Banderitsa Hut, Pirin Mts; (f) Yavorov Hut, Pirin Mts.

Table 1. Studied sample sites and some of their main characteristics (accessed at Forest Database of the Bulgarian Forest Executive Agency).

No.	Mountain	Sample site	Coordinates	Altitude (m)	Forest-forming tree species	Age (years)	Inclination (°)	Substrate base
1	Rila	Malyovitsa Hut	42.208961° 23.390046°	1760	*Pinus peuce* 50% : *Pinus sylvestris* 30% : *Picea abies* 20% : *Abies alba* single trees	100	42	Silicate
2		Treshtenik Hut	42.082165° 23.618036°	1915	*Pinus peuce* 80% : *Pinus sylvestris* 10% : *Picea abies* 10%	90	28	Silicate
3	Pirin	Vihren Hut	41.761884° 23.416967°	1969	*Pinus peuce* 80% : *Pinus sylvestris* 10% : *Picea abies* 10%	140	33	Carbonate rocks
4		Banderitsa Hut	41.768033° 23.423944°	1876	*Pinus heldreichii* 80% : *Pinus sylvestris* 10% : *Picea abies* 10%	140	35	Carbonate rocks
5		Yavorov Hut	41.823000° 23.377267°	1716	*Pinus heldreichii* 60% : *Pinus sylvestris* 40%	100	32	Carbonate rocks
6	Vitosha	Aleko Hut	42.591967° 23.292617°	1814	*Pinus peuce* 90% : *Picea abies* 10% (culture)	80	25	Silicate

The following indices were used to analyse α-diversity in the studied habitats:, Pielou's evennes, Hill's diversity and Simpson's concentration of dominance (λ). Taxonomic similarity was calculated using Sørensen's index and represented graphically by a dendogram using the unweighted pair group method with arithmetic mean (UPGMA) (Sokal & Michener, 1958). PRIMER 7 (PRIMER-e, Quest Research Limited) software was used for the analyses and QGIS for generating a map.

Results

A total of 692 carabid beetle specimens were collected from *Pinus peuce* and *Pinus heldreichii* forests during the field studies in Rila, Pirin and Vitosha Mts. Eighteen species and subspecies typical of forest habitats were recorded. Five of them were endemic to Bulgaria and five to the Balkan Peninsula (Table 2).

As expected, the estimated number of ground beetle species was relatively low. However, the carabids were more abundant and diverse in *P. heldreichii* forests than in natural *P. peuce* forests. A species common to all sites was *Calathus metallicus aeneus*. The species of ground beetles found in the studied forests were predators, mainly crevice or burrowing stratobionts in the leaf litter, rocks and soil, a few epigeobionts of the genera *Calosoma, Carabus* and *Cyhrus,* one botrobiont (*Laemostenus terricola*) and one mixophytophagous geohrotobiont (*Harpalus rufipalpis*). Classification of the life forms followed Sharova (1981).

A taxonomically interesting specimen of the genus *Tapinopterus* was found in the sample site of *Pinus peuce* near the Vihren Hut (Pirin Mts), which does not fit the descriptions of any of the known Bulgarian taxa. Further study of this genus will be necessary after the collection of more material and the publication of the expected revision of the group by Giachino, Picciau, Vailati and Casale (Gueorguiev, personal communication).

In three of the Macedonian pine sample sites – Pirin – Vihren Hut, Rila – Malyovitsa Hut and Rila – Treshchenik Hut, there was one strongly dominant species: *C. metallicus aeneus,* represented respectively by 85%, 81% and 67% of all collected specimens (Figs 3 and 4). In the fourth, the Macedonian pine forest plantation in Vitosha Mts, two species dominated almost equally: *P. rhilensis* (46%) and *C. metallicus* (43%). In the Bosnian pine forests of the

Table 2. List of the Carabidae species recorded from the high-altitude Macedonian and Bosnian pine forests in Bulgaria. *Bulgarian endemics; **Balkan endemics.

Species/Coniferous community	Rila Mts		Pirin Mts			Vitosha Mts
	Malyovitsa Hut	Treshtenik Hut	Vihren Hut	Yavorov Hut	Banderitsa Hut	Aleko Hut
	Pinus peuce	*Pinus peuce*	*Pinus peuce*	*Pinus heldreichii*	*Pinus heldreichii*	*Pinus peuce* (culture)
***Calathus metallicus aeneus* Putzeys, 1873	+	+	+	+	+	+
Calosoma inquisitor Linnaeus, 1758					+	
Carabus coriaceus cerisyi Dejean, 1826				+	+	
Carabus hortensis Linnaeus, 1758					+	+
***Carabus violaceus azurescens* Dejean, 1826	+			+	+	+
***Cyhrus semigranosus balcanicus* Hopffgarten, 1883						+
Harpalus rufipalpis Sturm, 1818		+				
Laemostenus terricola (Herbst, 1784)				+		
Leistus spinibarbis rufipes Chaudoir, 1843						+
**Molops alpestris rhilensis* Apfelbeck, 1904					+	
***Molops dilatatus dilatatus* Chaudoir, 1868					+	
**Molops rhodopensis kourili* Maran, 1942			+	+	+	
Notiophilus biguttatus (Fabricius, 1779)	+	+				+
**Pterostichus rhilensis* Rottenberg, 1874	+					+
**Tapinopterus balcanicus balcanicus* Ganglbauer, 1892		+	+		+	
Tapinopterus sp.			+			
**Trechus rhodopeius* Jeannel, 1921		+				+
***Xenion ignitum* (Kraatz, 1875)				+	+	

Pirin Mts, a high degree of evenness of the species abundance was found to exist, with a very slight predominance of *X. ignitum* in the Pirin – Yavorov Hut (43%) and *C. metallicus* in the Pirin – Banderitsa Hut (42%). Of all the coniferous sites studied, *C. coriaceus, C. hortensis* and *X. ignitum* (usually frequent species for the altitude) were only recorded in the Bosnian pine forests of Pirin and never in the Macedonian pine forests.

The ground beetles from the Bosnian pine forests in Pirin and from the forest plantation of Macedonian pine in Vitosha had the highest species richness, while those from the Macedonian pine forests in Rila – Malyovitsa Hut and Pirin – Vihren Hut had the lowest (Table 3). The Macedonian pine plantation in Vitosha was characterised by the highest ground beetle activity density, and the natural forest of Macedonian pine in Rila – Malyovitsa Hut and Bosnian pine in

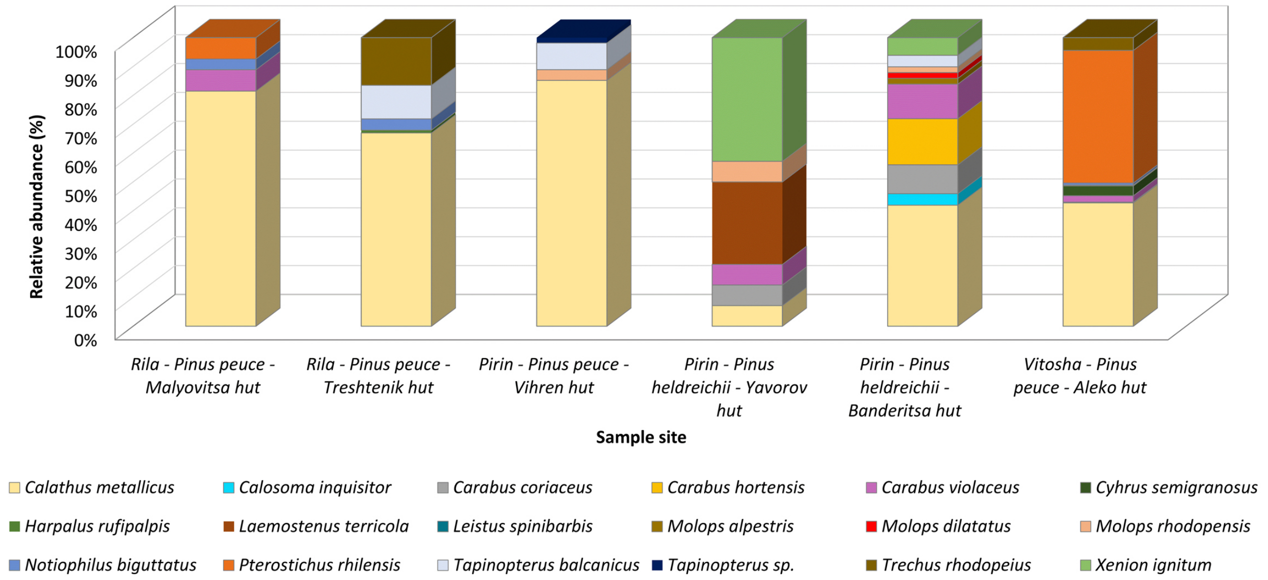

Fig. 3. Species composition and abundance of the ground beetles in the studied coniferous habitats.

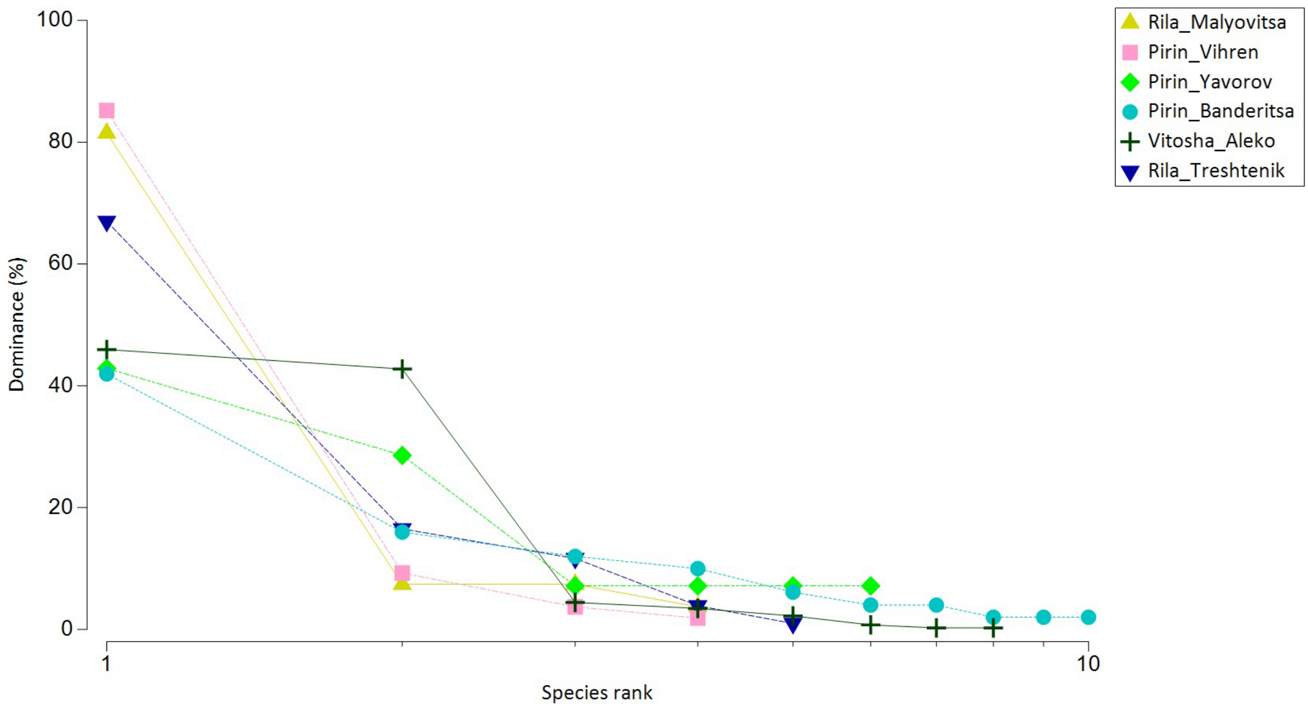

Fig. 4. Rank structure of the ground beetle taxocoenoses in the studied coniferous habitats.

Pirin – Yavorov Hut were characterised by the lowest activity density. Diversity indices showed that the carabid taxocoenose of *P. heldreichii* forests had the highest diversity and evenness of species. The *P. peuce* forest in Pirin – Vihren is characterised by the lowest diversity of ground beetles, low evenness and the presence of highly dominant species.

The classification of the carabid taxocoenoses by qualitative composition showed two main clusters: the first are ground beetles from the studied sites of

Table 3. Indices of α-diversity of the carabid taxocoenoses in the studied coniferous habitats.

Index	Rila Malyovitsa	Rila Treshtenik	Pirin Vihren	Pirin Yavorov	Pirin Banderitsa	Vitosha Aleko
Taxa number	4	5	4	6	10	8
Beetle number per 100 trap/days	6	11	11	5	7	45
Pielou's evenness	0.49	0.61	0.40	0.82	0.78	0.54
Hill's diversity N2	0.44	2.04	1.36	3.50	4.27	2.52
Simpson's dominance: λ'	0.62	0.44	0.71	0.12	0.11	0.38

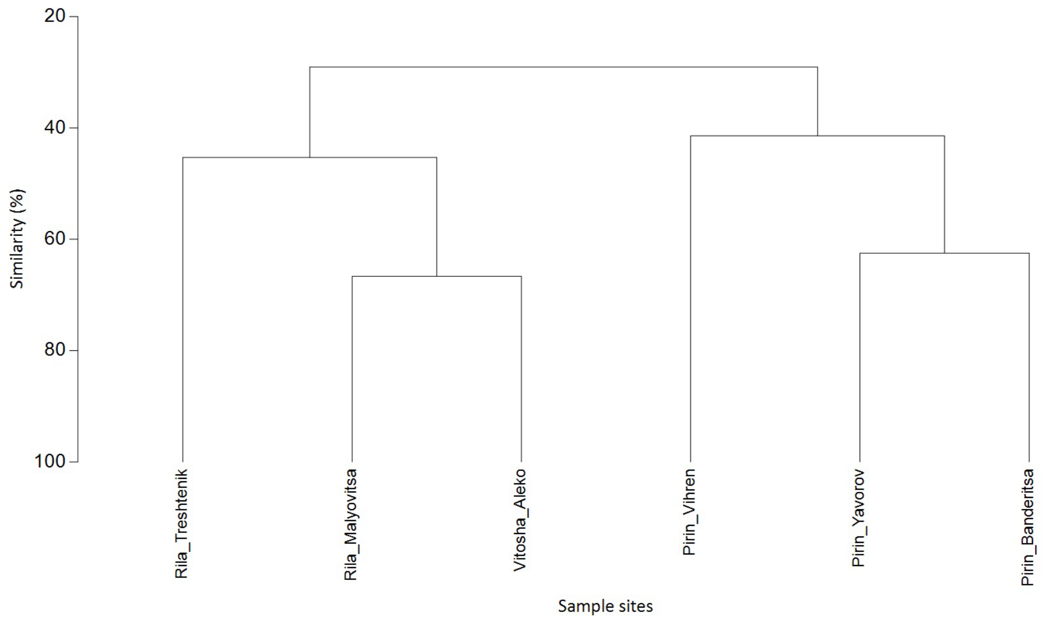

Fig. 5. Dendrogram of the taxonomic similarity of the ground beetles in the studied coniferous habitats. Sørensen index of similarity. UPGMA.

Vitosha Mts and Rila Mts (with the highest similarity being between Vitosha – Aleko Hut and Rila – Malovytsa Hut 67%) and the second one was formed by the taxocoenoses from Pirin Mts (with the highest similarity being between Pirin – Yavorov Hut and Pirin – Banderitsa Hut 63%) (Fig. 5).

Discussion

The results obtained showed an expected low number of taxa of the family Carabidae since the number of carabid taxa decreases with increasing altitude (Krusteva et al., 1995; Guéorguiev & Sakalian, 1997). In addition, carabids are often more numerous and species-rich in open habitats than in forests (Halme & Niemelä 1993; Koivula, 2011). Although the taxonomic diversity was low, the results showed a specificity of the ground beetle complexes in the Macedonian and Bosnian pine communities. The species found are characteristic of the high altitudes of the three mountains, but the coenoses they form are unique. The plant communities, with their different canopies, undergrowth, leaf litter layers and moisture levels, are the main reasons for the ground beetle arrangement (Kostova, 2009). Due to the particular sensitivity of carabids to soil moisture (Ludwiczak et al., 2020), major reasons for differences in the species composition at even closely spaced stationary sites, such as those of Macedonian and Bosnian pine in the Pirin Mountains, are the differences in the soil drainage due to the slope, the soil layer thickness, and the substrate rock beneath. The two main clusters in the taxonomic similarity analysis also showed the relationship of the carabid assemblages to the substrate type – the first representing the taxocenoses from Rila and Vitosha on a silicate substrate and the second representing the taxocenoses from Pirin on a carbonate substrate. In addition to the substrate and habitat type, the similarity of the taxa from Rila – Malyovitsa and Vitosha – Aleko may also be related to the origin of the seedlings for the Vitosha culture, which are very likely to be from Rila Mts (Georgiev, personal communication). Bosnian pine forests stand on a thicker layer of soil, which is well drained but not as dry and rocky, and have richer undergrowth than Macedonian pine forests. They provide more favourable conditions for communities of high-altitude ground beetles, where they are in a state of equilibrium with higher species richness and evenness than those of Macedonian pine. The low number of carabid species and the presence of a highly dominant species in the Macedonian pine communities are probably due to the unfavourable environmental conditions caused by the high slope and thin soil layer, leading to rapid loss of surface moisture after snowmelt and rain. This is especially true for Macedonian pine forests on carbonate bedrock, such as the Pirin – Vihren sample site (Dimitrov, 2005). In Vitosha, the old forest plantation of *Pinus peuce* is located on a relatively thicker layer of soil and provides, although not by much, a higher species richness of carabid beetles than the natural stands of the same tree species.

Calathus metallicus aeneus is dominant in most Bulgarian alpine and subalpine carabid taxocoenoses (Guéorguiev, 2007). It was confirmed as eudominant in most of the Macedonian and Bosnian pine habitats in our study; it was only in the Bosnian pine forest from the Yavorov Hut area that it was in lower abundance than *X. ignitum*. In the spruce forest in Mantaritsa Nature Reserve, the eudominants differ – *M. dilatatus* and *C. violaceus azurescens*. However, *C. metallicus aeneus, C. semigranosus balkanicus* and *X. ignitum* were also dominant but in significantly lower numbers (Kostova, 2009). With 9 common species, the ground beetle community of *P. heldreichii* of Pirin – Banderitsa Hut showed the closest taxonomic structure of the carabid beetle communities to that of the spruce forest in the Mantaritsa Nature Reserve, reported by Kostova (2009). In both habitats, there was also a high evenness of the ground beetle species. Hill's index of diversity showed almost the same value in both coenoses: N2 = 4.25 for the Bosnian pine forest and N2 = 4.78 for the spruce forest. The life forms' structure of the ground beetle taxocoenoses in the Macedonian and Bosnian pine forests is typical of forest ecosystems with prevailing stratobionts and epigeobionts, both in terms of species number and abundance (Sharova, 1981; Solodovnikov, 2008; Kostova, 2009).

In the Balkans, mountains higher than 2000 m above sea level serve as both refugia and centres of ongoing speciation for the carabid beetles (Guéorguiev, 2007). As one of the typical high-altitude forest habitats in Rila, Pirin and Vitosha Mountains, the studied Bosnian and Macedonian pine endemic and relict forests contain a significant part of the high mountain diversity of endemic and relict ground beetle species in the Balkans. The Balkan and Bulgarian endemics comprised 56% of the total number of carabid beetle species found in the studied habitats. The great conservation significance of the *Pinus peuce* and *Pinus heldreichii* forest communities in Bulgaria for ground beetles is obvious. These communities are very vulnerable to environmental disturbances, including climate change. Both types of trees are adversely affected by drought conditions in the summer and cold winter. The growth of *P. peuce* is dependent on summer temperatures, while that of P. *heldreichii* is dependent on the amount of summer rainfall, with both tree species being negatively affected by dry summer and cold winter conditions (Panayotov et al., 2010). These factors must be relatively stable over time for forests to maintain the necessary microhabitat conditions for the existence of carabid taxocenoses in them. In addition, a major anthropogenic threat is the fragmentation and direct destruction of these Bulgarian forests by logging, as they are often subjects of investment interest (especially in Pirin and Rila Mts) and need even stricter protection.

Acknowledgements

The study was supported by the Bulgarian Science Fund (Grant KP-06-N36/13/17.12.2019). The authors are thankful to Sevdalin Belilov (Forestry Institute – BAS) for the access to National Forestry database information. The authors thank Tsvetelina Tsvetanova, student at Faculty of Biology, Sofia University for pinning a part of the ground beetle material and for digitising the reference collection from the study.

References

Avgın S.S., Luff M.L. 2010 Ground beetles (Coleoptera: Carabidae) as bioindicators of human impact. Munis Entomology & Zoology 5 (1): 209–215.

Biolchev A. 1941 Zalesyavaniata na Vitosha i ski turizmat. Spisanie Balgarski turist 2. (In Bulgarian) https://www.360mag.bg/posts/118592

Dimitrov M. 2005 Macedonian and Bosnian Pines Forest. In: Kavrakova V., Dimova D., Dimitrov M., Tsonev R., Belev T. (eds) Guide for the designation of the habitats of European importance in Bulgaria. WWF, Danube – Carpathian Program and Zeleni Balkani, 102. (In Bulgarian)

Donabauer M. 2020 A contribution to the knowledge of the endemic and subendemic Carabidae (Coleoptera) from the Rila and Pirin mountain ranges in Bulgaria. Zeitschrift der Arbeitsgemeinschaft Österreichischer Entomologen 72: 95–107.

Fuller R., Oliver T., Leather S. 2008 Forest management effects on carabid beetle communities in coniferous and broadleaved forests: implications for conservation. Insect Conservation and Diversity 1: 242–252. https://doi.org/10.1111/j.1752-4598.2008.00032.x

Guéorguiev B. 1996 A contribution to the study of the ground-beetle fauna (Coleoptera, Carabidae) from the Osogovo Mountain. I. Historia naturalis bulgarica 6: 29–35.

Guéorguiev, B. 1999 Contribution to the study of the ground-beetle fauna (Coleoptera: Carabidae) of the Osogovo Mountain, Bulgaria. III. Historia naturalis bulgarica 10: 67–76.

Guéorguiev B. 2007 Biogeography of the Endemic Carabidae (Coleoptera) in the Central and Eastern Balkan Peninsula. In: Fet V., Popov A. (eds) Biogeography and Ecology of Bulgaria, Springer, 297–356.

Guéorguiev B., Georgiev G., Mirchev P., Tsankov G. 2003 Four New Coleopteran species (Coleoptera: Carabidae) for Bistrishko Branishte Biosphere Reserve in the Vitosha Mountain, Bulgaria. Acta zoologica bulgarica 55 (1): 107–112.

Guéorguiev V., Guéorguiev B. 1995 Catalogue of the ground-beetles of Bulgaria Coleoptera: Carabidae). Pensoft Publishers, Sofia–Moscow, 279 pp.

Guéorguiev B., Sakalian V. 1997 Vertical distribution of Carabinae (Coleoptera, Carabidae) in Bulgaria. Acta zoologica bulgarica 49: 52–57.

Halme E., Niemelä J. 1993 Carabid beetles in fragments of coniferous forest. Annales Zoologici Fennici 30 (1): 17–30.

Koivula M. 2011 Useful model organisms, indicators, or both? Ground beetles (Coleoptera, Carabidae) reflecting environmental conditions. ZooKeys 100: 287–317. https://doi.org/10.3897/zookeys.100.1533

Kostova R. 2009 Ground Beetles (Coleoptera: Carabidae) in Two Biosphere Reserves in the Rhodope Mountains, Bulgaria. Acta zoologica bulgarica 61 (2): 187–196.

Teofilova T. 2017 A contribution to the study of ground beetles (Coleoptera: Carabidae) in the Western Rhodope Mts. (Bulgaria). Journal of BioScience and Biotechnology 6: 203–209.

Kotze D.J., 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. In: Kotze D.J., Assmann T., Noordijk J., Turin H., Vermeulen R. (eds) Carabid Beetles as Bioindicators: Biogeographical, Ecological and Environmental Studies. ZooKeys 100: 55–148. https://doi.org/10.3897/zookeys.100.1523

Krusteva I., Popov V., Sakalian V. 1995 Indirect gradient analysis of carabid (Coleoptera, Carabidae) spatial pattern. In: Third National Scientific Conference on Entomology, 18–20 September 1995, Sofia, pp. 55–59.

Ludwiczak E., Nietupski M., Kosewska A. 2020 Ground beetles (Coleoptera; Carabidae) as an indicator of ongoing changes in forest habitats due to increased water retention. PeerJ 8: e9815. https://doi.org/10.7717/peerj.9815

Niemelä J. 2000 Biodiversity monitoring for decision-making. Annales Zoologici Fennici 37: 307–317.

Panayotov M., Trouet V., Bebi P., Yurukov S. 2010 Climate signals in *Pinus peuce* and *Pinus heldreichii* tree-ring chronologies from the Pirin Mountains in Bulgaria. Trees 24: 479–490. https://doi.org/10.1007/s00468-010-0416-y

Penev N. 1942 Izuchavania varhu estestvenoto razprostranenie na byalata mura (*Pinus peuce* Griesb.) vav Vitosha. Lesovadska misal 2/3: 101–112. (In Bulgarian)

Rainio J., Niemelä J. 2003 Ground beetles (Coleoptera: Carabidae) as bioindicators. Biodiversity and Conservation 12: 487–506. https://doi.org/10.1023/A:1022412617568

Rusakova V. 2015 Macedonian pine (*Pinus peuce*) forests. In: Biserkov V., Gussev Ch., Popov V., Hibaum G., Roussakova V., Pandurski I., Uzunov Y., Dimitrov M., Tzonev R., Tsoneva S. (eds) Red Data Book of the Republic of Bulgaria. Volume 3. Natural habitats. BAS & MoEW, Sofia, pp. 358–360.

Sakalian V., Guéorguiev B. 1997 Coleoptera. In: Sakalian V. (ed.) Endemic and relict insects in the Pirin National Park, Bulgaria. Pensoft Publishers, Sofia–Moscow, pp. 45–58.

Sharova I. 1981 Life form of carabids (Coleoptera, Carabidae). Nauka Publishers, Moscow, 360 pp. (In Russian)

Sokal R., Michener C. 1958 A Statistical Methods for Evaluating Relationships. University of Kansas Science Bulletin 38: 1409–1448.

Solodovnikov I.A. 2008 Zhuzhelitsui (Coleoptera, Carabidae) Belorusskovo Pooezerya. In: Katalogom vidov zhuzhelits Belarusi i sopredelnih gosudarstv. UO 'VGU im. PM. Masherov', 325 pp. (In Russian)

Thiele H.U. 1977 Carabid beetles in their environments. Zoophysiology and ecology 10, Springer-Verlag, Berlin, Heidelberg, 385 pp.

Valchev V., Rusakova V. 2015 White-barked pine (*Pinus heldreichii*) forests. In: Biserkov V., Gussev Ch., Popov V., Hibaum G., Roussakova V., Pandurski I., Uzunov Y., Dimitrov M., Tzonev R., Tsoneva S. (eds) Red Data Book of the Republic of Bulgaria. Volume 3. Natural habitats. BAS & MoEW, Sofia, pp. 356–357.

Zou Y., Sang W., Zhou H., Huang L., Axmacher J.C. 2014 Altitudinal diversity patterns of ground beetles (Coleoptera: Carabidae) in the forests of Changbai Mountain, Northeast China. Insect Conservation and Diversity 7: 161–171. https://doi.org/10.1111/icad.12039