

Review Article

Ant-Associated Beetle Fauna in Bulgaria: A Review and New Data

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The rich myrmecofauna in Bulgaria, comprising about 170 species, constitutes favorable settings for a diverse associated fauna. An attempt to summarize the fragmented faunal data on this ecological group in Bulgaria, together with inclusion of new data, has resulted in a comprehensive list of 121 beetle species from 14 families, obligate or facultative ant related. The extent of current knowledge on the various beetle families, host specificity, the nature of relations between guests and their ant hosts, and the regional characteristics of the myrmecophilous fauna are discussed.

1. Introduction

The social organization of ants and the conditions found within their nests are favorable to a number of organisms that coexist with them. These guests are mainly arthropods, and they form a variety of relationships with their hosts. Some guests enter the nests, where they feed as predators, scavengers, temporary commensals, or as ecto- and endoparasites. Others, commonly known as myrmecophiles, are dependent on ant communities for the whole or part of their life cycle [1]. Beetles are one of the ant-associated fauna groups that are the richest in number of species [2, 3]. Studies on these specific multispecies interactions are of particular faunistic, ecological, and evolutionary interest.

The number of documented ant-associated species has been steadily increasing since the beginning of intensive research on the myrmecophilous fauna in the 19th century. Even in 1841 and 1844 Märkel [4, 5] published detailed lists of about 280 beetle species associated to ant nests in Europe. The first significant review was made by Wasmann [6], who reported a total of 1,177 myrmecophilous species in the world. Soon after this, the number grew to a total of 1,500, of which 1,000 species are beetles [1]. Nearly a century later, Wilson [7], and after that Hölldobler and Wilson [2], listed 35 beetle families all over the world documented to have links with ants.

According to the latest taxonomic changes in Coleoptera, there are actually only 28 such families [8], but the families with myrmecophilous members expand their range. Here, we should add the first recently established myrmecophilous member of Buprestidae family [9]. Currently, it is estimated that the number of the ant-associated insects is not less than 10,000 species [10].

The diversity of ant-related fauna is closely connected with nest size [2, 11]. As a rule, larger colonies exist for longer and offer a wider variety of ecological niches that are useful to more guests. For these reasons, in the Palaearctic, the highest species richness of guests is found in the mound-building ants of the *Formica* genus and also in the *Lasius* species, which nest in tree trunks [2, 11–13].

There is a great variety of associated beetle species and a multitude of combinations of features from different behavioral categories that they might display. Different classifications have been suggested to describe the relationships between ants and their guests (e.g., [1, 6, 14–16]). Additionally, the natures of their relationships with ants are often not understood. For these reasons, I am using the broadly accepted definition of myrmecophiles, that is, that they are closely associated with ants and their nests and usually not found outside the ants' nests.

2. Ant-Associated Beetles in Bulgaria: A List with Comments

Bulgarian species of myrmecophilous beetles have not been thoroughly investigated, with the exception of a few faunistic contributions. Most data comes from single publications on specific beetle families, with information on their hosts frequently missing. Information about beetles associated with ants was found in 58 scientific publications, with 10 being devoted entirely to the Bulgarian myrmecophilous species.

The geographic location of Bulgaria in Southern Europe, the combination of typical temperate continental and transitional-Mediterranean climates, its diverse topography with inclination from sea level to 2925 m above sea level, and the presence of a diverse ant fauna of nearly 170 species [17, 18] suggest the presence of a rich myrmecophilous fauna.

A review of the current data on ant-associated beetles in Bulgaria will extend our knowledge on the degree about to which this specific ecological group has been studied.

The prepared list (Table 1) contains beetle species found in ants' nests in Bulgaria based on literature sources and new data. Some species are well-known myrmecophiles from other countries, even though ant hosts and nest collection are not always recorded from Bulgaria. Other parts of the beetle species collected from ants' nests in Bulgaria occur also in habitats outside them but regularly or accidentally enter into the ant' nests. Ant host species are also listed, with corresponding references, where information is available. Species that are widely accepted as typical inhabitants of ants' nests without using of subdivisions according to different classifications are highlighted as myrmecophiles. The beetle list is arranged using the classification proposed by Bouchard et al. [8], and the arrangement of species within the families is given by subfamilies.

2.1. Family Carabidae. Ground beetles from subfamily Paussinae are commonly known as “ant nest beetles” and “flanged bombardier beetles.” There are around 800 species, distributed mainly throughout the tropical and subtropical regions [76]. All 329 species in the genus *Paussus* (tribe Paussini) are myrmecophiles [77]. They prey on ant eggs, larvae and adults, piercing ants' bodies with mandibles and sucking out the fluid inside [10]. Extremely modified antennae with glandular hairs, secreting substances which ants lick, and the use of stridulatory organs are examples of adaptations that favor close integration with ant society.

Two species of the genus *Paussus* occur in Europe—*Paussus favieri* Fairmaire, 1851 and *P. turcicus* Frivaldszky von Frivald, 1835 [19]. The first of them occurs mainly in the Western Mediterranean. *P. turcicus* was described from the territory of Bulgaria, then still part of the Ottoman empire, and thus it is the first-known myrmecophilous species to be recorded in Bulgaria that is also distributed in Central Asia, the Middle East, Asia Minor, and the Balkans [78]. In Bulgaria, it is a rare species, located in the southern regions, and always found in the subterranean nests of its ant host *Pheidole pallidula* (Nylander, 1849) [21, 22], although it has also been collected from *Tetramorium semilaeve* Andre, 1883 and *Messor barbarus* (Linnaeus, 1767) nests [79].

2.2. Family Histeridae. Histeridae is worldwide in distribution with just under 4,300 known species, grouped into about 350 genera [80, 81], and reaches its highest diversity in the tropics. Both subfamilies Chlamydopsinae, mainly distributed in southern Asia, Pacific, and Australia, and Haeteriinae contain myrmeco- or termitophilous species. It is accepted that myrmecophiles feed on the larvae of ants or other insects or even regurgitated food from the host ants [2].

Haeteriinae is very rich in species, especially in the neotropics. In the Palaearctic it is represented by four genera *Eretmotus*, *Sternocoelis*, *Hetaerius*, and *Satrapes*, which include species living exclusively in ants' nests. *Eretmotus* and *Sternocoelis* are widespread in the Mediterranean region. Two species—*Sternocoelis merklia* (Schmidt, 1885) [26] with the ant *Messor structor* (Latreille, 1798) and *Haeterius ferrugineus* (Olivier, 1789), found in the nests of various *Formica* spp.—have been reported in Bulgaria so far [23, 25]. Unlike the wider distribution of *H. ferrugineus* in many European countries, *Sternocoelis merklia* also has been reported from several localities in Greece and Turkey [26].

In addition, it is the first time the presence of a member of the genus *Satrapes* is established in Bulgaria with the following collecting data.

Satrapes sartorii (L. Redtenbacher, 1857). Western Bulgaria, near Dolni Koriten vill., N422839 E223503, 889 m a.s.l., 10.04.2010: 1 specimen.

This rare species, more common in Central Europe [82], was found in a *Tetramorium* cf. *caespitum* (Linnaeus, 1758) nest under a stone in early spring. The sample locality is in a low-mountainous region with features determined by a typical temperate climate; hence, this finding was expected.

The fourth myrmecophilous member is a Dendrophilinae species—*Dendrophilus pygmaeus* (Linnaeus, 1758)—that typically occurs in the mound nests of *Formica*, which are built using plant materials [23, 24].

Two other species—*Acritus nigricornis* (Hoffmann, 1803) and *Onthophilus affinis* L. Redtenbacher, 1849—were also found with ants without being obligate inhabitants. The presence of *Acritus nigricornis* in ants' nests also was reported by Roubal [83] as well as in a termite nest of *Reticulitermes lucifugus* (Rossi, 1792) [84], but the presence of *Onthophilus affinis* may seem rather accidental.

2.3. Family Ptiliidae. Feather-winged beetles are among the smallest beetles, and, together with Staphylinidae, they can reach high numbers in ants' nests. Family Ptiliidae includes about 600 described species across some 80 genera [85]. In Europe, approximately 140 species of Ptiliidae are known [86]. Most species dwell in leaf litter and rotting organic matter in shady woodland areas, feeding on the spores and hyphae of fungi, as well as other organic food sources [86, 87].

Associations with ants range from an accidentally entering nests through to regular entry and strict myrmecophily. This has led to significant morphological changes in the subfamily Cephaloplectinae, known to inhabit America and Australia. There are a few ptiliid species in Europe which often inhabit ant nests, typically of species from the genera

TABLE 1: List of ant-associated beetles and their hosts (where data is available) according to the studied literature and new records. Facultative or undefined ant relations are not indicated.

Beetle families, genera, and species	Recorded ant hosts in Bulgaria	References	Ant-relation	Endemic beetles
Carabidae				
<i>Paussus turcicus</i> I. Frivaldszky von Frivald, 1835	<i>Pheidole pallidula</i> (Nylander, 1849)	[19–21] [22]	Myrmecophile	
Histeridae				
<i>Acrilus nigricornis</i> (Hoffmann, 1803)	<i>Formica rufa</i> Linnaeus, 1761	[23]		
<i>Dendrophilus pygmaeus</i> (Linnaeus, 1758)	<i>Formica exsecta</i> Nylander, 1846	[23, 24]	Myrmecophile	
	<i>Formica lugubris</i> Zetterstedt, 1838	[23]		
	<i>Formica rufa</i> Linnaeus, 1761	[23]		
<i>Haeterius ferrugineus</i> (Olivier, 1789)	<i>Formica fusca</i> Linnaeus, 1758	[23]	Myrmecophile	
	<i>Formica cinerea</i> Mayr, 1853	[25]		
	<i>Lasius niger</i> (Linnaeus, 1758)			
	<i>Messor structor</i> (Latreille, 1798)	New ant host record for Bulgaria	Myrmecophile	Balkans
<i>Sternocoelis merklii</i> (Schmidt, 1885)	<i>Tetramorium</i> cf. <i>caespitum</i> (Linnaeus, 1758)	[26]	Myrmecophile	
<i>Satrapes sartorii</i> (L. Redtenbacher, 1857)		New species for Bulgaria	Myrmecophile	
<i>Margarinotus ruficornis</i> (Grimm, 1852)		[27, 28]		
<i>Onthophilus affinis</i> L. Redtenbacher, 1849	<i>Formica fusca</i> Linnaeus, 1758	[23]		
	<i>Myrmica</i> sp.	[23]		
Ptiliidae				
<i>Ptenidium pusillum</i> (Gyllenhal, 1808)		[29]		
<i>Ptiliolum oedipus</i> (Flach, 1886)	<i>Formica pratensis</i> Retzius, 1783			
<i>Ptilium myrmecophilum</i> (Allibert, 1844)	<i>Formica pratensis</i> Retzius, 1783	New ant host record for Bulgaria	Myrmecophile	
	<i>Formica rufa</i> Linnaeus, 1761	New species for Bulgaria		
<i>Pteryx suturalis</i> (Heer, 1841)	<i>Formica rufa</i> Linnaeus, 1761			
<i>Acrotichis atomaria</i> (De Geer, 1774)	<i>Formica pratensis</i> Retzius, 1783	New ant host record for Bulgaria	Myrmecophile	
		New species for Bulgaria		
Leiostomatidae				
Cholevinae				
<i>Anemadus strigosus</i> Kraatz, 1852		[30, 31]		
<i>Eocatops pelopis</i> (Reitter, 1884)		[30, 32]	Myrmecophile	
	<i>Messor</i> sp.	[33]		
<i>Eocatops skopjensis</i> Karaman, 1957		[34]	Myrmecophile	Balkans
<i>Nemadus colonoides</i> (Kraatz, 1851)		[30, 31]	Myrmecophile	
<i>Dreposcia umbrina</i> Eriehson, 1837		[31, 34]		
<i>Attaephilus arenarius</i> (Hampe, 1852)		[30, 33]	Myrmecophile	
	<i>Messor structor</i> (Latreille, 1798)	[25], New record		
<i>Attaephilus</i> cf. <i>funebri</i> (Reitter, 1888)	<i>Messor</i> sp.	[25]		Balkans
<i>Attaephilus rambouseki</i> Jeannel, 1936		[32, 33]		Bulgaria
<i>Catopsimorphus marani</i> Roubal, 1936	<i>Messor</i> sp.	[33]	Myrmecophile	Bulgaria

TABLE I: Continued.

Beetle families, genera, and species	Recorded ant hosts in Bulgaria	References	Ant-relation	Endemic beetles
Staphylinidae				
Pselaphinae				
<i>Batrissodes buqueti</i> (Aubé, 1833)	<i>Lasius brunneus</i> (Latreille, 1798)	[25] [35]	Myrmecophile	
<i>Batrissodes delaporti</i> (Aubé, 1833)	<i>Lasius brunneus</i> (Latreille, 1798) <i>Lasius alienus</i> (Förster, 1850)	[36] [37] [25]	Myrmecophile	
<i>Batrissodes hubenthalii</i> Reitter, 1913		[25, 38]	Myrmecophile	
<i>Batrissodes oculatus</i> (Aubé, 1833)		[39]	Myrmecophile	
<i>Batrissodes sulcaticeps</i> Besuchet, 1981		[25, 40]	Myrmecophile	
<i>Batrissodes venustus</i> (Reichenbach, 1816)		[25, 36, 38]	Myrmecophile	
<i>Batrissodes formicarius</i> Aubé, 1833	<i>Lasius brunneus</i> (Latreille, 1798) <i>Lasius alienus</i> (Förster, 1850)	[35, 37, 41] [25]	Myrmecophile	
<i>Claviger elysius</i> Reitter, 1884		[25]	Myrmecophile	Balkans
<i>Claviger emgei</i> Reitter, 1885	<i>Lasius alienus</i> (Förster, 1850)	[25]	Myrmecophile	Balkans
<i>Claviger handmanni</i> Wasmann, 1898	<i>Lasius flavus</i> (Fabricius, 1782) <i>Lasius alienus</i> (Förster, 1850)	[37] [25]	Myrmecophile	Balkans
<i>Claviger longicornis</i> PW.J. Müller, 1818	<i>Lasius alienus</i> (Förster, 1850) <i>Lasius niger</i> (Linnaeus, 1758) <i>Lasius brunneus</i> (Latreille, 1798)	[37] [37] [37]	Myrmecophile	
<i>Claviger merkli</i> Reitter, 1885	<i>Lasius niger</i> (Linnaeus, 1758) <i>Lasius alienus</i> (Förster, 1850)	[35, 43] [25] [25]	Myrmecophile	Balkans
<i>Claviger testaceus</i> Preyßler, 1790		[25, 40]	Myrmecophile	
<i>Euplectus frater</i> Besuchet, 1964	<i>Lasius flavus</i> (Fabricius, 1782)	[37]		
<i>Euplectus nanus</i> (Reichenbach, 1816)	<i>Formica rufa</i> Linnaeus, 1761	[35, 44]		
<i>Euplectus signatus</i> (Reichenbach, 1816)	<i>Formica rufa</i> Linnaeus, 1761	[39]		
<i>Trichonyx sulcicollis</i> (Reichenbach, 1816)	<i>Formica pratensis</i> Retzius, 1783 <i>Formica</i> sp.	[37] [45]		
<i>Trinitium carpathicum</i> Saulcy, 1875	<i>Lasius alienus</i> (Förster, 1850)	[36]		
<i>Trinitium puncticeps</i> Reitter, 1880	<i>Formica rufa</i> Linnaeus, 1761	[25]		
<i>Bryaxis romaniae</i> Raffray, 1904	<i>Formica pratensis</i> Retzius, 1783	[35]		
<i>Centrotoma brucki</i> Saulcy, 1874	<i>Formica rufa</i> Linnaeus, 1761	[37]		
<i>Centrotoma lucifuga</i> C. Heyden, 1849	<i>Tetramorium caespitum</i> (Linnaeus, 1758)	[25]	Myrmecophile	Balkans
<i>Chennium bituberculatum</i> Latreille, 1807	<i>Tetramorium caespitum</i> (Linnaeus, 1758)	[37]	Myrmecophile	Balkans
<i>Chennium steigerwaldi</i> Reitter, 1882	<i>Tetramorium cf. caespitum</i> (Linnaeus, 1758) <i>Tetramorium ferox</i> Ruzscky, 1903	[25] [25]	Myrmecophile	

TABLE I: Continued.

Beetle families, genera, and species	Recorded ant hosts in Bulgaria	References	Ant-relation	Endemic beetles
Tachyporinae				
<i>Ischnosoma splendidum</i> (Gravenhorst, 1806)	<i>Lasius brunneus</i> (Latreille, 1798)	[46]		
<i>Tachinus rufipes</i> (Linnaeus, 1758)	<i>Formica rufa</i> Linnaeus, 1761	[46]		
<i>Tachyporus hypnorum</i> (Fabricius, 1775)	<i>Formica pratensis</i> Retzius, 1783	[46]		
<i>Tachyporus nitidulus</i> (Fabricius, 1781)	<i>Lasius fuliginosus</i> (Latreille, 1798)	[46]		
Aleocharinae				
<i>Piochardia reitteri</i> (Wasmann, 1894)	<i>Cataglyphis nodus</i> (Brullé, 1833)	[46]	Myrmecophile	
<i>Lyprocorrhoe anceps</i> (Erichson, 1837)	<i>Formica pratensis</i> Retzius, 1783	[46, 47]	Myrmecophile	
<i>Notothecta flavipes</i> (Gravenhorst, 1806)	<i>Formica pratensis</i> Retzius, 1783	[46, 47]	Myrmecophile	
	<i>Formica rufa</i> Linnaeus, 1761	[46]		
<i>Euryusa sinuata</i> Erichson, 1837	<i>Lasius brunneus</i> (Latreille, 1798)	[46]	Myrmecophile	
<i>Anaulacaspis nigra</i> (Gravenhorst, 1802)	<i>Formica pratensis</i> Retzius, 1783	[46]		
<i>Oligota pumilio</i> Kiesenwetter, 1858	<i>Formica pratensis</i> Retzius, 1783	[46]		
<i>Oligota inflata</i> (Mannerheim, 1830)	<i>Formica pratensis</i> Retzius, 1783	[46]		
<i>Lomechusa emarginata</i> (Paykull, 1789)		[48]	Myrmecophile	
	<i>Formica</i> sp.	[25]		
	<i>Myrmica rugulosa</i> Nylander, 1849	[46]		
	<i>Formica cinerea</i> Mayr, 1853	[46]		
	<i>Tetramorium caespitum</i> (Linnaeus, 1758)	[46]		
<i>Drusilla canaliculata</i> (Fabricius, 1787)		[49]	Myrmecophile	
<i>Myrmoecea plicata</i> (Erichson, 1837)		[39]	Myrmecophile	
<i>Pella funesta</i> (Gravenhorst, 1806)		[50]	Myrmecophile	
<i>Pella hampei</i> (Kraatz, 1862)		[51, 52]	Myrmecophile	
<i>Pella humeralis</i> (Gravenhorst, 1802)		[47]		
	<i>Formica pratensis</i> Retzius, 1783	[39]	Myrmecophile	
<i>Pella laticollis</i> (Märkel, 1844)		[48]	Myrmecophile	
<i>Pella limbata</i> (Paykull, 1789)		[53]	Myrmecophile	
<i>Pella lugens</i> (Gravenhorst, 1802)		[50]	Myrmecophile	
<i>Pella ruficollis</i> (Grim, 1845)		[45]	Myrmecophile	
<i>Zyras collaris</i> (Paykull, 1789)		[54]		
<i>Zyras fulgidus</i> (Gravenhorst, 1806)		[48]	Myrmecophile	
<i>Zyras haworthi</i> (Stephens, 1832)		[24, 46]	Myrmecophile	
<i>Dinarda hagensii</i> Wasmann, 1889	<i>Formica pratensis</i> Retzius, 1783	[46, 47]	Myrmecophile	
<i>Dinarda maerkelii</i> Kiesenwetter, 1843	<i>Formica sanguinea</i> Latreille, 1798	[25]	Myrmecophile	
<i>Dinarda</i> sp.	<i>Lasius fuliginosus</i> (Latreille, 1798)	[55]	Myrmecophile	
<i>Haploglossa gentilis</i> (Märkel, 1845)		[51]		
<i>Haploglossa pulla</i> (Gyllenhal, 1827)	<i>Formica rufa</i> Linnaeus, 1761	[46]	Myrmecophile	
<i>Oxyopoda formiceticola</i> Märkel, 1841	<i>Formica lugubris</i> Zetterstedt, 1838	[46]		
	<i>Formica exsecta</i> Nylander, 1846	[24]	Myrmecophile	
<i>Oxyopoda haenorrhhoa</i> (Mannerheim, 1830)	<i>Formica pratensis</i> Retzius, 1783	[46, 47]		
	<i>Formica pratensis</i> Retzius, 1783	[46, 47]	Myrmecophile	
<i>Oxyopoda pratensicola</i> Lohse, 1970	<i>Formica exsecta</i> Nylander, 1846	[24, 46]	Myrmecophile	
<i>Oxyopoda rugicollis</i> Kraatz, 1856		[46]		
	<i>Formica pressilabris</i> Nylander, 1846	[54, 56]	Myrmecophile	
<i>Oxyopoda vittata</i> Märkel, 1842				

TABLE 1: Continued.

Beetle families, genera, and species	Recorded ant hosts in Bulgaria	References	Ant-relation	Endemic beetles
<i>Thiasophila angulata</i> (Erichson, 1837)	<i>Formica rufa</i> Linnaeus, 1761	[46]	Myrmecophile	
<i>Thiasophila canaliculata</i> Mulsant and Rey, 1875	<i>Formica exsecta</i> Nylander, 1846	[24, 46]	Myrmecophile	
<i>Thiasophila lohsei</i> Zerche, 1987	<i>Formica pratensis</i> Retzius, 1783	[46, 47]	Myrmecophile	
Scydmaeninae				
<i>Eucyrtus chrysochomus</i> (Saulcy, 1864)	<i>Tetramorium</i> cf. <i>ferox</i> Ruzscky, 1903	[25]	Myrmecophile	
<i>Euthiconus conicollis</i> (Fairmaire and Laboulbène, 1854)		[57]		
<i>Microscydum nanus</i> (Schaum, 1844)		[39, 58]		
<i>Neuraphes parvulus</i> Rambousek, 1909	<i>Lasius fuliginosus</i> (Latreille, 1798)	[39]		
<i>Scydmorephes minutus</i> (Chaudoir, 1845)		[58]		
<i>Scydmaenus perrisi</i> Reitter, 1881		[39, 59]		
Steninae				
<i>Stenus aterrimus</i> Erichson, 1839	<i>Formica pratensis</i> Retzius, 1783	[46, 47]	Myrmecophile	
<i>Stenus heydeni</i> L. Benick, 1915	<i>Formica rufa</i> Linnaeus, 1761	[46]		Balkans
Paederinae				
<i>Lithocharis nigriceps</i> Kraatz, 1859	<i>Formica pratensis</i> Retzius, 1783	[47]		
<i>Astenus gracilis</i> (Paykull, 1789)	<i>Formica pratensis</i> Retzius, 1783	[46]		
<i>Sunitus melanocephalus</i> (Fabricius, 1793)	<i>Formica rufa</i> Linnaeus, 1761	[46]		
<i>Scopaeus pusillus</i> Kiesenwetter, 1843	<i>Formica pratensis</i> Retzius, 1783	[46]		
<i>Scopaeus sulcicollis</i> (Stephens, 1833)	<i>Formica rufa</i> Linnaeus, 1761	[46]		
Staphylininae				
<i>Leptacinus formicetorum</i> Märkel, 1841	<i>Formica pratensis</i> Retzius, 1783	[47]	Myrmecophile	
	<i>Formica rufa</i> Linnaeus, 1761	[46]		
	<i>Formica exsecta</i> Nylander, 1846	[46]		
<i>Gyrophypnus angustatus</i> Stephens, 1833	<i>Formica pratensis</i> Retzius, 1783	[46]		
	<i>Formica rufa</i> Linnaeus, 1761	[46]		
<i>Xantholinus linearis</i> (Olivier, 1795)	<i>Formica pratensis</i> Retzius, 1783	[46]		
<i>Gabrieus splendidulus</i> (Gravenhorst, 1802)	<i>Lasius brunneus</i> (Latreille, 1798)	[46]		
<i>Quedius brevis</i> Erichson, 1840	<i>Formica rufa</i> Linnaeus, 1761	[46]	Myrmecophile	
Monotomidae				
<i>Rhizophagus bipustulatus</i> (Fabricius, 1792)	<i>Lasius niger</i> (Linnaeus, 1758)	New ant host record for Bulgaria	Myrmecophile	
<i>Monotoma conicollis</i> Aubé, 1837		[29]		
	<i>Formica pratensis</i> Retzius, 1783	New ant host record for Bulgaria		
Cryptophagidae				
<i>Hypocopus latridioides</i> Motschulsky, 1839			Myrmecophile	
	<i>Formica exsecta</i> Nylander, 1846	[54]		
	<i>Formica rufa</i> Linnaeus, 1761	[24]		
	<i>Formica lugubris</i> Zetterstedt, 1838	New ant host record for Bulgaria		
		New ant host record for Bulgaria		
Nitidulidae				
<i>Amphotis marginata</i> (Fabricius, 1781)	<i>Lasius fuliginosus</i> (Latreille, 1798)	[29, 60, 61]	Myrmecophile	
<i>Amphotis orientalis</i> Reiche, 1861		[34, 62]	Myrmecophile	
Cerylonidae				
<i>Cerylon histeroideus</i> (Fabricius, 1792)	<i>Lasius brunneus</i> (Latreille, 1798)	New ant host record for Bulgaria		

TABLE I: Continued.

Beetle families, genera, and species	Recorded ant hosts in Bulgaria	References	Ant-relation	Endemic beetles
Endomychidae				
<i>Pleganophorus bispinosus</i> Hampe, 1855	<i>Lasius brunneus</i> (Latreille, 1798)	[63–66]	Myrmecophile	
<i>Cholovocera major</i> Reitter, 1887	<i>Messor structor</i> (Latreille, 1798)	[67]	Myrmecophile	Balkan-Anatolian
<i>Merophysia oblonga</i> Kiesenwetter, 1872	<i>Tetramorium cf. caespitum</i> (Linnaeus, 1758)	[68]	Myrmecophile	
<i>Mycetaca subterranea</i> Fabricius, 1801	<i>Formica rufa</i> Linnaeus, 1761	[67]		
Latridiidae				
<i>Dienerella costulata</i> (Reitter, 1877)	<i>Formica pratensis</i> Retzius, 1783	[67]		
	<i>Formica rufa</i> Linnaeus, 1761	[67]		
<i>Dienerella vincenti</i> Johnson, 2007	<i>Formica pratensis</i> Retzius, 1783	[67]		
	<i>Formica exsecta</i> Nylander, 1846	[67]		
<i>Corticaria longicollis</i> (Zetterstedt, 1838)	<i>Formica pratensis</i> Retzius, 1783	[67]	Myrmecophile	
	<i>Formica rufa</i> Linnaeus, 1761	[67]		
	<i>Formica exsecta</i> Nylander, 1846	[67]		
	<i>Tetramorium cf. caespitum</i> (Linnaeus, 1758)	[67]		
Tenebrionidae				
<i>Dichillus carinatus</i> (Küster, 1848)	<i>Pheidole pallidula</i> (Nylander, 1849)	[34, 69]	Myrmecophile	Balkan-Anatolian
<i>Eutagenia smyrnensis</i> (Solier, 1838)	<i>Formica rufa</i> Linnaeus, 1761	[69]	Myrmecophile	Balkan-Anatolian
<i>Palorus depressus</i> (Fabricius, 1790)	<i>Formica pratensis</i> Retzius, 1783		Myrmecophile	
<i>Myrmexixenus subterraneus</i> Chevrolat, 1835	<i>Formica rufa</i> Linnaeus, 1761		Myrmecophile	
	<i>Formica pressilabris</i> Nylander, 1846			
	<i>Formica cinerea</i> Mayr, 1853			
Chrysomelidae				
<i>Clytra laeviuscula</i> Ratzeburg, 1837	<i>Formica sanguinea</i> Latreille, 1798	[70, 71]	Myrmecophile	
<i>Clytra quadripunctata</i> (Linnaeus, 1758)	<i>Formica rufa</i> Linnaeus, 1761	[70, 71]	Myrmecophile	
	<i>Formica pratensis</i> Retzius, 1783			
Brentidae				
<i>Amorphocephala coronata</i> (Germar, 1817)	<i>Camponotus aethiops</i> Latreille, 1798	[29, 34, 72–75]	Myrmecophile	

Formica and *Lasius*, where there is a significant amount of decaying organic material without these beetles being limited to these habitats.

Feather-winged beetles are exceptionally under-researched in Bulgaria, with only scarce data being available. Ioakimov [29] reported the finding of *Ptenidium pusillum* (Gyllenhal, 1808) in ants' nests without this species being related to living with ants. During my investigation on the myrmecophilous fauna in some *Formica* species, I collected 4 more ptiliid species, which were kindly identified by Mikael Sörensson. *Ptilium myrmecophilum* (Allibert, 1844) and *Acrotrichis atomaria* (De Geer, 1774) were not previously known for the Bulgarian fauna. Collection and habitat data for these two species are presented below.

Ptilium myrmecophilum (Allibert, 1844). Southwestern Bulgaria, Vitosha Mt., near Bistritsa and Jeleznița vill., from January to October in 1994-1995: about 150 specimens in nests of *F. pratensis*; Vitosha Mt., near Simeonovo vill., 06.10.1998, 25.10.1998: 4 specimens in nests of *Formica rufa*.

Pt. myrmecophilum commonly lives in nests of *Formica rufa* and *F. pratensis*, recorded in Central and North Europe. The new data from Bulgaria affirms the preferred ant host species. Out of the 5 feather-winged beetle species collected in ants' nests, only *Ptilium myrmecophilum* is a tolerated guest, occurring in the explored nests in large numbers.

Acrotrichis atomaria (De Geer, 1774). Southwestern Bulgaria, Vitosha Mt., near Bistritsa vill., 1000 m a.s.l., 15.08.1995: 11 specimens; 15.10.1995: 110 specimens; 20.06.1997: 10 specimens; 14.11.1997: 31 specimens; 27.06.1998: specimens. It was found in and around *Formica pratensis* nests.

A. atomaria is a western Palaearctic species, which typically inhabits wet mosses, leaf-litter of *Castanea*, *Fagus* and *Quercus*, at the bases of *Ulmus* and *Salix* trees [86, 88].

2.4. *Family Leiodidae*. Family Leiodidae is represented by 111 species in Bulgaria [34, 89, 90], most of which inhabit forest habitats. They are saprophagous and mycophagous feeders, living on various decaying organic materials, and also in specific habitats such as ants' nests, caves or nests, and burrows of vertebrates [90].

Reports exist for 9 leiodids associated with ants in Bulgaria. Four of them—*Eocatops pelopis* (Reitter, 1884), *E. skopjensis* Karaman, 1957, *Nemadus colonoides* (Kraatz, 1851), and *Attaepphilus arenarius* (Hampe, 1852)—are treated in widest sense as myrmecophiles. The rest of the documented species are common both in nests and in other habitats. Arboricolous leiodids usually cohabit with *Lasius* ant species, while soil species are more likely to be found with *Messor* and *Aphaenogaster*. Most members of *Attaepphilus* are known as ant associated or cavernicolous.

Four of the 9 leiodid beetles show local distribution: 2 are endemic to the Balkans (*Eocatops skopjensis* Karaman, 1957, and *Attaepphilus cf. funebris* (Reitter, 1888)), and the other 2 have been established in Bulgaria without being reported from anywhere else (*Attaepphilus rambouseki* Jeannel, 1936, and *Catopsimorphus marani* Roubal, 1936). Until recently,

Eocatops skopjensis Karaman, 1957, has been known only from Macedonia [34, 91].

2.5. *Family Staphylinidae*. Rove beetles are the most diverse beetles found in ants' nests and display varying degrees of the ant-association. There are more than 200 staphylinid species in different relationships with ants in the Palaearctic [92]. The degree of relatedness ranges from occasional visits to indifferent relationships or full dependency on ants. In the latter case, different morphological modifications (modified antennae, glandular trichomes on the body, reduction of the mouthparts, specific body shape and coloration) and behavioral adaptations (depending on the ants to be fed, care for the offspring, moving under unfavorable conditions) have been involved. Close integration with the ant colony is mediated by morphological mimicry (Wasmannian mimicry) [93]. Chemical mimicry is also used. The entry of alien species into a highly discriminatory environment of ants is accomplished using cuticular hydrocarbons similar to those of ants, as well as "soothing substances" from special glands [94, 95]. The most integrated guests, categorized by Wasmann as "symphiles" [6], show the most diverse integrative mechanisms. This group of species is limited in number when compared with the facultative and obligate predators and commensals.

Although data on the ant-associated staphylinids in Bulgaria is reported in certain faunistic publications, there is still great scope for their exploration. Strictly myrmecophilous genera (such as *Thoracophorus*, *Lamprinus*, *Lamprinodes*, *Lomechusoides*) are widely distributed in Europe but have not been recorded from Bulgaria so far. From all of the 121 ant-associated beetle species listed in this paper, 79 species belong to family Staphylinidae where Pselaphinae (24 species) and Aleocharinae (33 species) are the richest subfamilies.

2.5.1. *Pselaphinae*. Members of the tribes Clavigerini, Ctenistini, and Batrisini are recognized as true myrmecophiles amongst the European pselaphines. The most specialized myrmecophiles are Clavigerini species, represented in Bulgaria by 6 species of *Claviger*. They are clearly distinguished by their reduced eyes and their modified mouthparts, which are adapted for regurgitated feeding by ant hosts, and for preying on ant eggs, larvae, and pupae [2]. The presence of trichome glands is another adaptation found in these species. The *Claviger* species form relationships with different *Lasius* ant species. Probably, all previous records for *Claviger longicornis* in Bulgaria should refer to *C. handmanni*, which is an endemic to the Balkans.

All 4 members of the genera *Centrotoma* and *Chennium* (tribe Ctenistini), which are known to occur in Bulgaria, are obligate myrmecophiles with ant species of the genus *Tetramorium*. One of them, *Centrotoma brucki* Saulcy, 1874, has been only recorded from Greece, but was recently added to the Bulgarian myrmecophilous fauna [25]. Ants care for these species and feed them with regurgitated food. In the *Centrotoma* species, the mouthparts are well developed, whereas in the case of *Chennium* the maxillary palps are reduced [14]. The trichomes are less developed, in contrast to the *Clavigerini* species of both genera.

Species from the tribe Batrisini (*Batrisus* and *Batrisodes*) are often found in the nests of different *Lasius* ants. They have no trichome glands, but despite this, ant workers seem to tolerate them. These species mainly eat mites found in the nests [14].

Some pselaphines, such as species from the genera *Euplectus*, *Trichonyx*, and *Trimium*, appear to be well adapted to both decaying plant material and ants' nests.

2.5.2. Aleocharinae. Aleocharines are the most successful group of beetles found in ants' nests. Thirty three ant-associated species have been recorded in Bulgaria. Despite the increase in their known number, the available records from Bulgaria are singular and often lack data on ant hosts.

A western Palaearctic member of the myrmecophilous genus *Piochardia* belonging to the tribe Aleocharini has recently been identified in a few localities in Southern Bulgaria [46]. *Piochardia reitteri* (Wasmann, 1894) is the only known myrmecophile in the nests of *Cataglyphis nodus* (Brullé, 1833) in Bulgaria, which is found in locations from the Southern Balkans to Anatolia, Caucasus, Iraq, Syria, and Iran [96].

Lomechusini are well known to be associated with ants, either being totally dependent on ant societies (like *Lomechusa*, *Lomechusoides*, *Myrmoecia*) or as predators of ants (*Zyras*, *Pella*, *Drusilla*). Altogether, 435 Lomechusini species or subspecies have been recorded living with ants all over the world [50]. Only 13 species have been established in Bulgaria. The high integrated *Lomechusa* species change ant hosts according to the seasons, wintering in *Myrmica* nests and spending the summer with *Formica* spp.

Different species of the genera *Oxypoda* and *Thiasophila* live in mound-built *Formica* ants' nests. Because they are tolerated by the ants, they often reach a significant number of specimens [21, 43, 47].

2.5.3. Scydmaeninae. Scydmaeninae, commonly known as ant-like stone beetles, have long been treated as a separate beetle family. They are known to live mostly in moist leaf litter and rotting logs in forests, feeding on oribatid mites and even collembolans [97, 98]. According to O'Keefe [97], 117 ant-associated species all over the world are known, but there are few really integrated Scydmaeninae guests. Only 1 European ant-like stone beetle—*Euconnus chrysocomus* (Saulcy, 1864)—is recognized as a true myrmecophile (symphile), while the relationships between neutral and facultative Scydmaeninae guests and their hosts remain to be studied [97].

2.6. Family Monotomidae. Mound-building *Formica* ants provide suitable conditions for 2 Euro-Siberian monotomids—*Monotoma conicollis* Aubé, 1837, and *M. angusticollis* (Gyllenhal, 1827). Only *M. conicollis* has been listed in Bulgaria so far. It is the first time that the association with *F. pratensis* has been reported. It is considered that *Monotoma* species are mycophagous as a whole [99].

2.7. Family Cryptophagidae. The species of family Cryptophagidae are typically small (0.8–5.2 mm), most diverse in

cool temperate environments. Most members are free living and mycophagous; inquilines in the nests of social insects have also been known [100].

Hypocopus latridioides Motschulsky, 1839, lives both inside and outside the nests of *Formica* species and cohabits particularly frequently with *Formica exsecta*. It has been reported in few localities in Bulgaria from sea level to 2000 m above sea level [24, 54]. The new data confirms its presence with *F. exsecta* but also adds 2 new ant host species for the country—*F. rufa* and *F. lugubris*.

2.8. Family Nitidulidae. Two European sap beetle species have close relationships with ants: *Amphotis marginata* (Fabricius, 1781), known to occur in the Palaearctic, and *A. orientalis* Reiche, 1861, restricted to the Mediterranean region of Europe and the Near East. *A. marginata* has long been known to cohabit with *Lasius fuliginosus* in Bulgaria, whereas *Amphotis orientalis* was recently found for the first time in soil traps in Southwestern Bulgaria in a region with increased mild Mediterranean climate [62]. It is believed that *A. orientalis* is more xerothermic than *A. marginata*, and that it lives in the nests of *Crematogaster scutellaris* [101]. The characteristic body shape of *Amphotis* species provides secure protection of the appendages in case of ant attacks. Ant workers have been observed feeding the adult beetles through regurgitation. Their larvae are mycophagous and phytosaprophagous [102].

2.9. Family Cerylonidae. Only few cerylonid species from Ceryloninae and Euxestinae show myrmecophilous life habits. *Cerylon histeroideus* (Fabricius, 1792) found in a nest of *Lasius brunneus* in Bulgaria usually lives under the bark of rotting deciduous trees [103]. Sieber [104] established it in a *Formica rufa* L. nest in Germany and treated this species as a winter guest.

2.10. Family Endomychidae. The majority of genera in the subfamily Merophysinae (*Cholovocera*, *Merophysia*, *Reitteria*) as well as in Pleganophorinae (*Pleganophorus*, *Trochoideus*) are closely related to ants and their nests [67]. Three species from Endomychidae family—*Cholovocera major* Reitter, 1887, *Merophysia oblonga* Kiesenwetter, 1872, and *Mycetaea subterranea* Fabricius, 1801—have been reported in ants' nests in Bulgaria. In Europe, *Cholovocera major* has only been collected in Bulgaria and Macedonia, after its description in Anatolia [67, 105]. It is thus the only representative of the genus *Cholovocera* in Bulgaria. *Mycetaea subterranea* can be found both inside and outside of ants' nests, for example, in birds' nests, and it has also been found in caves in Bulgaria [106, 107].

2.11. Family Latridiidae. Family Latridiidae, commonly known as minute brown scavenger beetles, has scarcely been investigated in Bulgaria. These beetles are frequently found in decaying vegetation, where they feed in a predominantly mycophagous manner. Only *Corticaria longicollis* (Zetterstedt, 1838) is a myrmecophile in nests of different *Formica* species [67], recorded in Bulgaria.

2.12. *Family Tenebrionidae.* Darkling beetles are one of the most diverse family within Coleoptera [108] with more than 15,000 species all over the world. They inhabit a wide range of localities and show a particular affinity to dry, warm habitats.

Myrmecixenus subterraneus Chevrolat, 1835, from family Tenebrionidae has not been reported for the Bulgarian fauna until now. It is a well-known Euro-Siberian species, common in the nests of *Formica* ant species and, more rarely, of *Lasius* [16]. The collecting data from Bulgaria are as follows.

In nests of Formica pratensis. Southwestern Bulgaria, Vitosha Mt., near Bistritsa vill., 1000 m a.s.l., from February to November 1994–2002: 130 specimens; near Zheleznitsa vill., 1250 m a.s.l., 17.08.1998: 21 specimens, 02.03.2002: 1 specimen; Lozen Mt., 900 m a.s.l., 23.02.2002: 1 specimen; Zemen gorge, 580 m a.s.l., 28.02.1998: 14 specimens, 18.10.1998: 3 specimens, 05.11.1998: 8 specimens; 27.03.2001: 3 specimens.

In nests of Formica rufa. Southwestern Bulgaria, Vitosha Mt., above Bistritsa vill., 1050 m a.s.l., 14.11.1997: 1 specimen; Rila Mt., 1400 m a.s.l., 24.07.1998: 2 specimens.

In a nest of Formica cinerea. Vitosha Mt., above Zheleznitsa vill., 1200 m a.s.l., 02.03.2002: 1 specimen.

In a nest of Formica pressilabris. Zemen gorge, the ridge above the town of Zemen, 900 m a.s.l., 26.09.1998: 33 specimens.

Picka [69] was the first to document 2 Balkan-Anatolian Stenosini species: *Eutagenia smyrnensis* (Solier, 1838) and *Dichillus carinatus* (Küster, 1848) as myrmecophilous in Bulgaria. Here, I include an ant host *Pheidole pallidula* for *D. carinatus*, observed under a stone in Southwestern Bulgaria (Zemen gorge).

2.13. *Family Chrysomelidae.* The larvae of *Clytra laeviuscula* Ratzeburg, 1837, and *C. quadripunctata* (Linnaeus, 1758), enclosed in cases, live in nests of *Formica* where they feed partly on vegetable refuse, but also on ant droppings and pellets [109]. The former mostly inhabits the ground nests of *Formica sanguinea*, in comparison with *C. quadripunctata*, which occurs in mound-built *Formica* nests.

2.14. *Family Brentidae.* Family Brentidae is distributed mainly within the tropics. The tribe Eremoxenini is represented in the Palaearctic by 2 myrmecophilous species—*Eremoxenus chan* Semenow, 1892 (living with *Camponotus turkestanicus* Emery, 1887 in Middle Asia) and *Amorphocephala coronata* (Germar, 1817).

Amorphocephala coronata occurs in the Mediterranean region, almost always in *Camponotus* ants' nests but also, more rarely, in *Lasius*, *Pheidole*, and *Crematogaster* nests where 2-way regurgitation feeding with the aim of close integration of beetles and ant workers has been observed [2, 110, 111].

The species has been recorded in a few localities in Bulgaria, but it is the first time that the association of *A.*

coronata with *Camponotus aethiops* has been established. The new collecting locality was in Southeastern Bulgaria, near the Turkish border (Strandzha Mt., Kalovo vill.).

3. Conclusions

Based on investigation of the available literature as well as new data on ant-associated beetles in Bulgaria, a total of 121 species from 14 Coleoptera families have been listed, and 71 of these species are referred to as myrmecophilous. Not surprisingly, the family Staphylinidae, with 79 species, are the most diverse and species-rich beetles found in ants' nests.

Of about 170 ant species in Bulgaria, only 22 ant host species have been documented in singular reports on the myrmecophilous beetle fauna. The largest proportion of the known ant-related beetles in Bulgaria inhabit the nests of the Formicinae ant species of *Formica* (76 species) and *Lasius* (25 species) genera, similar with findings from other countries in the Palaearctic [12, 13, 16]. Most beetle species have been reported in nests of the meadow ant *Formica pratensis* and the red wood ant *Formica rufa* (30 and 25 species, resp.). Together with species from other mound-building *Formica* (*F. exsecta*—9, *F. lugubris*—3, and *F. pressilabris*—2), the number of species totals 69. This is because, on the one hand, there have been more intensive studies on the nests of the above-mentioned species, and on the other hand, mound nests provide more of a variety of microhabitats which are suitable for a greater number of cohabitants. There is a lack of available information on myrmecophiles found with ant species from subfamilies Ponerinae and Dolichoderinae, although the Dolichoderinae such as *Tapinoma erraticum* (Latreille, 1798) and *Liometopum microcephalum* (Panzer, 1798) are common ant species in Bulgaria, and many myrmecophiles are known to inhabit their nests. Ant hosts for 31 ant-associated beetles listed for Bulgaria in previous studies have not been noted at all.

Bulgaria's location favors the existence of a diverse ant-associated fauna mainly composed by species with a wide range in the western Palaearctic, especially in Europe, but some species, are known to occur in limited regions only: 10 are endemic to the Balkans, 3 are Balkan-Anatolian species and 2 are currently known from Bulgaria (Table 1).

Ants' nests are unique habitats with a high local biodiversity, and the associated beetle species contributes to species richness in Bulgaria. The presence of only singular records for most of the listed species and the lack of data from the nests of most ant species in Bulgaria are valid reasons for more intensive investigation on this group of beetles in the future.

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