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Tree-fungus beetles collected on sawdust substrate with mycelium of selected fungal species on trees at the Experimental Forest Station in Rogów (central Poland)

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Abstract. This study of beetles attracted by a sawdust substrate overgrown with mycelium of rare species of wood-decay fungi was aimed to assess (1) ecological groups of the beetles caught in traps with such a substrate; (2) species composition of beetle communities attracted to sawdust substrate with the selected wood-decay fungi. To determine which tree-fungus beetles are associated with selected species of wood-decay fungi, we caught beetles in traps with sawdust substrate overgrown by the mycelium of seven species of wood-decay fungi: *Bondarzewia mesenterica* (Schaeff.) Kreisel, *Fistulina hepatica* (Schaeff.) With., *Fomitopsis rosea* (Alb. & Schwein.) P. Karst., *Grifola frondosa* (Dicks.) Gray, *Hericium alpestre* Pers., *H. coralloides* (Scop.) Pers. and *Meripilus giganteus* (Pers.) P. Karst. The research was carried out in central Poland, at the Forest Experimental Station in Rogów. One research season (April–October) yielded a total catch of 133 beetle species associated with wood-decay fungi, including 60 mycetobiontic species. The most abundant species of beetles were: *Trixagus carinifrons* (Bonvouloir, 1859), *Cortinicara gibbosa* (Herbst, 1793), *Dienerella ruficollis* (Marsham, 1802), *Rhizophagus bipustulatus* (Fabricius, 1792), and *Aulonothroscus brevicollis* (Bonvouloir, 1859). Two autonomous clusters of tree-fungus beetles were distinguished in the collected material: beetles associated with brown rot and beetles associated with white rot. The sawdust substrates with mycelium of wood-decay fungi, used in traps, attract mycetophilic and mycetobiontic beetles.

Key words. Coleoptera, mycetophilic beetles, mycetobiontic beetles, wood-decay fungi, Poland.

INTRODUCTION

The largest taxonomic group of animals that live in and on fungi are insects, mostly beetles. This group of organisms plays a major role in decomposition of tree fungi (Gilbertson 1984). Many fruiting bodies of wood-decay fungi are very attractive food for beetles, which feed also on the mycelium that penetrates wood (Benick 1952; Hammond & Lawrence 1989; Butin 1995; Pecci-Maddalena & Lopes-Andrade 2017). Some beetles are highly specific and associated only with a single fungal species. For example, bark beetles (Curculionidae: Scolytinae) live in symbioses with primarily ophiostomatoid Ascomycetes (Linnakoski et al. 2012; Six 2012).

However, little is known about beetles associated with rare wood-decay fungi because of their limited area of distribution (usually in natural or nearly natural forests), short period of occurrence of fruiting bodies, and their quick decomposition. Apart from the fruiting bodies of fungi that are commonly found on trees, such as *Fomes fomentarius* (L.) Fr., *Fomitopsis pinicola* (Sw.) P. Karst. or *Trametes* spp., also fruiting bodies of protected species are visited by many beetle species. Poland was the first country in Europe to introduce fungal species protection, in 1983 (Ordinance 1983). Since 2014, 54 species of macrofungi are strictly protected, while 63 are partly protected, so in total 117 fungal species are protected in Poland, including 20 wood-decay fungi (Ordinance 2014). A majority of the protected wood-decay fungi are associated mostly with primeval forests. Such habitats are located primarily in national parks and nature reserves, i.e., in areas where large amounts of dead wood lie on the forest floor. Creation of suitable conditions for development of wood-decay fungi by leaving dead wood or stopping timber harvesting in forests does not mean that valuable, rare species will immediately appear there. The natural process of wood colonization by fungi takes many years, and production of fruiting bodies is only one of the final stages of mycelium development in wood.

Among beetles of wood-decay and other tree fungi, some are mycetobiontic (obligatorily associated with fungi), while others are mycetophilic (facultatively as-

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sociated with fungi). According to published data, the following mycetobiontic beetles have been recorded on 7 species of wood-decay fungi (six species protected in Poland) selected for this study:

– on *Fistulina hepatica* (Schaeff.) With.: *Cryptophagus pubescens* Sturm, 1845, *C. scanicus* (Linnaeus, 1758), *Micrambe abietis* (Paykull, 1798), *Dacne bipustulata* (Thunberg, 1781), *Mycetophagus piceus* (Fabricius, 1777), *Psudotriphyllus suturalis* (Fabricius, 1801), *Triphyllus bicolor* (Fabricius, 1777), *Abdera flexuosa* (Paykull, 1799), *Orchesia micans* (Panzer, 1793) (Benick 1952; Burakowski et al. 1986, 1987; Nikitsky 1993; Nikitsky & Schigel 2004; Borowski 2006),
– on *Fomitopsis rosea* (Alb. & Schwein.) P. Karst.: *Agaricochara latissima* (Stephens, 1832), *Dolichocis laricinus* (Mellié, 1848), *Cis dentatus* Mellié, 1848, *C. glabratus* Mellié, 1848, *Ennearthron cornutum* (Gyllenhal, 1827) (Scheerpeltz & Höfler 1948; Krasutsky 1995, 1997),
– on *Grifola frondosa* (Dicks.) Gray: *Sepedophilus testaceus* (Fabricius, 1793) (Schigel 2007),
– on *Hericium coralloides* (Scop.) Pers.: *Scaphisoma agaricinum*, *Mycetophagus decempunctatus* Fabricius 1801, *M. multipunctatus* Fabricius, 1792, *M. quadriguttatus* Müller, 1821 (Benick 1952; Nikitsky 1993),
– on *Meripilus giganteus* (Pers.) P. Karst.: *Scaphisoma agaricinum* (Linnaeus, 1758), *Cryptophagus dentatus* (Herbst, 1793), *C. uncinatus* Stephens, 1830, *Cartodere nodifer* (Westwood, 1839), *Cortinicara gibbosa* (Herbst, 1793), *Cis micans* (Fabricius, 1792), *Orchesia micans* (Scheerpeltz & Höfler 1948; Benick 1952; Burakowski et al. 1987).

On the remaining two species of wood-decay fungi used in this study, i.e., *Bondarzewia mesentrica* (Schaeff.) Kreisel and *Hericium alpestre* Pers., no mycetobiontic beetles have been reported in the literature so far.

This study of beetles attracted by a sawdust substrate overgrown with mycelium of rare species of wood-decay fungi was aimed to assess (1) ecological groups of the beetles caught in traps with such a substrate; (2) species composition of beetle communities attracted to sawdust substrate with the selected wood-decay fungi.

MATERIAL AND METHODS

Study area

The study was conducted in 2008 in the arboretum of the Experimental Forest Station in Rogów (central Poland) (Fig. 1). The arboretum was created in 1925 in a forest and was associated since the very beginning with forest research. The arboretum now covers 53.76 ha, including 41 ha being open to visitors (Pewniak et al. 2004), but the research plot was established in the part that is closed to visitors. The plot is located in a modified low-lying oak-hornbeam forest *Tilio-Carpinetum stachyetosum*. It is dominated by *Pinus sylvestris* L. (aged about 130 years) and *Quercus robur* L. and *Quercus petraea* (Matt.) Liebl. (aged 100–200 years), with admixture of *Larix decidua* Mill., *Carpinus betulus* L., *Abies alba* Mill., *Betula pendula* Roth., and *Picea abies* (L.) H. Karst. The well-developed herb layer includes *Stellaria holostea* L., *Anemone nemorosa* L., *Galeobdolon luteum* Huds., *Deschampsia caespitosa* (L.) P. Beauv., *Poa trivialis* L., and *Rubus* spp.

The woodlands at Rogów are composed of small forest patches, covering less than 10 km^2. Moreover, the forest patches are clearly separated from one another and form a mosaic of small forest islands surrounded by farmland, characteristic of central Poland. They are poor in typical forest beetle species. However, the insect fauna of the Experimental Forest Station in Rogów is well studied, especially forest beetles (Borowski 2001).

Trapping

In the experiment, we used modified window traps designed by Økland (1996). A trap was made of two 20 × 30 cm Plexiglas plates crossing each other, a funnel and a preservative-filled bottle (ethylene glycol), and bait (sawdust substrate overgrown with mycelium) (Fig. 2). In the experiment we used mycelium of seven species of wood-decay fungi belonging to the division Basidiomycota, two of them causing brown rot: *Fistulina hepatica* (Schaeff.) With. and *Fomitopsis rosea*; and five causing white rot: *Bondarzewia mesenterica*, *Grifola frondosa*, *Hericium coralloides*, *H. alpestre*, and *Meripilus giganteus* (Table 1). Pure cultures of the fungi used to prepare the bait substrate originated from the collection of the Department of Forest Phytopathology and Mycology, Warsaw University of Life Sciences (SGGW). Identity of the mycelium was confirmed using molecular techniques, on the basis of the internal transcribed spacer (ITS) region of nuclear ribosomal DNA, which is used most often for research on genetic diversity of fungi (Seifert 2009). The analyses were performed at the laboratory of the Institute of Botany, Polish Academy of Sciences, Krakow.

The bait substrate was prepared by mixing and watering of sawdust of an appropriate tree species with ground wheat grain and inoculating it with mycelium. Beech sawdust (*Fagus sylvatica* L.) was prepared for *G. frondosa*, *H. coralloides*, and *M. giganteus*, fir sawdust (*Abies alba*) for *B. mesenterica* and *H. alpestre*, spruce sawdust (*Picea abies*) for *F. rosea*, and oak sawdust (*Quercus robur*) for *F. hepatica*. Each autoclavable polypropylene biohazard bag (7"×12", Cole-Parmer, US) was filled with 180 g of the substrate (150 g of sawdust of the appropriate tree species and 30 g of ground wheat grain). The components were thoroughly mixed with 180 ml of distilled water. The initial moisture content of the substrate was about 100%. The bags were placed in an autoclave and sterilized at 121°C for 2 h, next moved to a

Table 1. Characteristics of the fungi used to prepare the substrate attracting beetles (type of rot and major host plants according to: Kotlaba (1984), Kreisel (1987), Ryvarden & Gilbertson (1993, 1994), Wojewoda (2003)).

Species	Family	Rot type	Protection status in Poland	Major host plants
Bondarzewia mesenterica	Bondarzewiaceae	white	partial protection	*Abies*, *Picea*
Fistulina hepatica	Fistulinaceae	brown	partial protection	*Quercus*, *Castanea*
Fomitopsis rosea	Fomitopsidaceae	brown	partial protection	*Picea*, *Abies*
Grifola frondosa	Fomitopsidaceae	white	partial protection	*Quercus*, *Acer*, *Betula*, *Carpinus*, *Fagus*
Hericium alpestre	Hericiaceae	white	partial protection	*Abies*, *Picea*
Hericium coralloides	Hericiaceae	white	partial protection	*Fagus*
Meripilus giganteus	Meripilaceae	white	not protected	*Quercus*, *Fagus*, *Acer*, *Aesculus*

laminar air flow cabinet and left for a few hours, until they cooled down. The substrate was then inoculated with mycelium of an appropriate species (from cultures on Petri dishes), the bag was plugged with a cotton wool ball, and the neck of the bag was tightly wrapped in a colourless tape. The cotton wool was a filter that ensured gas exchange and simultaneously protected the substrate against microorganisms from the environment. Next the bags were kept for 8–10 weeks at 22°C in a Q-Cell 700 incubator, until the substrate was overgrown by mycelium, and then used in an experiment.

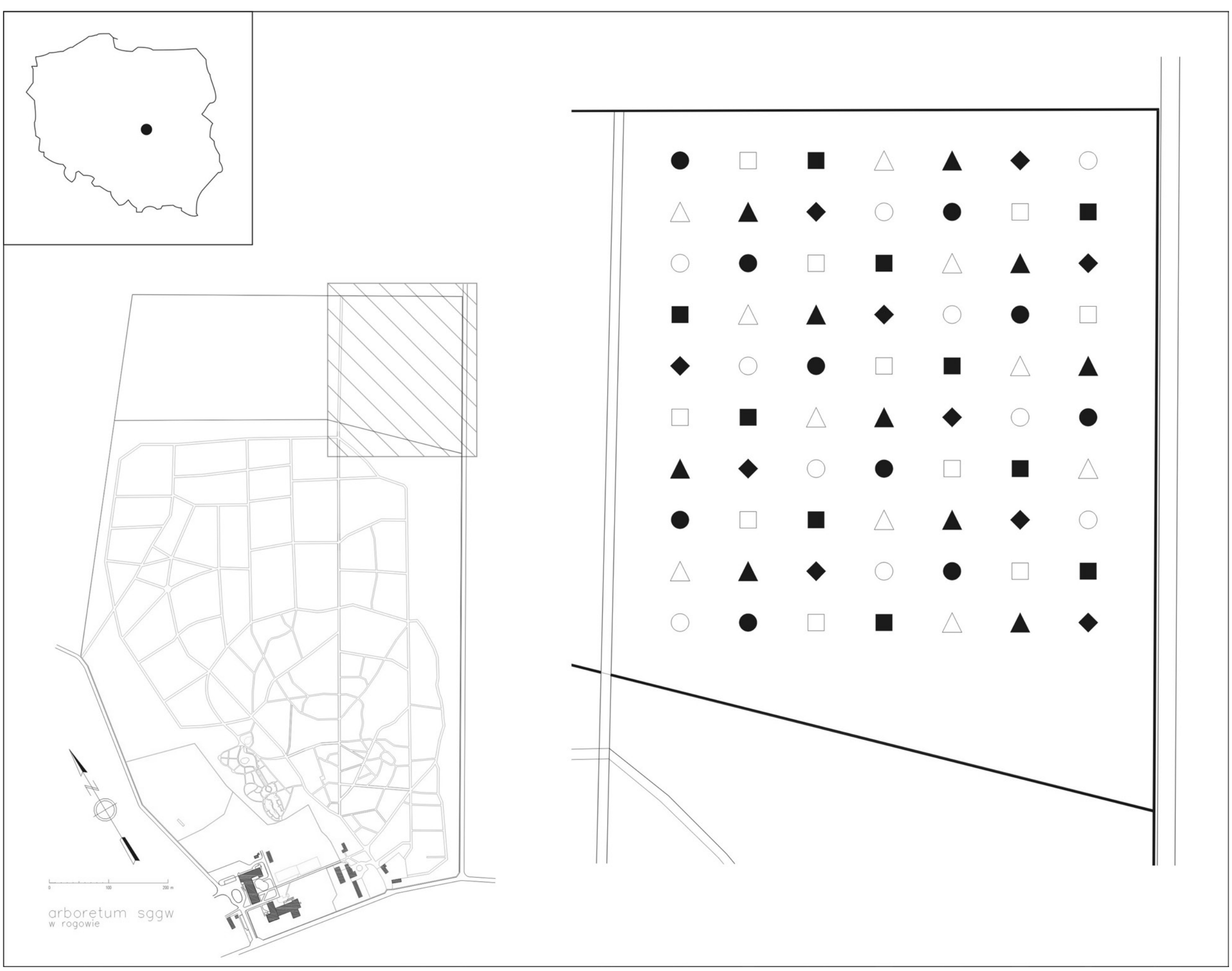

Fig. 1. Location of the study area and a scheme of distribution of the traps with mycelium of wood-decay fungi on sawdust substrate in the forest arboretum in Rogów. Symbols: ● = traps with *Bondarzewia mesentrica*; ○ = *Grifola frondosa*; ■ = *Fomitopsis rosea*; □ = *Meripilus giganteus*; ▲ = *Hericium coralloides*; Δ = *Hericium alpestre*; ♦ = *Fistulina hepatica*.

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Fig. 2. Trap with mycelium of wood-decay fungi on sawdust substrate, used to catch beetles (photo J. Piętka).

Then, small pieces of the polypropylene film were cut off (at the top and at the bottom), and the substrate was mounted above a window trap hung on a tree. The traps were hanged at a height of 2 m, on young trees without injuries, to make sure that the caught insects were attracted by the substrate, rather than by a dying tree. From April to October in the study area 70 such bait traps were used, 10 for each of the studied species of wood-decay fungi. Once a month, the caught material was collected, transported to the laboratory, and next sorted and identified. The taxonomic classification and names of the identified insects follow the *Catalogue of Palearctic Coleoptera* (Löbl & Smetana 2003–2013). When analysing their dominance structure, Kasprzak & Niedbała's (1981) scale was used: superdominants (>30.00%), dominants (5.01–30.00%), subdominants (1.01–5.00%), and accidentals (≤1.00%). The faunistic similarity of tree beetle communities caught in traps with mycelium of individual species of wood-decay fungi on sawdust substrate was analysed using numerical cluster analysis. This analysis was based on the species composition (presence/absence of species). To distinguish between groups, Ward's algorithm was used, and squared Euclidean distance was a measure of similarity. Additionally, the faunistic similarity of tree-fungus beetle communities was analysed using Nonmetric Multidimensional Scaling (NMDS). Data on number of individuals were subjected to Hellinger transformation and NMDS based on Bray-Curtis similarity index. NMDS stress 0.099.

Results

From April to October 2008, we caught 2038 beetles of 133 species, representing 35 families (Table 2). In the collected material, the families represented by the largest numbers of species were the Latridiidae (11.3% of the total number of species), Staphylinidae (9.0%), Ciidae (6.0%), Cryptophagidae (6.0%), Curculionidae, Melandryidae, and Mycetophagidae (5.3% each). The families represented by the largest numbers of individuals were the Throscidae (23.6%), Latridiidae (19.6%), Monotomidae (7.6%), Cryptophagidae (7.0%), Salpingidae (6.6%), and Leiodidae (5.5%). The most abundant species were: *Trixagus carinifrons* (14.9%), *Cortinicara gibbosa* (7.1%), *Dienerella ruficollis* (7.1%), *Rhizophagus bipustulatus* (6.9%), and *Aulonothroscus brevicollis* (5,5%). These species and 15 others (*Acalles camelus*, *Agathidium nigripenne*, *A. seminulum*, *Anaspis frontalis*, *A. rufilabris*, *Cerylon histeroides*, *Cryptophagus dentatus*, *C. dorsalis*, *Dacne bipustulata*, *Ennearthron palmi*, *Litargus connexus*, *Mycetophagus multipunctatus*, *Salpingus planirostris*, *S. ruficollis*, and *Trixagus dermestoides*) were caught on all types of bait. On the other hand, 35 species were recorded only with one of the seven variants of the bait, and only three of them were caught in the number of more than one individual, i.e., *Hemicoelus canaliculatus* (two individuals in one trap with *Grifola frondosa* mycelium), *Dendrophilus punctatus* (two individuals in two traps with *Hericium alpestre* mycelium) and *Cis festivus* (three individuals in two traps with *Meripilus giganteus* mycelium).

Among biotope groups of beetles, the major contributors to the total number of species were the organisms associated with mycelium and fruiting bodies of fungi (mycetocoles – 48.1%) (Table 3). The most abundant among them were: *Trixagus carinifrons, Cortinicara gibbosa, Dienerella ruficollis*, and *Aulonothroscus brevicollis*. The second most species-rich biotope group is associated with partly or completely dead wood (saproxylocoles – 24.1%), represented most abundantly by *Anaspis rufilabris* and *Melasis buprestoides*. Corticoles were another relatively large group (17.3%), and the most abundant among them were *Rhizophagus bipustulatus*, *Salpingus ruficollis*, and *S. planirostris*.

Among the trophic groups (Table 4), mycetophagous (fungivorous) beetles were the most numerous (46.6% of the total number of species), and the most abundant species of this group were *Dienerella ruficollis*, *Cortinicara gibbosa*, and *Trixagus carinifrons*. Zoophages ranked second (24.1%), and saproxylophages ranked

Table 2. List of beetles (Coleoptera) caught in traps with mycelium of wood-decay fungi on sawdust substrate in the arboretum in Rogów (central Poland) in 2008. Abbreviations: S = saproxylocoles; C = corticoles; M = mycetocoles; MY = myxomycetocoles; MI = myrmetocoles; sx = saproxylophages; z = zoophages; m = mycetophages; my = myxomycophages.

Family / Species	Biotope groups	Trophic groups	*Bondarzewia mesenterica*	*Fistulina hepatica*	*Fomitopsis rosea*	*Grifola frondosa*	*Hericium alpestre*	*Hericium coralloides*	*Meripilus giganteus*
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Anthribidae									
Dissoleucas niveirostris (Fabricius, 1798)	S	sx					1	1	
Pseudeuparius sepicola (Fabricius, 1792)	S	sx		1	1				
Platystomos albinus (Linnaeus, 1758)	S	sx			1				
Rhaphitropis marchica (Herbst, 1797)	S	sx							1
Cerambycidae									
Alosterna tabacicolor (DeGeer, 1775)	S	sx		1		1			
Grammoptera ruficornis (Fabricius, 1781)	S	sx	1						
Cerylonidae									
Cerylon ferrugineum Stephens, 1830	C	z		2	4	1	3		1
Cerylon histeroides (Fabricius, 1792)	C	z	2	8	5	4	11	4	4
Ciidae									
Cis boleti (Scopoli, 1763)	M	m		1	1	3			
Cis fagi Waltl, 1839	M	m			1				
Cis festivus (Panzer, 1793)	M	m							3
Cis micans (Fabricius, 1792)	M	m	2				1		
Ennearthron cornutum (Gyllenhal, 1827)	M	m		1	3	5	2	7	2
Ennearthron palmi Lohse, 1966	M	m	11	1	3	2	4	3	1
Octotemnus glabriculus (Gyllenhal, 1827)	M	m				1			
Orthocis pseudolinearis (Lohse, 1965)	M	m			2	1	1	3	1
Corylophidae									
Clypastraea brunnea (Brisout de Barneville, 1863)	M	m							1
Clypastraea pusilla (Gyllenhal, 1810)	M	m	3			1		2	2
Orthoperus brunnipes (Gyllenhal, 1808)	M	m			6				5
Sericoderus lateralis (Gyllenhal, 1827)	M	m		3		1	2		6
Cryptophagidae									
Atomaria analis Erichson, 1846	M	m	1			2	1		
Atomaria atricapilla Stephens, 1830	M	m	1						

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Table 2. continued.

Family / Species	Biotope groups	Trophic groups	*Bondarzewia mesenterica*	*Fistulina hepatica*	*Fomitopsis rosea*	*Grifola frondosa*	*Hericium alpestre*	*Hericium coralloides*	*Meripilus giganteus*
Cryptophagus dentatus (Herbst, 1793)	M	m	1	36	2	3	4	12	8
Cryptophagus dorsalis C. R. Sahlberg, 1819	M	m	7	5	2	8	5	5	9
Cryptophagus pilosus Gyllenhal, 1827	M	m		3	1	3	2		
Cryptophagus pubescens Sturm, 1845	M	m		1					1
Cryptophagus scutellatus Newman, 1834	M	m		5		2	2		1
Micrambe abietis (Paykull, 1798)	M	m	1	4			1	2	1
Curculionidae									
Acalles camelus (Fabricius, 1792)	S	sx	1	1	1	4	1	1	4
Anisandrus dispar (Fabricius, 1792)	M	m		1			3		
Trypodendron domesticum (Linnaeus, 1758)	M	m	2	2	2	1			1
Trypodendron signatum (Fabricius, 1792)	M	m		1					1
Xyleborinus attenuatus (Blandford, 1894)	M	m					1	1	
Xyleborinus saxesenii (Ratzeburg, 1837)	M	m	2	1	4				
Xyleborus monographus (Fabricius, 1792)	M	m				2	3		
Elateridae									
Ampedus pomorum (Herbst, 1784)	S	z		1		1	2		
Melanotus castanipes (Paykull, 1800)	S	z			2	3		2	1
Melanotus villosus (Geoffroy, 1785)	S	z		1	4			2	1
Endomychidae									
Endomychus coccineus (Linnaeus, 1758)	M	m			1				
Erotylidae									
Dacne bipustulata (Thunberg, 1781)	M	m	7	4	4	2	20	10	15
Triplax aenea (Schaller, 1783)	M	m	1			1			
Eucnemidae									
Eucnemis capucina Ahrens, 1812	S	sx				1			
Hylis foveicollis (C. G. Thomson, 1874)	S	sx	1		2		3		1
Melasis buprestoides (Linnaeus, 1761)	S	sx		9	3	5	4	2	1
Histeridae									
Dendrophilus punctatus (Herbst, 1792)	S	z					2		

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Table 2. continued.

Family / Species	Biotope groups	Trophic groups	*Bondarzewia mesenterica*	*Fistulina hepatica*	*Fomitopsis rosea*	*Grifola frondosa*	*Hericium alpestre*	*Hericium coralloides*	*Meripilus giganteus*
Laemophloeidae									
Cryptolestes corticinus (Erichson, 1846)	C	z	1			1			1
Cryptolestes ferrugineus (Stephens, 1831)	C	z						1	
Leptophloeus alternans (Erichson, 1846)	C	z	1	2	1	1			
Latridiidae									
Cartodere nodifer (Westwood, 1839)	M	m	1	5		2	4		
Corticaria pineti Lohse, 1960	M	m		1	1				
Corticaria serrata (Paykull, 1798)	M	m				1		1	1
Corticarina lambiana (Sharp, 1910)	M	m					1	1	1
Corticarina minuta (Fabricius, 1792)	M	m	3		4	4	2	5	1
Corticarina similata (Gyllenhal, 1827)	M	m		1	2				
Cortinicara gibbosa (Herbst, 1793)	M	m	17	43	21	16	13	22	13
Dienerella ruficollis (Marsham, 1802)	M	m	1	16	8	13	8	4	94
Enicmus fungicola C. G. Thomson, 1868	MY	my	1	6	1		1	1	1
Enicmus histrio Joy & Tomlin, 1910	MY	my						1	1
Enicmus rugosus (Herbst, 1793)	MY	my			4	2	12	3	
Enicmus transversus (A. G. Olivier, 1790)	MY	my	4	1	3	1	3		1
Latridius hirtus Gyllenhal, 1827	MY	my				1	1		1
Latridius porcatus (Herbst, 1793)	MY	my					1	2	3
Stephostethus angusticollis (Gyllenhal, 1827)	M	m	2	4	1	3	1		1
Leiodidae									
Agathidium confusum Brisout de Barneville, 1863	MY	my	2		12	4	1	3	14
Agathidium nigripenne (Fabricius, 1792)	MY	my	2	15	2	4	5	1	3
Agathidium seminulum (Linnaeus, 1758)	MY	my	4	3	3	3	4	3	2
Agathidium varians Beck, 1817	MY	my		1	1				
Anisotoma humeralis (Fabricius, 1792)	MY	my	1	4	1	3	9	2	
Lucanidae									
Platycerus caraboides (Linnaeus, 1758)	S	sx		1	1				
Lycidae									
Dictyoptera aurora (Herbst, 1784)	S	sx							1

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Table 2. continued.

Family / Species	Biotope groups	Trophic groups	*Bondarzewia mesenterica*	*Fistulina hepatica*	*Fomitopsis rosea*	*Grifola frondosa*	*Hericium alpestre*	*Hericium coralloides*	*Meripilus giganteus*
Lymexylidae									
Elateroides dermestoides (Linnaeus, 1761)	M	m	5	4		1	1		1
Melandryidae									
Abdera flexuosa (Paykull, 1799)	M	m					1		
Conopalpus testaceus (A. G. Olivier, 1790)	S	sx							1
Orchesia fasciata (Illiger, 1798)	S	sx	1	5	3	2	1		1
Orchesia micans (Panzer, 1793)	M	m				1			
Orchesia minor Walker, 1837	M	m		1		1		3	
Phryganophilus auritus Motschulsky, 1845	S	sx					1		
Serropalpus barbatus (Schaller, 1783)	S	sx			1				
Monotomidae									
Rhizophagus bipustulatus (Fabricius, 1792)	C	z	17	37	16	11	14	28	18
Rhizophagus cribratus (Gyllenhal, 1827)	C	z			1				
Rhizophagus dispar (Paykull, 1800)	C	z			1				
Rhizophagus fenestralis (Linnaeus, 1758)	C	z	1	1	2			2	5
Mordelidae									
Tomoxia bucephala A. Costa, 1854	S	sx						1	
Mycetophagidae									
Litargus connexus (Geoffroy, 1785)	M	m	1	5	3	2	3	7	3
Mycetophagus ater (Reitter, 1879)	M	m					2		1
Mycetophagus atomarius (Fabricius, 1787)	M	m	1		1			1	
Mycetophagus multipunctatus Fabricius, 1792	M	m	5	1	6	8	6	4	7
Mycetophagus piceus (Fabricius, 1777)	M	m	1					1	1
Mycetophagus quadriguttatus P. W. J. Müller, 1821	M	m							1
Mycetophagus quadripustulatus (Linnaeus, 1760)	M	m					1	2	
Nitidulidae									
Cybocephalus fodori Endrödy-Younga, 1965	M	z							1
Cyllodes ater (Herbst, 1792)	M	m		1		1			1
Epuraea biguttata (Thunberg, 1784)	C	z	2	9					5

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Table 2. continued.

Family / Species	**Biotope groups**	**Trophic groups**	***Bondarzewia mesenterica***	***Fistulina hepatica***	***Fomitopsis rosea***	***Grifola frondosa***	***Hericium alpestre***	***Hericium coralloides***	***Meripilus giganteus***
Glischrochilus quadripunctatus (Linnaeus, 1758)	C	z		1			1		
Soronia grisea (Linnaeus, 1758)	C	m		1					
Ptinidae									
Cacotemnus rufipes (Fabricius, 1792)	S	sx							1
Dorcatoma dresdensis Herbst, 1792	M	m	1		2		1		2
Dorcatoma lomnickii Reitter, 1903	M	m	1		3	1			3
Dorcatoma robusta A. Strand, 1938	M	m							1
Hemicoelus canaliculatus (C. G. Thomson, 1863)	S	sx				2			
Ptilinus pectinicornis (Linnaeus, 1758)	S	sx	1			4	2	2	6
Pyrochroidae									
Schizotus pectinicornis (Linnaeus, 1758)	C	sx							1
Salpingidae									
Salpingus planirostris (Fabricius, 1787)	C	z	9	8	8	5	11	16	1
Salpingus ruficollis (Linnaeus, 1760)	C	z	10	14	8	10	7	17	10
Sphaeriestes castaneus (Panzer, 1796)	C	z							1
Scraptiidae									
Anaspis frontalis (Linnaeus, 1758)	S	sx	2	1	2	4	2	3	1
Anaspis rufilabris (Gyllenhal, 1827)	S	sx	4	4	8	1	1	4	5
Anaspis thoracica (Linnaeus, 1758)	S	sx	1			1		1	
Cyrtanaspis phalerata (Germar, 1847)	S	sx	2			3			1
Scydmaenidae									
Neuraphes taplarum Lokay, 1920	MI	z				1	1		1
Stenichnus collaris (P. W. J. Müller & Kunze, 1822)	MI	z	1					1	
Sphindidae									
Sphindus dubius (Gyllenhal, 1808)	MY	my				1	1		
Staphylinidae									
Atheta crassicornis (Fabricius, 1793)	M	z					1	1	
Bibloporus bicolor (Denny, 1825)	C	z		1	1				
Bibloporus minutus Raffray, 1914	C	z	1	1		2	2	5	

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Table 2. continued.

Family / Species	Biotope groups	Trophic groups	*Bondarzewia mesenterica*	*Fistulina hepatica*	*Fomitopsis rosea*	*Grifola frondosa*	*Hericium alpestre*	*Hericium coralloides*	*Meripilus giganteus*
Bolitochara obliqua Erichson, 1837	M	z			2				1
Euplectus infirmus Raffray 1910	C	z	1				1		
Euplectus karstenii (Reichenbach, 1816)	C	z		1			1		
Euplectus punctatus Mulsant & Rey, 1861	C	z					1	2	
Leptusa pulchella (Mannerheim, 1830)	C	z					1		
Leptusa ruficollis (Erichson, 1839)	C	z	1				2		
Lordithon lunulatus (Linnaeus, 1760)	M	z					1	1	
Scaphisoma agaricinum (Linnaeus, 1758)	M	m	2			1	1	4	1
Sepedophilus littoreus (Linnaeus, 1758)	S	z			1				
Sepedophilus testaceus (Fabricius, 1793)	M	m						1	
Tenebrionidae									
Scaphidema metallicum (Fabricius, 1792)	S	sx	1						
Tetratomidae									
Tetratoma ancora Fabricius, 1790	M	m	1	5	4	4			
Tetratoma fungorum Fabricius, 1790	M	m	1						3
Throscidae									
Aulonothroscus brevicollis (Bonvouloir, 1859)	M	m	2	2	23	8	60	9	8
Trixagus carinifrons (Bonvouloir, 1859)	M	m	47	26	15	46	45	72	52
Trixagus dermestoides (Linnaeus, 1767)	M	m	16	6	6	7	10	5	15
Trogossitidae									
Grynocharis oblonga (Linnaeus, 1758)	S	sx						1	
Zopheridae									
Synchita humeralis (Fabricius, 1792)	S	m						1	

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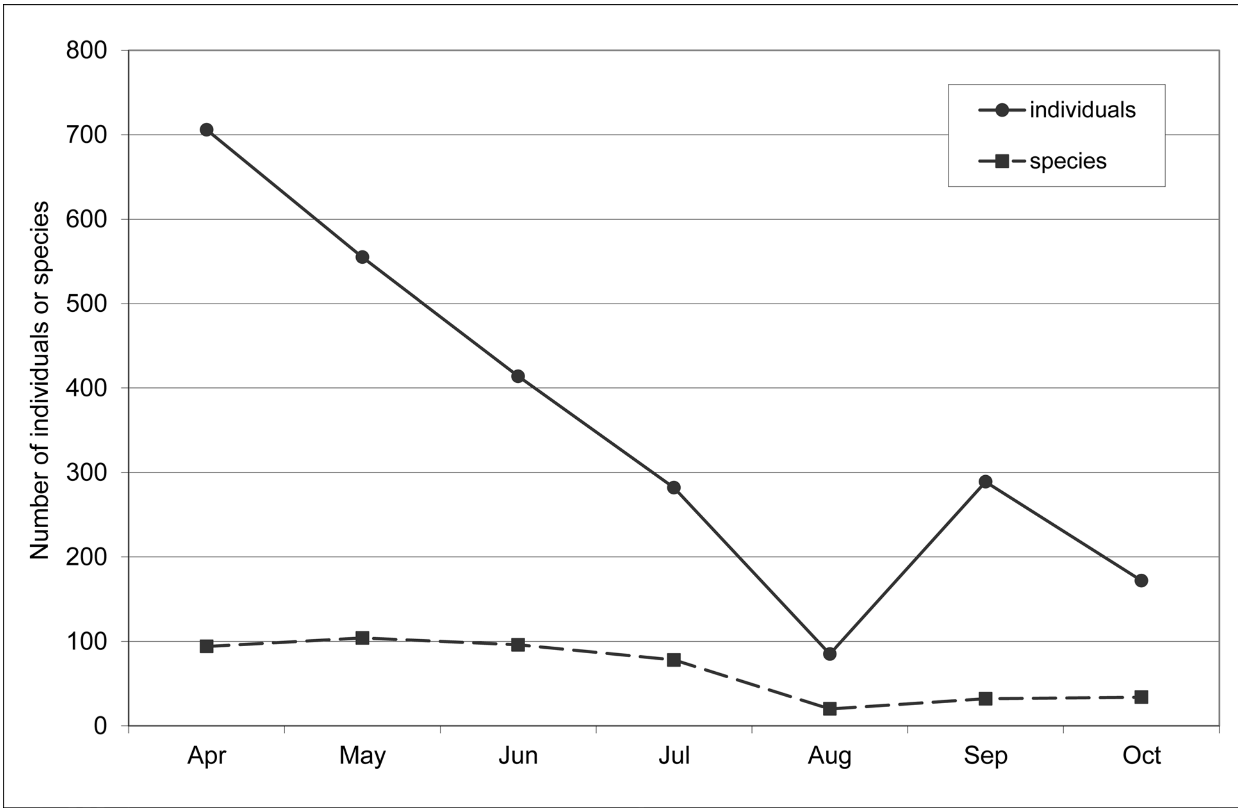

Fig. 3. Seasonal variation in numbers of individuals and species of beetles caught in traps with mycelium of wood-decay fungi on sawdust substrate.

third (20.3%). Species feeding on slime moulds were the least numerous (myxomycophages – 9.0%).

The largest number of individuals and species was caught in spring months (Fig. 3). Among the dominant species, *Rhizophagus bipustulatus* was caught primarily in early spring (April–May), *Cortinicara gibbosa* in spring (April–June) and autumn (October), whereas *Dienerella ruficollis*, in late summer and autumn (August–October). The seasonal dynamics of species of the family Throscidae shows that among *Aulonothroscus brevicollis, Trixagus carinifrons* (dominant species), and *T. dermestoides*, only *T. dermestoides* has one peak of abundance (in June), while the other two species have two peaks of abundance. This suggests that the latter species are bivoltine, i.e., have two generations a year. The first generation peaks in May, whereas the second generation of *A. brevicollis*, in July, and that of *T. carinifrons*, in September (Fig. 4).

Cluster analysis of species composition of the catch for the seven bait variants allowed us to distinguish two clusters of species composition. The first cluster was formed by the two beetle assemblages attracted to sawdust substrate with mycelium of *F. hepatica* and *F. rosea,* i.e., the fungi causing brown rot (Fig. 5). The second cluster was formed by all the other assemblages, including all species being attracted by sawdust substrate with the fungi causing white rot: *B. mesenterica, G. frondosa, H. alpestre, H. coralloides,* and *M. giganteus*. The latter cluster is composed again of two groups of species: the beetles associated with fungi of the genus *Hericium*, and beetles

Table 3. Biotope groups of beetles caught in traps with mycelium of wood-decay fungi on sawdust substrate..

Biotope group	**Number of species**		**Number of individuals**	
	S	%	N	%
Corticoles	23	17.3	391	19.2
Mycetocoles	64	48.1	1303	63.9
Myrmetocoles	2	1.5	5	0.2
Myxomycetocoles	12	9.0	170	8.3
Saproxylocoles	32	24.1	169	8.3

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Table 4. Trophic groups of beetles caught in traps with mycelium of wood-decay fungi on sawdust substrate.

Trophic groups	Number of species		Number of individuals	
	S	%	N	%
Mycetophages	62	46.6	1297	63.6
Myxomycophages	12	9.0	170	8.3
Saproxylophages	27	20.3	146	7.2
Zoophages	32	24.1	425	20.9

associated with the other fungi causing white rot (Fig. 5). A similar result was obtained using the Nonmetric Multidimensional Scaling analysis (Fig. 6).

In the cluster composed of beetles attracted by sawdust substrate with brown rot fungi, the dominant species were *Cortinicara gibbosa* (11.2%), *Rhizophagus bipustulatus* (9.3%), *Trixagus carinifrons* (7.2%), and *Cryptophagus dentatus* (6.7%) (Fig. 7). The most frequently caught species specific to brown rot (absent from the second cluster) was *Corticarina similata* (three individuals in three traps).

In the cluster composed of beetles attracted by sawdust substrate with white rot fungi, the dominant species were *Trixagus carinifrons* (17.8%), *Dienerella ruficollis* (8.2%), *Rhizophagus bipustulatus* (6.0%), *Aulonothroscus brevicollis* (5.9%), and *Cortinicara gibbosa* (5.5%) (Fig. 8). The most frequent species in the white rot were *Ptilinus pectinicornis* (15 individuals in 12 traps), *Scaphisoma agaricinum* (nine individuals in nine traps), and *Clypastraea pusilla* (eight individuals in six traps).

DISCUSSION

Trapping of 133 species of tree-fungus beetles with the use of sawdust substrate with mycelium during one growing season is a methodological success. As many as 90 of the species were recorded in the Experimental Forest Station in Rogów for the first time, and two new species for the fauna of Poland were found: *Corticaria pineti*

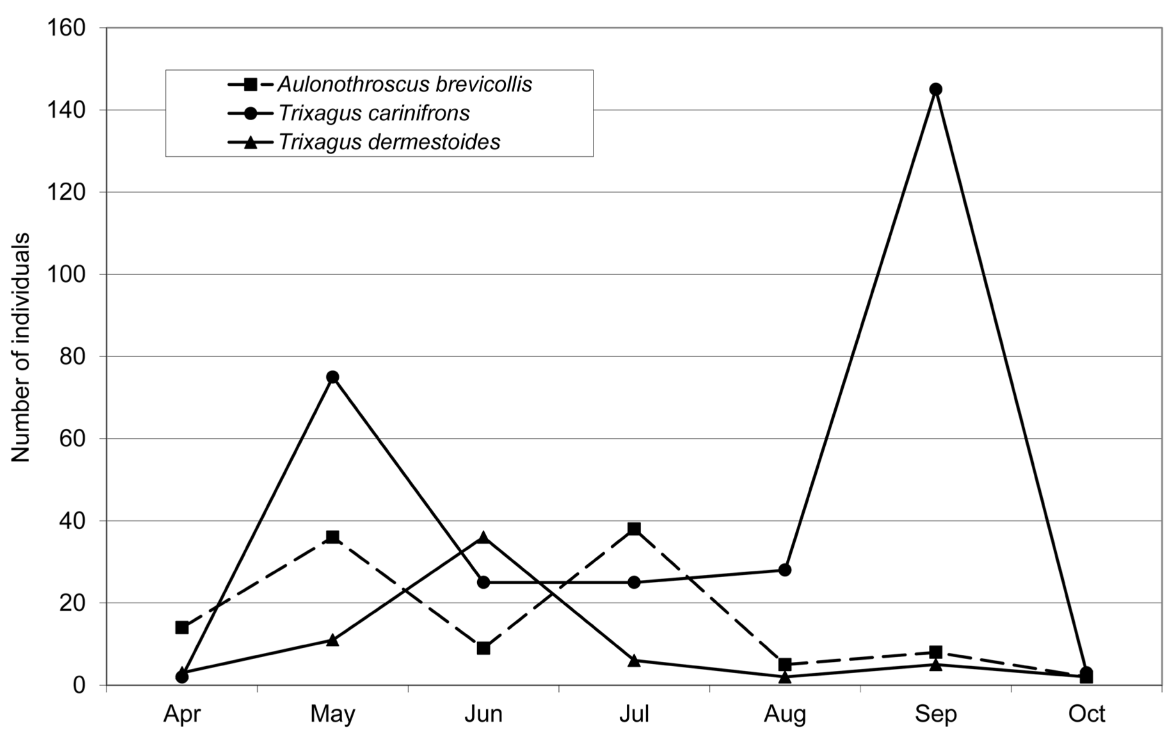

Fig. 4. Seasonal variation in abundance of species of the family Throscidae caught in traps with mycelium of wood-decay fungi on sawdust substrate.

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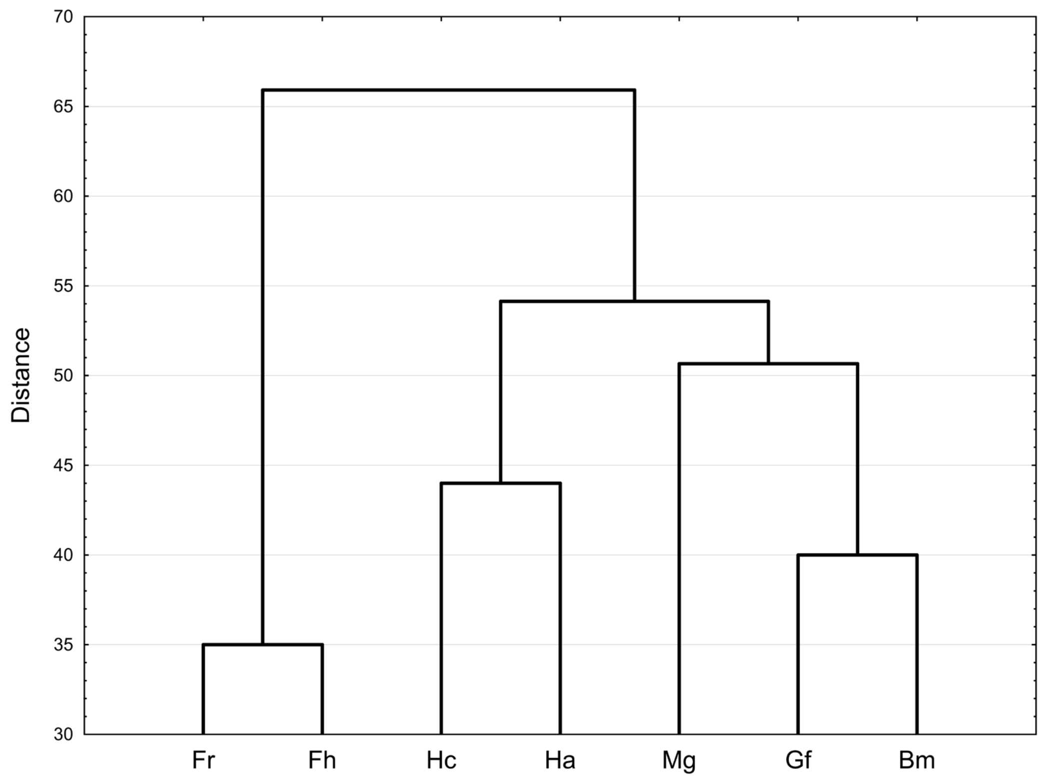

Fig. 5. Faunistic similarity of communities of beetles of wood-decay fungi (Cluster analysis), caught in traps with mycelium on sawdust substrate. Abbreviations: Bm = *Bondarzewia mesenterica*; Fr = *Fomitopsis rosea*; Fh = *Fistulina hepatica*; Gf = *Grifola frondosa*; Ha = *Hericium alpestre*; Hc = *Hericium coralloides*; Mg = *Meripilus giganteus*.

and *Euplectus infirmus*. The former is a rarely reported species living on moulds, known mostly from Central Europe and Scandinavia, reaching south to Greece and Italy. The latter species lives under the bark and has an Atlantic distribution, extending to Italy, Croatia, and Greece in the south and Germany in the east. It is known also from Morocco and Canary Islands. Its record in central Poland moves its eastern distribution limit more than 300 km eastward from records reported in the literature (Borowski et al. 2010).

Beetle species recorded in this study have various microbiotope preferences (mycetocoles, saproxylocoles, corticoles, myxomycetocoles, myrmetocoles). Some of them develop exclusively on fruiting bodies of tree fungi (e.g., *Orchesia micans*, *Cis micans*) or are spore-eating species (e.g., *Scaphisoma* spp.). Some others develop on fruiting bodies of tree fungi as well as mushrooms, e.g., *Dacne bipustulata* in fruiting bodies of tree fungi (Burakowski et al. 1986) and in mushrooms of the genus *Cortinarius* (Pers.) Gray (Borowski 2006). Zoophages were also numerous in the samples (e.g., species of the genus *Rhizophagus* Herbst). Johansson et al. (2006) confirmed that fruiting bodies of tree fungi attract not only beetles that feed on fungi but also many predatory species.

In total, the family Throscidae was represented most numerously, by 480 individuals of three species: *Aulonotroscus brevicollis*, *Trixagus dermestoides*, and *T. carinifrons*. Burakowski (1991) reported that species of this family are rarely found in the field, so their ecology is poorly studied. Supposedly they live in the soil or litter, near roots colonized by mycorrhizal fungi. Thanks to the applied trapping method, we collected new information on the ecology and phenology of emergence of the three species mentioned above. The presented results indicate that *T. carinifrons* and *A. brevicollis* have two peaks of abundance during the year, whereas *T. dermestoides* has only one. The existence of two peaks of abundance in *A. brevicollis* and one peak in *T. dermestoides* was reported also earlier by Leseigneur (2004). According to Hardersen et al. (2014), Throscidae were always present with two or three species, from early April to early November, mainly in Malaise traps at ground layer. Van Meer (1998) supposes that larvae of *A. brevicollis* can develop on dry rotten wood, very much like larvae of the closely related *A. laticollis* Rybinsky, 1897, which were observed by him in dry rotten oak wood. Mertlik & Leseigneur (2007) indicate that imagines of these species overwinter in dead wood. The luring properties of the substrate with mycelium and the presence of eggs and larvae of insects could be the causes of the high abundance of *Rhizophagus bipustulatus, Salpingus ruficollis*, and *S. planirostris*. According to Nunberg (1967), *R. bi-*

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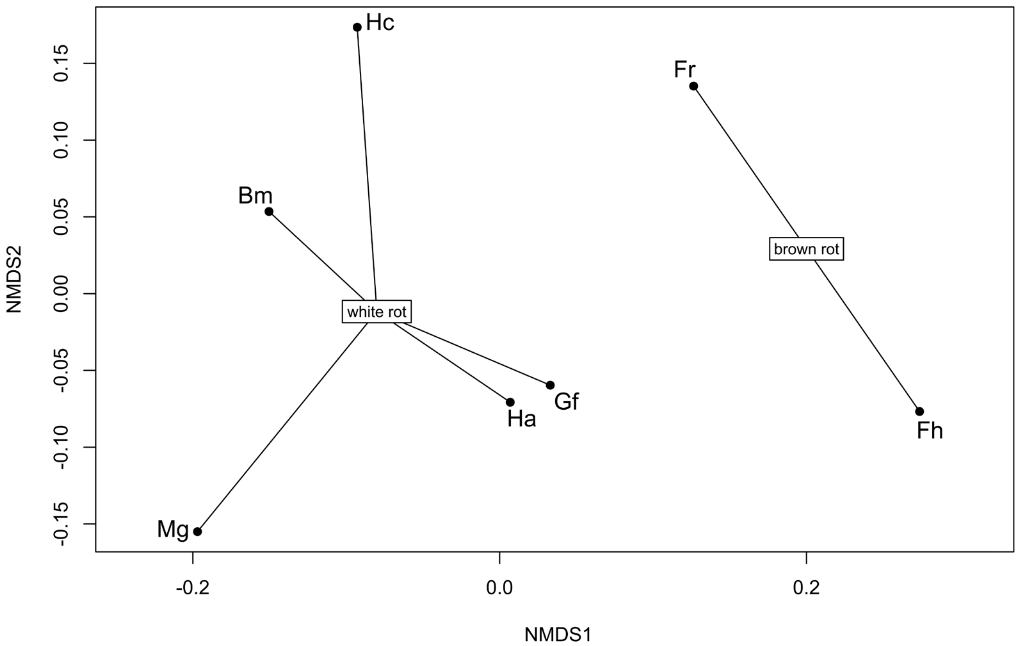

Fig. 6. Faunistic similarity of communities of beetles of wood-decay fungi (Nonmetric Multidimensional Scaling analysis), caught in traps with mycelium on sawdust substrate Abbreviations: Bm = *Bondarzewia mesenterica*; Fr = *Fomitopsis rosea*; Fh = *Fistulina hepatica*; Gf = *Grifola frondosa*; Ha = *Hericium alpestre*; Hc = *Hericium coralloides*; Mg = *Meripilus giganteus*.

pustulatus is predatory, living under the bark, or rarely in rotten wood, feeding mostly on eggs, larvae, free pupae and excrements of various insects and fungi growing at their feeding sites. Mendel et al. (1990) list it among

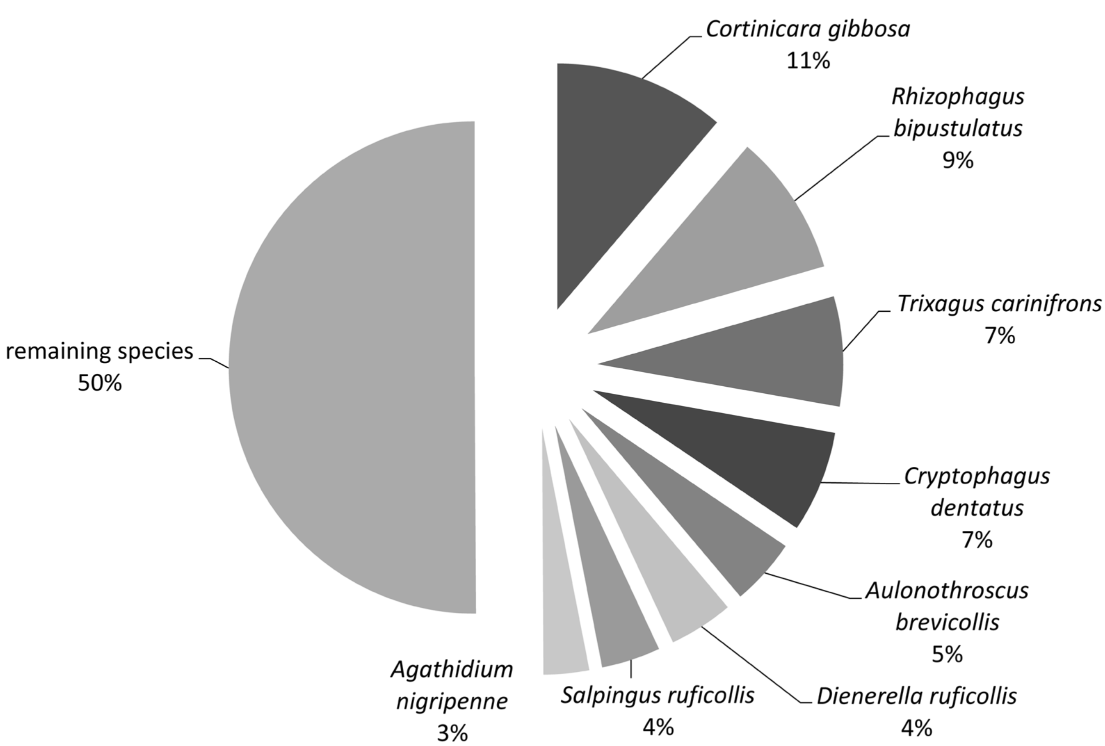

Fig. 7. Contributions of species to the total number of beetles attracted by sawdust substrate with fungi causing brown rot.

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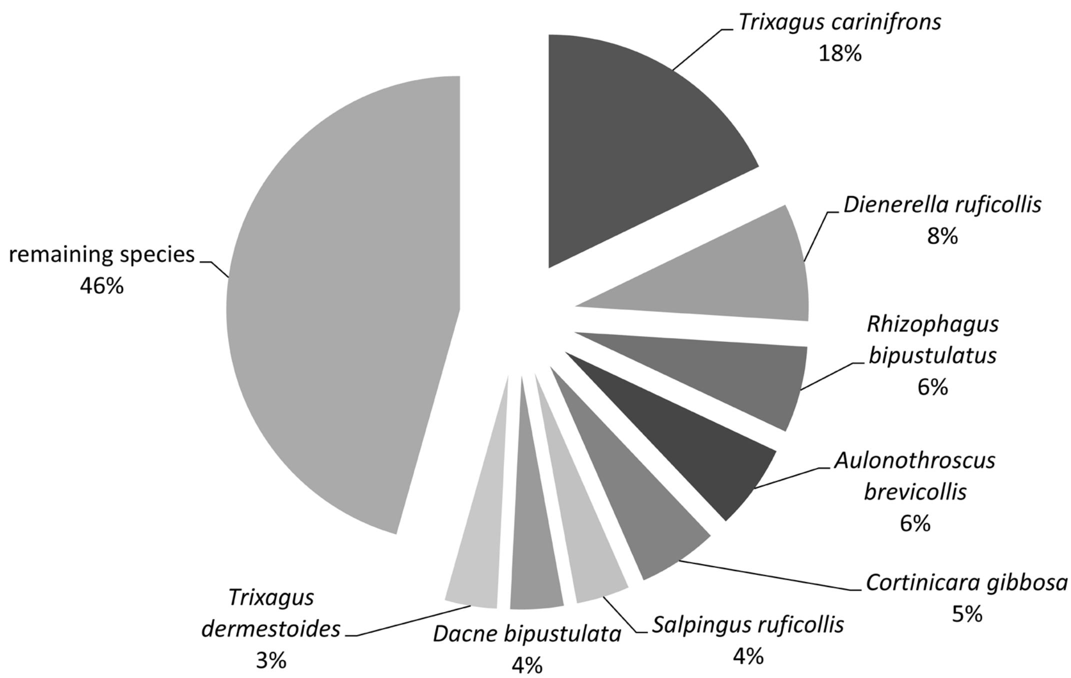

Fig. 8. Contributions of species to the total number of beetles attracted by sawdust substrate with fungi causing white rot.

predators feeding on bark beetles of the genera *Tomicus* Latreille, *Orthotomicus* Ferrari, and *Pityogenes* Bedel. It is also known that larvae and imagines of *S. planirostris* prey on bark beetles (Young 1991). The most abundant species among the trapped beetles included also *Cortinicara gibbosa*, *Dienerella ruficollis*, and *Cryptophagus dentatus*. They are some of the most common mould-eating insects.

The applied sawdust substrate with mycelium of wood-decay fungi attracted much more mycetobiontic beetles than reported in earlier studies of fruiting bodies of these fungal species (Scheerpeltz & Höfler 1948; Benick 1952; Burakowski et al. 1986, 1987; Nikitsky 1993; Krasutsky 1995, 1997; Nikitsky & Schigel 2004, 2007; Borowski 2006). In traps with mycelium of *G. frondosa*, we found 31 species of mycetobiontic beetles that were not reported earlier from this fungus, with *F. hepatica* 25 species, with *F. rosea* 24 species, with *H. coralloides* 21 species, and with *M. giganteus* 32 species. For the other two species of fungi, there are no published data on mycetobiontic beetles recorded on their fruiting bodies, but we found 29 species in traps with mycelium of *H. alpestre* and 27 species in those with *B. mesenterica.* According to Borowski (2006, 2007), 259 mycetobiontic beetles are reported from Poland, whereas 60 species were caught in our study. The findings of Piętka & Borowski (2011a) in the forest reserve "Las Natoliński" in Warsaw indicate that the traps with mycelium are highly effective in catching mycetobiontic beetles. Numerous fruiting bodies of *F. hepatica* in that area resulted in a relatively high abundance of the beetle *Triphyllus bicolor*, which was caught in traps with its mycelium. As many as 32 individuals of this rare mycetophagous species were trapped there. Interestingly, in that reserve, between the traps with mycelium of *F. hepatica*, traps with mycelium of another fungal species were located (*G. frondosa*, found on oaks), but no individual *T. bicolor* was caught in them.

In the collected material, two autonomous faunistic clusters of beetles of wood-decay fungi are noticeable: one associated with brown rot fungi, and the other with white rot fungi. The beetle communities attracted by sawdust substrate with brown rot fungi were dominated by *Cortinicara gibbosa*, *Rhizophagus bipustulatus, Cryptophagus dentatus*, and *Trixagus carinifrons*. The beetle communities attracted by sawdust substrate with white rot fungi were dominated by the same species except *C. dentatus*, but with the addition of *Dienerella ruficollis* and *Aulonothroscus brevicollis.* The three shared species are beetles living on moulds or their predators. Three beetle species were specific to the cluster composed of beetles attracted by traps with white rot fungi: saproxylophagous *Ptilinus pectinicornis* and mycetophagous *Scaphisoma agaricinum*, and *Clypastraea pusilla*. These beetles were caught exclusively in traps with mycelium of white rot fungi. Piętka & Borowski (2011b) reported that *P. pectinicornis* was very numerous (32.8% of the total catch) in beech stands in Świętokrzyski National Park.

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It was caught there in traps with sawdust substrate and mycelium of a white rot fungus, *Trametes gibbosa* (Pers.) Fr. Leather et al. (2014) confirm that *Ptilinus pectinicornis* commonly associated with dry and exposed beech wood was significantly associated with infested logs by *Hypholoma fasciculare* (Huds.) P. Kumm., which also causes white rot of wood.

The sawdust substrates with mycelium of wood-decay fungi, prepared in laboratory conditions, constituted a free and attractive ecological niche for many species.

CONCLUSIONS

The sawdust substrates with mycelium of wood-decay fungi, used in traps, attract mycetophilic and mycetobiontic beetles. In the study period (April-October 2008) we caught 73 mycetophilic species and 60 mycetobiontic species of beetles. This bait type was effective in the trapping of beetles associated with wood-decay fungi. Two new species for the fauna of Poland were recorded in this study: the mycetophilic *Euplectus infirmus* and the mycetobiontic *Corticarina pineti*. In the tree-fungus beetle community, mycetophages and zoophages feeding on them were the major trophic groups, while mycetocoles were the major microhabitat group. In the collected material, two clusters of beetle species of wood-decay fungi can be distinguished. The first one is associated with brown rot fungi (*Fistulina hepatica, Fomitopsis rosea*), and the other with white rot fungi (*Bondarzewia mesenterica, Grifola frondosa, Hericium alpestre, H. coralloides, Meripilus giganteus*). It seems that this method can be applied in studies on diversity of tree-fungus beetles, valorisation of forests and monitoring of environmental processes.

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