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ORIGINAL PAPER

Pathogens as creators of biodiversity. A study on influence of decayed bracket fungi on alpha diversity of microarthropods in the Karkonosze National Park, Poland

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ABSTRACT

Bracket fungi are organisms important to forestry, often perceived from the point of view of economic losses they cause, but they also play an important role in shaping biodiversity, *e.g.* by creating specific microhabitats to which their fruiting bodies belong. The fruiting bodies of this group of fungi are the place of occurrence of invertebrate assemblages specific for them, however, this topic is still poorly researched. The aim of the study was to assess the effect of the degree of decay (DD) of fruiting bodies on the microarthropod communities inhabiting them. The study material (100 fruiting bodies) was collected in the Karkonosze National Park, which areas were affected by a large-scale forest dieback process in the 1980s. 29,228 individuals of microarthropods belonging to 186 species were extracted. Oribatid mites were the most numerously represented group (87 species and 24,472 individuals) and the most numerous species was *Carabodes femoralis* (20,167 ind.). In addition to the species previously observed also in other substrates, species characteristic only for fruiting bodies of arboreal fungi were also observed (*e.g. Hoploseius oblongus*). Each DD's fauna differed from one another, in the majority of microarthropod groups there was a tendency for greater number of species and individuals in higher DDs; however, it was not a linear one. The NMDS and cluster analyses indicated that the 3 DD and 4 DD samples are similar to each other, whereas 1 DD and 2 DD samples differed from the samples belonging to the other DDs. Indicator species analysis has indicated species characteristic for each DD, among others *Hoploseius oblongus* for 1 DD and *Zerconopsis remiger* for 4 DD. The results encrease the knowledge on the poorly-understood aspekt of ecology and can be

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a useful source of information for effective protection of forest biodiversity and sustainable forest management.

KEY WORDS

pathogenic fungi, richness, Arachnida, Collembola, Insecta

Introduction

Despite extensive research devoted to a beneficial role of decayed wood in the ecosystem from the viewpoint of biodiversity formation (*e.g.* Lonsdale *et al.*, 2008) and the universal approach, according to which fungi decaying wood constitute a ubiquitous and functionally significant part of the environment (Jönsson *et al.*, 2008), these organisms are often perceived mainly through the prism of financial losses in forest industry caused by the decay of living trees as well as destruction of solid wood products (Sinclair *et al.*, 1987; Manion, 1991). The role of rotting wood in shaping biodiversity has been demonstrated in many groups of animals, such as various groups of invertebrates (Jonsell and Nordlander, 2002; Komonen, 2003; Kappes and Topp, 2004) as well as birds (Butler *et al.*, 2004; Jackson and Jackson, 2004) and mammals (Suter and Schielly, 1998; Bowman *et al.*, 2000). Moreover, it has been proven on the example of Uropodina, that dead wood not only increases the species diversity of this mites inhabiting it, but also promotes the occurrence of rare and stenotopic species (Błoszyk *et al.*, 2021). A much less studied microhabitat, as far as the fauna is concerned, is the fruiting bodies of bracket fungi. So far, the conducted studies have focused on insects (*e.g.* Jonsell and Nordlander, 2004), mites (*e.g.* Gwiazdowicz and Łakomy, 2002; Hågvar and Steen, 2013) or arthropods in general (*e.g.* O'Connell and Bolger, 1997a, b) which inhabited them. Most of the studies on the fauna inhabiting the fruiting bodies of fungi were usually faunistic in nature. The exceptions, however, are the studies by Thunes and Willasen (1997), which showed that the most significant variable for beetle communities occuring in sporohores was whether the inhabited fruiting body was dead or alive, or study by Gdula *et al.* (2021a, b) proved that the invertebrate fauna differs depending the degree of decay of the samples. The studies have shown a higher number of both individuals and species in the more decayed fruiting bodies, compared to the samples with lower degree of decay, fruiting bodies differently decayed, characterized also by the presence of different invertebrate species characteristic for them (Gdula *et al.*, 2021a, b).

In order to scrutinise the dependency between bracket fungi and invertebrates, the Karkonosze National Park (KNP) was chosen as the study area. Due to the species diversity of invertebrates, which is a result of mountainous character and changing altitude levels, hence different thermal and humidity conditions (Gwiazdowicz, 2003) and a significant specificity in comparison to other Polish mountains (Raj and Knapik, 2014), the park is interesting from the scientific viewpoint. Furthermore, it was subjected to long-term and devastating factors both natural and anthropogenic (Danielewicz *et al.*, 2002). In the 1980s due to such factors as air pollution (Baltensweiler, 1985), heavy metals (Guderian, 1977) and pests, such as bark beetles (Schelhaas *et al.*, 2003), about 15.000 ha at Western Sudety Mountain was deforested. One of the ramifications of the disaster was deficiency of soil mites in comparison to the research from the 1960s (Gwiazdowicz, 2003). Among the significant contemporary sources of threats to biodiversity in KPN are also issues connected with tourism, such as numerous ski runs, which impact the mites fauna (Gwiazdowicz, 2002a). Despite a large number of academic research (*e.g.* Mazur *et al.*, 2007; Szopka *et al.*, 2013; Marcinkowska *et al.*, 2014), the only research devoted to the communities of

microarthropods inhabiting the fruiting bodies of bracket fungi, which contained research material from the Karkonosze National Park, was the work of Gdula *et al.* (2021b). The authors of this publication confirmed the significant influence of the degree of decomposition of this substrate on the acarofauna that inhabits it and showed a lower species richness of the mite communities from KNP compared to the communities from Białowieża National Park.

The aim of the study was to analyse the microarthropod fauna which inhabit fruiting bodies of bracket fungi and also to determine the manner in which the degree of decay (DD) influences the species diversity of the analysed animal groups. Taking into consideration the results of the study conducted by Gwiazdowicz and Łakomy (2002), which proved that the fungi species is not a decisive factor for invertebrate assemblages and the studies by Gdula *et al.* (2021a, b) concerning the significance of DD of sporophores for the invertebrate communities inhabiting them, a hypothesis has been assumed that the diversity of microarthropod fauna occuring in fruiting bodies of bracket fungi depends on their degree of decay (DD).

Material and methods

Study area. The Karkonosze National Park (KNP) was created in 1959 in the Karkonosze Mountains (southwestern Poland), along the border with the Czech Republic in the highest part of the Sudetes. 72% of KNP consists of forests diversified into foothill zone with such communities as Central European oak-hornbeam forest *Galio sylvatici-Carpinetum betuli* or riverine alder forest *Alnetum incanae*, lower mountain zone with communities such as acidophilic montane beech forest *Luzulo luzuloidis-fagetum* or lower mountane fir-spruce forest *Abieti-Piceetum* (*montanum*) and upper mountain zone with upper mountane spruce forest *Calamagrostio villosae-Piceetum*. In subalpine zone there are, however, such communities as Sudety dwarf-pine thickets *Pinetum mugo sudeticum* and downy willow shrub *Salicetum lapponum* (Danielewicz *et al.*, 2002). The land that is a part of KNP has been strongly influenced by anthropopressure, the deforestation was conducted for settlements, herding and exploitation of minerals. The ecological catastrophe of 1980s was a consequence of human pressure and unfavorable conditions and its effects are still visible today in the case of numerous groups of animals (Jadczyk, 2008).

Collecting material. The fruiting bodies of bracket fungi were collected between 18th-19th July 2014 in Karkonosze National Park (KNP). In order to reflect the specificity of the studied location, during field work 100 perennial, woody fruiting bodies of the most numerously represented species of bracket fungi belonging to class Agaricomycetes (orders: Polyporales, Gloeophyllales, Hymenochaetales and Russulales) were collected from the most common plant communities in this national park. The collected fruiting bodies were marked according to the species, but this factor was omitted in the analyzes, as previous publications (O'Connell and Bolger, 1997b; Gwiazdowicz and Łakomy, 2002) indicated no influence of the fungi species on the species structure of microarthropods inhabiting them. In order to obtain research material, the fruiting bodies were secured in paper bags against the movement of microarthropods inhabiting them and were cut off from tree trunks with the use of a saw or an axe. The samples were taken randomly according to the diameter at breast height and the age of the trees. The fruiting bodies were harvested taking into consideration their degree of decay (DD). The size of fruiting bodies and the tree species from which the samples were taken were also examined, however, due to the lack of correlation between these factors and the number of individuals and species of microarthropods inhabiting the samples, these factors were omitted in further analyzes. With the aim of prevent the shifting of microarthropods between the samples, the fruiting bodies

were secured in separate paper bags during transport to the laboratory. In order to enable the survival of as many microarthropods as possible, the samples were stored in a laboratory cold store at a temperature not exceeding 8ºC until they were extracted in Tullgren funnels. A single fruiting body equals 1 sample.

Laboratory procedures. In laboratory conditions the fruiting bodies were divided according to DD using the classification by Gdula *et al.* (2021a), based on the differences in the occurrence of various features in the substrate with a different degree of decay (Table 1). Next, in order to extract mezofauna the fruiting bodies of the fungi were placed in Tullgren funnels for 72 hours.

The obtained microarthropods were preserved in 75% ethanol and then categorized into six taxonomic groups: spiders and opiliones (Aranae and Opiliones), pseudoscorpions (Pseudoscorpionida), two groups of mites (Mesostigmata, Oribatida), springtails (Collembola) and insects (Insecta).

The collected Aranae and Opiliones were counted and identified. The taxonomic keys of valid spiders and opiliones (Roberts, 1985; Rozwałka, 2017; Nentwig *et al.*, 2020) were used to identify the species.

The Pseudoscorpionida were identified during proper orientation of the specimen and under moderate to high magnifications using stereomicroscope. For some samples, temporary microscope slides were necessary to be prepared so that they could be studied under the compound microscope.

In order to identify Mesostigmata mites, semi-permanent (using lactic acid) and permanent (using Hoyers medium) microslides were prepared. All individuals of mesostigmatic mites were examined using light microscope (Zeiss Axioskope 2) and taxonomical literature (*e.g.* Karg, 1993; Mašán, 2001; Gwiazdowicz, 2007, 2010).

The Oribatida were identified at high magnification (l00-1000×) under a light microscope (Nikon Eclipse E600). Prior to the examination, the cuticle had been rendered transparent and the internal tissue in freshly collected individuals was removed using concentrated lactic acid (60%) as the clearing agent. The species level of the oribatid mites was determined by means of following taxonomic keys and original species descriptions (Olszanowski, 1996; Weigmann, 2006; Niedbała, 2008). The species names were updated according to Weigmann (2006).

The identification of Collembola was performed using a light microscope. The extracted specimens of springtails were mounted with Hoyer's medium (Coleman *et al.*, 2004), for which permanent microscopic slides necessary for taxonomic analysis were prepared. The taxonomic identification of the Collembola was carried out following the manuals by Fjellberg (1998, 2007), Bretfeld (1999), Potapov (2001), Thibaud *et al.* (2004), Dunger and Schlitt (2011) and Jordana (2012).

The specimens of the collected Insecta were killed and preserved in 75% ethanol. The identification of the immature stages was carried out by following Stehr's manuals (2005, 2008). The imagines of Coleoptera were counted and identified using taxonomic keys (*e.g.* Lohse,

Table 1.

Decay scale of bracket fungi. DD – degree of decay (Gdula *et al.* 2021a)

DD	Description
1.	Fruiting body with fresh hymenophore, without visible signs of decay
2.	Fruiting body with dry hymenophore, without visible signs of decay
3.	Fruiting body with few traces of decomposition, *e.g.* single (up to 10) insect galleries
4.	Fruiting body with numerous traces of decay, such as insect galleries, easily crumbled

1967; Besuchet and Sundt, 1971; Stebnicka, 1991) and the comparative collection of Natural History Collections, Adam Mickiewicz University.

The microarthropods which were determined only to higher taxonomic units, i.e. genus or family, were treated as separate species in statistical analyses.

All the material is deposited in acarological collection at Adam Mickiewicz University, the Faculty of Biology, Natural History Collections, Poznań, Poland (Aranae and Opiliones, Pseudoscorpionida, Insecta), Department of Entomology and Forest Pathology, Poznań University of Life Sciences (Mesostigmata); University of Silesia, Poland (Oribatida); Cardinal Stefan Wyszyński University, Poland (Collembola).

Statistics. In order to indicate the diversity of the microarthropods colonising the samples belonging to the particular DDs, cluster analysis with the Manhattan distance and Ward's method (Maechler *et al*., 2019) was adopted. Next, an iterative non-metric multidimensional scaling method (NMDS) with Bray-Curtis dissimilarity (McCune and Grace, 2002) was used in order to assess how the samplings can be categorised particular DDs as far as the colonising microarthropods are concerned. In addition, analysis of variance was conducted for the coordinate of points obtained from NMDS which was applied to find statistically significant differences between the DDs. When the significant differences were detected, multiple comparisons were conducted using a simultaneous Tukey's test. Microarthropods significantly influencing the variation in DDs were identified using the indicator species analysis. The analyses were carried out for the double Wisconsin standardization data. All of the statistical analyses were conducted in the R environment following the procedures of the vegan package (Oksanen *et al*., 2019) and the indicspecies package (De Caceres and Legendre, 2009) and STATISTICA 13.3. (TIBCO, 2017).

Results

General informations. The number of the microarthropod individuals per sample was different and was between 1 to 2,071 (mean 310.94 ±21.92), whereas the number of species per sample was between 1 to 41 (mean 13.62 ±0.78). The total number of collected microarthropods was 29,228 and the number of species was 186. Among the microarthropod groups, the most numerously represented were oribatid mites (24,472 ind.), next mesostigmatic mites (2,476), insects (1,630), springtails (633), spiders and opiliones (14), the least represented were pseudoscorpions (3). *Carabodes femoralis* (Nicolet) (20,167 ind.), *Carabodes areolatus* Berlese (1,455) and *Cis* spp. (1,308) were the most numerous species of microarthropods. As far as species are concerned, Oribatida (87 species) was the most numerous group with Mesostigmata (55), Insecta (20), Collembola (15), Aranae and Opiliones (8) and Pseudoscorpionida (1) to follow (see Appendix).

Diversity of microarthropod assemblages depending on DD. The results showed a trend for the occurrence of increased numbers of species and microarthropod individuals in the samples belonging to the higher DDs, however, the tendency was not linear and looked differently for each group of invertebrates (Fig. 1 A, B, Table 2, 3).

The microarthropod group which reacted differently to the DD of fruiting bodies than had been expected were spiders and opiliones. In the case of this group, the fewest number of species and individuals was not in the least decayed fruiting bodies, but in the 3 DD samples, whereas the most species in 2 DD samples. The mean number of individuals per sample was highest, as expected, in the most decayed samples. An interesting group, in reference to the

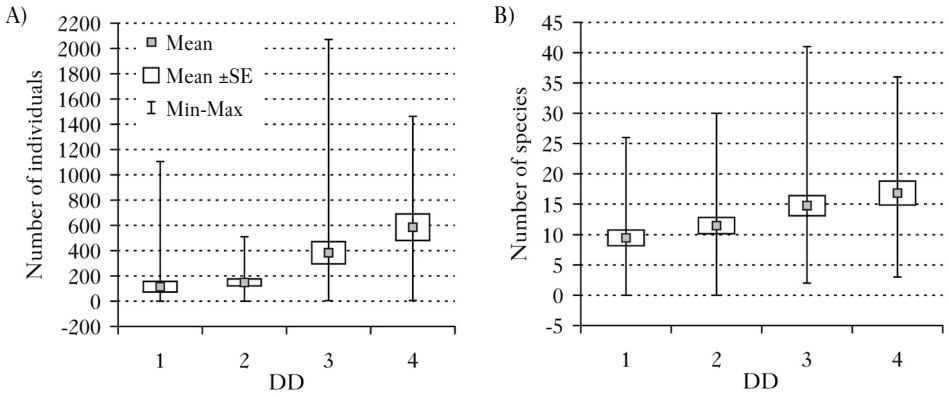

Fig. 1.

Minimum, maximum, mean number ±SE of (A) individuals and (B) species of microarthropods depending on DD of samples (1-4 – degrees of decay of fungi)

Table 2.

Minimum, maximum, mean number and ±SE of species of microarthropods per one sample depending on DD of samples (1-4 – degrees of decay of fungi)

Group of microarthropods	1	2	3	4
Aranae and Opiliones	0-2 (0.14) ±0.08	0-1 (0.17) ±0.08	0-1 (0.08) ±0.06	0-1 (0.14) ±0.07
Pseudoscorpionida	0-1 (0.04) ±0.04	0-1 (0.04) ±0.04	0-1 (0.04) ±0.04	0-0 (0) ±0
Acari – Mesostigmata	0-5 (1.43) ±0.27	0-10 (2.63) ±0.48	0-8 (2.84) ±0.47	0-13 (4.09) ±0.81
Acari – Oribatida	0-18 (6.11) ±0.85	0-15 (6.33) ±0.74	0-25 (8.56) ±1.06	2-18 (9.41) ±0.92
Collembola	0-3 (0.68) ±0.18	0-3 (0.79) ±0.18	0-4 (1.36) ±0.27	0-4 (1.45) ±0.3
Insecta	0-3 (0.96) ±0.22	0-4 (1.54) ±0.24	0-5 (1.88) ±0.23	0-7 (1.73) ±0.42
Total	0-26 (9.36) ±1.3	0-30 (11.5) ±1.34	2-41 (14.76) ±1.64	3-36 (16.82) ±1.98

Table 3.

Minimum, maximum, mean number and ±SE of species of microarthropods per one sample depending on DD of samples (1-4 – degrees of decay of fungi)

Group of microarthropods	1	2	3	4
Aranae and Opiliones	0-2 (0.14) ±0.08	0-1 (0.17) ±0.08	0-1 (0.08) ±0.06	0-2 (0.18) ±0.11
Pseudoscorpionida	0-1 (0.04) ±0.04	0-1 (0.04) ±0.04	0-1 (0.04) ±0.04	0-0 (0) ±0
Acari – Mesostigmata	0-88 (7.5) ±3.2	0-139 (22.96) ±6.68	0-188 (25.72) ±8.24	0-254 (48.73) ±16.82
Acari – Oribatida	0-1083 (99.54) ±41.49	0-357 (106.54) ±20.88	0-2000 (327.08) ±82.26	5-1439 (497.77) ±94.24
Collembola	0-22 (2.61) ±1.06	0-20 (3.38) ±1.08	0-23 (4.44) ±1.24	0-127 (16.73) ±7.09
Insecta	0-72 (4.75) ±2.57	0-73 (15.33) ±4.42	0-163 (26) ±7.62	0-112 (21.77) ±6.08
Total	0-1105 (114.57) ±41.97	0-510 (148.42) ±27.47	4-2071 (383.36) ±88.18	5-1463 (585.18) ±104.85

occurring differences between the groups in various DDs, were pseudoscorpions, both in the number of species as well as of the individuals in the first three DDs were comparable; however, in the most decayed samples not a single species was observed. A bit different tendency was noticed for the Mesostigmata mites, both in the case of the number of species and the number of individuals, there was a clear increase with the increasing DD of the samples. For oribatid mites, it is also clear that in the more decayed samples, there is, on average, a higher number of species and individuals per sample (although the highest numbers of individuals and species

were not in the 4 DD samples, but in the 3 DD ones). Also, among the springtails, as expected, there is an increasing number of species and individuals per sample with the increasing decay of the substrate. Above of all, in the case of mean and maximum numbers of Collembola individuals per sample, the highest DDs are prominent in comparison to others. In the last analysed group of the microarthropods – Insecta, both in the case of mean number of species and individuals per sample there is an increase from 1 DD to 3 DD and then a slight decrease in 4 DD (although the highest number of species per sample was in the sample from highest DD) (Table 2, 3).

Cluster analysis (Ward method) with Manhattan distances showed the grouping of the microarthropod assemblages occurring in bracket fungi belonging to particular DDs (Fig. 2). It was revealed that the samples belonging to 3 DD and 4 DD are the most similar and create a single cluster, however, the samples belonging to 1 DD and 2 DD differ from the samples belonging to other DDs.

In order to determine whether DD of fruiting bodies has effect on the number of individuals and species of microarthropods colonizing them, the NMDS analysis was conducted for double Wisconsin standardization of abundances data (Fig. 3). The results of this analysis showed that no area is separate from the other ones, 3 DD and 4 DD areas are most concen-

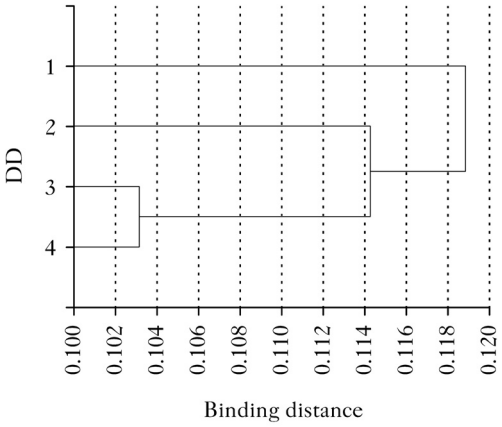

Fig. 2.

Cluster (Ward method) analysis of DD clusters based on Bray-Cutis dissimilarities of double Wisconsin standardization of abundances sums. 1, 2, 3, 4 – DDs

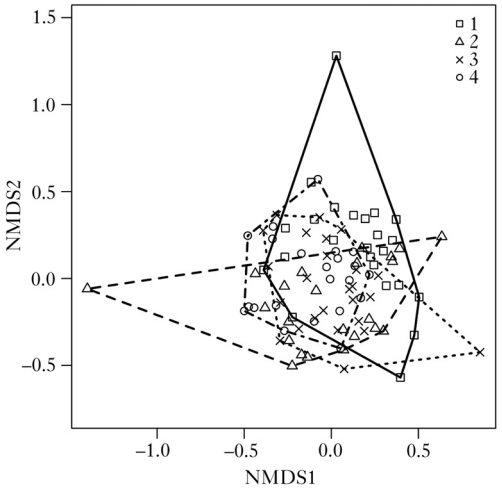

Fig. 3.

Non-metric multidimensional scaling (NMDS) of samples based on Bray-Curtis dissimilarities of double Wisconsin standardization of abundances with area for DDs. 1-4 – samples belonging to particular DDs

trated and, at the same time, most similar (superimposed), whereas 1 DD and 2 DD are the most scattered. Hence, a conclusion can be reached that the greatest diversity of microarthropod species and individuals can be found in 1 DD (the biggest area), but the lowest in 4 DD (the smallest area). Along NMDS1 the greatest diversity was found in the 2 DD samples and in NMDS2 the biggest diversity was in the 3 DD samples. The means along NMDS1 (Table 3) indicate the 1 DD, 3 DD, 2 DD, 4 DD gradient; the means 4 DD and 1 DD are positioned on the opposite poles and in the middle are the means of 3 DD and 2 DD, which are most similar to one another. The means along NMDS2 (Table 4) indicate the 1 DD, 4 DD, 3 DD, 2 DD gradient; the means 3 DD and 4 DD are most closely located, next the mean 1 DD is considerably bigger and 2 DD is considerably smaller than the rest. The result supports the conclusion reached by cluster analysis stating the 1 DD and 2 DD are significantly different from the rest. The biggest area encompasses the 1 DD and 2 DD samples among which there are single samples with characteristic colonies.

The analysis of variance for NMDS1 and NMDS2 revealed significant differences between different DDs both along NMDS1 (p=0.0491), as well as NMDS2, (p=0.0007, see Table 4). A simultaneous test of multiple comparisons has revealed that 1 DD is different from 4 DD along NMDS1 and 1 DD differs from 2 DD and 3 DD along NMDS2 (Table 4).

The above results have presented significant differences between the polypores of different DDs as far as the microarthropod colonisation is concerned; that is why, indicator species analysis was carried out in order to reveal which microarthropods have contributed to the distinction of the groups. The indicator species analysis (using multipatt function from indicspecies packet) indicated 13 taxa which distinct the groups. There are: 12 taxa associated only to one group and one species associated to two groups (Table 5). The occurrence of *Hoploseius oblongus* Mašán & Halliday and *Zygoribatula exilis* (Nicolet) is characteristic for 1 DD samples, for 2 DD samples *Chamobates spinosus* Sellnick and *Thenargamasus* sp. were characteristic. There are no species characteristic for 3 DD; for 4 DD samples the species *Damaeus* (*Paradamaeus*) *clavipes* (Hermann), *Steganacarus* (*Atropacarus*) *striculus* (C.L. Koch), *Zerconopsis remiger*, *Dinychus arcuatus* (Trägårdh), *Metabelba* sp., *Acrotrichis* sp., *Parasitus* sp. and *Pteryx suturalis* (Heer) were the characteristic ones (Table 5). *Dendrolaelaps pini* Hirschmann, has contributed to the homogeneity of 2 DD and 3 DD. The analysis shows that there are few microarthropods characteristic for each DD (most species were for 4 DD) Many microarthropod species are common for most

Table 4.

Analysis of variance of NMDS1 and NMDS2 coordinates as well as multiple comparisons following Tukey method

NMDS	Effect	SS	Degrees of freedom	MS	F	p
NMDS1	DDs	0.7327	3	0.2442	2.7200	0.0491
	Error	8.0810	90	0.0898		
NMDS2	DDs	1.3707	3	0.4569	6.2575	0.0007
	Error	6.5714	90	0.0730		
			DCA1		DCA2	
Tukey test D	DD	Means	Homogeneity groups	DD	Means	Homogeneity groups
	4	–0.1195	a	2	–0.1411	a
	2	–0.0223	ab	3	–0.0515	a
	3	0.0006	ab	4	0.0011	ab
	1	0.1303	b	1	0.1878	b

DDs or there is only one individual per one sample which substantiates the difficulty to establish the differences and similarities between DDs.

THE EFFECT OF DD OF FRUITING BODIES ON INDIVIDUAL MICROARTHROPOD GROUPS. On the basis of the obtained data it can be assumed that each particular microarthropod group reacts differently to the changeable DD of fruiting bodies. In the case of spiders and Opiliones, there is no linear increase with the DD of the substrate both as far as the number of species and individuals are concerned (Fig. 4 A, B). The observation of species structure of the samples from each DD group lead to the assumption that the majority of species was noticed only in the samples of one DD [*e.g. Thyreosthenius parasiticus* (Westring) and Amaurobiidae in 1 DD, or *Lophopilio palpinalis* (Herbst) and *Cryphoeca silvicola* (C.L. Koch) in 2 DD]. Only Linyphiidae were in three of the DD samples (1, 2 and 4); however, not a single species occurred in all DD samples (Appendix).

Table 5.

Species characteristic of a group of sites detected using indicator species analysis

Groups	Species	Stat	*p*.value
1	*Hoploseius oblongus*	0.279	0.005
	Zygoribatula exilis	0.297	0.025
2	*Chamobates spinosus*	0.296	0.019
	Thenargamasus sp.	2.266	0.049
3	–	–	–
4	*Damaeus* (*Paradamaeus*) *clavipes*	0.362	0.002
	Steganacarus (*Atropacarus*) *striculus*	0.287	0.027
	Zerconopsis remiger	0.277	0.045
	Dinychus arcuatus	0.245	0.010
	Metabelba sp.	0.264	0.049
	Acrotrichis sp.	0.264	0.044
	Parasitus sp.	0.263	0.045
	Pteryx suturalis	0.260	0.044
2+3	*Dendrolaelaps pini*	0.311	0.016

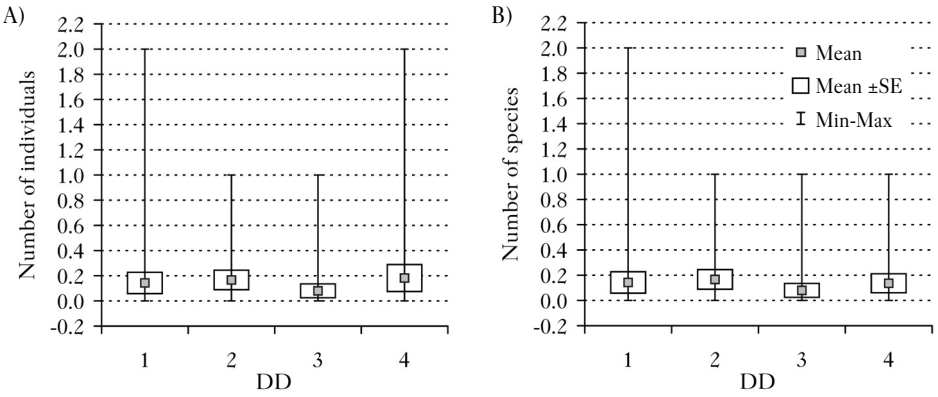

Fig. 4.

Minimum, maximum, mean number ±SE of (A) individuals and (B) species of Aranae and Opiliones depending on DD of samples (1-4 – degrees of decay of fungi)

Pseudoscorpiones was the least represented group both in terms of species number as well as individuals, in the study they were only found in the fruiting bodies of the first three DDs, but in each DD group there was only one individual, which in all cases belonged to the same taxon – Neobisiidae (Fig. 5 A, B and Appendix).

In the case of Mesostigmata, a clear increase can be observed in the number of species and individuals in the samples as the DD increases (Fig. 6 A, B). In the samples from 1 DD group there were a few species which did not occur in the other DD groups, *e.g. Asca bicornis* (Canestrini & Fanzago) or *Alloparasitus oblongus* (Halbert); however, the species such as *Hoploseius oblongus* and *Lasioseius muricatus* (C.L. Koch) occurred in these DD samples much more often than in the other ones. In 2 DD samples, there were also other species occurring only in the fruiting bodies of this DD, i.e. *Dinychus perforatus* Kramer, or *Gaeolaelaps brevipilis* (Hirschmann *et al.*). The species such as *Gamasellus montanus* (Willmann), or *Lasioseius ometes* (Oudemans) occurred also in the 2 DD samples more often than in the other ones. In the 3 DD samples, there were also species exclusive for this particular DD, i.e. *Geholaspis longispinosus* (Kramer) and *Veigaia transisalae* (Oudemans), whereas *Dendrolaelaps pini*, or *Pergamasus rühmi* Willmann were much more numerous in this

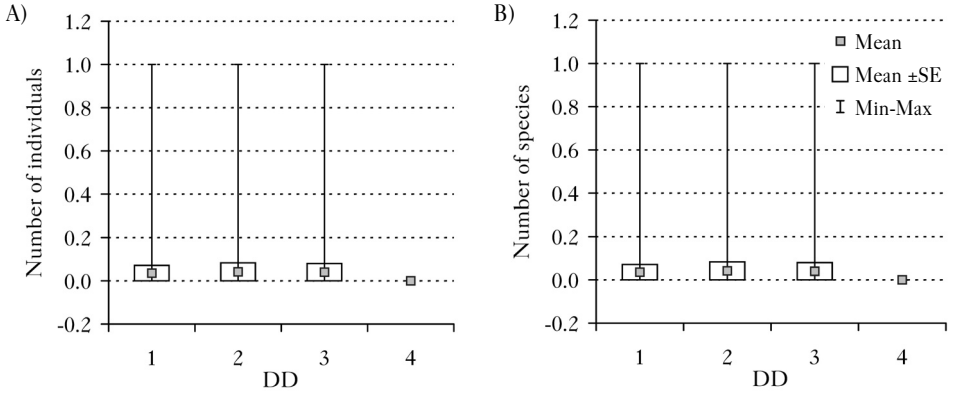

Fig. 5.

Minimum, maximum, mean number ±SE of (A) individuals and (B) species of Pseudoscorpionida depending on DD of samples (1-4 - degrees of decay of fungi)

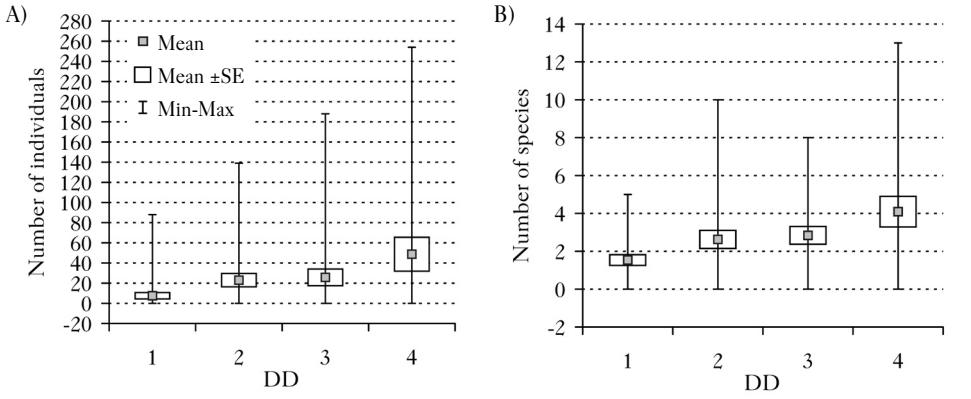

Fig. 6.

Minimum, maximum, mean number ±SE of (A) individuals and (B) species of Mesostigmata depending on DD of samples (1-4 - degrees of decay of fungi)

DD than in the other ones. In 4 DD samples, there were 17 species exclusive to this particular DD, among them *Dinychus arcuatus*, or *Gamasellodes bicolor* (Berlese). In the most decayed samples there were the most Mesostigmata species which did not occur in any other DD. In the case of this microarthropod group there is a clear selectivity in the occurrence of each species according to DD; 31 out of 55 Mesostigmata species were observed in the samples belonging to only one DD group. Noticeably fewer, because only 11 species (among them *Dendrolaelaps pini* and *Lasioseius ometes*) were observed in all DD groups. *Zercon curiosus* Trägårdh, was the only species observed in 1 DD and 2 DD samples, species such as the most numerous Mesostigamata mites in the study – *Dendrolaelaps pini*, or *Lasioseius zerconoides* Willmann were most numerous in the 2 DD and 3 DD samples. However, the species such as *Dendrolaelaps zwoelferi* Hirschmann, or *Trachytes aegrota* (C.L. Koch) were the most numerous in the last two DD sample groups (Appendix).

The data concerning Oribatida allows to observe the increase of mean number of individuals and species per sample together with the increasing decay of fruiting bodies. However, when it comes to the maximal numbers, certain deviations from the trend can be observed (Fig. 7 A, B). As far as the species structure in each DD is concerned, it can be stated that 36 out of the 87 observed species [*e.g. Acrogalumna longipluma* (Berlese) and *Berniniella sigma* (Strenzke)] are present only in fruiting bodies belonging to one DD. However, 24 species [*i.e. Belba corynopus* (Hermann) and *Carabodes femoralis* – the most numerous species of the oribatid mites in the study] were observed in all DDs. Oribatid mites rarely occurred exclusively or particularly often only in the two lowest DDs (*Zygoribatula exilis*, *Damaeus riparius* Nicolet), or only in 2 DD and 3 DD (*Autogneta dalecarlica* Forsslund). Oribatid mites occurred more often and in more considerable numbers in the samples belonging to the two highest DDs [*e.g. Autogneta longilamellata* (Michael), or *Chamobates borealis* (Trägårdh)]. At times, also some species were more numerous in 1 DD and 4 DD, *e.g. Carbodes coriaceus* C. L. Koch, or *Dissorhina ornata* (Oudemans). In the 1 DD samples there were 10 species [among them *Ceratoppia quadridentata* (Haller) and *Nanhermannia nana* (Nicolet)] which did not occur in any other DD groups. In the 2 DD samples there were 6 species [among them *Chamobates cuspidatus* (Michael) and *Epidamaeus bituberculatus* (Kulczyński)] which did not occur in any other groups. In the fruiting bodies from 3 DD, there were 12 species (among them *Acrogalumna longipluma* and *Cepheus latus* C.L. Koch) which occurred exclusively in this DD. However, in 4 DD samples there 8 species [among them *Berniniella*

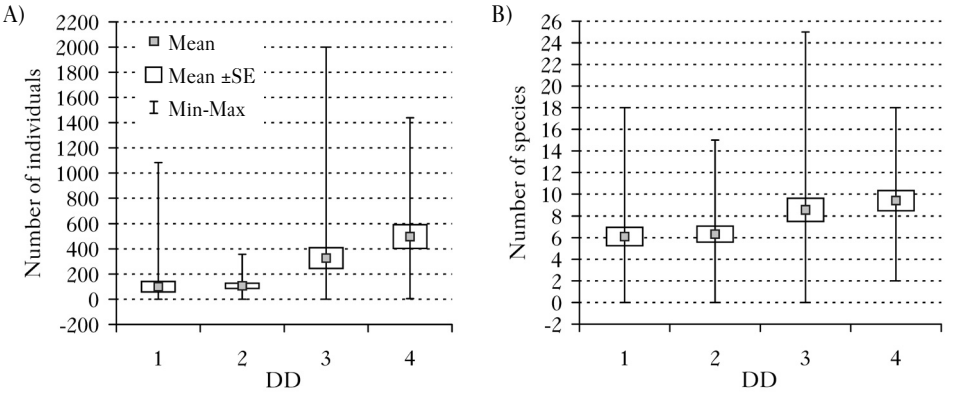

Fig. 7.

Minimum, maximum, mean number ±SE of (A) individuals and (B) species of Oribatida depending on DD of samples (1-4 - degrees of decay of fungi)

sigma (Strenzke) and *Eueremaus oblongus* (C.L. Koch)] which did not occur in the fruiting bodies of lower DDs (Appendix).

In the case of springtails both in the case of number of species and the number of individuals per sample, there is a tendency for greater diversity in the more decayed samples (Fig. 8 A, B). 7 out of the 15 species [among them *Folsomia quadrioculata* (Tullberg) and *Entomobrya quinquelineata* Börner] were exclusive for the samples belonging to only one DD; however, 5 species [among them *Pseudisotoma sensibilis* (Tullberg) and *Tomocerus minor* (Lubbock)] had been noticed in the samples of all DDs. *Isotomurus palustris* (Müller) individuals occurred only in the samples from 3 DD and 4 DD, whereas *Tomocerus minor* occurred only in the two highest DDs, more often than in comparison to others. The species which was exclusive for 1 DD samples was *Entomobrya quinquelineata*, for 2 DD – *Sinella myrmecophila* (Reuter), for 3 DD – *Ptenotrix atra* (Linnaeus), whereas for 4 DD there were 4 species: *Folsomia quadrioculata*, *Lepidocyrtus lanuginosus* (Gmelin), *Pseudosinella alba* (Packard) and *Lipathrix lubbocki* (Tullberg). Only in the samples from the two highest DDs there was *Isotomurus palustris*, whereas *Tomocerus minor* species was more numerous than in the other samples.

By analysing insects, a conclusion can be reached that both in the case of mean number of individuals and in the number of species per samples there is an increasing tendency in DDs from 1 to 3 and then a slight decrease in 4 DD (Fig. 9 A, B). 12 out of the 20 observed species [among them *Acrotrichis* sp. and *Aspidiphorus orbiculatus* (Gyllenhal)] occurred in the samples belonging only to one DD, whereas *Cis* spp., Coleoptera, Diptera and Staphylinidae occurred in the samples of all DDs. The number of species exclusive for particular DDs was the same, i.e. 3, for each DD. The species exclusive for 1 DD samples were *Octotemnus* sp., *Sulcacis* sp. and Thysanoptera, for 2 DD *Aspidiphorus orbiculatus*, *Bolitophagus reticulatus* (Linnaeus) and *Cerylon* sp., for 3 DD – *Anisotoma* sp., *Ropalodontus* sp. and *Ruteria hypocrita* (Boheman), whereas for 4 DD – *Acrotrichis* sp., *Ptenidium* sp. and *Pteryx suturalis* (Appendix).

Discussion

The fruiting bodies of bracket fungi are highly peculiar microhabitat of 'island character' (O'Connell and Bolger, 1997a, b) and may be particullary important especially for decomposer arthropods, such as collembolans, or oribatid mites (Maraun *et al.*, 2014). In the forest environment they constitute a type of biological hotspots, supporting high numbers of species within

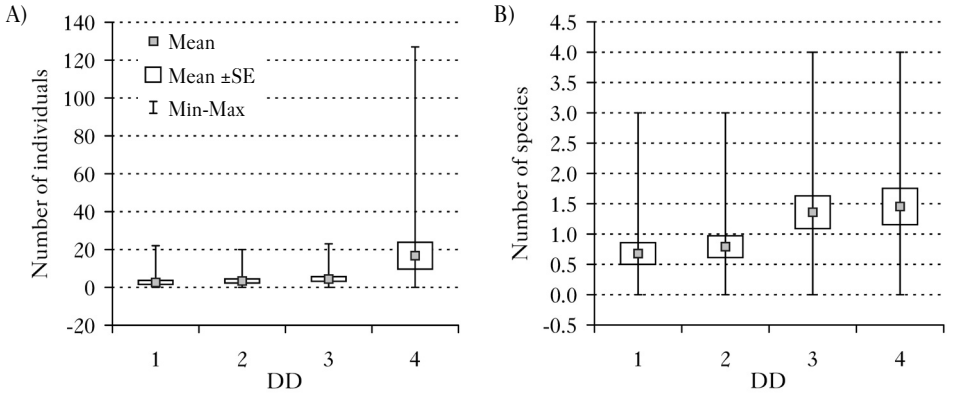

Fig. 8.

Minimum, maximum, mean number ±SE of (A) individuals and (B) species of Collembola depending on DD of samples (1-4 - degrees of decay of fungi)

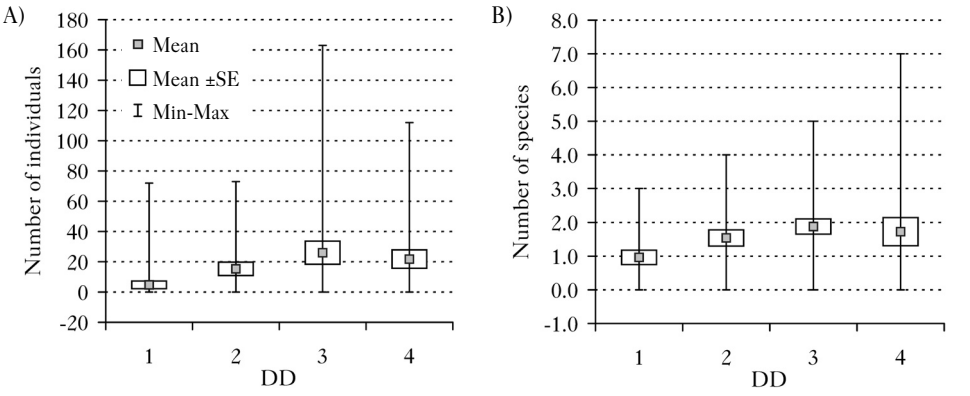

Fig. 9.

Minimum, maximum, mean number ±SE of (A) individuals and (B) species of Insecta depending on DD of samples (1-4 – degrees of decay of fungi)

small volumes (Komonen, 2003). This is also confirmed by the results of this research, which allowed for the identification of species not previously recorded in the Karkonosze Mountains, such as, for example, *Asca bicornis*, or *Zercon arcuatus* Trägårdh (Gabryś *et al*., 2008). The type of dependency between bracket fungi and the invertebrates encountered in the fruiting bodies can be various in nature, it can be antagonistic and/or mutualistic and can come down to, *e.g.* the fungi being visited by insects, which may act as predators on spores or other tissues, or may act as spore-dispersers (Tuno, 1999). Among the species, which are closely connected with the fruiting bodies of bracket fungi, indicated in this study are, for example, certain insects from *Megaselia* genus or mites from *Hoploseius* genus, which have not been noted in any other habitat (Gwiazdowicz, 2002b; Disney and Pagola-Carte, 2009; Mašán and Halliday, 2016). Furthermore, some of the organisms occurring in the fruiting bodies of bracket fungi, such as mesostigmatic mite *Hoploseius tenuis* Lindquist, are so closely linked with the microhabitat that they have developed morphological adaptations such as oblong and narrow body shape which facilitates their existence within the pores of the bracket fungi (Lindquist, 1965, 1995). Despite their specificity, fungal sporophores tend also to be in an close contact with the source area of the potential colonists, *e.g.* litter and decaying wood (O'Connell and Bolger, 1997b), as a result the invertebrates from these microhabitats can access the bracket fungi, resulting in a some similarities between the invertebrate fauna in fungi and in this microhabitats (Salmane and Brumelis, 2010).

Some of the species present in the study, such as *Hoploseius oblongus*, have been studied and characterised only from fruiting bodies of bracket fungi and their presence has been noticed only in this microhabitat (Mašán and Halliday, 2016; Gdula *et al*., 2021a, b). Moreover, some of the observed insect taxa, such as *Cis* spp. beetles (the third most numerous taxa) are among the most abundant and speciose fungivorous beetles (Graf-Peters *et al*., 2011), observed primarily in fruiting bodies of bracket fungi, rarely in other microhabitats, such as under the bark or in rotting wood (Lawrence, 2016). A separate group constitutes species with a bit wider spectrum of colonised microhabitats. The most numerous species in the study, *Carabodes femoralis*, is mycophagous species (Schneider *et al*., 2005) usually occurred in freshly damp forest soil and peat (Weigmann, 2006). However, it can be also observed various habitats – in litter and soil (*e.g.* Błoszyk and Olszanowski, 1997; Seniczak *et al*., 2006; Manu and Honciuc, 2010), in the nests of *Formica rufa* Linnaeus ants (Sell, 1990), mud caves, deadwood, leaves and guano (Maślak and

Barczyk, 2011) and in the fruiting bodies of bracket fungi (Hågvar *et al*., 2014). *Carabodes areolatus*, which is second as far as the number of individuals is concerned, is typical forest secondary decomposer species (Nae *et al*., 2021), noted in lichen and moss cushions, on tree stumps (Weigmann, 2006), in polypores (Hågvar and Steen, 2013; Hågvar *et al*., 2014; Maraun *et al*., 2014, Gdula *et al*., 2021a, b), but also in various soils (Błoszyk and Olszanowski, 1997; Hågvar *et al*., 2014), feathers of Corvidae (Krivolutsky and Lebedeva, 2004a) and non-passerines birds (Krivolutsky and Lebedeva, 2004b). What is more, other taxa high in numbers for each microarthropod group were observed in other microhabitats apart from the bracket fungi. The spiders from Linyphiidae are family were also found in various habitats, with a slight preference to forests (Wiśniewski *et al*., 2018), agricultural habitats (Downie *et al*., 2000; Schmidt and Tscharntke, 2005) and grass (Thomas and Jepson, 2003), they were also recorded from fruiting bodies of bracket fungi (Gdula *et al*., 2021a). The representative of the only observed pseudoscopions taxa, Neobisiidae, occurred so far mainly in caves (Chamberlin, 1962; Reboleira *et al*., 2013; Mahnert and Li, 2020), leaf litter (Hong and Kim, 1996) and soil (Nassirkhani and Doustaresharaf, 2018). It should be noted, however, that the presence of a few individuals of spiders, opiliones, or pseudoscorpions could have been accidental and in order to make a broader inference about their occurrence in fruiting bodies, it would be necessary to continue research on a wider research material. The most numerous in the study mesostigmatic mite, *Dendrolaelaps pini*, apart from the fruiting bodies of bracket fungi (Gdula *et al*., 2021a, b) is also recognized in decayed wood (Gwiazdowicz *et al*., 2011), galleries of *Ips typographus* (Linnaeus) (Salavatulin *et al*., 2018), pine stumps and under elytra of *Hylurgus ligniperda* (Fabricius) and *Hylastes* sp. (Hirschmann and Wiśniewski, 1982). *Pseudisotoma sensibilis*, the most numerous species of the springtail, is known as the corticolous and bryophilous species (Weiner, 1981; Fjellberg, 2007).

Like the present study, also the works by Gdula *et al*. (2021a, b) showed significant differences between the microarthropod fauna inhabiting the fruiting bodies of bracket fungi with different degree of decay, in particular in the case of the 3 DD samples, which differed most from the others. Study by Gdula *et al*. (2021a) also allowed to show the species of microarthropods characteristic for particular DDs; in the case of 1 DD it was, inter alia, *Hoploseius oblongus*, which also in this study was classified as characteristic of the fruiting bodies from this DD. Also the results of the work of Gdula *et al*. (2021b) concerning the research material from the Karkonosze National Park indicated *Hoploseius oblongus* as a characteristic species for the samples belonging to 1 DD, but also allowed to show different characteristic species than in this study, *e.g. Cepheus cepheiformis* (Nicolet) for 3 and 4 DD. Similar results were also obtained from studies in which a similar, but better tested substrate, such as dead wood, was analyzed. In the studies focused in various invertebrate groups in wood at consecutive stages of decay (*e.g.* Braccia and Batzer 2001; Skubała and Sokołowska 2006; Gwiazdowicz *et al*., 2011) it has been indicated that with the progressing decay of the substrate, the number of invertebrate species colonising it increases. Similarly, it has been observed for a number of exclusive species, unfortunately, in the latter case this increase in not linear. Moreover, in the above study similar dependencies can be observed: with an increasing decay of fruiting bodies expressed in DDs, the number of the microarthropod individuals and species increases as well, but the tendency was not linear and differs between each animal group. The NMDS analysis has confirmed the differences between the samples of each DD and indicated that the samples in the most decayed samples (3 DD and 4 DD) are most concentrated and the most similar, however, 1 DD and 2 DD are most scattered. According to the predictions, the means along NMDS1 for the extreme DD samples – 4 DD and 1 DD positioned on opposing ends of the scale. The similar results provided

by cluster analysis revealed that the samples belonging to 1 DD differed from the samples belonging to others DDs and the cluster was joined by the samples from other DDs: 2 DD, 3 DD and 4 DD (the last two groups are similar and form a cluster). Similarly, in the research conducted by Gwiazdowicz *et al.* (2011), it is possible to observe that some microarthropod species are linked to a particular DD and in the other groups they are less numerous. The indicator species analysis has revealed exactly which species are characteristic of particular DD groups, but also the ratio of total number of characteristic species is low.

Conclusions

The study contributes new information to the poorly-understood microarthropod ecology and the dependency between them and bracket fungi, which have been mainly perceived through the prism of economic aspect of forestry. The research shows both the general characteristics and uniqueness of microarthropod communities occurring in fruiting bodies, as well as the influence of the degree of substrate decomposition on the structure of these communities. The results of the study can facilitate to change the perception of the fungi group, as well as a valuable source of information for effective protection of forest biodiversity. Due to the still small amount of research on microarthropod communities occurring on fruiting bodies of bracket fungi, it is necessary to conduct further research, aimed at, inter alia, to learn more about the factors influencing the formation of this assemblages and to refine the methodology in the best possible way.

Authors' contributions

A.K.G. – conceived the idea and designed the methodology excluding statistics (equal), acquired the financial support for the project leading to this publication (lead), collected the samples and performed the laboratory work (lead), identified specimens of Mesostigmata (equal), identified specimens of bracket fungi (lead), wrote most of the manuscript (lead), approvals the final version of article (equal); Sz.K. – identified specimens of Insecta (lead), revised methods and other information of the analyzed group of invertebrates (equal), approvals the final version of article (equal); I.O. – identified specimens of Collembola (lead), revised methods and other information of the analyzed group of invertebrates (equal), approvals the final version of article (equal); T.R. – identified specimens of Aranae, Opiliones and Pseudoscorpionida (lead), revised methods and other information of the analyzed group of invertebrates (equal), approvals the final version of article (equal); P.S. – identified specimens of Oribatida (lead), revised methods and other information of the analyzed group of invertebrates (equal), approvals the final version of article (equal); B.Z. – designed statistical methods (lead), analyzed the data and described statistical analyses (lead), approvals the final version of article (equal); D.J.G. – conceived the idea and designed the methodology excluding statistics (lead), acquired the financial support for the project leading to this publication (equal), identified specimens of Mesostigmata (equal), wrote most of the manuscript (equal), approvals the final version of article (equal).

Conflicts of interest

We have no conflicts of interest to disclose.

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Appendix

Microarthropods occuring on fruiting bodies of bracket fungi in the Karkonosze National Park, Poland. Ab – abundance, Fr – frequency, Do – dominance, 1-4 – degrees of decay of fungi

	1			2			3			4			All		
Species	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do
Aranae and Opiliones	4	0,3	>0,1	4	0,1	>0,1	2	0,1	0,00	4	0,1	>0,1	14	0,1	>0,1
Amaurobiidae	1	0,0	0,0	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Araneae	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Callobius claustrarius (Hahn, 1833)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,0	>0,1	1	>0,1	>0,1
Cryphoeca silvicola (C.L. Koch, 1834)	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Linyphiidae	2	0,1	>0,1	2	0,1	>0,1	0	0,0	0,0	3	0,1	>0,1	7	0,1	>0,1
Lophopilio palpinalis (Herbst, 1799)	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
cfr. *Platybunus* sp.	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Thyreosthenius parasiticus (Westring, 1851)	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Pseudoscorpionida	1	0,3	>0,1	1	>0,1	>0,1	1	>0,1	>0,1	0	0,0	0,0	3	>0,1	>0,1
Neobisiidae	1	>0,1	>0,1	1	>0,1	>0,1	1	>0,1	>0,1	0	0,0	0,0	3	>0,1	>0,1

Appendix contniued (2)

Species	1			2			3			4			All		
	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do
Mesostigmata	210	0,2	0,07	551	0,8	0,1	643	0,7	0,1	1072	0,7	0,1	2476	0,7	0,1
Alloparasitus oblongus (Halbert, 1915)	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Asca bicornis (Canestrini & Fanzago, 1887)	2	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	>0,1	>0,1
Dendrolaelaps armatus Hirschmann, 1960	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Dendrolaelaps cornutulus Hirschmann, 1960	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Dendrolaelaps cornutus (Kramer, 1886)	5	0,1	>0,1	9	0,1	>0,1	11	0,1	>0,1	22	0,1	>0,1	47	0,1	>0,1
Dendrolaelaps pini Hirschmann, 1960	4	0,1	>0,1	328	0,4	0,1	383	0,3	>0,1	68	0,3	>0,1	783	0,2	>0,1
Dendrolaelaps punctatulus Hirschmann, 1960	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Dendrolaelaps sp.	0	0,0	0,0	0	0,0	0,0	4	>0,1	>0,1	3	0,1	>0,1	7	>0,1	>0,1
Dendrolaelaps zwoelferi Hirschmann, 1960	0	0,0	0,0	0	0,0	0,0	2	>0,1	>0,1	5	0,1	>0,1	7	>0,1	>0,1
Dermanyssus gallinae (De Geer, 1778)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Dinychus arcuatus (Trägårdh, 1943)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	4	0,1	>0,1	4	>0,1	>0,1
Dinychus perforatus Kramer, 1882	0	0,0	0,0	5	0,0	0,0	0	0,0	0,0	0	0,0	0,0	5	0,0	0,0
Discourella modesta (Leonardi, 1899)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Gaeolaelaps brevipilis (Hirschmann, 1969)	0	0,0	0,0	3	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	3	>0,1	>0,1
Gamasellodes bicolor (Berlese, 1918)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	13	0,1	>0,1	13	>0,1	>0,1
Gamasellus montanus (Willmann, 1936)	2	>0,1	>0,1	5	0,1	>0,1	4	0,1	>0,1	3	0,1	>0,1	14	0,1	>0,1
Geholaspis longispinosus (Kramer, 1876)	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Geholaspis mandibularis (Berlese, 1904)	1	>0,1	>0,1	6	0,1	>0,1	0	0,0	0,0	5	0,1	>0,1	12	0,1	>0,1
Holoparasitus calcaratus (C.L. Koch, 1839)	0	0,0	0,0	5	0,1	>0,1	0	0,0	0,0	0	0,0	0,0	5	>0,1	>0,1
Holoparasitus micherdzinskii Witaliński, 1981	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	2	0,1	>0,1	3	>0,1	>0,1
Holoparasitus sp.	2	0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	>0,1	>0,1
Hoploseius oblongus Mašán & Halliday, 2016	126	0,3	0,4	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	127	0,1	>0,1
Lasioseius muricatus (C.L. Koch, 1839)	11	0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	12	>0,1	>0,1
Lasioseius ometes (Oudemans, 1903)	5	>0,1	>0,1	16	0,2	>0,1	5	0,1	>0,1	5	0,1	>0,1	31	0,1	>0,1
Lasioseius zerconoides Willmann, 1954	34	0,2	>0,1	52	0,3	>0,1	62	0,3	>0,1	13	0,2	>0,1	161	0,3	>0,1
Lysigamasus runcatellus (Berlese, 1903)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Macrocheles tridentinus (G. & R. Canestrini, 1882)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Pachylaelaps longisetis Halbert, 1915	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Parasitidae	3	0,1	>0,1	6	0,1	>0,1	6	0,1	>0,1	21	0,2	>0,1	36	0,1	>0,1
Parasitus sp.	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	4	0,1	>0,1	4	>0,1	>0,1
Parazercon radiatus (Berlese, 1910)	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	2	>0,1	>0,1
Pergamasus (*Pergamasus*) *ruehmi* Willmann, 1938	0	0,0	0,0	2	0,1	>0,1	10	0,1	>0,1	4	0,1	>0,1	16	0,1	>0,1
Pergamasus (*Pergamasus*) sp.	1	>0,1	>0,1	3	0,1	>0,1	22	0,2	>0,1	5	0,2	>0,1	31	0,1	>0,1
Pergamasus (*Thenargamasus*) *barbarus* Berlese, 1904	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Pergamasus (*Thenargamasus*) *quisquiliarum* (Canestrini, 1882)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	0,1	>0,1	2	>0,1	>0,1
Pergamasus (*Thenargamasus*) sp.	0	0,0	0,0	5	0,2	>0,1	0	0,0	0,0	16	0,1	>0,1	21	0,1	>0,1
Pneumolaelaps lubrica (Voigts & Oudemans, 1904)	0	0,0	0,0	6	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	6	>0,1	>0,1
Porrhostaspis lunulata Trägårdh, 1859	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Trachytes aegrota (C.L. Koch, 1841)	1	>0,1	>0,1	8	>0,1	>0,1	14	0,1	>0,1	12	0,2	>0,1	35	0,1	>0,1
Trichouropoda sociata (Vitzthum, 1923)	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	2	>0,1	>0,1
Trichouropoda structura Hirschmann & Zirngiebl-Nicol, 1961	0	0,0	0,0	4	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	4	>0,1	>0,1
Uroobovella sp.	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Uroobovella vinicolora (Vitzthum, 1926)	0	0,0	0,0	1	>0,1	>0,1	4	0,1	>0,1	0	0,0	0,0	5	>0,1	>0,1
Veigaia kochi (Trägårdh, 1901)	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	2	0,1	>0,1	3	>0,1	>0,1

Appendix contniued (3)

Species	1			2			3			4			All		
	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do
Veigaia nemorensis (C.L. Koch, 1839)	1	>0,1	>0,1	0	0,0	0,0	2	0,1	>0,1	10	0,1	>0,1	13	0,1	>0,1
Veigaia sp.	0	0,0	0,0	0	0,0	0,0	2	0,1	>0,1	0	0,0	0,0	2	>0,1	>0,1
Veigaia transisalae (Oudemans, 1902)	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Zercon arcuatus Trägårdh, 1931	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	0,1	>0,1	2	>0,1	>0,1
Zercon curiosus Trägårdh, 1910	2	0,1	>0,1	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	3	>0,1	>0,1
Zercon gurensis Mihelcic, 1962	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	0,1	>0,1	2	>0,1	>0,1
Zercon occultus Błaszak, 1972	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	0,1	>0,1	2	>0,1	>0,1
Zercon schweizeri Sellnick, 1944	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	80	0,1	>0,1	80	>0,1	>0,1
Zercon storkani Halašková, 1969	1	>0,1	>0,1	4	>0,1	>0,1	18	0,3	>0,1	67	0,1	>0,1	90	0,1	>0,1
Zerconopsis michaeli Evans & Hyatt, 1960	2	0,1	>0,1	37	0,2	>0,1	6	0,1	>0,1	284	0,21	>0,1	329	0,1	>0,1
Zerconopsis remiger (Kramer, 1876)	4	0,1	>0,1	42	0,3	>0,1	83	0,3	>0,1	405	0,5	>0,1	534	0,3	>0,1
Oribatida	2787	0,3	0,9	2557	0,9	0,7	8177	1,0	0,9	10951	1,0	0,9	24472	0,9	0,8
Acrogalumna longipluma (Berlese, 1904)	0	0,0	0,0	0	0,0	0,0	3	>0,1	>0,1	0	0,0	0,0	3	>0,1	>0,1
Adoristes ovatus (C. L. Koch, 1839)	0	0,0	0,0	0	0,0	0,0	3	0,1	>0,1	3	0,1	>0,1	6	0,1	>0,1
Autogneta dalecarlica (Forsslund, 1947)	0	0,0	0,0	2	>0,1	>0,1	7	>0,1	>0,1	1	0,1	>0,1	10	>0,1	>0,1
Autogneta longilamellata (Michael, 1885)	0	0,0	0,0	1	>0,1	>0,1	8	0,2	>0,1	18	0,1	>0,1	27	0,1	>0,1
Banksinoma lanceolata (Michael, 1885)	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Belba corynopus (Hermann, 1804)	2	>0,1	>0,1	7	0,2	>0,1	3	0,1	>0,1	22	0,3	>0,1	34	0,1	>0,1
Berniniella sigma (Strenzke, 1951)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Caleremaeus monilipes (Michael, 1882)	6	0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	7	>0,1	>0,1
Carabodes areolatus Berlese, 1916	306	0,6	0,1	127	0,4	>0,1	666	0,8	0,1	356	0,7	>0,1	1455	0,6	0,1
Carbodes coriaceus C. L. Koch, 1835	106	0,2	>0,1	22	0,2	>0,1	29	0,2	>0,1	113	0,2	>0,1	270	0,2	>0,1
Carabodes femoralis (Nicolet, 1855)	1733	0,8	0,5	1969	0,9	0,6	6925	0,9	0,7	9540	1,0	0,7	20167	0,9	0,7
Carabodes labyrinthicus (Michael, 1879)	32	0,4	>0,1	14	0,2	>0,1	25	0,3	>0,1	45	0,4	>0,1	116	0,3	>0,1
Carabodes ornatus Štorkán, 1925	41	0,3	>0,1	2	0,1	>0,1	28	0,2	>0,1	13	0,3	>0,1	84	0,2	>0,1
Carabodes reticulatus Berlese, 1913	158	0,3	0,1	74	0,5	>0,1	61	0,5	>0,1	109	0,6	>0,1	402	0,4	>0,1
Carabodes tenuis Forsslund, 1953	3	0,1	>0,1	1	>0,1	>0,1	11	0,2	>0,1	11	0,1	>0,1	26	0,1	>0,1
Cepheus cepheiformis (Nicolet, 1855)	29	0,3	>0,1	5	0,1	>0,1	24	0,2	>0,1	30	0,4	>0,1	88	0,2	>0,1
Cepheus dentatus (Michael, 1888)	3	0,1	>0,1	25	0,4	>0,1	22	0,3	>0,1	29	0,3	>0,1	79	0,3	>0,1
Cepheus latus C. L. Koch, 1835	0	0,0	0,0	0	0,0	0,0	2	>0,1	>0,1	0	0,0	0,0	2	>0,1	>0,1
Ceratoppia bipilis (Hermann, 1804)	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Ceratoppia quadridentata (Haller, 1882)	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Chamobates borealis (Trägårdh, 1902)	10	0,2	>0,1	11	0,3	>0,1	70	0,4	>0,1	22	0,3	>0,1	113	0,3	>0,1
Chamobates cuspidatus (Michael, 1884)	0	0,0	0,0	3	0,1	>0,1	0	0,0	0,0	0	0,0	0,0	3	>0,1	>0,1
Chamobates spinosus Sellnick, 1928	1	>0,1	>0,1	42	0,2	>0,1	0	0,0	0,0	6	0,1	>0,1	49	0,1	>0,1
*Chamobates voigts*i (Oudemans, 1902)	0	0,0	0,0	5	0,1	>0,1	6	0,1	>0,1	6	0,2	>0,1	17	0,1	>0,1
Cymbaeremaeus cymba (Nicolet, 1855)	0	0,0	0,0	0	0,0	0,0	2	0,1	>0,1	0	0,0	0,0	2	>0,1	>0,1
Damaeus (*Adamaeus*) *onustus* C.L. Koch, 1844	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Damaeus (*Paradamaeus*) *clavipes* (Hermann, 1804)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	4	0,2	>0,1	4	>0,1	>0,1
Damaeus riparius Nicolet, 1885	2	0,1	>0,1	8	0,2	>0,1	1	>0,1	>0,1	7	0,2	>0,1	18	0,1	>0,1
Dameobelba minutissima (Sellnick, 1920)	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Dissorhina ornata (Oudemans, 1900)	9	0,1	>0,1	2	0,1	>0,1	3	>0,1	>0,1	10	0,2	>0,1	24	0,1	>0,1
Epidamaeus bituberculatus (Kulczyński, 1902)	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Eueremaus oblongus (C. L. Koch, 1835)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	0,1	>0,1	2	>0,1	>0,1
Eupelops plicatus (C. L. Koch, 1835)	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Eupelops subulinger (Berlese, 1916)	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Euphthiracarus cribrarius (Berlese, 1904)	0	0,0	0,0	0	0,0	0,0	4	0,1	>0,1	1	0,1	>0,1	5	>0,1	>0,1

Appendix contniued (3)

Species	1			2			3			4			All		
	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do
Galumna lancelata Oudemans,1900	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Hermannia gibba (C. L. Koch, 1839)	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Lagenobates lagenulus (Berlese,1904)	0	0,0	0,0	1	>0,1	>0,1	12	0,1	>0,1	1	0,1	>0,1	14	>0,1	>0,1
Liacarus coracinus (C. L. Koch, 1841)	2	>0,1	>0,1	0	0,0	0,0	3	0,1	>0,1	1	0,1	>0,1	6	>0,1	>0,1
Liebstadia lagenula (Berlese,1904)	0	0,0	0,0	0	0,0	0,0	2	>0,1	>0,1	0	0,0	0,0	2	>0,1	>0,1
Liebstadia longior (Berlese, 1908)	3	0,1	>0,1	0	0,0	0,0	4	0,1	>0,1	1	0,1	>0,1	8	0,1	>0,1
Liebstadia pannonica (Willmann, 1951)	3	0,1	>0,1	1	>0,1	>0,1	4	0,1	>0,1	1	0,1	>0,1	9	0,1	>0,1
Liebstadia similis (Michael, 1888)	1	>0,1	>0,1	0	0,0	0,0	4	>0,1	>0,1	0	0,0	0,0	5	>0,1	>0,1
Metabelba propexa (Kulczyński, 1902)	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	3	0,1	>0,1	4	>0,1	>0,1
Metabelba sp.	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	0,1	>0,1	2	>0,1	>0,1
Minunthozetes pseudofusiger (Schweizer,1922)	73	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	4	0,1	>0,1	77	>0,1	>0,1
Nanhermannia comitalis Berlese, 1916	0	0,0	0,0	0	0,0	0,0	4	0,1	>0,1	79	0,1	>0,1	83	>0,1	>0,1
Nanhermannia cf. *coronata* Berlese, 1913	4	0,1	>0,1	12	0,2	>0,1	16	0,2	>0,1	145	0,3	>0,1	177	0,2	>0,1
Nanhermannia nana (Nicolet, 1855)	5	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	5	>0,1	>0,1
Nothrus silvestris Nicolet, 1855	1	>0,1	>0,1	0	0,0	0,0	5	0,2	>0,1	2	0,1	>0,1	8	0,1	>0,1
Oppiella (*Moritzoppia*) *keilbachi* (Moritz, 1969)	0	0,0	0,0	1	>0,1	>0,1	11	>0,1	>0,1	2	0,1	>0,1	14	>0,1	>0,1
Oppiella (*Moritzoppia*) *translamellata* (Willmann, 1923)	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Oppiella (*Moritzoppia*) *unicarinata* (Paoli, 1908)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	0,05	0,00	2	0,01	0,00
Oppiella (*Oppiella*) *falcata* (Paoli, 1908)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,05	0,00	1	0,01	0,00
Oppiella (*Oppiella*) *maritima* (Willmann, 1929)	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Oppiella (*Oppiella*) *nova* (Oudemans, 1902)	0	0,0	0,0	2	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	2	>0,1	>0,1
Oppiella (*Rhinoppia*) *subpectinata* (Oudemans, 1900)	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Oribatella calcarata (C. L. Koch, 1835)	52	0,3	>0,1	52	0,5	>0,1	39	0,6	>0,1	182	0,6	>0,1	325	0,5	>0,1
Oribatella quadricornuta Michael, 1880	24	>0,1	>0,1	25	0,1	>0,1	12	0,1	>0,1	44	0,3	>0,1	105	0,1	>0,1
Oribatella similesuperbula Weigmann, 2001	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	0,1	>0,1	2	>0,1	>0,1
Oribatella superbula (Berlese, 1904)	0	0,0	0,0	2	>0,1	>0,1	0	0,0	0,0	1	0,1	>0,1	3	>0,1	>0,1
Oribatula tibialis (Nicolet, 1855)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Phthiracarus anonymus Grandjean, 1934	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Phthiracarus bryobius Jacot, 1930	0	0,0	0,0	0	0,0	0,0	4	0,1	>0,1	7	0,1	>0,1	11	>0,1	>0,1
Phthiracarus compressus Jacot, 1930	2	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	>0,1	>0,1
Phthiracarus longulus (C. L. Koch, 1841)	15	0,3	>0,1	11	0,3	>0,1	37	0,4	>0,1	26	0,4	>0,1	89	0,3	>0,1
Platynothrus peltifer (C. L. Koch, 1839)	2	>0,1	>0,1	0	0,0	0,0	21	0,1	>0,1	4	0,1	>0,1	27	0,1	>0,1
Porobelba spinosa (Sellnick, 1920)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Ramusella clavipectinata (Michael, 1885)	2	0,1	>0,1	1	>0,1	>0,1	9	0,2	>0,1	8	0,1	>0,1	20	0,1	>0,1
Ramusella insculpta (Paoli,1908)	0	0,0	0,0	0	0,0	0,0	2	>0,1	>0,1	0	0,0	0,0	2	>0,1	>0,1
Scheloribates pallidulus (C. L. Koch, 1841)	49	0,4	>0,1	11	0,2	>0,1	39	0,4	>0,1	9	0,2	>0,1	108	0,3	>0,1
Scheloribates (*Hemileius*) *initialis* (Berlese, 1908)	6	0,1	>0,1	4	0,2	>0,1	7	0,1	>0,1	1	0,1	>0,1	18	0,1	>0,1
Siculobata leontonycha (Berlese, 1910)	1	>0,1	>0,1	0	0,0	0,0	5	0,1	>0,1	0	0,0	0,0	6	>0,1	>0,1
Spatiodamaeus boreus (Bulanova-Zachvatkina, 1957)	3	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1	1	0,1	>0,1	5	>0,1	>0,1
Steganacarus (*Atropacarus*) *striculus* (C. L. Koch, 1835)	2	>0,1	>0,1	3	0,1	>0,1	10	0,2	>0,1	50	0,3	>0,1	65	0,1	>0,1
Tectocepheus velatus alatus Berlese, 1913	3	0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	4	>0,1	>0,1
Tectocepheus velatus velatus (Michael, 1880)	5	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	5	>0,1	>0,1
Trichoribates novus (Sellnick, 1928)	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Zygoribatula exilis (Nicolet, 1855)	63	0,2	>0,1	3	0,1	>0,1	0	0,0	0,0	0	0,0	0,0	66	0,1	>0,1
Carabodes sp. (juv.)	4	0,1	>0,1	96	0,1	>0,1	2	0,1	>0,1	0	0,0	0,0	102	0,1	>0,1

Appendix contniued (4)

Species	1			2			3			4			All		
	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do	Ab	Fr	Do
Cepheus sp. (juv.)	0	0,0	0,0	1	>0,1	>0,1	9	0,1	>0,1	3	0,1	>0,1	13	0,1	>0,1
Nanhermannia sp. (juv.)	2	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1	7	0,1	>0,1	10	0,1	>0,1
Oppidae (juv.)	4	>0,1	>0,1	1	>0,1	>0,1	2	0,1	>0,1	5	0,1	>0,1	12	0,1	>0,1
Oribatella sp. (juv.)	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Scheloribates sp. (juv.)	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Tectocepheus sp. (juv.)	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Other juveniles	8	0,2	>0,1	4	0,1	>0,1	1	>0,1	>0,1	6	0,1	>0,1	19	0,1	>0,1
Collembola	73	0,3	>0,1	81	0,5	>0,1	111	0,6	>0,1	368	0,6	>0,1	633	0,6	>0,1
Caprainea marginata (Schoett, 1893)	1	>0,1	>0,1	9	0,1	>0,1	11	0,1	>0,1	7	0,1	>0,1	28	0,1	>0,1
Entomobrya corticalis (Nicolet, 1842)	17	0,3	>0,1	44	0,3	>0,1	14	0,2	>0,1	1	0,1	>0,1	76	0,2	>0,1
Entomobrya quinquelineata Börner, 1901	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Folsomia quadrioculata (Tullberg, 1871)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	0,1	>0,1	2	>0,1	>0,1
Isotomurus palustris (Müller, 1776)	0	0,0	0,0	0	0,0	0,0	6	0,1	>0,1	8	0,1	>0,1	14	0,1	>0,1
Lepidocyrtus lanuginosus (Gmelin, 1788)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	4	0,1	>0,1	4	>0,1	>0,1
Lipothrix lubbocki (Tullberg, 1872)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	0,1	>0,1	2	>0,1	>0,1
Proisotoma minuta (Tullberg, 1871)	3	>0,1	>0,1	0	0,0	0,0	4	0,1	>0,1	21	0,1	>0,1	28	0,1	>0,1
Pseudisotoma sensibilis (Tullberg, 1876)	43	0,2	>0,1	16	0,1	>0,1	42	0,3	>0,1	272	0,5	>0,1	373	0,3	>0,1
Pseudosinella alba (Packard, 1873)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	6	0,1	>0,1	6	>0,1	>0,1
Ptenotrix atra (Linnaeus, 1758)	0	0,0	0,0	0	0,0	0,0	2	>0,1	>0,1	0	0,0	0,0	2	>0,1	>0,1
Sinella myrmecophila (Reuter, 1886)	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Sminthurinus niger (Lubbock, 1868)	7	0,1	>0,1	3	0,1	>0,1	9	0,2	>0,1	1	0,1	>0,1	20	0,1	>0,1
Tetracanthella pilosa Schoett, 1891	0	0,0	0,0	1	>0,1	>0,1	7	0,1	>0,1	12	0,1	>0,1	20	0,1	>0,1
Tomocerus minor (Lubbock, 1862)	1	>0,1	>0,1	7	0,1	>0,1	16	0,3	>0,1	32	0,3	>0,1	56	0,2	>0,1
Insecta	133	0,3	>0,1	368	0,8	0,1	650	0,9	0,1	479	0,7	>0,1	1630	0,7	0,1
Acrotrichis sp.	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	2	0,1	>0,1	2	>0,1	>0,1
Anisotoma sp.	0	0,0	0,0	0	0,0	0,0	2	>0,1	>0,1	0	0,0	0,0	2	>0,1	>0,1
Aspidiphorus orbiculatus (Gyllenhal, 1808)	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Bolitophagus reticulatus (Linnaeus, 1767)	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1
Cerylon sp.	0	0,0	0,0	3	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	3	>0,1	>0,1
Cis spp.	19	0,3	>0,1	278	0,7	0,1	606	0,6	0,1	405	0,7	>0,1	1308	0,6	>0,1
Coleoptera	82	0,2	>0,1	43	0,3	>0,1	12	0,4	>0,1	28	0,3	>0,1	165	0,3	>0,1
Diptera	19	0,2	>0,1	35	0,2	>0,1	12	0,3	>0,1	24	0,2	>0,1	90	0,2	>0,1
Hadraule elongatula (Gyllenhal, 1827)	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	2	0,1	>0,1	3	>0,1	>0,1
Hemiptera	3	>0,1	>0,1	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	4	>0,1	>0,1
Hymenoptera	1	>0,1	>0,1	2	0,1	>0,1	2	0,1	>0,1	0	0,0	0,0	5	0,1	>0,1
Insecta	0	0,0	0,0	0	0,0	0,0	3	0,08	0,00	5	0,05	0,00	8	0,03	0,00
Octotemnus sp.	3	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	3	>0,1	>0,1
Ptenidium sp.	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	0,1	>0,1	1	>0,1	>0,1
Pteryx suturalis (Heer, 1841)	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	3	0,1	>0,1	3	>0,1	>0,1
Rhopalodontus sp.	0	0,0	0,0	0	0,0	0,0	5	0,1	>0,1	0	0,0	0,0	5	>0,1	>0,1
Ruteria hypocrita (Boheman, 1837)	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1	0	0,0	0,0	1	>0,1	>0,1
Staphylinidae	1	>0,1	>0,1	4	0,2	>0,1	7	0,2	>0,1	9	0,2	>0,1	21	0,1	>0,1
Sulcacis sp.	3	0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	3	>0,1	>0,1
Thysanoptera	1	>0,1	>0,1	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0	1	>0,1	>0,1

STRESZCZENIE

Rola patogenów w kreowaniu różnorodności biologicznej. Wpływ rozkładających się hub na różnorodność gatunkową mikrostawonogów w Karkonoskim Parku Narodowym

Grzyby patogeniczne mają istotne znaczenie w gospodarce leśnej. Zazwyczaj są one postrzegane przez pryzmat wywoływanej zgnilizny drewna, generującej straty ekonomiczne powstałe na skutek deprecjacji surowca drzewnego. Należy jednak pamiętać, że wpływając m.in. na obieg energii i materii w ekosystemie oraz kreując specyficzne mikrosiedliska, decydują one także o różnorodności biologicznej w środowisku leśnym. Ważną rolę w tym procesie odgrywają owocniki, które są miejscem występowania specyficznych zgrupowań bezkręgowców. Pomimo swojego wyjątkowego charakteru zgrupowania bezkręgowców zasiedlających ten specyficzny substrat były dotąd przedmiotem nielicznych badań. Celem niniejszej pracy była ocena wpływu stopnia zmurszenia (DD) owocników grzybów nadrzewnych na charakter zgrupowania zasiedlających je bezkręgowców: pająków i kosarzy (Aranae i Opiliones), zaleszczotków (Pseudoscorpionida), dwóch grup roztoczy (Mesostigmata oraz Oribatida), skoczogonków (Collembola), a także owadów (Insecta) (tab. 1). Materiał badawczy (100 owocników grzybów nadrzewnych) zebrano w Karkonoskim Parku Narodowym, w którym środowisko przyrodnicze zostało nacechowane m.in. procesem masowego zamierania lasów w latach 80. XX wieku, a także trwającą do dziś silną antropopresją. W badanych próbach wykazano 29 228 osobników bezkręgowców należących do 186 gatunków. Najliczniej reprezentowaną grupą były roztocze Oribatida (24 472 osobniki należące do 87 gatunków), a najliczniejszym gatunkiem był *Carabodes femoralis* (20 167 osobników) (Załącznik). Oprócz gatunków obserwowanych wcześniej także w innych substratach zaobserwowano gatunki charakterystyczne tylko dla owocników grzybów nadrzewnych, jak np. *Hoploseius oblongus*. Analiza statystyczna wyszczególniła różnice pomiędzy charakterem zgrupowań bezkręgowców a stopniem rozkładu owocników. Większość grup bezkręgowców reagowała na silniejszy stopień rozkładu owocników wzrostem liczby gatunków i osobników (ryc. 1, 4, 5, 6, 7, 8, 9; tab. 2, 3). Analiza skupień oraz analiza NMDS wykazały podobieństwo pomiędzy fauną zasiedlającą owocniki silnie rozłożone (3 DD i 4 DD) oraz różnice pomiędzy fauną występującą w owocnikach słabiej rozłożonych (1 DD i 2 DD) a pozostałymi próbami (ryc. 2, 3; tab. 4). Różnice pomiędzy fauną występującą w owocnikach o różnym stopniu zmurszenia były widoczne także w analizie gatunków wskaźnikowych, która wskazała gatunki charakterystyczne dla każdego stopnia zmurszenia, m.in. *Hoploseius oblongus* i *Zygoribatula exilis* dla 1 DD oraz *Pteryx suturalis* i *Dinychus arcuatus* dla owocników najsilniej zmurszałych (tab. 5). Wyniki niniejszych badań dostarczają wiedzy na temat słabo dotąd poznanego aspektu zależności ekologicznych w środowisku leśnym, a ponadto mogą być użyteczne z punktu widzenia prowadzenia zrównoważonej gospodarki leśnej, dla której jednym z ważnych celów jest skuteczna ochrona różnorodności biologicznej.