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Macroscopic fungi of pine forests in the Olkusz Ore-bearing Region

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Introduction

The landscape of Olkusz and Bolesław, dominated by partially recultivated mining waste heaps, excavations and industrial infrastructure, is not attractive terrain for mycological investigations. Mycologists have done less work in this area than in the rest of the Silesia-Cracow Upland (e.g. Wojewoda 1973; Kućmierz and Wojewoda 1976).

The first mycological research in the Olkusz Ore-bearing Region (OOR) examined mycorrhizae. In the 1990s, Turnau and colleagues (1996, 2001, 2002) studied the effects of heavy metals on ectomycorrhizae of selected fungal species and conifers occurring on calamine soil. Arbuscular mycorrhizae of plants growing on calamine substrate were investigated by Pawłowska *et al*. (1996), Jurkiewicz *et al*. (2001) and Orłowska *et al*. (2002). Scientists from Silesia also examined the relationships between heavy metals and mycorrhizae (Krupa 2004). The first list of macroscopic fungi from the Bolesław area was published by Mleczko (2004). He recorded 38 species, mostly agaricoid fungi, in an area covering ca. 300 m^2 of a post-excavation site partly recultivated with *Pinus sylvestris* and partly overgrown by herbaceous plants. Those observations were made close to sites nos. 24 and 29, which were examined during the investigations presented here.

The work undertaken within project EEA FM PL0265, "Vegetation of calamine soils and its importance for biodiversity and landscape conservation in post-mining areas", was the first detailed study of the mycobiota of pine forests of the OOR.

Methods

Field and laboratory studies

Observations of the occurrence of macroscopic fungi sporocarps on 21 permanent sites established in pine forests were made during four vegetation seasons in 2008–2011. Data on the location of the sites, their edaphic conditions and plant community characteristics are presented in Chapters 6, 12 and 13 (Kapusta and Godzik – Chapter 6; Zielonka *et al.* – Chapter 12; Kapusta *et al.* – Chapter 13, this volume). Every site was visited once a month on average. During each observation the following information was recorded: (1) date of collection, (2) substrate on which sporocarps of particular species occurred, and (3) number of sporocarps present on the site on that date. Quantitative data were not gathered for aphyllophoroid species, that is, those forming polyporoid and corticioid sporocarps. The species were identified from fresh or dry specimens. Keys and descriptions published in taxonomic works were consulted, also in regard to the ecology of the fungi (e.g. Gilbertson and Ryvarden 1993, 1994; Hansen and Knudsen 1997, 2000; Gminder *et al.* 2000; Krieglsteiner 2000; Krieglsteiner and Gminder 2001, 2003, 2010; Bernicchia 2005; Horak *et al.* 2005; Bernicchia and Gorjon 2010; Knudsen and Vesterholt 2012).

Microscopic structures were observed on free-hand sporocarp fragment preparations mounted in 3% KOH aqueous solution (dried specimens) or water (fresh specimens) for general observations, and in Melzer's reagent to observe the dextrinoid or amyloid reaction of hyphal or spore walls. Some sections were mounted in Congo red ammonium solution to enhance the contrast of the observed structures. The observations used a Nikon Eclipse 80i with Nomarski interference contrast (NIC). Measurements employed Lucia Measurement v. 4.82 image analysis software (LIM Laboratory Imaging, Czech Republic).

Mean dry mass of sporocarps was determined by averaging the weight of all harvested and air-dried sporocarps of a particular species.

Nomenclature and synonyms of agaricoid, boletoid, cyphelloid and gasteroid fungi follow Knudsen and Vesterholt (2012), with the exception of *Atheniella adonis* (after Redhead 2012), *Russula exalbicans* (after Sarnari 1998) and *Gymnopus perforans* (after Noordeloos and Antonín 2008). Nomenclature and synonyms follow Bernicchia (2005) for polyporoid fungi (except for *Antrodiella pallescens*: after Miettinen *et al.* 2006), Bernicchia and Gorjon (2010) for corticioid fungi, Hansen and Knudsen (1997) for the remaining basidiomycetes, and Hansen and Knudsen (2000) for ascomycetes.

Information on the occurrence of fungal species in Poland and their localities was taken from published databases by Wojewoda (2003), Chmiel (2006), Kujawa (2005), and Kujawa and Gierczyk (2007, 2010, 2011, 2011a, 2012, 2013) as well as from the internet database of Polish mycological papers published after 2000 (Kujawa 2013).

The collected specimens of fungi are deposited in the fungal collection of the Jagiellonian University Herbarium in Kraków (KRA).

Analysis of similarities between mycobiota

To compare the mycobiota of the investigated sites in terms of taxonomic diversity, we calculated Sørensen's coefficient (SI), a similarity index commonly used in fungal ecology (see Kałucka 2008). The coefficient includes only presence-absence data for the fungi observed on the sites:

$$SI = \frac{2j}{a + b}$$

where: j – the number of species common to both sites, a – the number of species present on site A, and b – the number of species present on site B.

Results and discussion

General characterisation of the mycobiota

Sporocarps of 206 species and varieties of macroscopic fungi were noted in pine forests on permanent sites covering 8000 m^2. Between 14 and 42 species were identified on particular sites. The most taxonomically diverse genera were *Cortinarius* (19 species), *Mycena* (15), *Inocybe* (10), *Clitocybe*, *Gymnopus* (7 each),

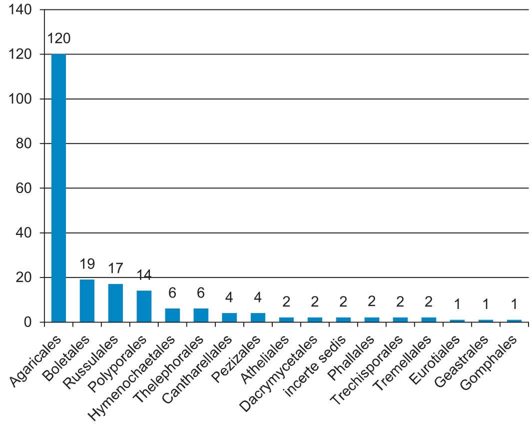

Fig. 1. Number of recorded species from different orders

Ryc. 1. Liczba zanotowanych gatunków z poszczególnych rzędów

Amanita, *Galerina*, *Russula* and *Tricholoma* (6 each). The most diverse families were all of the order Agaricales: Tricholomataceae, Cortinariaceae, Mycenaceae, Strophariaceae, Inocybaceae, Marasmiaceae and Russulaceae. All of the other orders except for Boletales, Russulales and Polyporales were represented by fewer than 10 species (Fig. 1).

The species diversity of the investigated sites seems to be on the average level when compared to the results from other research in pine forests of similar age or older. For example, Kałucka (2009) found 183 species of macroscopic fungi in spontaneously regenerating 30-year-old pine forest growing on post-agricultural sites covering 2000 m^2; Lisiewska (1982) noted 109 species from pine forest over 50 years old covering ca. 3000 m^2; Friedrich (1994) reported 232 species in suboceanic pine forest covering 8000 m^2, and Łuszczyński (2007) found 142 and 78 species in suboceanic and subcontinental pine forests covering 2000 m^2. Hintikka (1988) found 72 species of ectomycorrhizal and humus- and litter-inhabiting saprobic fungi in 20–50-year-old boreal pine forests covering 9000 m^2 (we noted 142 species of fungi of those groups in the present study). Väre *et al*. (1996) recorded 207 species of macroscopic fungi from 100–200-year-old oligotrophic pine forests in northern Finland, with a total area of 8400 m^2.

Southern European pine forests seem to have a less diverse macromycete biota: Lagana *et al*. (2004) found 170 species in 20–60-year-old pine forests (not *Pinus sylvestris*) with a total area of 9000 m^2 in Italy.

Comparison of the present results with those from other studies is hampered by differences in methods (e.g. number and area of permanent sites, time of observations), the age and character of the studied forests, and the degree of attention to fungi of specific groups (usually the least studied are aphyllophoraceous fungi).

Bioecological groups

Nearly 60% of the noted species were saprobic fungi, including facultative necrotrophic tree pathogens (112 species), bryophilic fungi (5 species) and mycophilic fungi (2 species) (Fig. 2).

Due to the character of the investigated forest and the manner of its exploitation, dead wood was present in low quantities, mostly

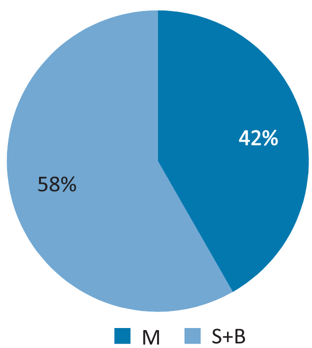

Fig. 2. Percentage of number of saprobic (including bryophilic) species (S + B) and mycorrhizal species (M)

Ryc. 2. Stosunek procentowy liczby gatunków saprobiontycznych (w tym briofilnych) (S + B) i mykoryzowych (M)

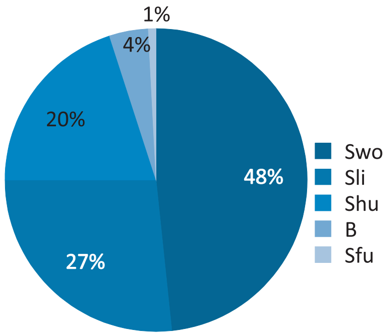

Fig. 3. Percentage of saprobic species from different substrate groups (abbreviations as in Table 1)

Ryc. 3. Stosunek procentowy liczby gatunków saprobiontycznych należących do różnych grup substratowych (wyjaśnienie symboli w Tabeli 1)

as branches and twigs, rarely stumps and logs usually not exceeding 20 cm in diameter. The quality and availability of this substrate limited the growth and occurrence of wood-decomposing species, but this group of fungi was the most diverse. It was represented by 58 species from 40 genera, 27 families and 12 orders (Fig. 3). Twigs and dead branches were decayed by numerous corticioid fungi including *Botryobasidium*, *Ceraceomyces*, *Coniophora*, *Peniophora*, *Trechispora* and *Xylodon* species, polyporoid fungi including *Antrodia*, *Diplomitoporus*, *Oligoporus*, *Polyporus*, *Skeletocutis* and *Trametes* species, and agaricoid and pleurotoid fungi including *Galerina*, *Gymnopilus*, *Hygrophoropsis*, *Panellus* and *Pholiota* species. Three *Mycena* species (*M. abramsii*, *M. galericulata*, *M. leptocephala*) as well as *Galerina marginata*, *Gymnopilus penetrans* and *Pholiota spumosa* occurred at the highest frequency. Sporocarps of *Tricholomopsis rutilans*, *Heterobasidion annosum* and species of *Lentinellus* and *Tapinella* were found on coniferous logs and stumps; *Daedaleopsis confragosa* and *Piptoporus betulinus* occupied hardwood logs and stumps; and species of *Hypholoma* were noted on both kinds of dead wood. Another saprobic species often recorded on the investigated sites was *Trichaptum fuscoviolaceum*, one of the first colonisers of dead coniferous wood (Renvall 1995).

The group of humus- and litter-decaying species was equally species-rich but taxonomically less diverse than the wood-associated fungi. It was represented by 54 species from 24 genera, classified in 11 families and 5 orders (Fig. 3). It comprised mostly agaricoid fungi such as *Clitocybe*, *Cystoderma*, *Entoloma*, *Galerina*, *Gymnopus*, *Hemimycena*, *Infundibulicybe*, *Mycena*, *Strobilurus* and *Stropharia*, the gasteroid genera *Bovista*, *Disciseda*, *Geastrum* and *Lycoperdon*, and aphyllophoroid fungi such as *Auriscalpium* and *Ramaria*. Such fungi as *Gymnopus androsaceus*, *Gymnopus dryophilus*, *Cystoderma carcharias*, *Hemimycena lactea*, *Mycena galopus*, *M. pura* and species of the genus *Stropharia* were among the most frequently encountered taxa in this group. The humus-associated fungi most often found were *Clitocybe* (mostly *C. metachroa*, *C. marginella* and *C. diatreta*), *Infundibulicybe*, *Lycoperdon* and *Mycena* species. Dead pine cones were inhabited by *Auriscalpium vulgare*, *Baeospora myosura* and species of *Strobilurus*. Bryophilic

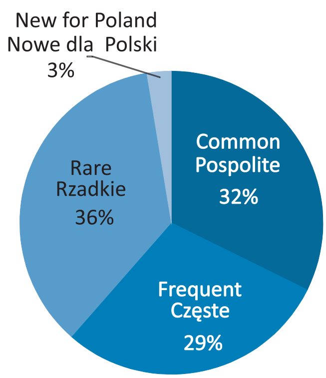

Fig. 4. Percentage of number of species common, frequent, rare and new for Poland

Ryc. 4. Stosunek liczby gatunków pospolitych, częstych, rzadkich i nowych dla Polski species were represented by taxa of the genus *Galerina* and by *Rickenella fibula*.

Mycorrhizal fungi were less diverse than saprobic ones (Fig. 2). This group was represented by 87 species from 27 genera, classified in 25 families and 12 orders. The majority of them formed agaricoid sporocarps: for example, fungi of the genera *Amanita*, *Cortinarius*, *Hebeloma*, *Inocybe*, *Laccaria*, *Lactarius*, *Russula*, *Tricholoma* and *Xerocomus*. Some aphyllophoroid fungi were also noted, such as species of *Amphinema*, *Coltricia*, *Thelephora* and *Tomentella*, gasteroid fungi including *Scleroderma* and *Rhizopogon*, as well as ascomycetes *Helvella* and *Elaphomyces*. The most frequently encountered and most abundant fungi were those often found in different pine forests and associated with coniferous or both coniferous and broadleaved trees, such as *Amanita muscaria*, *A. pantherina*, *Chalciporus piperatus*, *Cortinarius casimiri*, *Hebeloma mesophaeum*, *Inocybe sindonia*, *Laccaria laccata*, *Lactarius rufus*, *Paxillus involutus*, *Russula xerampelina*, *Thelephora terrestris*, *Tricholoma scalpturatum*, *T. terreum*, *Xerocomus badius* and *Tomentella lilacinogrisea*, as well as *Chroogomphus rutilus*, *Suillus bovinus* and *S. luteus*, symbionts exclusively associated with pines. Exclusive symbionts of the deciduous trees accompanying Scots pine also occurred. *Leccinum scabrum*, *Lactarius torminosus* and *Russula exalbicans* were most often found with birch trees. The presence of coniferous trees other than pine, namely larch, also influenced the mycobiota by adding *Larix* symbionts: *Suillus viscidus* and, found outside the investigated sites, *Suillus cavipes*.

The species composition of the studied forest sites is typical for young and middle-age forest successional stages: on the one hand, early colonisers of trees (e.g. *Amanita muscaria*, *Hebeloma mesophaeum*, *Laccaria laccata*, *Paxillus involutus*, *Suillus luteus*, *Thelephora terrestris*, *Tricholoma scalpturatum*) were found at high frequency and abundance; on the other, late successional fungi were present (e.g. several species of *Cortinarius*, *Inocybe*, *Scleroderma* and *Xerocomus*, some species of *Amanita*, *Lactarius* and *Tricholoma*) (Dighton *et al*. 1986; Termorshuizen 1991; Shaw and Lankey 1994; Visser 1995; Kałucka 2009).

All the species mentioned above are typical members of the mycobiota of pine forests and mixed forests in Poland (e.g. Rudnicka-Jezierska 1969; Bujakiewicz 1975, 1986; Wojewoda 1975; Bujakiewicz and Lisiewska 1983; Friedrich 1984, 1985; Ławrynowicz and Szkodzik 1998) as well as in Central and Northern Europe (e.g. Richardson 1970; Kalamees and Silver 1988; Sammler 1988; Schmid-Heckel 1988, 1989; De Vries *et al*. 1995).

Protected, rare and endangered species

More than 60% of the noted species are frequently recorded in Poland (Fig. 4). This stems from the fact that pine forests are the most common forests in Poland, but also the age and character of the forests – younger and managed forests preclude colonisation by the rare fungi most often associated with old unmanaged woods, which are uncommon habitats (Parmasto 2001; Molina 2008). Nevertheless, fungi that are uncommon or considered rare in Poland were found in pine forests of the Olkusz area.

Some recorded species are known from only a few localities in Poland and are on the *Red list of macrofungi in Poland* (Wojewoda and Ławrynowicz 2006): *Antrodiella pallescens* (category I – indeterminate; as *Antrodiella semisupina*), *Arrhenia acerosa* (V – vulnerable), *Bovista tomentosa* (V), *Ceraceomyces serpens* (E – endangered), *Cortinarius croceus* (R – rare), *Dacrymyces estonicus* (V), *Disciseda candida* (E), *Helvella ephippium* (R), *Tricholoma focale*

(E), and *Antrodia ramentacea* (E), a saprotroph growing on *Pinus sylvestris* twigs (Gilbertson and Ryvarden 1993), which is known from two historical and one contemporary locality in the Puszcza Białowieska Primeval Forest (Wojewoda 2003). Unpublished observations indicate that the last species may actually not be so rare (Dariusz Karasiński, W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków – pers. comm.).

Twelve other species found in the OOR are on the *Red list of macrofungi in Poland*, though they are now not regarded as rare: *Cortinarius fulvescens* (E), *Gloeoporus taxicola* (R) and *Gymnopus ocior* (E) – recorded from over 20 localities, *Atheniella adonis* (R), *Diplomitoporus flavescens* (R), *Geastrum minimum* (E), *Helvella lacunosa* (R) *Mycena viridimarginata* (V), *Phaeomarasmius erinaceus* (R), *Tricholoma scalpturatum* (V) and *Porphyrellus porphyrosporus* (R) – recorded from over 30 localities in Poland. Kujawa *et al*. (2012) assessed the number of known localities and habitats of *Geastrum minimum* and proposed a low IUCN category, NT (near threatened), for this species. In the light of our present knowledge, *Mutinus caninus*, a fungus under legal protection in Poland, is not threatened and should lose its status (Szczepkowski and Obidziński 2012); it was also found during this study.

A few other fungi not red-listed but rarely recorded in Poland were found in the studied pine forests. Such species as *Cortinarius pluvius*, *Entoloma neglectum*, *Gymnopus hybridus*, *Hemimycena pseudolactea*, *Russula cessans*, *Tomentella cinerascens* and *T. lilacinogrisea* were previously known from single or very few localities. Two *Cortinarius* species, *C. comptulus* and *C. croceoconus*, were noted in Poland just recently from single localities (Ślusarczyk 2014). The presence of *Inocybe ochroalba* in Poland, a species first mentioned by Bujakiewicz (2011) as *I.* cf. *ochroalba*, has been confirmed. Another 26 species are known from a few to a dozen or more localities in Poland. This group includes fungi forming resupinate, corticioid sporocarps, such as the saprobic, wood-inhabiting *Botryobasidium conspersum*, *Xylodon brevisetus*, *Xylodon spathulatus*, *Kneiffiella subalutacea*, *Leptosporomyces galzinii* and *Trechispora candidissima*, and the ectomycorrhizal *Tomentella coerulea*, as well as fungi producing agaricoid sporocarps, above all the saprobic *Clitocybe diatreta*, *Galerina atkinsoniana*, *G. clavata*, *Gymnopus impudicus*, *Hemimycena lactea* and *Infundibulicybe costata*, and the ectomycorrhizal *Cortinarius casimiri*, *Inocybe nitidiuscula*, *I. sindonia*, *I. whitei* and *Russula exalbicans*. Some of these species probably are not rare or are even frequent in Poland but are often overlooked due to their inconspicuous sporocarps or difficulties in identification. This applies to corticioid fungi such as those of the genera *Leptosporomyces*, *Trechispora* and *Xylodon*, which are widespread in Europe (Jülich 1984; Hansen and Knudsen 1997; Bernicchia and Gorjon 2010).

A few species not previously recorded from Poland were discovered during this research. They include *Inocybe leiocephala*, an ectomycorrhizal symbiont of both coniferous and deciduous trees, and *Clitocybe marginella*, a saprobic fungus decaying coniferous and deciduous litter. Also a variety of *Hemimycena lactea*, *H. lactea* var. *tetraspora*, has not been noted from Poland until now. The present research resulted in the discovery of a species of *Paullicorticium*, *P.* cf. *allantosporum*, a genus not mentioned in Polish mycological literature previously. Apart from this finding, *P.* cf. *allantosporum* was recorded in northern Poland but is not published yet (Dariusz Karasiński, W. Szafer Institute of Botany, PAS, Kraków – pers. comm.). *Tomentella radiosa* was also noted in the Olkusz area, although some research indicates that it is only a resupinate form of the well known and widely distributed *Thelephora terrestris* (Kõljalg *et al.* 1998).

Comparison of pine forests on sandy and calamine sites

The sites in the present study were established in pine forests growing on different types of substrate: sandy soil, and calamine material left from mining activity. They differed considerably in their plant assemblages and edaphic conditions, and those differences influenced the fungal communities as well. The calamine substrate was loamy due to a higher silt fraction, contained dolomite rock fragments, and had higher pH (neutral or nearly neutral) and higher content of organic carbon, calcium, magnesium and heavy metals than the typical sandy-soil sites (Kapusta *et al.* – Chapter 13, this volume). Those sites were on sandy podsol with acidic pH. The sandy sites generally had denser tree cover than the calamine sites, and their trees were taller and thicker (Zielonka

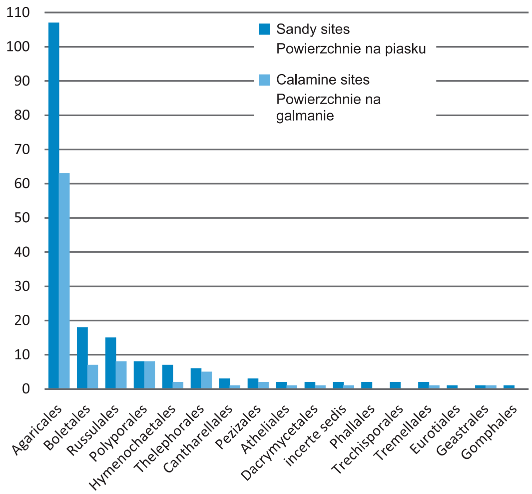

Fig. 5. The number of species from different orders, on sandy and calamine sites

Ryc. 5. Liczba gatunków w poszczególnych rzędach na powierzchniach wykształconych na piasku i na galmanie

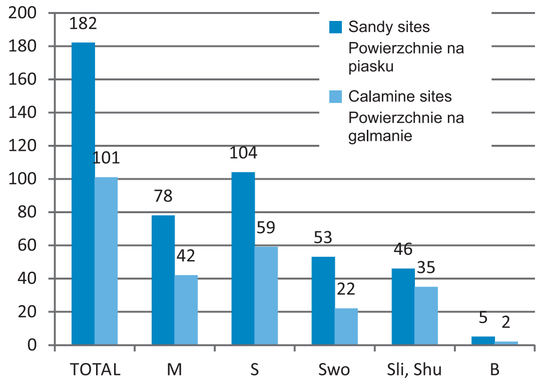

Fig. 6. The number of species from different bioecological groups on calamine and sandy sites (abbreviations as in Table 1)

Ryc. 6. Liczba gatunków grzybów z poszczególnych grup troficzno-substratowych na powierzchniach wykształconych na piasku i na galmanie (symbole jak w Tabeli 1)

et al. – Chpater 12, this volume). At least some of these sites had more woody debris, mostly in the form of twigs and branches, and the litter layer was thicker than on calamine sites.

Fewer species were recorded on calamine sites than on sandy sites (Figs 5, 6), probably because there were fewer sites of that type.

The proportions of saprobic and mycorrhizal species recorded from the two site types were similar (Fig. 7) but there were differences in species composition. Several fungi clearly preferred sandy or calamine sites. These species were noted exclusively or mostly on sites of one type, and the majority of their sporocarps were noted on those sites. Association with a particular site type was especially evident in the case of ectomycorrhizal fungi (Table 1). The fungi noted at considerably higher frequency on sandy sites included all species of *Amanita*, *Chalciporus piperatus*, most species of *Cortinarius* (e.g. *C. casimiri*, *C. croceoconus*), *Inocybe sindonia*, *Laccaria laccata*, *Lactarius rufus*, most species of *Russula*, *Suillus bovinus*, *Thelephora palmata*, *Xerocomus badius* and *X. ferrugineus*. Some species recorded also on calamine sites

Table 1. List of species recorded on particular forest sites (No. 23–47)

M – mycorrhizal species, Swo – saprotrophic wood-decaying species, Sli – saprotrophic litter-inhabiting species, Shu – saprotrophic humus-inhabiting species, Sfu – saprotrophic fungal sporophore-decaying species, B – bryophilic species, Pwo – tree-parasitic species; comm – common, freq – frequent; E, I, R, V – threat categories according to "Red list of Polish macroscopic fungi" (RL) (Wojewoda and Ławrynowicz 2006); F – frequency; C – calamine sites, S – sandy sites

Tabela 1. Lista gatunków odnotowanych na poszczególnych leśnych powierzchniach badawczych (Nr 23–47)

M – gatunek mikoryzowy, Swo – saprobiont nadrewnowy, Sli – saprobiont naściółkowy, Shu – saprobiont nahumusowy, Sfu – saprobiont nagrzybowy, B – gatunek briofilny, Pwo – pasożyt drzew; comm – pospolity, freq – częsty, rare – rzadki; E, I, R, V – kategorie zagrożenia według polskiej Czerownej Listy (Wojewoda i Ławrynowicz 2006); F – frekwencja; C – powierzchnie na podłożu galmanowym, S – powierzchnie na podłożu piaszczystym

Species Gatunki	Trophic status Status troficzny	Occurrence in Poland Występowanie w Polsce	RL status Kategoria zagrożenia	23	24	25	27	29	38	22	26	28	32	33	36	37	39	40	41	42	43	44	45	47	F
				C	C	C	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	
Amanita citrina (Schaeff.) Pers. var. *citrina*	M	freq																		x					1
Amanita fulva Fr.	M	freq																	x						1
Amanita gemmata (Fr.) Bertill.	M	freq																	x				x		2
Amanita muscaria (L.) Lam. var. *muscaria*	M	freq								x	x		x	x			x		x	x	x	x	x	x	11
Amanita pantherina (DC.) Krombh.	M	freq								x				x		x	x		x		x		x	x	8
Amanita rubescens Pers.	M	freq								x					x		x					x			4
Amphinema byssoides (Pers.) J. Erikss.	M	freq				x			x							x						x			4
Antrodia ramentacea (Berk. & Broome) Donk	Swo	rare	E						x																1
Antrodiella pallescens (Pilát) Niemelä & Miettinen	Swo	rare	I								x														1
Arrhenia acerosa (Fr.) Kühner	Sli	rare	V						x									x		x					3
Atheniella adonis (Bull.) Redhead, Moncalvo, Vilgalys, Desjardin & B.A. Perry	Sli	rare	R						x		x								x	x					4
Auriscalpium vulgare Gray	Sli	comm		x	x	x	x	x	x	x	x	x				x	x		x	x	x				14
Baeospora myosura (Fr.) Singer	Sli	freq		x					x							x									3
Botryobasidium conspersum J. Erikss.	Swo	rare							x																1
Botryobasidium pruinatum (Bres.) J. Erikss.	Swo	rare	R														x								1
Bovista aestivalis (Bonord.) Demoulin	Shu	freq																	x				x		2
Bovista tomentosa (Vittad.) De Toni	Shu	rare	V																	x					1

Cantharellus cibarius Fr.	M	comm								x															1
Ceraceomyces serpens (Tode) Ginns	Swo	rare	E										x		x										2
Chalciporus piperatus (Bull.) Bataille	M	freq								x				x			x		x	x		x	x		7
Chondrostereum purpureum (Pers.) Pouzar	Swo	comm											x										x		2
Chroogomphus rutilus (Schaeff.) O.K. Mill.	M	comm				x	x	x								x		x							5
Clitocybe cf. *candicans* (Pers.) P. Kumm.	Shu	freq		x	x	x	x	x		x		x		x	x			x							1
Clitocybe cf. *fragrans* (With.) P. Kumm.	Shu	freq		x												x									2
Clitocybe diatreta (Fr.) P. Kumm.	Shu	rare															x			x	x		x		4
Clitocybe marginella Harmaja	Shu	new for PL			x	x			x	x	x				x	x	x		x	x	x				11
Clitocybe metachroa (Fr.) P. Kumm.	Shu	freq			x	x		x	x	x	x		x		x	x	x	x	x		x				13
Clitocybe nebularis (Batsch) P. Kumm. var. *nebularis*	Shu	freq																		x					1
Clitocybe phyllophila (Pers.) P. Kumm.	Shu	freq		x							x					x							x	x	5
Collybia cirrata (Schumach.) Quél.	Sfu	freq							x												x				2
Coltricia perennis (L.) Murrill	M	freq																			x				1
Coniophora arida (Fr.) P. Karst.	Swo	comm															x				x	x			3
Cortinarius casimiri (Velen.) Huijsman	M	rare			x			x		x	x	x	x					x	x	x		x	x		11
Cortinarius cf. *biformis*	M	rare	V																x						1
Cortinarius cf. *depressus* Fr.	M	rare																				x			1
Cortinarius cf. *umbrinoilens*	M	rare	E								x														1
Cortinarius comptulus M.M. Moser	M	rare							x					x								x			3
Cortinarius croceoconus Fr.	M	rare								x												x			2
Cortinarius croceus (Schaeff.) Gray var. *croceus*	M	rare	R		x												x						x		3
Cortinarius decipiens (Pers.) Fr. var. *decipiens*	M	freq				x	x									x									3
Cortinarius fulvescens Fr.	M	rare	E																				x		1
Cortinarius fusisporus Kühner	M	rare																					x		1
Cortinarius hemitrichus (Pers.) Fr.	M	freq				x					x														2
Cortinarius mucosus (Bull.) J. Kickx f.	M	freq																				x			1
Cortinarius pluvius (Fr.) Fr.	M	rare																				x			1
Cortinarius sp. 1	M										x														1
Cortinarius sp. 2	M																x								1
Cortinarius sp. 3	M																			x					1
Cortinarius sp. 4	M																						x		1
Cortinarius sp. 5	M							x														x			2

Table 1. Continued – Tabela 1. Kontynuacja

Species Gatunki	Trophic status Status troficzny	Occurrence in Poland Występowanie w Polsce	RL status Kategoria zagrożenia	23	24	25	27	29	38	22	26	28	32	33	36	37	39	40	41	42	43	44	45	47	F
				C	C	C	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	
Cortinarius sp. 6	M																							x	1
Cystoderma carcharias (Pers.) Fayod var. *carcharias*	Sli	comm			x			x		x		x	x	x	x						x				8
Dacrymyces estonicus Raitv.	Swo	rare	V																		x				1
Dacrymyces stillatus Nees	Swo	comm							x						x										2
Daedaleopsis confragosa (Bolton) J. Schröt.	Swo, Pwo	comm							x		x	x			x										4
Diplomitoporus flavescens (Bres.) Domański	Swo	freq	R								x	x													2
Disciseda candida (Schwein.) Lloyd	Shu	rare	E																			x		x	2
Elaphomyces granulatus Fr.	M	freq																			x				1
Entoloma cf. *papillatum* (Bres.) Dennis	Shu	rare	V		x		x																		2
Entoloma neglectum (Lasch) Arnolds	Shu	rare																					x		1
Entoloma sp. 1	Shu																							x	1
Entoloma sp. 2	Shu				x																				1
Galerina atkinsoniana A.H. Sm.	B	rare			x																x				2
Galerina clavata (Velen.) Kühner	Shu	rare								x															1
Galerina marginata (Batsch) Kühner	Swo	freq/ comm						x	x						x	x	x		x		x		x		8
Galerina mniophila (Lasch) Kühner	B	freq																						x	1
Galerina pumila (Pers.) M. Lange	B	freq								x											x	x	x		4
Galerina vittiformis (Fr.) Singer	B	rare																		x	x			x	3
Geastrum minimum Schwein.	Shu	rare	E		x																	x			2
Gloeoporus taxicola (Pers.) Gilb. & Ryvarden	Swo	freq	R												x										1
Gymnopilus penetrans (Fr.) Murrill	Swo	comm								x		x	x				x	x	x		x	x	x		9
Gymnopus androsaceus (L.) J.L. Mata & R.H. Petersen	Sli	comm			x	x	x	x			x	x			x	x						x			9
Gymnopus confluens (Pers.) Antonín, Halling & Noordel.	Sli	comm							x																1

Gymnopus dryophilus (Bull.) Murrill	Sli	comm						x	x					x	x					x				5
Gymnopus hybridus (Kühner & Romagn.) Antonín & Noordel.	Sli	rare						x	x		x	x												4
Gymnopus impudicus (Fr.) Antonín, Halling & Noordel.	Shu, Sli	rare		x																				1
Gymnopus ocior (Pers.) Antonín & Noordel.	Sli	rare	E													x								1
Gymnopus perforans (Hoffm.) Antonín & Noordel.	Sli	freq									x													1
Hebeloma crustuliniforme (Bull.) Quél.	M	freq				x					x													2
Hebeloma mesophaeum (Pers.) Quél.	M	freq		x	x	x	x	x	x	x	x	x				x	x	x		x	x	x	x	x	17
Hebeloma sp. (sect. Denudata)	M				x		x	x				x												4
Helvella elastica Bull.	M	comm							x															1
Helvella ephippium Lév.	M	rare	R						x		x													2
Helvella lacunosa Afzel.	M	freq	R								x													1
Helvella macropus (Pers.) P. Karst.	M	freq									x													1
Hemimycena lactea (Pers.) Singer	Sli	rare			x	x		x									x					x		5
Hemimycena lactea var. *tetraspora* Kühner & Valla	Sli	new for PL							x		x					x			x	x				5
Hemimycena pseudolactea (Kühner) Singer	Sli	rare																	x					1
Hemimycena sp. 1	Sli								x															1
Heterobasidion annosum (Fr.) Bref.	Swo, Pwo	comm										x					x					x		3
Hygrophoropsis aurantiaca (Wulfen) Maire	Swo	comm																					x	1
Hypholoma fasciculare (Huds.) P. Kumm. var. *fasciculare*	Swo	comm											x			x								2
Hypholoma lateritium (Schaeff.) P. Kumm.	Swo	comm											x											1
Infundibulicybe costata (Kühner & Romagn.) Harmaja	Shu	rare		x	x	x	x	x	x							x	x							8
Inocybe cf. *jakobi* Kühner	M	rare	E								x													1
Inocybe flocculosa Sacc.	M	rare				x																		1
Inocybe leiocephala D.E. Stuntz	M	new for PL							x										x	x				3
Inocybe mixtilis (Britzelm.) Sacc.	M	rare							x															1
Inocybe nitidiuscula (Britzelm.) Lapl.	M	rare														x		x						2
Inocybe ochroalba Bruylands	M	rare																				x		1
Inocybe rimosa (Bull.) P. Kumm.	M	comm							x									x			x			3

Table 1. Continued – Tabela 1. Kontynuacja

Species Gatunki	Trophic status Status troficzny	Occurrence in Poland Występowanie w Polsce	RL status Kategoria zagrożenia	23	24	25	27	29	38	22	26	28	32	33	36	37	39	40	41	42	43	44	45	47	F
				C	C	C	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	
Inocybe sindonia (Fr.) P. Karst.	M	rare							x			x	x	x				x						x	6
Inocybe sp. 1	M						x										x								2
Inocybe whitei (Berk. & Broome) Sacc.	M	rare							x		x														2
Kneiffiella subalutacea (P. Karst.) Jülich & Stalpers	Swo	rare																			x				1
Laccaria laccata (Scop.) Cooke	M	comm								x					x		x				x		x		5
Laccaria proxima (Boud.) Pat.	M	freq / comm												x											1
Lactarius delicious (L.) Gray	M	freq							x									x			x		x		4
Lactarius necator (Bull.: Fr.) Pers.	M	comm									x	x													2
Lactarius pubescens Fr.	M	freq					x																		1
Lactarius rufus (Scop.) Fr.	M	comm								x	x	x	x	x	x		x	x			x	x	x		11
Lactarius torminosus (Schaeff.) Gray	M	comm				x	x	x			x														4
Leccinum scabrum (Bull.) Gray	M	comm					x	x	x		x	x										x			6
Lentinellus cochleatus (Pers.) P. Karst.	Swo	freq															x								1
Lepiota cristata (Bolton) P. Kumm.	Sli	comm						x								x									2
Leptosporomyces galzinii (Bourdot) Jülich	Swo	rare																			x	x			2
Lycoperdon molle Pers.	Shu	freq						x	x		x				x						x				5
Lycoperdon nigrescens Pers.	Shu	freq																			x	x			2
Mutinus caninus (Huds.) Fr.	Shu	rare										x													1
Mycena abramsii (Murrill) Murrill	Swo	rare		x				x	x	x				x	x	x							x		8
Mycena aetites (Fr.) Quél.	Shu	freq			x																				1
Mycena amicta (Fr.) Quél.	Sli	rare										x			x										2
Mycena capillaripes Peck	Sli	rare	V													x									1
Mycena cf. *purpureofusca* (Peck) Sacc.	Swo	rare	V						x												x				2
Mycena cf. *villicaulis* Maas Geest.	Sli	new for PL													x										1
Mycena citrinomarginata Gillet	Shu	rare			x	x		x								x									4

Mycena epipterygia (Scop.) Gray var. *epipterygia*	Swo, Sli	comm							x	x						x	x							4
Mycena galericulata (Scop.) Gray	Swo	comm							x	x		x	x				x	x				x		7
Mycena galopus (Pers.) P. Kumm.	Sli	comm							x	x		x			x					x	x	x	x	8
Mycena haematopus (Pers.) P. Kumm.	Swo	comm							x			x											x	3
Mycena leptocephala (Pers.) Gillet	Sli, Swo	freq			x	x				x	x	x	x		x		x	x	x	x	x	x	x	14
Mycena metata (Secr. ex Fr.) P. Kumm.	Sli	freq							x															1
Mycena pura (Pers.) P. Kumm.	Sli	comm		x	x	x	x	x	x		x	x	x			x		x						11
Mycena viridimarginata P. Karst.	Swo	rare	V	x																				1
Mycetinis scorodonius (Fr.) A.W. Wilson & Desjardin	Sli	comm							x		x													2
Oligoporus cf. *undosus* (Peck) Gilb. & Ryvarden	Swo	rare	E							x													x	2
Oligoporus leucomallellus (Murrill) Gilb. & Ryvarden	Swo	comm				x		x	x				x					x		x			x	7
Oligoporus stipticus (Pers.) Gilb. & Ryvarden	Swo	comm							x															1
Panellus mitis (Pers.) Singer	Swo	freq															x							1
Paullicorticium cf. *allantosporum* J. Erikss.	Swo	new for PL													x									1
Paxillus involutus (Batsch) Fr.	M	comm				x	x		x		x	x	x	x			x				x			9
Peniophora cinerea (Pers.) Cooke	Swo	comm							x								x				x			3
Peniophorella praetermissa (P. Karst.) K.H. Larss.	Swo	freq				x								x										2
Peniophorella pubera (Fr.) P. Karst.	Swo	comm													x									1
Phaeomarasmius erinaceus (Fr.) Scherff. ex Romagn.	Swo	rare	R							x														1
Phallus impudicus L. var. *impudicus*	Shu	comm										x												1
Pholiota lenta (Pers.) Singer	Swo	freq																				x		1
Pholiota spumosa (Fr.) Singer	Swo	freq								x						x	x	x	x	x	x	x		8
Piptoporus betulinus (Bull.) P. Karst.	Pwo, Swo	comm				x																		1
Polyporus cf. *brumalis* (Pers.) Fr.	Swo	comm						x	x															2
Porphyrellus porphyrosporus (Fr. & Hök) E.-J. Gilbert	M	rare	R																	x				1
Pseudohydnum gelatinosum (Scop.) P. Karst.	Swo	comm																					x	1
Ramaria abietina (Pers.) Quél.	Sli	freq														x	x		x					3
Resupinatus applicatus (Batsch) Gray	Swo	rare																			x			1

Table 1. Continued – Tabela 1. Kontynuacja

Species Gatunki	Trophic status Status troficzny	Occurrence in Poland Występowanie w Polsce	RL status Kategoria zagrożenia	23	24	25	27	29	38	22	26	28	32	33	36	37	39	40	41	42	43	44	45	47	F
				C	C	C	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	
Rhizopogon roseolus (Corda) Th. Fr.	M	freq					x																		1
Rhodocollybia butyracea (Bull.) Lennox f. *asema* (Fr.) Antonín, Halling & Noordel.	Sli	comm									x														1
Rickenella fibula (Bull.) Raithelh.	B	comm					x			x	x		x	x							x	x	x	x	9
Russula cessans A. Pearson	M	rare								x													x		2
Russula exalbicans (Pers.) Melzer & Zvára	M	rare				x	x	x			x														4
Russula sanguinea (Bull.) Fr.	M	comm															x								1
Russula sp. 1 (subsect. *Puellerinae*)	M										x			x						x			x		4
Russula sp. 2	M								x																1
Russula xerampelina (Schaeff.) Fr.	M	comm					x		x	x				x			x			x	x	x	x		9
Schizophyllum commune Fr.	Swo	comm								x							x				x	x			4
Scleroderma bovista Fr.	M	freq									x														1
Scleroderma citrinum Pers.	M	comm						x			x								x						3
Skeletocutis amorpha (Fr.) Kotl. & Pouzar	Swo	freq													x		x								2
Steccherinum ochraceum (Pers.) Gray	Swo	freq							x																1
Stereum hirsutum (Willd.) Pers.	Swo	comm																				x			1
Stereum sanguinolentum (Alb. & Schwein.) Fr.	Swo	comm											x												1
Strobilurus stephanocystis (Kühner & Romagn. ex Hora) Singer	Sli	comm			x		x	x									x							x	5
Strobilurus tenacellus (Pers.) Singer	Sli	comm			x							x					x								3
Stropharia aeruginosa (Curtis) Quél.	Sli	comm		x	x			x																	3
Stropharia cyanea (Bull.) Tuom.	Sli	comm			x		x					x													3
Suillus bovinus (Pers.) Roussel	M	comm												x			x				x		x	x	5
Suillus grevillei (Klotzsch) Singer	M	comm										x													1
Suillus luteus (L.) Roussel	M	comm		x	x	x	x	x		x	x	x		x			x			x			x	x	13
Suillus viscidus (L.) Roussel	M	freq					x	x	x		x														4
Tapinella atrotomentosa (Batsch) Šutara	Swo	freq													x		x								2
Tapinella panuoides (Batsch) E.-J. Gilbert	Swo	freq													x										1

Thelephora palmata (Scop.) Fr.	M	freq															x			x	x				3
Thelephora terestris Ehrh.	M	comm		x		x	x				x					x	x					x			7
Tomentella cf. *coerulea* (Bres.) Höhn. & Litsch.	M	rare		x																					1
Tomentella cinerascens (P. Karst.) Höhn. & Litsch.	M	rare				x					x										x				3
Tomentella lilacinogrisea Wakef.	M	rare			x	x			x												x		x		5
Tomentella radiosa (P. Karst.) Rick	M	new for PL				x											x								2
Trametes pubescens (Schumach.) Pilát	Swo	rare	R							x			x									x			3
Trametes versicolor (L.) Lloyd	Swo	comm				x							x												2
Trechispora candidissima (Schwein.) Bondartsev & Singer	Swo	rare															x				x				2
Trechispora farinacea (Pers.) Liberta	Swo	rare													x										1
Tremella encephala Willd.	Swo	freq							x							x									2
Trichaptum fuscoviolaceum (Ehrenb.) Ryvarden	Swo	comm				x			x		x	x			x	x	x		x	x					9
Tricholoma argyraceum (Bull.) Gillet	M	rare	V				x																		1
Tricholoma focale (Fr.) Ricken	M	rare	E							x															1
Tricholoma imbricatum (Fr.) P. Kumm.	M	freq				x	x															x	x		4
Tricholoma portentosum (Fr.) Quél.	M	comm				x																			1
Tricholoma saponaceum (Fr.) P. Kumm. var. *saponaceum*	M	comm																					x		1
Tricholoma scalpturatum (Fr.) Quél.	M	rare	V	x	x	x	x	x			x														6
Tricholoma terreum (Schaeff.) P. Kumm.	M	comm			x		x	x			x	x				x	x								7
Tricholomopsis rutilans (Schaeff.) Singer	Swo	comm								x		x			x		x	x			x	x			7
Tylopilus felleus (Bull.) P. Karst.	M	freq																		x					1
Xerocomus badius (Fr.) E.-J. Gilbert	M	comm								x							x		x	x		x	x		6
Xerocomus ferrugineus (Schaeff.) Alessio	M	rare									x		x								x				3
Xylodon brevisetus (P. Karst.) Hjortstam & Ryvarden	Swo	rare														x									1
Xylodon cf. *spathulatus* (Schrad.) Kuntze	Swo	rare															x						x		2
Xylodon spathulatus (Schrad.) Kuntze	Swo	rare															x								1
Number of species				**15**	**27**	**24**	**29**	**29**	**37**	**32**	**42**	**28**	**15**	**17**	**17**	**27**	**16**	**36**	**22**	**26**	**33**	**30**	**34**	**14**	

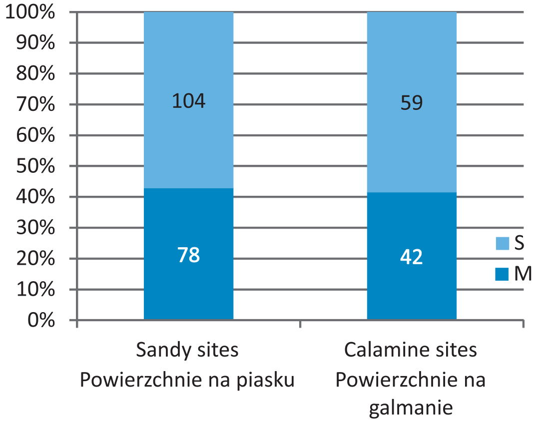

Fig. 7. Ratios between the number of mycorrhizal (M) and saprobic (S) species on calamine and sandy sites

Ryc. 7. Proporcje pomiędzy liczbą gatunków mykoryzowych (M) i saprobiontycznych (S) na powierzchniach wykształconych na piasku i na galmanie

produced considerably more sporocarps on sandy sites. Examples are *Cortinarius casimiri*, *C. comptulus*, *Inocybe leiocephala*, *Russula xerampelina* and *Scleroderma citrinum*. These fungi are known to prefer acid soils.

Another group of fungi was clearly associated with calamine sites: for example, *Chroogomphus rutilus*, *Hebeloma* sp. (sect. *Denudata*) and *Tricholoma scalpturatum*, as well as *Hebeloma mesophaeum*, *Suillus luteus*, *Thelephora terrestris*, *Tricholoma imbricatum* and *T. terreum*, species noted also on sandy sites but producing many more sporocarps on calamine sites. The situation was similar for several birch symbionts, although birch trees were also present on sandy sites: for example, *Lactarius torminosus*, *L. pubescens*, *Russula exalbicans* and *Leccinum scabrum*. Some of these species are known as early-stage fungi, often occurring at sites bearing initial soil (e.g. former farmland) and without accumulated tree litter. Examples are *Hebeloma mesophaeum*, *Thelephora terrestris* and *Suillus luteus*. A few species with a clear preference for calamine sites have calciphilic tendencies, such as *Chroogomphus rutilus*, *Russula exalbicans*, *Tricholoma terreum* and *T. scalpturatum*.

The distribution of particular ectomycorrhizal species among the sites depended on edaphic conditions to a large extent. Statistical analyses that included soil characteristics (physical properties, chemical content, pH), plant community characteristics (e.g. species composition, plant cover), and the presence of mycorrhizal fungal species at frequency of 20% or more (i.e. found on at least 4 sites) disclosed that fungal community diversity was shaped in large part by macronutrient content (nitrogen, calcium), organic matter and substrate pH (Mleczko and Kapusta 2010, 2011, 2012).

The presence of saprobic species on sites of one type or the other depended mostly on the availability of the substrate. Such fungi as *Clitocybe* (e.g. *C. marginella*, *C. metachroa*, *C.* cf. *candicans*), *Hemimycena*, *Strobilurus*, *Gymnopus* (e.g. *G. dryophilus*, *G. adrosaceus*), *Auriscalpium vulgare* and *Lycoperdon molle* occurred on both types of sites. The preference of litter- and humus-associated fungi for sites of a particular type was much less pronounced than in the case of mycorrhizal symbionts. Species with a preference for calamine sites included *Infundibulicybe costata*, found mostly on soils with higher pH, often calcareous, and *Stropharia cyanea*, often recorded from ruderal anthropogenic sites with higher pH. The production of sporocarps of *Lycoperdon molle*, which prefers rich and alkaline soils, was higher on calamine sites. *Geastrum minimum*, a calciphilic species also characteristic for xerothermic grassland, was recorded on these sites (Jaworska *et al.* 2012; Tomaszewska *et al.* 2012). Acidophilic species such as *Disciseda candida* and *Lycoperdon nigrescens* (Saar *et al.* 2009) were noted on sandy sites, together with *Clitocybe diatreta*, which shows no clear preference for soil pH but is associated with sandy soils, and *Cystoderma carcharias*, which produced considerably more sporocarps there. The generally thicker litter layer on sandy sites was probably the reason for the more frequent occurrence of several *Mycena* species (e.g. *M. galopus*, *M. epipterygia*, *M. leptocephala*), as well as *Clitocybe diatreta* and *Ramaria abietina*.

The much greater availability of dead wood on sandy sites, mostly as twigs and branches and rarely as stumps, resulted in higher diversity of saprobic, wood-decaying fungi there (Fig. 8). The most frequent species of this group were *Galerina marginata*, *Gymnopilus penetrans*, *Mycena abramsii*, *M. galericulata*, *Pholiota spumosa* and *Tricholomopsis rutilans*. Also present were several polyporoid and corticioid fungi of the genera *Coniophora*, *Leptosporomyces*, *Oligoporus*, *Skeletocutis*, *Trechispora*, *Xylodon* and others. *Oligoporus leucomallelus* and *Trichaptum fuscoviolaceum* were found on both site types at similar frequency. Bryophilic fungi also showed higher diversity on sandy sites.

Although statistical analyses did not show any significant differences in the number

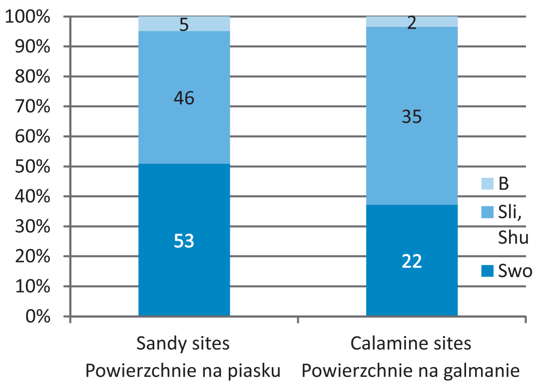

Fig. 8. Ratios between the number of saprobic species from different substrate groups on calamine and sandy sites (abbreviations as in Table 1)

Ryc. 8. Proporcje pomiędzy gatunkami poszczególnych grup substratowych grzybów saprobiontycznych na powierzchniach wykształconych na piasku i na galmanie (symbole, jak w Tabeli 1)

and biomass of sporocarps between site types (see: Mleczko and Kapusta 2011, 2012), both indexes were higher for calamine sites (Figs 3, 4). Particular fungal groups did show significant differences, however. Greater availability of substrate (especially wood) on sandy sites, coupled with higher diversity of saprobic species, mostly lignicolous ones, resulted in higher production of sporocarps of these fungi there. The diversity of mycorrhizal fungi was also higher on sandy sites, but the production of their sporocarps on calamine sites was much higher than on sandy sites. Apart from the differences in the sporocarp production capabilities of particular species, this phenomenon may be linked with the younger age of forests on calamine sites and the lower amount of accumulated litter there. Some studies of pine forests in the Netherlands (Baar 1996; Baar and Ter Braak 1996; Baar and Kuyper 1988) suggest that litter is a factor limiting the formation of mycorrhizal fungal sporocarps, although the influence of this factor may also be species-dependent (Tarvainen 2009).

Species richness on the calamine and sandy sites was similar (Table 1) but the similarities between particular sites as measured by Sørensen's diversity index (SI) were small; in most cases the index values did not exceed 0.4 (Tables 2, 3). This was because the frequency of the majority of species was lower than 20%; that is, they occurred on 4 sites or less. The index values within the same group of sites, calamine vs. sandy, were generally higher than between groups, probably indicating similar edaphic conditions. In the case of a few sandy sites (26, 28, 37, 40), their mycobiota was found to be similar to the mycobiota of calamine sites. The OOR is under continuous and strong anthropopression, leading to contamination of some sites with material of industrial or municipal origin, such as polluted water or dustfall. This has raised the soil concentrations

Table 2. Sørensen's diversity index values calculated for all recorded species
C – calamine sites, S – sandy sites; color scale: ☐ – value range 0.20–0.29, ☐ – value range 0.30–0.39, ☐ – values ≥ 40

Tabela 2. Wartości współczynnika Sørensena obliczone na podstawie wszystkich zanotowanych gatunków
C – powierzchnie na podłożu galmanowym, S – powierzchnie na podłożu piaszczystym; skala kolorów: ☐ – wartości 0.20–0.29, ☐ – wartości 0.30–0.39, ☐ – wartości ≥ 40

		23	24	25	27	29	38	26	28	37	40	36	22	32	33	39	41	42	43	44	45	47
		C	C	C	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
23	C		0.36	0.33	0.36	0.38	0.18	0.22	0.21	0.38	0.18	0.09	0.20	0.05	0.18	0.15	0.05	0.13	0.07	0.08	0.14	0.20
24	C			0.46	0.46	0.58	0.18	0.29	0.43	0.31	0.26	0.21	0.29	0.20	0.13	0.31	0.20	0.21	0.23	0.18	0.18	0.14
25	C				0.48	0.47	0.27	0.45	0.28	0.41	0.27	0.20	0.21	0.22	0.16	0.29	0.18	0.23	0.21	0.20	0.16	0.09
27	C					0.53	0.20	0.39	0.36	0.30	0.17	0.07	0.19	0.12	0.21	0.26	0.04	0.14	0.14	0.21	0.14	0.19
29	C						0.35	0.41	0.38	0.39	0.29	0.27	0.24	0.19	0.20	0.23	0.19	0.20	0.16	0.15	0.17	0.13
38	C							0.35	0.29	0.35	0.26	0.26	0.21	0.17	0.18	0.24	0.22	0.30	0.32	0.16	0.20	0.06
26	S								0.41	0.31	0.18	0.21	0.24	0.26	0.18	0.25	0.29	0.32	0.27	0.24	0.21	0.16
28	S									0.19	0.40	0.33	0.36	0.34	0.24	0.32	0.18	0.23	0.24	0.32	0.22	0.13
37	S										0.24	0.20	0.24	0.12	0.08	0.33	0.33	0.20	0.19	0.15	0.14	0.13
40	S											0.22	0.38	0.46	0.17	0.24	0.24	0.26	0.30	0.29	0.24	0.13
36	S												0.35	0.20	0.22	0.29	0.20	0.18	0.28	0.18	0.18	0.00
22	S													0.36	0.38	0.48	0.38	0.38	0.46	0.53	0.48	0.20
32	S														0.31	0.20	0.23	0.16	0.28	0.28	0.26	0.17
33	S															0.24	0.15	0.26	0.26	0.22	0.34	0.38
39	S																0.36	0.33	0.48	0.40	0.36	0.19
41	S																	0.46	0.27	0.23	0.32	0.11
42	S																		0.31	0.30	0.35	0.19
43	S																			0.38	0.39	0.21
44	S																				0.34	0.16
45	S																					0.26

Table 3. Sørensen's diversity index values calculated for species recorded on at least four sites, without wood-inhabiting saprobic species
C – calamine sites, S – sandy sites; colour scale: ☐ – value range 0.20–0.29, ☐ – value range 0.30–0.39, ☐ – values ≥ 40

Tabela 3. Wartości współczynnika Sørensena obliczone na podstawie gatunków zanotowanych na co najmniej czterech powierzchniach, z pominięciem saprobiontów nadrewnowych

C – powierzchnie na podłożu galmanowym, S – powierzchnie na podłożu piaszczystym; skala kolorów: ☐ – wartości 0.20–0.29, ☐ – wartości 0.30–0.39, ☐ – wartości ≥ 40

		23	24	25	27	29	38	26	28	37	40	22	39	32	33	36	41	42	43	44	45	47
		C	C	C	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
23	C		0.52	0.56	0.64	0.50	0.24	0.44	0.36	0.45	0.33	0.23	0.29	0.12	0.19	0.11	0.00	0.18	0.08	0.19	0.22	0.40
24	C			0.49	0.38	0.55	0.27	0.38	0.43	0.33	0.32	0.48	0.29	0.27	0.15	0.26	0.22	0.24	0.27	0.15	0.21	0.11
25	C				0.47	0.37	0.32	0.38	0.26	0.43	0.28	0.34	0.30	0.19	0.13	0.18	0.14	0.17	0.24	0.22	0.19	0.10
27	C					0.40	0.22	0.26	0.33	0.33	0.21	0.25	0.29	0.11	0.19	0.05	0.00	0.14	0.13	0.19	0.17	0.11
29	C						0.29	0.29	0.38	0.31	0.29	0.35	0.20	0.20	0.18	0.24	0.10	0.18	0.17	0.09	0.12	0.11
38	C							0.25	0.24	0.29	0.17	0.34	0.20	0.21	0.23	0.22	0.10	0.19	0.27	0.13	0.14	0.07
26	S								0.30	0.26	0.21	0.43	0.30	0.25	0.17	0.17	0.21	0.26	0.25	0.20	0.24	0.15
28	S									0.13	0.33	0.50	0.23	0.34	0.27	0.23	0.10	0.22	0.24	0.22	0.24	0.15
37	S										0.20	0.31	0.31	0.11	0.06	0.10	0.15	0.09	0.17	0.14	0.12	0.16
40	S											0.43	0.14	0.39	0.21	0.21	0.22	0.19	0.29	0.26	0.27	0.16
22	S												0.74	0.44	0.52	0.62	0.59	0.63	0.63	0.65	0.65	0.32
39	S													0.24	0.42	0.25	0.24	0.29	0.36	0.29	0.35	0.18
32	S														0.29	0.25	0.27	0.17	0.32	0.24	0.20	0.14
33	S															0.28	0.22	0.38	0.40	0.26	0.43	0.40
36	S																0.16	0.19	0.36	0.20	0.17	0.00
41	S																	0.38	0.25	0.28	0.29	0.13
42	S																		0.30	0.38	0.46	0.17
43	S																			0.21	0.39	0.16
44	S																				0.36	0.09
45	S																					0.26
47	S																					

of some elements, such as calcium and heavy metals, together with higher pH, and in consequence has influenced the fungal communities. For example, the pH of sandy site no. 28 was close to neutral, and the mycobiota of this site showed similarities with that of calamine sites.

Conclusions

Although influenced and transformed by industrial activity, the investigated pine forests in the vicinity of Olkusz developed a mycobiota typical for coniferous forests but also relatively diverse. Several species rarely recorded in Poland were noted there in the course of this study. Mining in this area resulted in the formation of a set of habitats that differ in edaphic conditions, especially those with calamine substrate. This has influenced the biota of macroscopic fungi in the pine forests and generally has increased fungal diversity there.

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