Acta Mycologica

DOI: 10.5586/am.1080

Publication history
Received: 2016-08-04
Accepted: 2016-09-02
Published: 2016-10-14

Handling editor
Tomasz Leski, Institute of Dendrology, Polish Academy of Sciences, Poland

Authors' contributions
ILK, AMJ: conceived and designed the field work; MN: performed soil analyses; ILK: collected and analyzed fungal materials; ILK, AMJ, MN: contributed reagents/analysis tools; ILK: wrote the paper; AMJ, MN: reviewed the final version of the manuscript

Funding
This study was supported by the Polish Ministry of Science and Higher Education (grant Nos. 3 P04G 031 23 and N N305 2996 40), by the General Directorate of State Forests, Warsaw, Poland (research project "Environmental and genetic factors affecting productivity of forest ecosystems on forest and post-industrial habitats"), and by the University of Łódź (task grants 505/415: 2007-2010; statutory funds of the Department of Algology and Mycology).

Competing interests
No competing interests have been declared.

Citation
Kałucka IL, Jagodziński AM, Nowiński M. Biodiversity of ectomycorrhizal fungi in surface mine spoil restoration stands in Poland – first time recorded, rare, and red-listed species. Acta Mycol. 2016;51(2):1080. http://dx.doi.org/10.5586/am.1080

ORIGINAL RESEARCH PAPER

Biodiversity of ectomycorrhizal fungi in surface mine spoil restoration stands in Poland – first time recorded, rare, and red-listed species

Izabela Lidia Kałucka[1]*, Andrzej M. Jagodziński[2,3], Mirosław Nowiński[4]

[1] Department of Algology and Mycology, Faculty of Biology and Environmental Protection, University of Łódź, Banacha 12/16, 90-237 Łódź, Poland
[2] Institute of Dendrology, Polish Academy of Sciences, Parkowa 5, 62-035 Kórnik, Poland
[3] Department of Game Management and Forest Protection, Faculty of Forestry, Poznań University of Life Sciences, Wojska Polskiego 71c, 60-625 Poznań, Poland
[4] Department of Forest Sites and Ecology, Faculty of Forestry, Poznań University of Life Sciences, Wojska Polskiego 71e, 60-625 Poznań, Poland

* Corresponding author. Email: ikalucka@biol.uni.lodz.pl

Abstract
Results of mycological research conducted in the years 2001–2013 in the restoration stands growing on reclaimed mine spoils are presented. Four opencast lignite mine spoil heaps in Poland were examined: Pątnów-Jóźwin, Adamów, Mt Kamieńsk, and Turów. The paper focuses on 71 species of ectomycorrhizal fungi: recorded for the first time in the country (16 taxa), currently red-listed (23 taxa), known from few localities only (32 taxa). Notes on their ecology and habitats are provided, as well as their distribution in Europe and in Poland. Restoration tree stands, established as part of the reclamation process of mine spoils, form a unique habitat for many rare and interesting fungal taxa. Among them are pioneer species, species known mainly from Northern Europe or mountainous locations, highly specialized and narrow-niche taxa, and many threatened species. Afforested mine spoils contribute significantly to the fungal biodiversity, both at a local and at a larger scale.

Keywords
fungal conservation; distribution; threatened species; pioneer fungi; mining disturbance; dumping grounds; afforestation; forest reclamation

Introduction

The research on biodiversity of macrofungi in Poland has been most frequently carried out in the areas, which represent more or less natural or developed vegetation or habitats valuable for plant diversity and conservation [1]. Often, they are mature or old-growth forest communities in protected areas – nature reserves, national parks, that are usually expected also to show high fungal species richness and the presence of rare and valuable species. Young, dynamic vegetation, especially if developing on disturbed grounds, has rarely been an object of macrofungal biodiversity observations, although, it may be unexpectedly rich in that respect, as has been shown for spontaneously established young forest communities on abandoned fields [2] and isolated woodland patches in agricultural landscape [3]. Also, the restoration tree stands, established as part of the reclamation process of post-industrial areas, have been hardly studied in the context of fungal biodiversity. Fungi, especially ectomycorrhizal (ECM) symbionts, are key organisms enabling trees to colonize open land, survive in a harsh

environment, and form a healthy forest community [4]. Although young reclamation stands planted on mine spoils are not believed to support diversified fungal communities valuable in biodiversity or conservation respect [5], it has been shown that older forests on spoil heaps may not differ very much in terms of ECM community richness and diversity from the surrounding woods [5,6] or other mature forests [7]. The fungal species composition may not be equivalent, however, afforested mine spoil heaps may form a unique habitat for many rare and interesting fungal taxa. To outline the diversity of ECM fungi in young restoration forests on reclaimed mine spoils, extensive research has been conducted on the four largest lignite mine spoil heaps in Poland (Central Europe). Here, we present the species recorded for the first time in the country, species red-listed as threatened and rare, and interesting species known from just a few localities. These records are not only a contribution to the knowledge of the distribution of these species in Poland and Europe but also help our understanding of their specific ecological requirements.

Material and methods

The study area

The study has been carried out on the outer spoil heaps resulting from the activity of the four largest opencast brown coal (lignite) mines in Poland: Pątnów-Jóźwin (KWB Konin S.A. lignite mine), Adamów (KWB Adamów S.A. lignite mine), Mt Kamieńsk (PGE KWB Bełchatów S.A. lignite mine), and Turów (PGE KWB Turów S.A. lignite mine; Fig. 1).

The heaps Pątnów-Jóźwin and Adamów are situated in the area of Konin lignite region [8] in the eastern part of the Wielkopolska Province. According to Kondracki [9], the former is situated in the mesoregion of Pojezierze Gnieźnieńskie within the Pojezierze Wielkopolsko-Kujawskie macroregion (on younger deposits of the Vistulian glaciation moraine), and the latter in the mesoregion of Wysoczyzna Turecka within the Nizina Południowowielkopolska macroregion (on older deposits of the Riss glaciation). The hydroclimatic conditions within this area are rather poor [10]. Mean annual temperature is 9.2°C and shows an increasing trend in the last 30 years (1980–2012). The mean annual precipitation is 517 mm and is lower than the mean in the Wielkopolska region and in Poland.

Pątnów-Jóźwin spoil heap (52.322574° N, 18.212444° E) was built in the period from 1962 to the beginning of the 1980's, west of Kamienica village (north of Konin town) as an outer dumping ground for the overburden from the Pątnów opencast pit. Its altitude reaches 70 m above the neighboring land (ca. 165 m a.s.l.), it covers an area of ca. 340 ha and has a cubature of 133.6 mln m^3 [11]. Its strongly diverse relief includes long mounded ridges and very steep slopes prone to water erosion, with numerous landslides, precipices, cracks, deep troughs and alluvial fans, as well as leveled plateaus and small, periodic or permanent water bodies [12]. Non-selective methods of overburden deposition have been applied, resulting in high spatial diversity of superficial physical and chemical features: on the heap surface, mainly grey boulder clays rich in $CaCO_3$ (Riss glaciation), Neogene clays of the Poznań series, and Quaternary sands and gravels of different origin have been tipped. These materials, most often of neutral or calcareous character, are thought to form a bedrock for better soils than fluvio-glacial or fluvial materials. However, there are also sites where Neogene acid sands and materials containing toxic sulphur compounds or mobile aluminum are present [10,13,14]. After the heap formation, the reclamation measures were limited and rather

Fig. 1 Geographical location of the research sites: 1 – Pątnów-Jóźwin; 2 – Adamów; 3 – Mt Kamieńsk; 4 – Turów.

ineffective [12]. Most of the heap has been afforested. At present, the stands are managed by the State Forests National Forest Holding (Kazimierz Forest District, Konin Inspectorate). Clays, sandy clays, and sandy clay loams prevailing on the heap surface, form the habitat for mesophilous (fresh) deciduous forest [15]. The prevailing type of reclamation stands are poplar (*Populus* spp.) stands 28, 25, and 16 years old, at places mixed with willow (*Salix* spp.), black alder (*Alnus glutinosa*) and black locust (*Robinia pseudoacacia*), and pure black locust stands. Also, smaller fragments of pedunculate, sessile and northern red oak (*Quercus robur*, *Q. petraea*, and *Q. rubra*), beech (*Fagus sylvatica*), and European larch (*Larix decidua*) stands are present (trees 16–28 years old) as well as groups of sycamore maple (*Acer pseudoplatanus*), hornbeam (*Carpinus betulus*), common ash (*Fraxinus excelsior*), Scots pine (*Pinus sylvestris*), birch (*Betula pendula*), and lime trees (*Tilia cordata*). More humid places are covered with willow shrubs (*Salix* spp.).

Adamów spoil heap (52.032322° N, 18.582870° E) was tipped in the period 1959–1970 north west of Warenka village (north east of Turek town) as an outer dumping ground of the Adamów opencast pit. It is a ca. 38-m-high hill (ca. 150 m a.s.l.) covering 318 ha, formed of 125 mln m^3 of the overburden [16,17]. Non-selective methods of overburden deposition have been applied. The heap is formed of similar deposits to the Pątnów-Jóźwin heap, mainly Quaternary boulder clays, clayey sands, and other fluvio-glacial deposits as well as some Neogene Poznań clays [18]. The slopes are intensively eroded and unstable, with numerous forms of landslide microrelief, including embankments, precipices, cracks, deep troughs, and alluvial fans. The landslides continue to happen today and are especially intensive in the areas devoid of trees. Most of the heap has been afforested. At present, the stands are managed by the State Forests National Forest Holding (Krwony Forest District, Turek Inspectorate). Potentially, the heap is a habitat of mesophilous (fresh) deciduous forest (on clays, sandy clays, and sandy clay loams) as well as of mesophilous (fresh) mixed deciduous forest (mainly on sandy loams) [15]. The reclamation stands are variable and form a mosaic of different tree species, e.g., sessile oak (*Quercus petraea*), poplar (*Populus* spp.), birch (*Betula pendula*), black alder (*Alnus glutinosa*), black locust (*Robinia pseudoacacia*), Scots pine (*Pinus sylvestris*), European larch (*Larix decidua*), and spruce (*Picea abies*), with groups or single trees of beech (*Fagus sylvatica*), aspen (*Populus tremula*), willow (*Salix* spp.), Norway and sycamore maple (*Acer platanoides* and *A. pseudoplatanus*), common ash (*Fraxinus excelsior*), and lime (*Tilia cordata*) at different ages (16–45 years old).

Mt Kamieńsk spoil heap (51.215085° N, 19.428860° E) is situated west of Kamieńsk and south of Bełchatów town, in the Bełchatów lignite region [8], in the geographical mesoregion of Wysoczyzna Bełchatowska within Wzniesienia Południowomazowieckie macroregion [9]. Interactions between polar maritime and continental air masses result in variable and transitional climatic features. The average annual temperature is 7.6°C and the average annual precipitation is 580–600 mm [19]. Mt Kamieńsk was formed in the years 1977–1993 as an outer dumping ground of the Bełchatów opencast lignite mine. It is the second largest mine spoil heap in Poland and the highest hill in the central part of the country; its height ranges from 120 to 180 m (386 m a.s.l.) and it covers 1483 ha [19,20]. According to some authors, the height of the heap reaches 195 m [11]. The mine spoil comprises 1350 mln m^3 of various Quaternary and Tertiary overburden sediments covering the coal seam. Selective methods of overburden deposition have been applied, so that the surface spoil substrates are mainly of slightly alkaline sandy-clayey character (mixed sands, gravel, loams, silts, clays, boulder clays, sometimes with brown coal admixture). In some places, Neogene clays of Poznań series are present as well as phytotoxic acid sands, frequently with loads of geogenic carbon and sulphur compounds from Tertiary pyritic strata. In cases where such materials had not been isolated inside the heap, but were instead deposited near the spoil surface, extensive amounts of lime (lacustrine chalk from the open pit) and alkaline ash (from the nearby power plant) were applied to neutralize the high acidity. Top soil, humus, lignite, and charcoal were also used to enhance the soil substrate features. The reclamation procedure involved mineral fertilization (N and K – 60 kg ha^{-1}, P – 70 kg ha^{-1}) and sowing mixed grass species and legumes (50–85 kg ha^{-1}) [19–25]. Reclamation works, aiming at forest restoration, started in the mid-eighties and were finished in 1994; 10 to 14 thousand tree seedlings

per hectare were planted [25,26]. Most of the reclaimed grounds have been handed over to the State Forests National Forest Holding (Adamów Forest District, Bełchatów Inspectorate). The most common tree species used for afforestation were Scots pine (*Pinus sylvestris*; 50%), birch (*Betula pendula*; 20%) and other deciduous species, e.g., black alder (*Alnus glutinosa*), black locust (*Robinia pseudoacacia*), pedunculate, sessile, and northern red oak (*Quercus robur*, *Q. petraea*, and *Q. rubra*), aspen (*Populus tremula*) and other poplar species (*Populus* spp.), different willow species (*Salix* spp.), Norway and sycamore maple (*Acer platanoides* and *A. pseudoplatanus*), common ash (*Fraxinus excelsior*), and European larch (*Larix decidua*) [20,27]. The heap is a habitat of mesophilous (fresh) mixed coniferous forest [15]. The reclamation stands are (10)15–30 years old, usually mixed in different proportions, composed mainly of clusters of Scots pine, birch, black locust, alder, larch, and poplar, with smaller patches of oak and single trees of various species. Accumulation of organic matter and formation of the soil horizons is very slow, even under the oldest stands [28,29].

Turów spoil heap (50.947965° N, 14.974363° E) is situated south of Zgorzelec town, between Działoszyn and Bogatynia, in the Kotlina Turoszowska basin, the southern part of the geographical mesoregion of Obniżenie Żytawsko-Zgorzeleckie within Pogórze Zachodniosudeckie macroregion [9]. Kotlina Turoszowska is a tectonic depression filled with Tertiary (Miocene) lacustrine deposits with brown coal seams, which are part of the Western lignite region [8,9]. According to data from the closest Polish (Zgorzelec) and German (Zittau-Hirschwelde) meteorological stations, mean annual temperature is 8.3 and 7.9°C, and mean annual precipitation reaches 706 and 716 mm, respectively. The climate is of mountain type [30]. The spoil heap is an outer dumping ground of the Turów opencast lignite mine and it is the highest and largest object of this kind in Poland, 245 m high (465 m a.s.l.), with the surface of ca. 2175 ha and cubature 1470 mln m^3 [30,31]. Tertiary deposits comprise 90% of the overburden, with compact clays prevailing. Among them are kaolinitic clays with various proportions of sandy materials, mica and illite, and other sandy clays, sandy loams, sands and gravels, frequently carbonated and sulfurized with iron sulfides, e.g., pyrites, causing strong acidification. Quaternary deposits from surface strata consist of fluvio-glacial sands, gravels, and various loams as well as Holocene sands and gravels of river terraces. Also, slightly acidic, low-Ca ash from the Turów power station and the products of dry flue gas desulphurization were mixed with the overburden and deposited in the years 1972–1999 and 1994–1999, respectively [30]. The heap has been continuously used for overburden deposition for over 60 years, which makes it the longest functioning outer spoil heap in the world. Its formation was eventually finished in 2006, although many landslides, faults and horizontal displacements of the hydrated clayey spoil occurred [31]. The heap has been formed non-selectively. The surface materials are mainly clays (over 80%) with high proportion of fine fractions (up to 37%), and poor in N, P, K, and Ca [30]. They are highly compact during drought and insufficiently aerated when wet [32]. Most of them were strongly acidic (pH <3.5) before reclamation, sometimes showing phytotoxic effects due to sulphur compounds. Biological reclamation comprised surface neutralization of acid spoil (with a mixture of calcium oxide, dolomite and phosphate rock flour) followed by cultivation, then hydroseeding grasses and legumes (usually 35–65 kg ha^{-1}) mixed with mineral or lignite-based mineral-organic fertilizer, and tree planting. Most frequently used species include birch (*Betula pendula*), black and grey alders (*Alnus glutinosa* and *A. incana*), European larch (*Larix decidua*), pedunculate and northern red oak (*Quercus robur* and *Q. rubra*), Norway and sycamore maple (*Acer platanoides* and *A. pseudoplatanus*), Scots and black pine (*Pinus sylvestris* and *P. nigra*), lime (*Tilia cordata*), hornbeam (*Carpinus betulus*), common ash (*Fraxinus excelsior*), and beech (*Fagus sylvatica*). Within the first years after outplanting, the stands were additionally fertilized with urea and potassium salts [30,33]. The pH of the upper several centimeters of the spoil in the restoration stands of different ages varies between 3.8 and 6.2 in H_2O, and between 3.4 and 5.6 in KCl and decreases towards deeper layers; the content of mobile aluminum is high, frequently exceeding 2.5 cmol kg^{-1}. Accumulation of organic matter is slow and becomes more visible in 12–16 years old stands [30]. Afforestation of the heap, which had been carried out in older parts since the 1960s, was generally accomplished in 2008 [34]. Ten thousand tree seedlings per hectare were usually outplanted [35]. Most of the reclamation stands are currently managed by the

State Forests National Forest Holding (Bogatynia Forest District, Pieńsk Inspectorate) or other State Treasure entities. The majority of the heap is a habitat of mixed deciduous upland forest [33]. The reclamation stands are 4–50 years old, mostly consisting of alders and birch in different proportions with smaller clusters and single trees of other species. In some places, there are also some stands with prevailing black locust, Scots pine, larch, poplar or northern red oak, or with a higher proportion of aspen or willows [15].

Mycological surveys and methods of analysis

The observations were focused on sporophores of ectomycorrhizal (ECM) fungi forming symbiotic relationships with trees on the mine spoils examined. The species were regarded as ECM following Tedersoo and Smith [36]. The field work was carried out on the four spoil heaps described above in the years 2001–2013. It included:

(A) regular 3-year sporocarp observations (2001–2003) on Mt Kamieńsk in eight permanent plots, 1000 m^2 each, set in the chronosequence of *Pinus sylvestris* stands 1–14 years old; 20 visits per plot;
(B) regular 3-year sporocarp observations (2011–2013) on Mt Kamieńsk in 22 permanent plots, 400 m^2 each, set in 17–20(25) years old stands of *Pinus sylvestris* (nine plots), *P. nigra* (one plot), *Quercus robur* (three plots), *Q. rubra* (one plot), *Betula pendula* (four plots), and *Alnus glutinosa* (four plots); 12 visits per plot;
(C) occasional sporocarp surveys on Mt Kamieńsk in the years 2001–2013 outside the permanent plots, route method (within the walking distance from roads and pathways);
(D) sporocarp surveys on the spoil heaps Pątnów-Jóźwin (2011–2013, four visits), Adamów (2011–2013, five visits), Turów (2012–2013, three visits), each visit 1–3 days long, route method (within the walking distance from roads and pathways).

The surveys were conducted from spring (March) till late fall (November) including sporophore collections for documentation and identification purposes. Collected materials were studied with standard methods used in the taxonomy of macromycetes. They were macroscopically examined, dried and preserved as herbarium vouchers in the University of Łódź as part of the ILK collection (with letters IK and collection number). Analyses of microscopic characters and microscopic measurements were performed on preparations fixed in KOH or Melzer reagent under 400 or 1000 magnification using a light microscope. Species nomenclature follows Index Fungorum [37]; for some species frequently used synonyms are also given.

As most of the collections described in this study are difficult to identify morphologically and represent rare species, part of the material examined was subject to molecular analysis using the internal transcribed spacer (ITS) region of nuclear ribosomal RNA genes (nrDNA). ITS sequence data were generated based on PCR amplification with primer pair ITS1f or ITS5 and ITS4 [38,39] and direct sequencing of both strands from total DNA extracts of dried specimens. The extracts were prepared with GeneMATRIX Plant & Fungi DNA Purification Kit (EURx Ltd., Gdańsk, Poland) according to the manufacturer's instructions using small hymenophore portions. Further procedure followed Leski and Rudawska [40]. The sequences obtained were manually edited and aligned using BioEdit Sequence Alignment Editor (7.2, 2013) [41]. Selected sequences have been deposited in GenBank (Tab. S1).

Soil analyses

Thirty-two soil samples of the surface mineral layer (0–15 cm) from each of the heaps Pątnów-Jóźwin, Adamów, and Turów were collected in 2013, following fungal collection routes (96 samples). Similar soil samples from Mt Kamieńsk were collected in 2015, five from each of the 22 permanent plots mentioned under (B) above (115 samples). The soil pH in H_2O (potentiometric method, according to the PN-ISO 10390:1997 standard) and the content of $CaCO_3$ (Scheibler method) were measured

in each sample. Also, the soil texture in plots (B) was examined. Soil parameters of the plots mentioned under (A) above were published by Świtoniak et al. [28,29].

Results and comments

On the mine spoils examined, over 180 species of ectomycorrhizal fungi were identified (Kałucka, unpublished). Here, we present 71 species that we consider to be the most interesting. Among them are 16 species whose sporophores were recorded for the first time in Poland (marked with an asterisk "*" in the list below), 23 species which are currently red-listed (#) [42], among which are two species that are protected by law in the country (§) [43], and the other 32 species that are currently known from not more than 10 contemporary (recorded after 1970) localities in Poland and may be worth considering for conservation reasons, e.g., for red-listing. The numbers of localities of the species in Poland were estimated based mainly, but not exclusively, on the records listed by Wojewoda [44], and according to the data accessible at the Grzyby Polski (Fungi of Poland) website, namely, the records published after the year 2000 [45] and records included in the register of protected and threatened species (GREJ) [46]. If a particular record is specified in the text, full citation is provided. The data on the occurrence of the species in Europe were retrieved and compiled from Knudsen and Vesterholt [47], Krieglsteiner [48,49], Legon et al. [50], Global Biodiversity Information Facility (GBIF) [51], and the UNITE database [52,53].

In the checklist below, up to three collections from each spoil heap examined are quoted. If not otherwise indicated, all the specimens mentioned were collected and determined by the first author (ILK). Color photographs of selected species collected in the study sites are provided (Fig. 2–Fig. 6).

Soil characteristics are given whenever the specimens were collected in the sample plots or near the sites of soil sampling. The soil acidity was expressed using the terms described in the U.S. Department of Agriculture Soil Survey Manual [54]. The results of soil analyses in the mine spoils examined are summarized in Tab. 1.

The following abbreviations are used:

- locality: P-J (Pątnów-Jóźwin), Ada (Adamów), MtK (Mt Kamieńsk), Tur (Turów);
- type of protection by law (according to the current legislation [43]): S (strictly protected species), P (partially protected species);
- red list categories (according to the current "Red list of the macrofungi in Poland" [42]): Ex – extinct, E – endangered, V – vulnerable, I – indeterminate, R – rare.

Ascomycota

Geopora arenosa (Fuckel) S. Ahmad (Fig. 5a)

Specimens examined. MtK, in young Scots pine plantation (moderately alkaline sand, 0.8% $CaCO_3$), soil profile 1 in Świtoniak et al. [29], on bare ground, among sparse herbs, IK-00580 (2004-10-12); on open escarpment near the Scots pine stand, among sparse herbs, IK-00581 (2013-06-13); in birch plantation (slightly alkaline sandy loam, 4.20–7.52% $CaCO_3$), on steep slope, among sparse vegetation, IK-00582 (2013-10-08). P-J, in a ditch, on mineral soil among short mosses and grass, near *Betula pendula*, IK-00616 (2013-09-20).

Commentary. The species is known from the loess ravine in the Kazimierz Landscape Park [55], Kampinos National Park [56], a few records on Mt Kamieńsk and a few records near the gravel pit in Ładzice commune [57]. The present study showed that *Geopora arenosa* appeared in Mt Kamieńsk in thousands of ascomata. It was especially abundant in open sites on bare ground or among sparse vegetation, usually near pines and/or birches, and in young pine plantations until canopy closure (e.g., in 1000 m^2 of 5-year-old pine plantation on strongly alkaline calcareous sand, ca. 14 400 ascomata were recorded over three seasons). Later, the species gradually disappeared and in stands older than 15 years could be found only occasionally (e.g., in 1000 m^2

of 14-year-old pine plantation on moderately alkaline calcareous loamy sand, 22 ascomata were found over three seasons, while no ascomata were found in older pine stands). It prefers alkaline (calcareous) soil and seems much less abundant on the acid substrates. The presence of mycorrhizas of *Geopora arenosa* on the roots of Scots pine was confirmed (Mleczko and Kałucka, unpublished).

#***Helvella lacunosa*** Afzel.

Specimens examined. MtK, in Scots pine stand (moderately alkaline clay loam, 3.5% $CaCO_3$), soil profile 7 in Świtoniak et al. [29], among pine needles, IK-00577 (2001-10-22); in pedunculate oak stand (strongly acid to neutral sand, 0–0.54% $CaCO_3$), among grass and oak leaves, IK-00584 (2013-06-13); in birch stand (slightly acid to neutral sandy clay loam, 0.34–1.12% $CaCO_3$), among mosses, IK-00585 (2011-07-28).

Commentary. R. The species is widespread across Europe.

#***Paxina queletii*** (Bres.) Stangl (syn. *Helvella queletii* Bres.)

Specimens examined. MtK, in loose, mixed stand with birch, poplar and Scots pine, among grass, mosses and litter, IK-00586 (2012-06-13).

Commentary. R (as *Helvella queletii*). The species is widespread across Europe.

Basidiomycota

#***Cortinarius bivelus*** (Fr.) Fr. (Fig. 2a)

Specimens examined. MtK, in birch stand (slightly alkaline to moderately alkaline sandy loam, 6.01–13.06% $CaCO_3$), among mosses, grass and birch leaves, IK-00234 (2012-09-28), IK-00237 (2011-08-28); near *Betula pendula* in pedunculate oak stand (slightly acid to slightly alkaline clay, 1.17–5.96% $CaCO_3$), among mosses, grass, and mixed leaf litter, IK-00254 (2013-10-02). Ada, near *Betula pendula* and *Quercus robur* in poplar plantation, among grass and mixed leaf litter, IK-00518 (2013-09-22).

Commentary. V. The species is widespread across Europe. It was reported from less than 10 contemporary localities in Poland. On Mt Kamieńsk, it was recorded more than 10 times, mainly in different birch stands, usually as groups of sporophores.

#***Cortinarius casimiri*** (Velen.) Huijsman, (syn. *C. subsertipes* Romagn.; Fig. 2b)

Specimens examined. MtK, near *Betula pendula* and *Quercus robur* in Scots pine-dominated stands, among mosses and mixed leaf litter (slightly acid to slightly alkaline sandy loam, 0.37–8.76% $CaCO_3$), IK-00224 (2013-10-07), IK-00228 (2012-11-10); near *Populus* sp. in pedunculate oak stand (very strongly acid to moderately acid sand, 0–0.24% $CaCO_3$), among mosses and oak leaves, IK-00266 (2012-11-03). Tur, under *Betula pendula* in larch stand, among mosses and larch needle litter, IK-00502 (2012-11-22), IK-00505 (2012-11-22); in sparse birch/larch thicket, among lichens and mixed litter, IK-00499 (2012-11-23).

Commentary. R (as *C. subsertipes*). The species is widespread across Europe. It was reported from less than 15 localities in Poland. Both on Mt Kamieńsk and Turów spoil heap, it was recorded fairly frequently, usually as groups of sporophores.

#***Cortinarius croceus*** (Schaeff.) Gray (Fig. 2c)

Specimens examined. MtK, in Scots pine stand (extremely to very strongly acid clay), among mosses, lichens and needle litter, IK-00230 (2012-11-03), IK-00617 (2013-10-02), IK-00618 (2013-10-26).

Commentary. R. The species is widespread across Europe.

Cortinarius depressus Fr.

Specimens examined. MtK, in Scots pine stand (very strongly acid to strongly acid loamy sand), among pine needles, IK-00225 (2013-10-26), IK-00619 (2012-11-03).

Commentary. The species is known mainly from Northern Europe. Four records of this species were reported in Poland; one in the Karkonosze Mts (the Sudetes), two near Świebodzin (southwestern Poland) [58], and one near Krynki (northeastern Poland) [59].

Cortinarius diasemospermus Lamoure (Fig. 2d)

Specimens examined. MtK, in birch stand (slightly alkaline sandy loam, 4.20–7.52% $CaCO_3$), among mosses and birch leaves, IK-00239 (2013-10-08); near *Betula pendula* in northern red oak stand (moderately to slightly acid sandy loam, 0.1–0.99% $CaCO_3$), among thick litter, IK-00262 (2011-11-13); in pedunculate oak stand (strongly acid to neutral sand, 0–0.54% $CaCO_3$), among grass and oak leaves, IK-00264 (2013-10-03). Tur, in young mixed plantation of birch, Scots pine, larch and alder, among leaf litter and plant remnants, IK-00498 (2013-11-11); under *Betula pendula* in sparse brushwood of birch, Scots pine, larch and alder, on mineral substrate with lignite, IK-00510 (2012-11-24).

Commentary. The species is common in Fennoscandia, single records from mountainous areas are known from France, Germany, and Slovakia. In Poland, the species was recorded in Kampinos National Park [56]. It was found also as mycorrhiza on poplar roots near Kórnik (based on ITS) [60]. On Mt Kamieńsk, it was found more than 10 times, usually as groups of sporophores.

Cortinarius helobius Romagn.

Specimens examined. MtK, in Scots pine stands (moderately acid to slightly alkaline sandy loam with 0–1.72% $CaCO_3$; moderately alkaline clay loam and loamy sand, 1.3 to 3.5% $CaCO_3$), soil profiles 7 and 8 in Świtoniak et al. [29], on bare soil, among mosses or among needle litter, IK-00213 (2011-07-28), IK-00135 (2001-08-13), IK-00144 (2003-09-16).

Commentary. The species is widespread across Europe. It was reported from Kampinos National Park [56]. In our study, it was recorded fairly frequently in pine stands of different age.

****Cortinarius murinascens*** Kytöv., Niskanen & Liimat. (Fig. 2e)

Specimens examined. MtK, in birch stand (slightly alkaline sandy loam, 4.20–7.52% $CaCO_3$), among mosses, birch leaves, IK-00236 (2013-10-08); in northern red oak stand with some birch (moderately to slightly acid sandy loam, 0.1–0.99% $CaCO_3$), among oak litter, IK-00257 (2012-11-10); near *Betula pendula* in Scots pine stand (strongly alkaline loamy sand, 3.5% $CaCO_3$), soil profile 6 in Świtoniak et al. [29], among needle litter and plant remnants, IK-00567 (2001-09-19). Tur, in birch/alder/larch stand (slightly acid soil, 0.34% $CaCO_3$), among mosses, grass and mixed leaf litter, IK-00503 (2013-09-27). Ada, under *Betula pendula* in spruce-dominated stand (moderately alkaline soil, 4.88% $CaCO_3$), among mosses, grass and mixed litter, IK-00519 (2012-10-09).

Commentary. The species was described for the first time in 2014 from Finland, and a locality in Canada was also confirmed [61]. On Mt Kamieńsk, it was recorded several times in different stands, most often under birch.

Cortinarius pseudofallax* Carteret (Fig. 2f)

Specimens examined. MtK, in northern red oak stand with some birch (moderately to slightly acid sandy loam, 0.1–0.99% $CaCO_3$), among leaf litter, IK-00259 (2012-11-10). Tur, in birch/poplar stand, among mosses and leaves, IK-00506 (2013-11-10), IK-00507 (2013-11-10); in birch/Scots pine stand, among mosses and birch leaves, IK-00512 (2013-11-10).

Commentary. The species was described for the first time in 2004 from France [62]. Its occurrence in Spain, Finland, Sweden, and Estonia was also confirmed [63]. On the Turów spoil heap, the species was found a few times, but seems rather rare.

#Cortinarius saniosus (Fr.) Fr.

Specimens examined. Tur, in mixed stand of birch, poplar, oak, Scots pine and larch, among mosses and leaf litter, IK-00497 (2013-11-10).

Commentary. R. The species is widespread across Europe.

#Cortinarius saturninus (Fr.) Fr.

Specimens examined. P-J, in willow thicket growing in a shallow wet depression, neighboring with poplar plantation, among mosses and litter, IK-00527 (2012-10-19).

Commentary. V. The species seems to be widespread across Europe, especially in the northern part. Less than 10 contemporary localities of this species are known in Poland.

Cortinarius subbalaustinus Rob. Henry (Fig. 2g)

Specimens examined. Ada, in birch/pedunculated oak stand in wet place, among grass and litter, IK-00514 (2013-09-22); under birches by the path, among mosses and litter, IK-00515 (2013-09-16); in mixed stand of birch, willow, pedunculate oak and poplar, among mosses and grass, IK-00517 (2012-10-09).

Commentary. The species occurs mainly in Northern Europe. Only two records of this species were reported in Poland in Szklarska Poręba (the Sudetes) [58] and in Kampinos National Park [56]. According to the species hypothesis (SH) concept [53], the specimens found on the Adamów spoil heap belong to the *Cortinarius balaustinus* complex (with at least 98.5% similarity) [64]. However, the collections' characteristics, especially microscopic ones, match the description of *C. subbalaustinus* Rob. Henry and not *C. balaustinus* Fr. [47]. Moreover, collections of *C. subbalaustinus* from Finland (JX407335) and Germany (AY669692) are included in this SH complex, as well. Taxonomical interpretation of *C. subbalaustinus* is uncertain and needs further studies.

Cortinarius vernus* H. Lindstr. & Melot (Fig. 2h)

Specimens examined. Tur, in birch stand (very strongly acid soil), among mosses and sparse litter, IK-00504 (2013-09-28).

Commentary. The species is widespread across Europe. In Poland, it was listed from Kampinos National Park [56], however, it was synonymized with *C. erythrinus*. According to the present knowledge, these are two different species [37,47], so the record should be verified.

#Gomphidius glutinosus (Schaeff.) Fr.

Fig. 2 **a** *Cortinarius bivelus*, 03.10.2013, Mt Kamieńsk. **b** *Cortinarius casimiri*, 23.11.2012, Turów. **c** *Cortinarius croceus*, 03.11.2012, Mt Kamieńsk. **d** *Cortinarius diasemospermus*, 13.11.2011, Mt Kamieńsk. **e** *Cortinarius murinascens*, 27.09.2013, Turów. **f** *Cortinarius pseudofallax*, 10.11.2013, Turów. **g** *Cortinarius subbalaustinus*, 16.09.2013, Adamów. **h** *Cortinarius vernus*, 28.09.2013, Turów. Photographs by Izabela L. Kałucka.

Specimens examined. Ada, in spruce stand mixed with some birch and larch, among dense mosses, IK-00587 (2012-08-21), IK-00588 (2013-09-16).

Commentary. R. The species is widespread across Europe.

#***Gomphidius maculatus*** (Scop.) Fr. (Fig. 5b)

Specimens examined. Tur, under *Larix decidua* in young alder/larch plantation, among grass, IK-00471 (2013-09-27).

Commentary. R. Although the species is not rare in Europe, it seems to be much rarer than *G. glutinosus* and *G. roseus*.

#***Gomphidius roseus*** (Fr.) Fr.

Specimens examined. MtK, in Scots pine stand (very strongly acid to slightly acid loamy sand, 0–0.17% $CaCO_3$), among pine needles, in the site where *Suillus bovinus* was also present, IK-00583 (2012-09-27).

Commentary. R. The species is widespread across Europe.

Hebeloma aanenii Beker, Vesterh. & U. Eberh.

Specimens examined. MtK, in 12–17-year-old Scots pine stands with some birch, alder, willow, poplar and larch (strongly alkaline sand, 3.5% $CaCO_3$), soil profile 5 in Świtoniak et al. [29]; moderately alkaline loamy sand and clay loam, 1.3–3.5% $CaCO_3$), soil profile 7 and 8 in Świtoniak et al. [29], among pine needles and mosses, IK-H0013 (HJB13186; 2002-10-23; det. I. L. Kałucka, H. J. Beker & U. Eberhardt), IK-H0068 (2004-11-02; det. I. L. Kałucka, H. J. Beker & U. Eberhardt), IK-H0222 (2006-06-07; det. I. L. Kałucka, H. J. Beker & U. Eberhardt).

Commentary. The species is widely distributed and ubiquitous in all types of woodland in Europe. However, its identification is difficult, as it belongs to the group of species very similar morphologically (crustuliniforme-complex: *H. aanenii*, *H. crustuliniforme*, *H. eburneum*, *H. geminatum*) and molecularly (alpinum-complex: *H. aanenii*, *H. alpinum*, *H. eburneum*, *H. geminatum*) [65]. The holotype was described in 2015 from Białowieża National Park, Poland, another Polish record reported comes from Mt Kamieńsk [65,66]. Verification of the *Hebeloma* collections originating from mine spoils and deposited in the Herbarium POZ of the Adam Mickiewicz University in Poznań, Poland, revealed the presence of *H. aanenii* in the exsiccates collected in 1979 on the Smolnica central dumping ground in Zabrze (part of the collections identified as *H. mesophaeum* and *H. longicaudum*, published by Lisiewska and Siedlaczek [67]) and in 1983 on the Kazimierz spoil heap near Konin (part of the collection identified as *H. crustuliniforme*, published by Lisiewska et al. [68]).

Hebeloma cavipes Huijsman

Specimens examined. Ada, at the edge of pure spruce thicket (neutral soil, 0.6% $CaCO_3$), among grass and mosses, IK-H0357 (2013-09-16). MtK, in Scots pine stands (very strongly acid to strongly acid loamy sand; strongly to slightly acid loamy sand with 0–0.45% $CaCO_3$, moderately acid to slightly alkaline sandy loam with 0–1.72% $CaCO_3$), among abundant pine needles, IK-H0119 (2011-08-26), IK-H0335 (2012-11-03), IK-H0401 (2013-10-01). Tur, in birch/alder/larch stand (slightly acid soil with 0.34% $CaCO_3$), among grass, herbs and mosses, IK-H0388 (2013-09-27).

Commentary. The species is one of the most common and widely distributed *Hebeloma* spp. in Europe and it was found also in a number of localities in Poland [56,65,69]. It was recorded (based on the ITS sequence) also as mycorrhizas on the roots of beech seedlings from a nursery in Prudnik [70].

Hebeloma celatum Grilli, U. Eberh. & Beker

Specimens examined. Ada, in pedunculate oak/birch stand, among grass and mosses, IK-H0360 (2013-09-17). MtK, in alder stand with *Betula pendula* nearby (neutral to slightly alkaline clay with 3.84–11.83% $CaCO_3$), among grass and litter, IK-H0245 (2012-09-27).

Commentary. The species was first described in 2016 [71] with many localities widespread across Europe, usually on calcareous soil and under a variety of trees, most commonly *Fagus* and *Quercus*. It belongs to a complex of three very similar species (not distinguishable by ITS) with *H. quercetorum* and *H. erebium*. In Poland, it was reported from Białowieża National Park [65], with further localities shown on the distribution map of *H. celatum* European database collections (p. 360 in [65]): Biebrza National Park (two records), and Lisi Jar gorge near Jastrzębia Góra (the Baltic coast).

****Hebeloma crustuliniforme*** (Bull.) Quél. emend. Beker, Vesterh. & U. Eberh.

Specimens examined. P-J, in oak plantation with some birch, among mosses and grass, IK-H0324 (2012-10-20; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in beech plantation, with *Salix* sp. in vicinity (slightly alkaline soil, with ca. 11% $CaCO_3$), on ± bare soil, IK-H0325 (2012-10-20; det. I. L. Kałucka, H. J. Beker & U. Eberhardt).

Commentary. As pointed out by Vesterholt et al. [72], the name *H. crustuliniforme* was used at various times for several different medium to large taxa most often from the sections *Denudata* and *Velutipes*, at best it represented a crustuliniforme-complex of four closely related species. Finally, it has been tied to one of them and epitypified, excluding the three remaining species: *H. aanenii*, *H. eburneum*, and *H. geminatum* [65,66], with a recommendation that this taxon be referred to as *H. crustuliniforme* (Bull.) Quél. emend. Beker, Vesterh. & U. Eberh. The species is ubiquitous and widespread in Europe, although so-far known records seem to be more confined to Western and Southern Europe. The two collections found on Pątnów-Jóźwin spoil heap are the first records of this species in Poland and in Central Europe.

Hebeloma cylindrosporum Romagn. (Fig. 3a)

Specimens examined. MtK, in Scots pine stands, among pine needles, (strongly alkaline loamy sand, 3.5% $CaCO_3$, soil profile 6 in Świtoniak et al. [29]; very strongly acid to strongly acid loamy sand; strongly acid to slightly alkaline loamy sand with 0–2.03% $CaCO_3$), IK-H0050 (HJB13069; 2001-10-22), IK-H0399 (2013-10-02), IK-H0467 (2013-10-27).

Commentary. The species is widespread across Europe and often locally common, especially in sandy habitats, under *Pinus* [65]. It was reported in Poland from a few localities at the Baltic coast; Słowiński National Park [65,73], Białogóra reserve [65], and Wejherowo region [74]. On Mt Kamieńsk, six collections of the species were recorded. One of them, IK-H0050 (HJB13069), was published by Beker et al. [65].

Hebeloma danicum Gröger

Specimens examined. MtK, in pedunculate oak stand (very strongly acid to moderately acid sand, 0–0.24% $CaCO_3$), among abundant litter, IK-H0170 (2011-11-16).

Commentary. The species is widespread in Europe, although it seems to be rare. Its presence in France, Denmark, Finland, Sweden, and Poland was confirmed by Beker et al. [65]. The Polish collection cited in this monograph (IK-H0205, HJB14170) comes from Mt Kamieńsk and was collected in the same oak plantation as the specimen mentioned above. As the only record of *H. danicum* had been listed by Kaufmann [75] from the vicinity of Elbląg (north Poland), the species was considered extinct

[76]. More recently, Łuszczynski [77] reported this species from the *Tilio-Carpinetum* forest on Mt Milechowska in the Świętokrzyskie Mts.

Hebeloma dunense L. Corb. & R. Heim (syn. *H. collariatum* Bruchet; Fig. 3b)

Specimens examined. P-J, under *Populus* sp. and *Betula pendula* in poplar plantation, among mosses and litter, IK-H0297 (2012-10-19); in shallow wet depression, in willow thicket mixed with birch and aspen (slightly alkaline soil, 3.42% $CaCO_3$), on wet soil among sedges, mosses and litter, IK-H0307 (2012-10-20); in a ditch among grass, mosses and herbs, with birches nearby, IK-H0365 (2013-09-20). Ada, in the middle of the track between mixed stands of poplar, birch, willow and larch (slightly alkaline soil with $CaCO_3$), IK-H0361 (2013-09-17). MtK, in Scots pine stand with some aspen, willow, alder, and larch (moderately alkaline clay loam, 3.5% $CaCO_3$), soil profile 7 in Świtoniak et al. [29], among litter, IK-H0054 (2004-05-26); in a ditch on the soil among some litter, with willow, birch and Scots pine in vicinity, IK-H0409 (2013-10-01); in pedunculate oak stand with poplar and birch in vicinity (slightly acid to slightly alkaline clay, 1.17–5.96% $CaCO_3$), among grass and litter, IK-H0211 (2011-11-12).

Commentary. The species is fairly common in Europe, it occurs in woodlands with Salicaceae, also in slag heaps [65]. In Poland, it was reported from the Tatra Mts [78], Kampinos National Park [56], Mt Kamieńsk [65], and near Białystok (northeastern Poland) [79]. *Hebeloma xerophilum* Rudn.-Jez. (published as *H. xerophila* [80]) described from the Kampinos National Park turned out to be *H. dunense* [65]. In the Pątnów-Jóźwin and Mt Kamieńsk spoil heaps, the species was relatively frequent.

Hebeloma eburneum Malençon (Fig. 3c)

Specimens examined. P-J, in birch stand (slightly alkaline soil, with ca. 12% $CaCO_3$), among grass and mosses, IK-H0294 (2012-10-19; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); by the roadside, with birch, willow, and larch in vicinity (slightly alkaline soil, with 8.82% $CaCO_3$), among grass and decaying leaves, IK-H374 (2013-09-21; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in poplar/oak plantation with birch (slightly alkaline soil, with 4.10% $CaCO_3$), among grass, herbs, and mosses, IK-H0379 (2013-09-21; det. I. L. Kałucka, H. J. Beker & U. Eberhardt). Ada, in oak/birch/alder stand (on acid soil), among grass and mosses, IK-H0270 (2012-10-09; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in spruce stand (neutral soil, with 0.6% $CaCO_3$), among grass, herbs, and mosses, IK-H0276 (2012-10-09; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in spruce stand (slightly alkaline soil, with 4.88% $CaCO_3$), among grass and mosses, IK-H0358 (2013-09-16; det. I. L. Kałucka, H. J. Beker & U. Eberhardt). MtK, in birch stand (slightly to moderately alkaline sandy loam, 3.86–7.45% $CaCO_3$), among grass and litter, IK-H0153 (2011-11-12; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in pedunculate oak stand, with Scots pine in vicinity (slightly acid to slightly alkaline clay, 1.17–5.96% $CaCO_3$), among grass and litter, IK-H0236 (2012-09-27; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in Scots pine stand with some northern red oak (slightly alkaline sandy loam, 0.89–8.76% $CaCO_3$), among abundant litter, IK-H0438 (2013-10-07; det. I. L. Kałucka, H. J. Beker & U. Eberhardt). Tur, in sparse Scots pine and birch shrubs (extremely acid soil), among grass, herbs, and litter, IK-H0397 (2013-09-28; det. I. L. Kałucka, H. J. Beker & U. Eberhardt).

Commentary. *Hebeloma eburneum* is one of the four species of the crustuliniforme-complex, together with *H. aanenii*, *H. crustuliniforme*, and *H. geminatum*. In many cases, the species cannot be identified by ITS alone. It is widely distributed across all of Europe except for alpine and arctic habitats in various types of woodland, including slag heaps [65,66]. In Poland, it was reported from Mt Kamieńsk and from Jelonka reserve (undisturbed part; northeastern Poland; one of the *Hebeloma* sp. 1 collections published in [2]) [65,66]. Further localities shown on the distribution map of *H. eburneum* European database collections (p. 225 in [65]) include Białogóra reserve and Łeba (both at the Baltic coast), European Bison Show Reserve (Białowieża National

Park), Biebrza National Park, and Ojców National Park. On all the spoil heaps examined except for Turów the species is very common.

Hebeloma erebium (Huijsman) Beker & U. Eberh.

Specimens examined. MtK, in pedunculate oak stand (slightly acid to slightly alkaline clay, 1.17–5.96% $CaCO_3$), among grass and litter, IK-H0150 (2011-11-12); among litter, IK-H0416 (2013-10-02).

Commentary. *Hebeloma erebium* is a new combination published in 2016 [71], earlier known as *Naucoria erebia* and *Alnicola erebia*. It belongs to the group of three very similar species, with *H. quercetorum* and *H. celatum*. *Hebeloma erebium* appears to be widespread across Northern Europe; all the known collections are from locations greater than 48° N. Four records of this species were published from Poland [65,71]: from Białowieża Forest (two records), Biebrza National Park, and Mt Kamieńsk. The records published in the present paper come from the same oak stand on Mt Kamieńsk as the collection IK-H0195 (HJB14164) cited by Grilli et al. [71] and Beker et al. [65].

Hebeloma fragilipes Romagn.

Specimens examined. P-J, in a young beech plantation (slightly alkaline soil, 11.07% $CaCO_3$), among grass and litter, IK-H0373 (2013-09-21). Ada, in mixed alder/poplar stand, among litter, IK-H0274 (2012-10-09); in mixed birch/poplar stand with *Salix* sp., among herbs, IK-H0362 (2013-09-17).

Commentary. The species is widely distributed in Europe. However, it is very similar to the more common *H. pseudofragilipes*, both morphologically and molecularly (the ITS does not separate these two species), so at least part of the known collections of *H. fragilipes* are misidentified [81]. In Poland, the species was reported from Jelonka reserve (northeastern Poland) [65]. Also, the collection reported from the Jodły Łaskie reserve (central Poland) as *H. testaceum* by Kałucka [82] turned out to be *H. fragilipes* (collection LOD 15219, HJB13149; H. J. Beker, personal communication, 2015). This record is shown, apart from the record from the Jelonka reserve, on the distribution map of *H. fragilipes* European database collections (p. 286 in [65]).

Hebeloma geminatum Beker, Vesterh. & U. Eberh. (Fig. 3d)

Specimens examined. P-J, in beech plantation (slightly alkaline soil, with 11.07% $CaCO_3$), among grass and litter, IK-H0318 (2012-10-20; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in oak plantation with some birch, among mosses, herbs, and litter, IK-H0323 (2012-10-20; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in beech plantation, with Scots pine, oak and willow in vicinity (slightly alkaline soil, with ca. 11% $CaCO_3$), among dense grass and litter, IK-H0326 (2012-10-20; det. I. L. Kałucka, H. J. Beker & U. Eberhardt). Ada, in spruce stand with birch (moderately alkaline soil, with 4.88% $CaCO_3$), among grass and mosses, IK-H0264 (2012-10-09; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in pedunculate oak stand with birch, alder and larch (moderately alkaline soil, with 6.82% $CaCO_3$), among grass, mosses, and litter, IK-H0284 (2012-10-10; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in poplar plantation, with *Quercus robur* in vicinity, among grass and abundant litter, IK-H0381 (2013-09-22; det. I. L. Kałucka, H. J. Beker & U. Eberhardt). MtK, in birch stand, with *Quercus robur* in vicinity (slightly alkaline to moderately alkaline sandy loam, 6.01–13.06% $CaCO_3$), among grass and litter, IK-H0253 (2012-09-28; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in Scots pine stand with some *Quercus rubra* (slightly acid to slightly alkaline sandy loam, 0.37–3.22% $CaCO_3$), among litter, IK-H0337 (2012-11-10; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in northern red oak stand with birch (moderately to slightly acid sandy loam, 0.1–0.99% $CaCO_3$), among grass and litter, IK-H0448 (2013-10-07; det. I. L. Kałucka, H. J. Beker & U. Eberhardt). Tur, in larch/birch/Scots pine stand, among mosses and litter, IK-H0345 (2012-11-22; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in birch/alder/larch stand (slightly acid soil,

with 0.34% $CaCO_3$), among grass, mosses and litter, IK-H0389 (2013-09-27; det. I. L. Kałucka, H. J. Beker & U. Eberhardt); in birch/Scots pine/spruce stand (strongly acid soil), among grass and mosses, IK-H0394 (2013-09-28; det. I. L. Kałucka, H. J. Beker & U. Eberhardt).

Commentary. *Hebeloma geminatum* is one of the four species of the crustuliniforme-complex, together with *H. aanenii*, *H. crustuliniforme*, and *H. eburneum*. The species cannot be identified by ITS alone. It is widespread across Northern Europe and occurs in various types of woodland including slag heaps [65,66]. In Poland, it was reported from Białowieża National Park, Mt Kamieńsk, and a vicinity of Wólka Łękawska (central Poland) [65,66]. Further localities shown on the distribution map of *H. geminatum* European database collections (p. 230 in [65]) include Słowiński National Park and Biebrza National Park. On all the spoil heaps examined, the species is very common.

Hebeloma hiemale Bres.

Specimens examined. Tur, in pure poplar plantation (strongly acid soil), among short mosses, IK-H0349 (2012-11-23); in birch/Scots pine stand, among litter, IK-H0472 (2013-11-10).

Commentary. The species appears to be widespread across Europe and ubiquitous [65]. In Poland, it was reported from less than 10 contemporary localities. Further records from Białowieża Forest, Białogóra reserve (the Baltic coast), a vicinity of Wólka Łękawska (central Poland), and Popradzki Landscape Park (the Western Carpathians) are shown on the distribution map of *H. hiemale* European database collections (p. 330 in [65]).

Hebeloma incarnatulum A. H. Sm. (Fig. 3e)

Specimens examined. Ada, in poplar stand (slightly alkaline soil, with 7.75% $CaCO_3$), among grass and litter, IK-H0273 (2012-10-09). MtK, in alder stand with birch in vicinity (neutral to slightly alkaline clay, 1.54–11.83% $CaCO_3$), among grass and abundant litter, IK-H0148 (2011-11-09; det. I. L. Kałucka, H. J. Beker & U. Eberhardt), IK-H0413 (2013-10-02); in Scots pine stand with some birch and oak (slightly acid to slightly alkaline sandy loam, 0.37–3.22% $CaCO_3$), among litter, IK-H0444 (2013-10-07).

Commentary. Macroscopically, the species may be confused with *H. leucosarx* and *H. velutipes*. Also, it is not always possible to distinguish between *H. incarnatulum* and *H. velutipes* based on ITS [71]. The species seems widespread in Northern Europe, especially around the Baltic area, it occurs also in more southerly locations in subalpine areas [65]. In Poland, it was reported from Słowiński National Park (Czerwona Szopa neighborhood) [65,71], further record from Sarbska Spit reserve is shown on the distribution map of *H. incarnatulum* European database collections (p. 371 in [65]).

Hebeloma ingratum Bruchet (Fig. 3f)

Specimens examined. MtK, in northern red oak stand with some birch (moderately to slightly acid sandy loam, 0.1–0.99% $CaCO_3$), among litter, IK-H0163 (2011-11-13), IK-H0212 (2011-11-13), IK-H0258 (2012-09-28). Tur, in birch/Scots pine stand, among mosses and litter, IK-H0473 (2013-11-10).

Commentary. The species is of rather Northern European distribution, with most eastern known localities in Poland [65]. In Poland, it was reported from Mt Kamieńsk [65] from the same tree stand as the records published in the present paper. Further records from Biebrzański National Park and Białowieża National Park are shown on the distribution map of *H. ingratum* European database collections (p. 290 in [65]).

Hebeloma laterinum (Batsch) Vesterh. (syn. *H. edurum* Métrod; Fig. 3g)

Specimens examined. P-J, in pedunculate oak/birch thicket (slightly alkaline soil, with $CaCO_3$), among grass and litter, IK-H0332 (2012-10-20). MtK, in 11-year-old Scots pine plantation mixed with larch and birch (strongly alkaline sand, with 3.5% $CaCO_3$), soil profile 5 in Świtoniak et al. [29], IK-H0002 (2004-11-02; HJB13191; det. H. J. Beker & U. Eberhardt), IK-H0015 (2003-10-10; HJB13187; H. J. Beker & U. Eberhardt), IK-H0070 (2003-10-10).

Commentary. The species is widely distributed across Europe and locally very common in calcareous areas [65]. Contemporary localities of this species in Poland include the Świętokrzyskie Mts [77], Cieszyn (the Silesian Foothills) [83], and Mt Kamieńsk [65].

****Hebeloma odoratissimum*** (Britzelm.) Sacc. (syn. *H. hetieri* Boud.; Fig. 3h)

Specimens examined. P-J, in poplar plantation with birch (slightly alkaline soil, with $CaCO_3$), among grass, herbs, mosses, and litter, IK-H0296 (2012-10-19); in a shallow wet depression with willow thicket, poplar and birch, among dense grass, herbs, and litter, IK-H0313 (2012-10-20); in pure poplar plantation, among grass and litter, IK-H0316 (2012-10-20). MtK, in a ditch between the roadside and woodland, under *Salix* sp., among mosses, IK-H0248 (2012-09-27; det. H. J. Beker).

Commentary. The species seems to be widespread although relatively uncommon in Europe [65]. The first records of this species in Poland were signaled by Tadeusz Twardy in 2010 and 2012 (unpublished, personal communication, 2012), who found numerous basidiomata in two localities in the Ustronie Morskie Commune (Baltic coast), in shallow wet grassy depressions with thickets of different willow species, birch and alder. The localities in Poland are the most eastern ones already known in Europe.

****Hebeloma populinum*** Romagn.

Specimens examined. P-J, three collections within the distance of 30 m in a shallow depression with *Salix* spp. and birch, with poplar in vicinity (slightly alkaline soil, with 3.4% $CaCO_3$), on wet soil among litter, IK-H0309 and IK-H0310 (2012-10-20), also with *Populus* sp., among mosses, sedges, and litter, IK-H-0312 (2012-10-20).

Commentary. The species appears to be widespread across Europe, however, it must be rare and/or overlooked as only three records of this taxon have been confirmed so far, namely from England, France, and Greece [65,81]. However, many other *Hebeloma* species had been wrongly originally determined as *H. populinum*. In Poland, this species has not been reported, so far. The record verified as probable *H. populinum* mentioned by Vesterholt [84] and later cited by Wojewoda [44], which was a part of the mixed collection described by Rudnicka-Jezierska [80] as *H. xerophila*, eventually turned out to represent *H. velutipes* (H. J. Beker, personal communication, 2016).

Hebeloma pseudofragilipes Beker, Vesterh. & U. Eberh.

Specimens examined. Ada, in mixed alder/beech/birch stand (neutral soil, 0.25% $CaCO_3$), among grass, mosses and litter, IK-H0271 (2012-10-09; det. H. J. Beker, U. Eberhardt & I. L. Kałucka); in mixed beech/alder stand, by the path, among mosses and grass, IK-H0355 (2013-09-16).

Commentary. Although the species has been described only recently [81], it appears to be widespread across Europe and even more frequent than the very similar *H. fragilipes*. The Polish records shown on the distribution map of *H. pseudofragilipes* European database collections (p. 306 in [65]) include the collections from Hel Spit (near Jastarnia, Baltic coast), Ojców National Park (two collections), and Jurassic Landscape Parks (two collections from Góra Zborów and Parkowe reserves).

Fig. 3 **a** *Hebeloma cylindrosporum*, 27.10.2013, Mt Kamieńsk. **b** *Hebeloma dunense*, 01.10.2013, Mt Kamieńsk. **c** *Hebeloma eburneum*, 19.10.2012, Pątnów-Jóźwin. **d** *Hebeloma geminatum*, 28.09.2012, Mt Kamieńsk. **e** *Hebeloma incarnatulum*, 02.10.2013, Mt Kamieńsk. **f** *Hebeloma ingratum*, 02.10.2013, Mt Kamieńsk. **g** *Hebeloma laterinum*, 20.10.2012, Pątnów-Jóźwin. **h** *Hebeloma odoratissimum*, 19.10.2012, Pątnów-Jóźwin. Photographs by Izabela L. Kałucka.

Hebeloma vaccinum Romagn.

Specimens examined. MtK, in Scots pine stand with birch, poplar, and willow in vicinity (strongly alkaline loamy sand, 3.5% $CaCO_3$), soil profile 6 in Świtoniak et al. [29], among litter, IK-H0066 (2002-10-16; det. I. L. Kałucka & H. J. Beker), IK-H0069 (2003-09-16). Tur, in sparse birch stand, with larch in vicinity, among litter, IK-H0348 (2012-11-23; det. I. L. Kałucka & H. J. Beker); in grassy larch/birch/alder thicket (slightly acid soil with 0.34% $CaCO_3$), among grass, herbs, and mosses, IK-H0387 (2013-09-27; det. I. L. Kałucka & H. J. Beker); under a group of birches near a ditch, among grass and herbs, IK-H0391 (2013-09-27; det. I. L. Kałucka & H. J. Beker).

Commentary. The species seems to be widespread across Europe, although all the so-far known records originating from latitudes lower than 48° N. are alpine. It occurs almost always with Salicaceae in various, mostly Western European woodlands [65]. Although it is different morphologically from *H. cavipes*, it cannot be separated from this species by ITS [65,81]. The only two published Polish records come from the Świętokrzyskie Mts [77] and Kampinos National Park [56]. All three collections found on the Turów spoil heap were recorded with *Betula pendula*, although the presence of a small, overlooked *Salix* or *Populus* in the vicinity cannot be excluded.

Hygrophorus lucorum Kalchbr. (Fig. 5c)

Specimens examined. Tur, under *Larix decidua*, in young larch stand with birch, among mosses and larch needles, IK-0059 (2012-11-22); in older larch stand, in deep larch litter, IK-00590 (2012-11-23).

Commentary. The species is known to form ectomycorrhiza with *Larix* and, in Europe, it occurs together with its host. It is known from less than 15 localities in Poland (always with larch), most of them represent mountainous habitats, nearly all are located in the southern part of the country. On the Turów spoil heap, it was recorded fairly frequently in relatively older larch stands.

#***Inocybe glabripes*** Ricken (syn. *I. microspora* J. E. Lange; Fig. 4a)

Specimens examined. Tur, in over 50 years old birch stand with some alder, black locust, aspen, oak, and Scots pine, on strongly acid soil rich in organic matter, among litter and sparse herbs, IK-00085 (2013-09-28).

Commentary. E. The species is widespread and rather common in Europe. It was reported from six contemporary localities in Poland; Dębina reserve near Wągrowiec [85], Poznań (two records, [86,87]), Sarnia Skała in the Tatra Mts [88], Trójmiejski Landscape Park [89], Kampinos National Park [56], and Biebrza National Park [87].

Inocybe griseotarda* Poirier

Specimens examined. MtK, in Scots pine stand with some oak and birch (slightly acid to slightly alkaline sandy loam, 0.37–3.22% $CaCO_3$), among litter, IK-00065 (2011-07-27).

Commentary. The species was described for the first time in 2002 from France [90]. Until present, apart from the type specimen, only single collections of the species have been recorded from the Netherlands [91] and Croatia [92].

Inocybe lanatopurpurea* Esteve-Rav. & G. Moreno

Specimens examined. P-J, in Scots pine woodland with birch and oak (rather acid soil), among litter, IK-00127 (2013-09-21).

Commentary. The species was described for the first time in 2014 from Spain [93]. Three collections were made in pine forests consisting of *Pinus radiata*, *P. sylvestris*, and *P. pinaster*, on acid soil and humus. One record of the species is known from Estonia, submitted as *Inocybe* sp. P156 to GenBank [94]. The collection from Pątnów-Jóźwin spoil heap is the fifth known record of this species.

Inocybe malenconii R. Heim (Fig. 4b)

Specimens examined. MtK, in Scots pine stands (strongly alkaline sand and loamy sand, 1.7 and 3.5% $CaCO_3$), soil profiles 3 and 6 in Świtoniak et al. [29], on bare ground, among sparse herbs or in pine needles, IK-00015 (2004-05-26), IK-00018 (2004-05-26); in birch stand (slightly acid to neutral sandy clay loam, 0.34–1.12% $CaCO_3$), among sparse herbs, IK-00326 (2012-07-03).

Commentary. The species seems to occur occasionally in Europe. It was reported from two localities in Poland; Lublin (east Poland) [95] and Kampinos National Park [56]. On Mt Kamieńsk, it occurs frequently and was recorded in dozens of sporophores in most of the Scots pine stands examined.

****Inocybe myriadophylla*** Vauras & E. Larss. (Fig. 4c)

Specimens examined. MtK, in Scots pine stand near *Betula pendula* (strongly to slightly acid loamy sand, 0–0.45% $CaCO_3$), in mosses and pine needles, IK-00039 (2011-08-02); in birch stand (slightly alkaline sandy loam, 4.20–7.52% $CaCO_3$), among mosses, sparse herbs, and birch leaves, IK-00325 (2011-07-27); in pedunculate oak stand (slightly acid to slightly alkaline clay, 1.17–5.96% $CaCO_3$) with birch and Scots pine nearby, among sparse grass and oak leaves, IK-00041 (2011-08-28). Ada, in poplar stand with birch and alder, on the slope, among mosses and litter, IK-00095 (2013-09-16).

Commentary. The species was described for the first time in 2011 from Finland and Sweden [96], where it was found on calcareous soil, in localities often close to limestone processing plants (chalk dust emission), in association with birch. Other records come from Svalbard and Estonia [97]. Similarly to the populations found in Fennoscandia, those found in the spoil heaps examined were growing in abundant groups of sporophores. On Mt Kamieńsk, they were recorded fairly frequently, especially in birch and Scots pine stands.

****Inocybe ochracea*** Stangl

Specimens examined. MtK, in alder stands, in some places with birch, willow, and Scots pine in vicinity (neutral sandy clay loam with 0.52–3.80% $CaCO_3$, neutral to slightly alkaline clay with 3.84–11.83% $CaCO_3$), among herbs and litter, IK-00287 (2013-10-26), IK-00607 (2012-09-27), IK-00608 (2013-10-26).

Commentary. According to Stangl [98] and Index Fungorum [37], *I. ochracea* and *I. alnea* are two different species. However, Vauras and Kokkonen [99] claim that microscopical features of the type specimens of both species proved to be nearly identical, and the DNA analysis supported their conspecificity. Indeed, the sequence KX602264 (Tab. S1) representing the collection IK-00287 differs in one gap and one base pair from the holotype of *I. ochracea* (J755803) and differs in one gap from the two sequences from the holotype of *I. alnea* (FJ755801 and FJ755802). Both *I. ochracea* and *I. alnea* seem to be rare in Europe. *Inocybe alnea* was reported from Poland from different alder forests in the Babia Góra massif (the Western Carpathians) [100–102].

Inocybe ochroalba Bruyl. (Fig. 4d)

Specimens examined. MtK, in pedunculate oak stand (slightly acid to slightly alkaline clay, 1.17–5.96% $CaCO_3$), among mosses and litter, IK-00044 (2011-08-02); in birch stand (slightly alkaline sandy loam, 4.20–7.52% $CaCO_3$), among mosses and

litter, IK-00052 (2011-08-29); in Scots pine stand (strongly to slightly acid loamy sand, 0–0.45% $CaCO_3$), among short mosses, lichens, and pine needles, IK-00076 (2011-08-02). Ada, in spruce stand with larch and birch (moderately alkaline soil, 4.88% $CaCO_3$), among mosses and litter, IK-00108 (2012-10-09), IK-00109 (2013-09-12), IK-00110 (2013-09-12). P-J, in poplar stand, among abundant litter, IK-00120 (2012-10-19); in young beech stand, with birch and poplar nearby (moderately alkaline soil, 7.85% $CaCO_3$), among beech leaves, IK-00121 (2013-09-20); in poplar stand, among litter and sedges, IK-00122 (2013-09-21).

Commentary. The species is widespread and rather common in Europe. It was reported from six localities in Poland; in the Babia Góra massif [102], Białowieża Forest (two records [103,104]), Kampinos National Park [56], Biebrza National Park [87], and in Radomsko district [87]. In the spoil heaps examined, it seems not to be rare.

#***Inocybe rufoalba*** Sacc. (syn. *I. jacobi* Kühner; Fig. 4e)

Specimens examined. MtK, in Scots pine stands of different age (extremely acid sandy clay loam, soil profile 4 in Świtoniak et al. [29]; very strongly acid to strongly acid loamy sand; strong acid to neutral loamy sand, 0–0.74% $CaCO_3$), usually on ± bare ground or among short mosses and lichens, IK-00032 (2001-10-28), IK-00063 (2011-08-26), IK-00067 (2011-08-29).

Commentary. E (as *I. jacobi*). The species is fairly widespread in Europe, especially in the northern part, but occurs occasionally. It was reported from five contemporary localities in Poland, always in open or disturbed sites (e.g., meadows, coal mine dumps, road sides); Kampinos National Park (two records [56,105]), near Gliwice [106] and in Katowice [107] (the Upper Silesia), and near Krasny Las (northeastern Poland) [108]. On Mt Kamieńsk, it was, fairly frequently, observed under pines.

*****Inocybe semifulva*** Grund & D. E. Stuntz (Fig. 4f)

Specimens examined. MtK, in pedunculate oak stand (slightly acid to slightly alkaline clay, 1.17–5.96% $CaCO_3$), with birch and Scots pine in vicinity, among liter, IK-00048 (2011-08-02).

Commentary. So far, few basidiomata of the species have been collected in Europe, only in Estonia and Germany [109], and in Finland (as *I. auricoma*) [110]. In Poland, *I. semifulva* was also found as mycorrhiza on poplar roots (based on ITS sequence, as *I. hirtella*) [60].

Inocybe subporospora Kuyper

Specimens examined. MtK, in young Scots pine stands (strongly alkaline sand and moderately alkaline clay loam, 3.5% $CaCO_3$), soil profiles 5 and 7 in Świtoniak et al. [29], on mineral soil, among short mosses and pine needles, IK-00020 (2001-10-15), IK-00027 (2001-10-22), IK-00622 (2002-10-23).

Commentary. The species is widespread but occasional across Europe. It was recorded only from one locality in Poland in Kampinos National Park [56]. According to GBIF [111], 40 occurrences of the species are known from Norway, Sweden, Denmark, Netherlands, Germany, Spain, and Portugal. However, only one ITS sequence from an identified sporophore is available (AM882931 [112]). On Mt Kamieńsk, fairly numerous sporophores were observed a number of times, always in young, semi-open pine stands.

*****Inocybe tjallingiorum*** Kuyper (Fig. 4g)

Specimens examined. MtK, in Scots pine stands of different age (strongly alkaline sand and moderately alkaline clay loam, 3.5% $CaCO_3$), soil profiles 5 and 7 in Świtoniak

et al. [29]; moderately acid to slightly alkaline sandy loam, 0–1.72% $CaCO_3$), on mineral soil, among short mosses and pine needles, IK-00022 (2004-05-26), IK-00026 (2003-09-16), IK-00080 (2011-07-28). P-J, in mixed deciduous stands (poplar, pedunculated oak, birch) with Scots pine (e.g., moderately alkaline soil, 6.57% $CaCO_3$), among mosses and litter, IK-00123 (2012-10-19), IK-00124 (2013-09-20); in a ditch near poplar/pedunculate oak plantation (slightly to moderately alkaline soil, ca. 10% $CaCO_3$), among grass and mosses, IK-00125 (2013-09-21).

Commentary. The species seems to be widespread across Europe, although not common. During the present study, it was found a number of times, especially on Mt Kamieńsk.

Inocybe vulpinella Bruyl. (Fig. 4h)

Specimens examined. MtK, in Scots pine stand (moderately alkaline clay loam, 3.5% $CaCO_3$), soil profile 7 in Świtoniak et al. [29], with alder, poplar, and willow in vicinity, on mineral soil, among pine needles, IK-00033 (2001-10-22), IK-00034 (2004-05-26); in the open space between Scots pine stands, with alder and birch in vicinity, on bare mineral substrate, IK-00061 (2011-08-26).

Commentary. The species occurs occasionally mainly in temperate and subarctic regions of Northern Europe, elsewhere it seems to be very rare. It was reported from one locality in Poland, in Biebrza National Park [87].

****Laccaria macrocystidiata*** (Migl. & Lavorato) Pázmány

Specimens examined. Tur, in mixed stand of birch, black locust, and alder, among mosses, herbs, and grass, IK-00152 (2013-09-28).

Commentary. The species seems extremely rare. It was described from Sardinia, Italy [113]; few records are known from France [114,115].

#***Lactarius acerrimus*** Britzelm. (Fig. 5d)

Specimens examined. Ada, in pedunculate oak stand, among grass and litter, IK-00556 (2013-09-16).

Commentary. R. The species is widespread across Europe. It was reported from four localities in Poland; Ińsko Landscape Park (northwestern Poland) [116], the vicinity of Mstów (Jurassic Landscape Parks, south Poland) [117], Tuł Mt near Cieszyn (the Western Carpathians) [118], Pieniny Mts National Park [119].

#***Lactarius controversus*** Pers. (Fig. 5e)

Specimens examined. P-J, in poplar stand (slightly alkaline soil, 10.38% $CaCO_3$), among litter, IK-00603 (2013-09-20).

Commentary. E. The species is widespread across Europe. It is not common in Poland, however, it seems to be not very rare either, having more than 15 known localities in the country. The species was found also on the Adamów spoil heap (Ada), in poplar stands (slightly alkaline to neutral soil, 0.25–7.75% $CaCO_3$), among deep litter and in the site of humid organic matter accumulation (groups of sporophores, 2012-10-09, 2013-09-12, 2013-09-22; no voucher collection).

Lactarius cyathuliformis Bon

Specimens examined. MtK, in alder stand (neutral sandy clay loam, 0.52–3.80% $CaCO_3$), among herbs and alder leaves, IK-00158 (2012-11-03). Tur, in alder stand (slightly acid soil, 0.34% $CaCO_3$), among litter, IK-00493 (2013-09-27).

Fig. 4 **a** *Inocybe glabripes*, 28.09.2013, Turów. **b** *Inocybe malenconii*, 29.07.2011, Mt Kamieńsk. **c** *Inocybe myriadophylla*, 02.08.2011, Mt Kamieńsk. **d** *Inocybe ochroalba*, 12.09.2013, Adamów. **e** *Inocybe rufoalba*, 26.08.2011, Mt Kamieńsk. **f** *Inocybe semifulva*, 03.08.2011, Mt Kamieńsk. **g** *Inocybe tjallingiorum*, 21.09.2013, Pątnów-Jóźwin. **h** *Inocybe vulpinella*, 26.08.2011, Mt Kamieńsk. Photograps by Izabela L. Kałucka.

Commentary. The species is known mainly from Northern Europe. It has been recently recorded from two localities in Poland; Białowieża Forest [104] and Kampinos National Park [56]. It is very similar to *L. obscuratus* (Lasch) Fr., which is not rare in Poland. The collections presented here show the features highlighted by Heilmann-Clausen et al. [120]; *L. cyathuliformis* forms relatively larger, more robust basidiomata which are usually tinted olivaceous, and has slightly larger spores than *L. obscuratus*.

#***Lactarius lacunarum*** Romagn. ex Hora

Specimens examined. Tur, pure poplar stand (strongly acid soil), among abundant litter, IK-00494 (2012-11-23).

Commentary. E. The species is widespread in Europe, although more frequent in its northern part. It has less than 10 known localities in Poland.

Lactarius mammosus Fr. (Fig. 5f)

Specimens examined. MtK, in Scots pine stand, on mineral soil among pine needles, (extremely to very strongly acid clay), IK-00156 (2012-09-28), IK-00596 (2013-10-02). Tur, in mixed Scots pine/spruce/birch stand (ca. slightly acid soil, 0.49% $CaCO_3$), among mosses, IK-00491 (2013-09-28); in Scots pine/birch thicket, among litter, IK-00492 (2013-09-28).

Commentary. The species occurs mainly in Fennoscandia, also in other parts of Europe but usually in mountainous localities. It was recorded in less than 10 localities in Poland.

Lactarius quieticolor Romagn. (Fig. 5g)

Specimens examined. Tur, in Scots pine/spruce stand with some birch and larch, among mosses, IK-00481a (2013-09-28); in Scots pine/birch stand, among mosses, grass and litter, IK-00481b (2013-09-28); under young *Pinus sylvestris* and *Betula pendula* in open grass/sedges community with scattered trees (birch, Scots pine, larch, alder), IK-00482 (2012-11-24).

Commentary. The species is widespread across Europe. It was reported from two localities in Poland, in young Scots pine stand on post-arable land near Białowieża [2] and in Roztocze region (southeastern Poland) [121].

Leccinum melaneum (Smotl.) Pilát & Dermek (Fig. 5h)

Specimens examined. Ada, at the edge of pedunculate oak/birch stand, among grass and mosses, IK-00555 (2013-09-16).

Commentary. The species seems to be infrequent outside Fennoscandia. It was reported from less than 10 contemporary localities in Poland (also as *L. roseofractum*).

****Paxillus ammoniavirescens*** Contu & Dessì (Fig. 6a)

Specimens examined. MtK, in pedunculate oak stands, among grass, herbs, and litter (slightly acid to slightly alkaline clay, 1.17–5.96% $CaCO_3$; moderately to slightly acid sandy loam, 0.10–0.99% $CaCO_3$), IK-00188 (2013-08-22), IK-00189 (2012-09-29). P-J, in beech/pedunculate oak plantation (slightly alkaline soil, 11.07% $CaCO_3$), among sparse grass and abundant litter, IK-00554 (2013-09-21).

Commentary. The species seems to be widespread and not infrequent in Europe [122]. It was also found in Poland as mycorrhizas (based on ITS sequence, as *P. involutus*) on nursery oak seedlings [123].

Fig. 5 **a** *Geopora arenosa*, 13.06.2013, Mt Kamieńsk. **b** *Gomphidius maculatus*, 27.09.2013, Turów. **c** *Hygrophorus lucorum*, 23.11.2012, Turów. **d** *Lactarius acerrimus*, 16.09.2013, Adamów. **e** *Lactarius controversus*, 12.09.2013, Adamów. **f** *Lactarius mammosus*, 28.09.2012, Mt Kamieńsk. **g** *Lactarius quieticolor*, 28.09.2013, Turów. **h** *Leccinum melaneum*, 16.09.2013, Adamów. Photographs by Izabela L. Kałucka.

#***Pisolithus arhizus*** (Scop.) Rauschert (Fig. 6b)

Specimens examined. MtK, in Scots pine stands (extremely to very strongly acid clay, strongly acid loamy sand), on mineral soil, among short mosses and lichens, IK-00593 (2011-07-05), IK-00594 (2012-07-02).

Commentary. R (as *P. arhizos*). The species is widespread and not rare across Europe, its recent distribution and ecology was presented by Fraiture and Otto [124]. On Mt Kamieńsk, the species was recorded several times, usually as groups of basidiomata, always in places that were rather acidic. A few records of this species from Mt Kamieńsk were also reported to GREJ by another collector [125]. *Pisolithus arhizus* was also found on the Adamów spoil heap (Ada) under *Quercus robur* and *Populus tremula* in oak/birch stand, not far away from a Scots pine stand (2012-08-21; no voucher collection).

****Rhizopogon mohelnensis*** Velen.

Specimens examined. MtK, in pedunculate oak stand (slightly acid to slightly alkaline clay, 1.17–5.96% $CaCO_3$), in mineral soil, IK-00184 (2011-08-28), IK-00185 (2012-09-27).

Commentary. Basidiomata of *R. mohelnensis* were collected in the Czech Republic (type material), Spain, United Kingdom, and Estonia, records of ectomycorrhizae are known also from France, Germany, Lithuania, and Latvia [126]. The species is usually confused with *R. rubescens*/*roseolus* and belongs in *R. roseolus* group [127].

Russula exalbicans (Pers.) Melzer & Zvára [syn. *R. depallens* (Pers.) Fr.; Fig. 6c]

Specimens examined. MtK, in birch stands (slightly acid to neutral sandy clay loam with 0.34–1.12% $CaCO_3$, slightly alkaline sandy loam with 4.20–7.52% $CaCO_3$), among litter, IK-00160 (2012-07-03), IK-00167 (2013-10-03); in northern red oak stand with birch, among short mosses and litter, IK-00176 (2011-07-27). Ada, in spruce/larch/birch stand (moderately alkaline soil, 4.88% $CaCO_3$), among mosses and litter, IK-00547 (2013-09-12); in young Scots pine/birch stand (slightly alkaline soil, 0.98% $CaCO_3$), among grass, herbs, and litter, IK-00552 (2013-09-12). P-J, in shallow wet depression with willow thicket, poplar and birch, among abundant litter, IK-00541 (2012-10-19), IK-00542 (2012-10-19); in pedunculate oak/birch stand (slightly alkaline soil, 19.93% $CaCO_3$), among litter, IK-00544 (2013-09-20).

Commentary. The species is widespread across Europe. It was reported from three contemporary localities in Poland (as *R. depallens*); Lasy Łochowskie n. Wyszków [128], on zinc wastes near Olkusz [129], and in the Świętokrzyskie Mts [77]. On all the spoil heaps examined in the present study, the species was frequently recorded, especially on Mt Kamieńsk.

Russula medullata Romagn.

Specimens examined. Ada, in pedunculate oak/birch stand, IK-00549 (2012-08-21).

Commentary. The species is widespread across Europe, especially in the northern part and in mountainous habitats. It was reported from only one locality in Poland – in the Gorce Mts (the Western Carpathians) [130].

#***Sistotrema confluens*** Pers. (Fig. 6d)

Specimens examined. Tur, in mixed stand of Scots pine, birch, spruce, and northern red oak, among short mosses, lichens, and litter, IK-00495 (2013-11-10).

Commentary. E. The species is not rare in Europe, especially in Fennoscandia and in some mountainous regions. It is known from less than 10 contemporary localities in Poland.

§#***Suillus cavipes*** (Klotzsch) A. H. Sm. & Thiers (Fig. 6e)

Specimens examined. Tur, under *Larix decidua* in larch/birch stand, among mosses and lichens, IK-00576 (2013-11-11).

Commentary. P, R (as *Boletinus cavipes*). The species is widely distributed in Europe except for the southern part.

#***Thelephora caryophyllea*** (Schaeff.) Pers. (Fig. 6f)

Specimens examined. MtK, in Scots pine stands, among pine needles, (strongly alkaline sand, 3.5% $CaCO_3$, soil profile 5 in Świtoniak et al. [29]; strongly to slightly acid loamy sand, 0–0.45% $CaCO_3$), IK-00597 (2004-09-15), IK-00599 (2012-09-27); in black pine stand (slightly alkaline sandy clay loam, 2.60–4.19% $CaCO_3$), among litter, IK-00598 (2011-07-28). Ada, in spruce/larch/birch stand, among mosses, IK-00600 (2012-10-09), IK-00601 (2013-09-12). Tur, in Scots pine/birch/larch stand, among mosses, IK-00602 (2013-09-27).

Commentary. V. The species is widespread across Europe and, in some regions, rather common.

§#***Tricholoma aurantium*** (Schaeff.) Ricken (Fig. 6g)

Specimens examined. MtK, in Scots pine stand (very strongly acid to strongly acid loamy sand), among pine litter, IK-00604 (2012-09-28). Ada, in mixed birch/spruce/larch stand (moderately alkaline soil, 4.88% $CaCO_3$), among abundant litter, IK-00620 (2012-10-09).

Commentary. P, R. The species is widespread in Europe. It was reported from four contemporary localities in Poland; Tatra Mts National Park [131], Jasieniowa Mt in the Cieszyn Foothils [132], Pieniny Mts National Park [133], and Kampinos National Park [56]. *Tricholoma aurantium* is a species found usually on calcareous soil. On Mt Kamieńsk, the species was found in the plot where all five soil samples were acid, however, solitary calcareous spots cannot be excluded.

#***Tricholoma equestre*** (L.) P. Kumm.

Specimens examined. MtK, in Scots pine stands, among pine litter, (extremely to very strongly acid clay; moderately acid to slightly alkaline sandy loam with 0–1.72% $CaCO_3$), IK-00605 (2013-10-26), IK-00606 (2013-10-26). Tur, under *Pinus sylvestris* in Scots pine/birch/poplar stand, among mosses and litter, IK-00621 (2013-11-10).

Commentary. I. The species is widely distributed in Europe and rather common.

#***Tricholoma focale*** (Fr.) Ricken

Specimens examined. MtK, in Scots pine stand (very strongly acid to strongly acid loamy sand; moderately acid to slightly alkaline sandy loam with 0–1.72% $CaCO_3$), among pine needles, IK-00203 (2013-10-26), IK-00204 (2013-10-26).

Commentary. E. The species is widespread across Europe, although more frequent in Fennoscandia. The species has over 30 contemporary records in Poland.

#***Tricholoma populinum*** J. E. Lange (Fig. 6h)

Fig. 6 **a** *Paxillus ammoniavirescens*, 22.08.2013, Mt Kamieńsk. **b** *Pisolithus arhizus*, 05.07.2011, Mt Kamieńsk. **c** *Russula exalbicans*, 03.07.2012, Mt Kamieńsk. **d** *Sistotrema confluens*, 10.11.2013, Turów. **e** *Suillus cavipes*, 11.11.2013, Turów. **f** *Thelephora caryophyllea*, 12.09.2013, Adamów. **g** *Tricholoma aurantium* 09.10.2012, Adamów. **h** *Tricholoma populinum*, 20.10.2012, Pątnów-Jóźwin. Photographs by Izabela L. Kałucka.

Tab. 1 Acidity and $CaCO_3$ content of the superficial soil on the reclaimed lignite mine spoil heaps Pątnów-Jóźwin, Adamów, Turów, and Mt Kamieńsk (in four stand types).

		pH in H_2O			$CaCO_3$ (%)			
Spoil heap	***N***	**range**	**mean (*SD*)**	**median**	***n***	**range**	**mean (*SD*)**	**median**
Pątnów-Jóźwin	32	7.46–8.15	7.78 (0.15)	7.76	32	3.42–19.93	9.25 (3.71)	9.17
Adamów	32	4.20–7.95	6.67 (1.23)	7.35	23	0.13–9.07	3.74 (2.98)	3.83
Turów	32	3.43–7.84	5.01 (1.02)	4.87	7	0.34–2.21	0.74 (0.66)	0.49
Mt Kamieńsk								
Pinus	50	4.14–7.74	6.24 (1.15)	6.40	31	0.15–8.76	1.95 (1.95)	1.40
Betula	20	6.32–7.98	7.43 (0.49)	7.56	20	0.34–13.06	5.32 (3.27)	6.30
Quercus	20	4.77–7.62	6.15 (0.86)	6.12	12	0.10–5.96	1.80 (1.96)	0.95
Alnus	25	6.05–7.83	7.22 (0.47)	7.35	25	0.08–11.83	3.72 (3.17)	3.35

N – number of samples; *n* – number of samples with $CaCO_3$ present.

Specimens examined. P-J, in mixed stand of poplar, beech, pedunculate oak, and birch, among grass and litter, IK-00533 (2012-10-20); in poplar plantation with birch, among litter, IK-00534 (2012-10-19).

Commentary. V. The species is widespread across Europe. It has over 50 contemporary records in Poland. Among them, there is a record from Mt Kamieńsk (MtK) [134].

****Tubaria umbrina*** R. Maire [syn. *Alnicola umbrina* (R. Maire) Kühner]

Specimens examined. MtK, in alder stand (neutral sandy clay loam, 0.52–3.80% $CaCO_3$), among rich herb layer, alder leaves, and other plant remnants, IK-00155 (2011-08-28), IK-00210 (2013-10-02).

Commentary. The species is known also as *Alnicola umbrina* and mainly under this name is known to form ectomycorrhizas on *Alnus* spp. roots [135]. The species seems to be overlooked but widespread in Europe.

Conclusions

Spoil heaps are piles built of loosened, mixed, and aerated masses of overburden and other waste rock materials brought to the earth's surface from the mine pits. They are not contaminated with any chemical waste but usually show poor physical and chemical features. For reinstatement of utility and natural functions, they are reclaimed by means of technical and biological recultivation, and frequently, the final stage of this process is achieved by afforestation [4]. The restoration forests planted on mine spoils are thought to be important especially for their soil protective functions, landscape improvement, and recreational goals. However, their ecological functions associated with increasing local and general biodiversity seem equally significant.

Early successional habitats typical of opencast mine spoils are generally infrequent in the European landscape and they provide unique sites for pioneer ECM fungal species, species associated with transitional, short-lived open and semi-open early stages of forest development, on mineral soil with low organic matter accumulation, or adapted to disturbed soil conditions, like *Geopora arenosa*, *Cortinarius helobius*, *Hebeloma dunense*, *Inocybe rufoalba*, *I. subporospora*, *I. tjallingiorum*, and *Pisolithus arhizus*.

Mine spoils are isolated hills of waste rock material and raw overburden that is not present on the surrounding earth surface for hundreds of kilometers. They may serve as a refuge for many rare fungi known from distant, especially northern or mountainous locations, from oligotrophic or severe habitats. Such species are represented, e.g., by *Cortinarius diasemospermus*, *C. murinascens*, *Inocybe griseotarda*, *I. lanatopurpurea*, *I. myriadophylla*, *I. semifulva*, *Laccaria macrocystidiata*, *Lactarius mammosus*, and *Sistotrema confluens*.

As a result of mixed overburden deposition and using different amelioration measures and amendments (like chalk, ash, mineral fertilizers, or geogenic carbon), the mine spoil surface is composed of various materials, patchily distributed, exhibiting different physical and chemical properties. Usually, as in the case of spoil heaps examined in this study, an afforestation process takes years and restoration stands are of different age and also are composed of different tree species. This, in turn, results in exceptional diversification and heterogeneity of habitats and site conditions on a small scale, and in a high diversity of ECM fungi. In the spoil heaps examined, a large group of species associated with rich and/or calcareous soils can be clearly distinguished, like *Hebeloma odoratissimum*, *H. laterinum*, *Inocybe myriadophylla*, *Russula exalbicans*, *Tricholoma aurantium*, *T. populinum*. However, species typical of poor and sandy soils are also present, like *Cortinarius depressus*, *Hebeloma cylindrosporum*, *Inocybe subporospora*, *Suillus cavipes*, as well as species occurring on mostly acidic soils, like *Gomphidius glutinosus*, *G. roseus*, *Hebeloma cavipes*, *Tricholoma focale*. It is also possible that in accordance with the successional model of ECM fungi proposed by Jumpponen and Egerton-Warburton [136], strong environmental filters, e.g., extreme soil pH, very low or high nutrient level, infrequent soil texture and physical conditions, harsh microclimatic conditions, and their unusual combinations, may eliminate great part of the locally and regionally available competitive ECM species pool and this, in turn, enables successful colonization and existence of vast range of rare, less competitive, highly specialized and narrow-niche fungal taxa.

All the seventy-one species of ECM fungi collected on the lignite mine spoil heaps examined, presented in this paper, are the species recorded for the first time in Poland or currently red-listed, or extremely rarely recorded. The number is unexpectedly high. It is even more impressive, as it comprises more than one third of all ECM taxa identified during this study. These findings reveal very high potential of young restoration forests for hosting a diversity of ECM symbionts. Such habitats should not be neglected or ignored in fungal biodiversity studies or in conservation considerations. New data on the currently red-listed species [42] may suggest, at least in the case of some taxa, the need for re-evaluation of the threat category. Examples include *Helvella lacunosa* (R), *Pisolithus arhizus* (R), *Thelephora caryophyllea* (V), *Tricholoma equestre* (I), and *T. populinum* (V), which seem not to be rare or threatened at present. Also, high threat category (E) may be no longer adequate in the case of *Inocybe glabripes*, *I. rufoalba*, *Lactarius controversus*, and *Tricholoma focale*. At the same time, some species may be worth considering for including into the red list, like the group of northern taxa (*Cortinarius murinascens*, *C. depressus*, *C. diasemospermus*, *C. subbalaustinus*, *Hebeloma incarnatulum*, *Inocybe myriadophylla*, *I. vulpinella*, *Lactarius cyathuliformis*, *L. mammosus*, *Leccinum melaneum*), and taxa which seem to be rare and scattered in Europe (*Cortinarius pseudofallax*, *Hebeloma danicum*, *H. odoratissimum*, *H. populinum*, *Inocybe griseotarda*, *I. lanatopurpurea*, *I. ochracea*, *I. semifulva*, *I. subporospora*, *Laccaria macrocystidiata*, *Rhizopogon mohelnensis*).

The results of the present study show the importance of detailed and long-term mycological field observations and taxonomical studies, which, especially if combined with molecular analyses, can provide reliable and credible data for further studies on fungal ecology and distribution. The importance of field observations and morphological analysis is particularly important in the context of numerous studies based exclusively on molecularly identified OTUs and environmental samples, which sometimes automatically or in indiscriminate manner use the sequence data available in public databases and duplicate misidentification errors (compare [137,138]).

Acknowledgments

We are thankful to Prof. Maria Rudawska (Laboratory of Symbiotic Associations, Institute of Dendrology, Polish Academy of Sciences), Dr hab. Paweł Stonczek (Section of Microbial Genetics, Department of Industrial Microbiology and Biotechnology, University of Łódź), and Dr Sława Glińska (Laboratory of Microscopic Imaging and Specialised Biological Technics, University of Łódź) for sharing lab facilities. We are greatly indebted to Dr Marcin Pietras and Dr hab. Tomasz Leski (Laboratory of Symbiotic Associations, Institute of Dendrology, Polish Academy of Sciences) for consulting molecular analyses and Dr Agnieszka Salamaga for her help in the field work. We are grateful to Dr Ursula Eberhardt (Staatliches Museum für Naturkunde, Stuttgart, with help from Nicole Schütz) for verification of our ITS sequences of *Hebeloma* spp. We would like to express special thanks to Prof. Henry J. Beker (Brussels) for his help in *Hebeloma* spp. identification, valuable comments and linguistic revision of the manuscript.

Supplementary material

The following supplementary material for this article is available at http://pbsociety.org.pl/journals/index.php/am/rt/suppFiles/am.1080/0:

Tab. S1 GenBank accession numbers of the selected collections of ectomycorrhizal fungi from the mine spoil heaps Pątnów-Jóźwin, Adamów, Mt Kamieńsk, and Turów.

References

1. Ławrynowicz M, Bujakiewicz A, Mułenko W. Mycocoenological studies in Poland – 1952–2002. Łódź: Polish Botanical Society; 2004. (Monographiae Botanicae; vol 93). http://dx.doi.org/10.5586/mb.2004.001
2. Kałucka I. Macrofungi in the secondary succession on the abandoned farmland near the Białowieża old-growth forest. Łódź: Polish Botanical Society; 2004. (Monographiae Botanicae; vol 99). http://dx.doi.org/10.5586/mb.2009.001
3. Kujawa A. Macrofungi in wooded patches in the agricultural landscape. I. Species diversity. Acta Mycol. 2009;44(1):49–75. http://dx.doi.org/10.5586/am.2009.007
4. Kałucka IL, Jagodziński AM. Successional traits of ectomycorrhizal fungi in forest reclamation after surface mining and agricultural disturbances: a review. Dendrobiology. 2016;76:91–104. http://dx.doi.org/10.12657/denbio.076.009
5. Gebhardt S, Neubert K, Wöllecke J, Müenzenberger B, Hüttl RF. Ectomycorrhiza communities of red oak (*Quercus rubra* L.) of different age in the Lusatian lignite mining district, East Germany. Mycorrhiza. 2007;17:279–290. http://dx.doi.org/10.1007/s00572-006-0103-4
6. Glen M, Bougher NL, Colquhoun IJ, Vlahos S, Loneragan WA, O'Brien P, et al. Ectomycorrhizal fungal communities of rehabilitated bauxite mines and adjacent, natural jarrah forest in Western Australia. For Ecol Manage. 2008;255:214–225. http://dx.doi.org/10.1016/j.foreco.2007.09.007
7. Krpata D, Peintner U, Langer I, Fitz WJ, Schweiger P. Ectomycorrhizal communities associated with *Populus tremula* growing on a heavy metal contaminated site. Mycol Res. 2008;112:1069–1079. http://dx.doi.org/10.1016/j.mycres.2008.02.004
8. Kasiński J, Mazurek S, Piwocki M. Waloryzacja i ranking złóż węgla brunatnego w Polsce. Warszawa: Państwowy Instytut Geologiczny; 2006. (Prace Państwowego Instytutu Geologicznego; vol 187).
9. Kondracki J. Geografia regionalna Polski. 3rd ed. Warszawa: Wydawnictwo Naukowe PWN; 2013.
10. Stachowski P, Oliskiewicz-Krzywicka A, Kozaczyk P. Ocena warunków meteorologicznych na terenach pogórniczych Konińskiego Zagłębia Węgla Brunatnego. Rocznik Ochrona Środowiska. 2013;15:1834–1861.
11. Zajączkowski M. Metoda wyboru lokalizacji zwałowiska na przykładzie wieloodkrywkowej kopalni węgla brunatnego [PhD thesis]. Kraków: Akademia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie, Wydział Górnictwa i Geoinzynierii, Katedra Górnictwa Odkrywkowego; 2012.
12. Balcerkiewicz S, Pawlak G. Zbiorowiska roślinne zwałowiska zewnętrznego Pątnów-Jóźwin w Konińskim Zagłębiu Węgla Brunatnego. Badania Fizjograficzne nad Polską Zachodnią – Seria B. Botanika. 1990;40:57–106.

13. Wysocki W. Odtwarzanie gleb dla rolniczego zagospodarowania zwałowisk Kopalni Węgla Brunatnego Konin. Roczniki Gleboznawcze. 1975;26(1):61–98.

14. Gilewska M, Otręba K. Kształtowanie krajobrazu rolniczego na terenach pogórniczych Kopalni Węgla Brunatnego w rejonie Konina. Roczniki Gleboznawcze. 2011;62(2):109–114.

15. Bank Danych o Lasach [Internet]. 2016 [cited 2016 Apr 17]. Available from: http://www.bdl.lasy.gov.pl/portal/mapy#

16. Orlikowski D, Szwed L. Zagospodarowanie terenów pogórniczych KWB "Adamów" SA w Turku – krajobraz przed rozpoczęciem działalności górniczej i po jej zakończeniu. Górnictwo i Inżynieria. 2011;35(3):225–240.

17. Cuske M, Pora E, Musztyfaga E, Gałka B. Ewaluacja prac rekultywacyjnych zwałowiska wewnętrznego odkrywki węgla brunatnego "Adamów" w KWB Adamów. Inżynieria Środowiska. 2014;33:32–40.

18. Okupny D. Morfologiczne skutki procesów stokowych zachodzących na zboczach zwałowiska zewnętrznego Adamów. In: Machowski R, Rzętała MA, editors. Z badań nad wpływem antropopresji na środowisko. Tom 9. Sosnowiec: Studenckie Koło Naukowe Geografów Uniwersytetu Śląskiego, Wydział Nauk o Ziemi Uniwersytetu Śląskiego; 2009. p. 32–43.

19. Krzaklewski W, Kowalik S, Wójcik J. Rekultywacja utworów toksycznie kwaśnych w górnictwie węgla brunatnego. Monografia. Kraków: Wydawnictwo MONOS; 1997.

20. Pietrzykowski M. 2. Założenia, obiekty, zakres i metody badań. In: Pietrzykowski M, editor. Analiza i optymalizacja metod klasyfikacji siedlisk i kryteriów oceny rekultywacji leśnej na wybranych terenach pogórniczych w Polsce. Kraków: Wydawnictwo Uniwersytetu Rolniczego w Krakowie; 2010. p. 45–63.

21. Hołubowicz K. Rekultywacja i zagospodarowanie zwałowisk Kopalni Węgla Brunatnego "Bełchatów". In: Liszewski S, editor. Zmiany w środowisku przyszłego Bełchatowskiego Okręgu Przemysłowego. Stan z okresu przedinwestycyjnego i wstępnej fazy pracy elektrowni. Warszawa: Uniwersytet Łódzki, Państwowe Wydawnictwo Naukowe; 1985. p. 273–285.

22. Krzaklewski W. Rekultywacja w KWB "Bełchatów" – zamierzenia, stan i perspektywy. Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej. Konferencje. 2005;112(44):411–421.

23. Pająk M, Krzaklewski W. Selected physical properties of initial soils on the outside spoil bank of the Bełchatów brown coal mine. Journal of Forest Science. 2007;53:308–313.

24. Pietrzykowski M. Scots pine (*Pinus sylvestris* L.) ecosystem macronutrients budget on reclaimed mine sites – stand trees supply and stability. Nat Sci. 2010;2(6):590–599. http://dx.doi.org/10.4236/ns.2010.26074

25. PGE GiEK S.A., Oddział Kopalnia Węgla Brunatnego Bełchatów [Internet]. Rekultywacja zwałowisk. 2016 [cited 2016 Apr 28]. Available from: https://www.kwbbelchatow.pgegiek.pl/index.php/ochrona-srodowiska/rekultywacja/rekultywacja-zwalowisk/

26. PGE GiEK S.A., Oddział Kopalnia Węgla Brunatnego Bełchatów [Internet]. Zwałowisko zewnętrzne P/Bełchatów. 2016 [cited 2016 Apr 28]. Available from: https://www.kwbbelchatow.pgegiek.pl/index.php/ochrona-srodowiska/rekultywacja/zwalowisko-zewnetrzne-pbelchatow/

27. Pająk M, Forgiel M, Krzaklewski W. Growth of trees used in reforestation of a northern slope of the external spoil bank of the "Bełchatów" brown coal mine. Electronic Journal of Polish Agricultural Universities. 2004;7(2):2.

28. Świtoniak M, Hulisz P, Kałucka I, Różański S. Rola monokultur sosnowych w kształtowaniu zasobów węgla organicznego w glebach zwałowiska zewnętrznego KWB Bełchatów. Roczniki Gleboznawcze. 2011;62:395–405.

29. Świtoniak M, Hulisz P, Różański S, Kałucka I. Soils of the external dumping ground of the Bełchatów open-cast lignite mine. In: Charzyński P, Hulisz P, Bednarek R, editors. Technogenic soils of Poland. Toruń: Polish Society of Soil Science; 2013. p. 255–274.

30. Nietrzeba-Marcinonis J. Wpływ rekultywacji leśnej terenów pokopalnianych na wybrane właściwości gleb inicjalnych na przykładzie zwałowiska nadkładu Kopalni Węgla Brunatnego Turów S.A. [PhD thesis]. Zielona Góra: Uniwersytet Zielonogórski, Wydział Inżynierii Lądowej i Środowiska; 2007.

31. Kaczarewski T, Milkowski D, Dymarski J, Wójcicka-Milewska M. Warunki końcowe formowania najwyższych pięter i wierzchowiny zwałowiska zewnętrznego w BOT KWB Turów S.A. In: Proceedings: "Zagrożenia naturalne w górnictwie"; 2006 Jun 12–14;

Kraków-Tomaszowice, Poland. Kraków: Wydawnictwo IGSMiE PAN; 2006. p. 131–141. (Sympozja i Konferencje; vol 67).

32. Wąchalewski T, Krzaklewski W, Wójcik J. Rekultywacja zwałowisk kopalnictwa węgla brunatnego jako element ich bezpieczeństwa w toku i po zakończeniu formowania na przykładzie kopalni "Turów". Zeszyty Problemowe Postępu Nauk Rolniczych. 1995;418(2):133–137.
33. PGE GiEK S.A., Oddział Kopalnia Węgla Brunatnego Turów [Internet]. Rekultywacja. 2016 [cited 2016 Apr 28]. Available from: https://www.kwbturow.pgegiek.pl/index.php/ochrona-srodowiska/rekultywacja/
34. PGE GiEK S.A., Oddział Kopalnia Węgla Brunatnego Turów [Internet]. Ochrona środowiska. 2016 [cited 2016 Apr 28]. Available from: https://www.kwbturow.pgegiek.pl/index.php/ochrona-srodowiska/
35. Kasztelewicz Z, Kozioł K, Klich J. Rekultywacja terenów poeksploatacyjnych w kopalniach węgla brunatnego w Polsce. Górnictwo i Geoinżynieria. 2007;31(2):295–307.
36. Tedersoo L, Smith M. Lineages of ectomycorrhizal fungi revisited: foraging strategies and novel lineages revealed by sequences from belowground. Fungal Biol Rev. 2013;27:83–99. http://dx.doi.org/10.1016/j.fbr.2013.09.001
37. Index Fungorum [Internet]. Search Index Fungorum. 2016 [cited 2016 Jun 20]. Available from: http://www.indexfungorum.org/Names/Names.asp
38. White TJ, Bruns T, Lee S, Taylor J. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis MA, Gelfand DH, Sninsky JJ, White TJ, editors. PCR protocols: a guide to methods and applications. San Diego, CA: Academic Press; 1990. p. 315–322. http://dx.doi.org/10.1016/b978-0-12-372180-8.50042-1
39. Gardes M, Bruns TD. ITS primers with enhanced specificity for Basidiomycetes – application to the identification of mycorrhizae and rusts. Mol Ecol. 1993;2:113–118. http://dx.doi.org/10.1111/j.1365-294X.1993.tb00005.x
40. Leski T, Rudawska M. Ectomycorrhizal fungal community of naturally regenerated European larch (*Larix decidua*) seedings. Symbiosis. 2012;56:45–53. http://dx.doi.org/10.1007/s13199-012-0164-4
41. Hall TA. BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. Nucleic Acids Symp Ser. 1999;41:95–98.
42. Wojewoda W, Ławrynowicz M. Red list of the macrofungi in Poland. In: Mirek Z, Zarzycki K, Wojewoda W, Szeląg Z, editors. Red list of plants and fungi in Poland. Cracow: W. Szafer Institute of Botany, Polish Academy of Sciences; 2006. p. 53–70.
43. Rozporządzenie Ministra Środowiska z dnia 9 października 2014 r. w sprawie ochrony gatunkowej grzybów. Journal of Laws of the Republic of Poland (Dziennik Ustaw), 16 October 2014, item 1408.
44. Wojewoda W. Checklist of Polish larger Basidiomycetes. Cracow: W. Szafer Institute of Botany, Polish Academy of Sciences; 2003. (Biodiversity of Poland; vol.7).
45. Kujawa A. Grzyby makroskopijne Polski w literaturze mikologicznej [Internet]. 2016 [cited 2016 Jun 20]. Available from: http://www.grzyby.pl/grzyby-makroskopijne-Polski-w-literaturze-mikologicznej.htm
46. Kujawa A, Gierczyk B. Rejestr gatunków grzybów chronionych i zagrożonych [Internet]. 2016 [cited 2016 Jun 20]. Available from: http://www.grzyby.pl/rejestr-grzybow-chronionych-i-zagrozonych.htm
47. Knudsen H, Vesterholt J, editors. Funga Nordica: agaricoid, boletoid and cyphelloid genera. Copenhagen: Nordsvamp; 2008.
48. Krieglsteiner GJ. Verbreitungsatlas der Großpilze Deutschlands (West). Band 1: Ständerpilze. Teil A: Nichtblätterpilze. Stuttgart: Ulmer; 1991.
49. Krieglsteiner GJ. Verbreitungsatlas der Großpilze Deutschlands (West). Band 1: Ständerpilze. Teil B: Blätterpilze. Stuttgart: Ulmer; 1991.
50. Legon M, Henrici A, Roberts TJ, Spooner VN, Watling R. Checklist of the British & Irish Basidiomycota. Kew: Royal Botanic Gardens, Kew; 2005.
51. The Global Biodiversity Information Facility [Internet]. 2016 [cited 2016 May 20]. Available from: http://www.gbif.org/dataset/d7dddbf4-2cf0-4f39-9b2a-bb099caae36c
52. Kõljalg U, Larsson KH, Abarenkov K, Nilsson RH, Alexander IJ, Eberhardt U, et al. UNITE: a database providing web-based methods for the molecular

identification of ectomycorrhizal fungi. New Phytol. 2005;166:1063–1068. http://dx.doi.org/10.1111/j.1469-8137.2005.01376.x

53. Kõljalg U, Nilsson RH, Abarenkov K, Tedersoo L, Taylor AFS, Bahram M, et al. Towards a unified paradigm for sequence-based identification of fungi. Mol Ecol. 2013;22(21):5271–5277. http://dx.doi.org/10.1111/mec.12481
54. Soil Survey Division Staff. Soil survey manual. Chapter 3. Examination and description of soils. Washington, D.C.: Soil Conservation Service, U.S. Department of Agriculture; 1993. (Agriculture Handbook; vol 18).
55. Chmiel MA. Discomycetes of the Kazimierz Landscape Park. Annales Universitatis Mariae Curie-Sklodowska. Sectio C, Biologia. 1991;46:21–27.
56. Karasiński D, Kujawa A, Gierczyk B, Ślusarczyk T, Szczepkowski A. Grzyby wielkoowocnikowe Kampinoskiego Parku Narodowego. Izabelin: Kampinoski Park Narodowy; 2015.
57. Snowarski M. *Geopora arenosa* (Fuckel) S. Ahmad [Internet]. 2016 [cited 2016 June 20]. Available from: http://www.grzyby.pl/gatunki/Geopora_arenosa.htm
58. Ślusarczyk T. Nowe stanowiska grzybów z rodzaju zasłonak (*Cortinarius*) w Polsce. Przegląd Przyrodniczy. 2013;24(4):42–68.
59. Ślusarczyk T, Gryc M, Wantoch-Rekowski M. Nowe stanowiska grzybów z rodzaju zasłonak *Cortinarius* w Polsce. Przegląd Przyrodniczy. 2015;26(2):3–21.
60. Karliński L, Rudawska M, Leski T. The influence of host genotype and soil conditions on ectomycorrhizal community of poplar clones. Eur J Soil Biol. 2013;58:51–58. http://dx.doi.org/10.1016/j.ejsobi.2013.05.007
61. Niskanen T. Nomenclatural novelties. Index Fungorum. 2014;201.
62. Bidaud A, Carteret X, Eyssartier G, Moënne-Loccoz P, Reumaux P. Sous-genre *Hydrocybe*, section *Obtusi*, sous-section *Obtusoides*. Atlas des Cortinaires. 2004;14:863–982.
63. Esteve-Raventós F, Niskanen T, Platas G, Liimatainen K, Ortega A. *Cortinarius pseudofallax* (Cortinariaceae, Agaricales), the first records from the Iberian Peninsula and Fennoscandia, and taxonomic notes on the *C. parvannulatus/cedriolens* group. Mycol Prog. 2014;13:393–398. http://dx.doi.org/10.1007/s11557-013-0925-3
64. Kõljalg U, Abarenkov K, Nilsson RH, Larsson KH, Aas AB, Adams R, et al. SH188517.07FU [Internet]. UNITE Community; 2015 [cited 2016 Jun 15]. Available from: http://dx.doi.org/10.15156/BIO/SH188517.07FU
65. Beker HJ, Eberhardt U, Vesterholt J. *Hebeloma* (Fr.) P. Kumm. Lomazzo: Edizioni Tecnografica; 2016. (Fungi Europaei; vol 14).
66. Eberhardt U, Beker HJ, Vesterholt J. Decrypting the *Hebeloma crustuliniforme* complex: European species of *Hebeloma* section *Denudata* subsection *Denudata* (Agaricales). Persoonia. 2015;35:101–147. http://dx.doi.org/10.3767/003158515X687704
67. Lisiewska M, Siedlaczek S. Wstępne badania nad występowaniem grzybów kapeluszowych na zwałowisku górniczym "Smolnica". Archiwum Ochrony Środowiska. 1982;1–4:93–110.
68. Lisiewska M, Linkowska R, Kaźmierczak B. Obserwacje mikologiczne na rekultywowanych zwałowiskach Konińskiego Zagłębia Węgla Brunatnego. Badania Fizjograficzne nad Polską Zachodnią – Seria B. Botanika. 1986;37:131–165.
69. Kałucka I, Beker HJ. *Hebeloma cavipes* Huijsman – a common species not distinguished so far in Poland. Acta Soc Bot Pol. 2010;79(1 suppl):74.
70. Pietras M, Rudawska M, Leski T, Karliński L. Diversity of mycorrhizal fungus assemblages on nursery grown European beech seedlings. Ann For Sci. 2013;70:115–121. http://dx.doi.org/10.1007/s13595-012-0243-y
71. Grilli E, Beker H, Eberhardt U, Schütz N, Leonardi M, Vizzini A. Unexpected species diversity and contrasting evolutionary hypotheses in *Hebeloma* (Agaricales) sections *Sinapizantia* and *Velutipes* in Europe. Mycol Prog. 2016;15:5. http://dx.doi.org/10.1007/s11557-015-1148-6
72. Vesterholt J, Eberhardt U, Beker HJ. Epitypification of *Hebeloma crustuliniforme*. Mycol Prog. 2014;13:553–562. http://dx.doi.org/10.1007/s11557-013-0938-y
73. Bujakiewicz A, Lisiewska M. Mikoflora zbiorowisk roślinnych Słowińskiego Parku Narodowego. Badania Fizjograficzne nad Polską Zachodnią – Seria B. Botanika. 1983;34:49–77.
74. Wantoch-Rekowski M. Bio-forum.pl [Internet]. *Hebeloma cylindrosporum*. ID 253678. 2015 [cited 2016 Jul 29]. Available from: http://www.bio-forum.pl/messages/7259/819733.html#POST253678
75. Kaufmann F. Die in Westpreußengefundenen Pilze der Gattungen *Psalliota*, *Stropharia*,

Hebeloma, *Inocybe*, *Gomphidius* und *Paxillus*. Bericht des Westpreussischen Botanisch-Zoologischen Vereins. 1913;35:86–130.

76. Wojewoda W, Ławrynowicz M. Red list of threatened Macrofungi in Poland. In: Zarzycki K, Wojewoda W, Heinrich Z, editors. List of threatened plants in Poland. Cracow: W. Szafer Institute of Botany, Polish Academy of Sciences; 1992. p. 27–56.
77. Łuszczyński J. Diversity of Basidiomycetes in various ecosystems of the Góry Świętokrzyskie Mts. Łódź: Polish Botanical Society; 2007. (Monographiae Botanicae; vol 97). http://dx.doi.org/10.5586/mb.2007.001
78. Eberhardt U, Ronikier A, Nicole Schütz N, Beker HJ. The genus *Hebeloma* in the alpine belt of the Carpathians including two new species. Mycologia. 2015;107(6):1285–1303. http://dx.doi.org/10.3852/15-097
79. Gryc M. Bio-forum.pl [Internet]. *Hebeloma collariatum*. ID 276558. 2016 [cited 2016 Jul 29]. Available from: http://www.bio-forum.pl/messages/7259/7269.html#POST276558
80. Rudnicka-Jezierska W. Nowe gatunki grzybów psammofilnych. Acta Mycol. 1967;3:183–187. http://dx.doi.org/10.5586/am.1967.008
81. Eberhardt U, Beker HJ, Vesterholt I, Schütz N. The taxonomy of the European species of *Hebeloma* section *Denudata* subsections *Hiemalia*, *Echinospora* subsect. nov. and *Clepsydroida* subsect. nov. and five new species. Fungal Biol. 2016;120:72–103. http://dx.doi.org/10.1016/j.funbio.2015.09.014
82. Kałucka I. Macromycetes in the forest communities of the Jodły Łaskie nature reserve (central Poland). Acta Mycol. 1995;30(1):3–26. http://dx.doi.org/10.5586/am.1995.001
83. Chachuła P, Dorda A, Fiedor M, Rutkowski R. Grzyby Cieszyna. Cieszyn: Urząd Miejski w Cieszynie; 2015.
84. Vesterholt J. Taxonomic notes on *Hebeloma* (Agaricales, Cortinariaceae). Windahlia. 1993;20:55–61.
85. Lisiewska M, Bujakiewicz A. Grzyby (Fungi). Badania Fizjograficzne nad Polską Zachodnią – Seria B. Botanika. 1976;29:57–67.
86. Lisiewska M, Malinger M. Macromycetes w różnych postaciach grądu środkowoeuropejskiego na terenie uroczyska Marcelin w Poznaniu. Badania Fizjograficzne nad Polską Zachodnią – Seria B. Botanika. 2001;50:7–40.
87. Kujawa A, Gierczyk B, Domian G, Wrzosek M, Stasińska M, Szkodzik J. Preliminary studies of fungi in the Biebrza National Park. Part IV. Macromycetes – new data and the synthesis. Acta Mycol. 2015;50(2):1070. http://dx.doi.org/10.5586/am.1070
88. Ronikier A. Fungi of the Sarnia Skała massif in the Tatra Mountains (Poland). Cracow: Polish Academy of Sciences, W. Szafer Institute of Botany; 2012. (Polish Botanical Studies; vol 28).
89. Wantoch-Rekowski M. Bio-forum.pl [Internet]. *Inocybe microspora*. ID 253862. 2015 [cited 2016 Jul 29]. Available from: http://www.bio-forum.pl/messages/7259/819733.html#POST253862
90. Poirier J. Notes on the genus *Inocybe* – 1. Doc Mycol. 2002;31(124):3–13.
91. The Global Biodiversity Information Facility [Internet]. *Inocybe griseotarda* Poirier, 2002. 2016 [cited 2016 May 20]. Available from: http://www.gbif.org/species/3331185
92. Osmundson TW, Robert VA, Schoch CL, Baker LJ, Smith A, Giovanni Robich G, et al. Filling gaps in biodiversity knowledge for macrofungi: contributions and assessment of an herbarium collection DNA barcode sequencing project. PLoS One. 2013;8(4):e62419. http://dx.doi.org/10.1371/journal.pone.0062419
93. Crous PW, Shivas RG, Quaedvlieg W, van der Bank M, Zhang Y, Summerell BA, et al. Fungal Planet Description Sheets: 214–280. Persoonia. 2014;32:184–306. http://dx.doi.org/10.3767/003158514X682395
94. Kõljalg U, Abarenkov K, Nilsson RH, Larsson KH, Aas AB, Adams R, et al. SH174199.07FU [Internet]. UNITE Community; 2015 [cited 2016 Jun 15]. Available from: http://dx.doi.org/10.15156/BIO/SH174199.07FU
95. Flisińska Z. Studia nad grzybami wielkoowocnikowymi (macromycetes) Lublina. Annales Universitatis Mariae Curie-Sklodowska. Sectio C, Biologia. 1996;51:13–39.
96. Vauras J, Larsson E. *Inocybe myriadophylla*, a new species from Finland and Sweden. Karstenia. 2011;51:31–36.
97. Kõljalg U, Abarenkov K, Nilsson RH, Larsson KH, Aas AB, Adams R, et al. SH209543.07FU

[Internet]. UNITE Community; 2015 [cited 2016 Jun 15]. Available from: http://dx.doi.org/10.15156/BIO/SH209543.07FU

98. Stangl J. Die Gattung *Inocybe* in Bayern. Hoppea. Denkschriften der Regensburgischen Botanischen Gesellschaft. 1989;46:5–388.
99. Vauras J, Kokkonen K. Finnish records of the genus *Inocybe*. The new species *Inocybe saliceticola*. Karstenia. 2009;48:57–67.
100. Bujakiewicz A. Grzyby wielkoowocnikowe Babiogórskiego Parku Narodowego. In: Wołoszyn BW, Jaworski A, Szwagrzyk J, editors. Babiogórski Park Narodowy. Monografia przyrodnicza. Kraków: Publikacje Komitetu Ochrony Przyrody PAN przy współpracy Babiogórskiego Parku Narodowego; 2004. p. 215–257.
101. Bujakiewicz A. Macrofungi in the *Caltho-Alnetum* association on the northern slopes of the Babia Góra massif (West Carpathians). In: Holeksa J, Mirek Z, Wójcicki JJ, editors. Krystyna Falińska & Janusz B. Faliński Festschrift. Cracow: W. Szafer Institute of Botany, Polish Academy Of Sciences; 2006. p. 81–93. (Polish Botanical Studies; vol 22).
102. Bujakiewicz A. Macrofungi in the *Alnetum incanae* association along Jaworzyna and Skawica river valleys (Western Carpathians). Pol Bot J. 2011;56(2):267–285.
103. Gierczyk B, Kujawa A, Szczepkowski A, Karasiński D. Materiały do poznania mykobioty Puszczy Białowieskiej. Przegląd Przyrodniczy. 2014;25(1):3–36.
104. Gierczyk B, Kujawa A, Szczepkowski A, Ślusarczyk T, Kozak M, Mleczko P. XXI Wystawa Grzybów Puszczy Białowieskiej. Materiały do poznania mykobioty Puszczy Białowieskiej. Przegląd Przyrodniczy. 2015;26(3):10–50.
105. Sadowska B. Peliminary analysis of productivity of fruiting fungi on Strzeleckie meadows. Acta Mycol. 1974;10(1):141–158. http://dx.doi.org/10.5586/am.1974.003
106. Lisiewska M. Floristic-ecological investigations of Macromycetes on a coal mine dump in the Silesia region (S. Poland). Feddes Repert. 1987;98(3–4):265–272. http://dx.doi.org/10.1002/fedr.4910980309
107. Karasiński D. Grzyby większe rezerwatu przyrody "Ochojec". In: Parusel JB, editor. Rezerwat przyrody "Ochojec" w Katowicach (Górny Śląsk). Monografia naukowo-dydaktyczna. Katowice: Centrum Dziedzictwa Przyrody Górnego Śląska; 2009. p. 86–103.
108. Snowarski M. *Inocybe jacobi* Kühner [Internet]. 2016 [cited 2016 Jun 22]. Available from: http://grzyby.pl/gatunki/Inocybe_jacobi.htm
109. The Global Biodiversity Information Facility [Internet]. *Inocybe semifulva*. 2016 [cited 2016 May 20]. Available from: http://www.gbif.org/species/3330742
110. Kõljalg U, Abarenkov K, Nilsson RH, Larsson KH, Aas AB, Adams R, et al. SH178661.07FU [Internet]. UNITE Community; 2015 [cited 2016 Jun 15]. Available from: http://dx.doi.org/10.15156/BIO/SH178661.07FU
111. The Global Biodiversity Information Facility [Internet]. *Inocybe subporospora*. 2016 [cited 2016 May 20]. Available from: http://www.gbif.org/species/3331115
112. Kõljalg U, Abarenkov K, Nilsson RH, Larsson KH, Aas AB, Adams R, et al. SH222185.07FU [Internet]. UNITE Community; 2015 [cited 2016 Jun 15]. Available from: http://dx.doi.org/10.15156/BIO/SH222185.07FU
113. Pázmány D. Zur Systematik der Gattung *Laccaria* Bk et Br. Z Mykol. 1994;60(1):5–11.
114. Vincenot L, Nara K, Sthultz, C, Labbé J, Dubois MP, Tedersoo L, et al. Extensive gene flow over Europe and possible speciation over Eurasia in the ectomycorrhizal basidiomycete *Laccaria amethystina* complex. Mol Ecol. 2012;21(2):281–299. http://dx.doi.org/10.1111/j.1365-294X.2011.05392.x
115. The Global Biodiversity Information Facility [Internet]. *Laccaria macrocystidiata*. 2016 [cited 2016 May 20]. Available from: http://www.gbif.org/species/7244206
116. Ławrynowicz M, Stasińska M. Macromycetes of the *Stellario-Carpinetum* in the Ińsko Landscape Park (NW Poland) – monitoring studies. Acta Mycol. 2000;33(2):157–182. http://dx.doi.org/10.5586/am.2000.019
117. Ławrynowicz M. Macromycetes of oak forests in the Jurassic Landscape Park (Częstochowa Upland) – monitoring studies. Acta Mycol. 2001;36(1):81–110. http://dx.doi.org/10.5586/am.2001.007
118. Skirgiełło A. Grzyby (Mycota). T. 25. Kraków: Instytut Botaniki im. W. Szafera, Polska Akademia Nauk; 1998. (Flora Polska).
119. Gumińska B. Mikoflora Pienińskiego Parku Narodowego (część III). Zeszyty Naukowe Uniwersytetu Jagiellońskiego. Prace Botaniczne. 1976;4:127–141.

120. Heilmann-Clausen J, Verbeken A, Vesterholt J. The genus *Lactarius*. Denmark: Danish Mycological Society; 1998. (Fungi of Northern Europe; vol 2).

121. Kozłowska M, Heluta VP, Mułenko W, Bazyuk-Dubey IV. Fungi of the Roztocze region (Poland and Ukraine). Part I. A checklist of larger Basidiomycota. Lublin: Towarzystwo Wydawnictw Naukowych Libropolis; 2015.

122. Kõljalg U, Abarenkov K, Nilsson RH, Larsson KH, Aas AB, Adams R, et al. SH210481.07FU [Internet]. UNITE Community; 2015 [cited 2016 Jun 16]. Available from: http://dx.doi.org/10.15156/BIO/SH210481.07FU

123. Leski T, Pietras M, Rudawska M. Ectomycorrhizal fungal communities of pedunculate and sessile oak seedlings from bare-root nurseries. Mycorrhiza. 2010;20:179–190. http://dx.doi.org/10.1007/s00572-009-0278-6

124. Fraiture A, Otto P, editors. Distribution, ecology and status of 51 macromycetes in Europe. Results of the ECCF Mapping Programme. Meise: Botanic Garden Meise; 2015. (Scripta Botanica Belgica; vol 53).

125. Snowarski M. *Pisolithus arrhizus* (Scop.) Rauschert [Internet]. 2016 [cited 2016 May 12]. Available from: http://www.grzyby.pl/gatunki/Pisolithus_arrhizus.htm

126. Kõljalg U, Abarenkov K, Nilsson RH, Larsson KH, Aas AB, Adams R, et al. SH221092.07FU [Internet]. UNITE Community; 2015 [cited 2016 Jun 16]. Available from: http://dx.doi.org/10.15156/BIO/SH221092.07FU

127. Martín MP, García MA. How many species in the *Rhizopogon roseolus* group? Mycotaxon. 2009;109:111–128. http://dx.doi.org/10.5248/109.111

128. Domański Z. Grzyby Lasów Łochowskich. Warszawa: author-publisher; 2001.

129. Mleczko P. Mycorrhizal and saprobic macrofungi of two zinc wastes in southern Poland. Acta Biol Crac Ser Bot. 2004;46:25–38.

130. Mleczko P, Kozak M, Zubek S. *Russula medullata* (Russulales, Basidiomycota): a new species in the mycobiota of Poland. Pol Bot J. 2010;55(2):483–488.

131. Domański Z. Nowe stanowiska rzadkich i interesujących grzybów w Polsce. Warszawa: author-publisher; 1997.

132. Krotoski T. Chronione i rzadkie gatunki grzybów wielkoowocnikowych Góry Jasieniowej na Podgórzu Cieszyńskim. Centrum Dziedzictwa Przyrody Górnego Śląska, Katowice. Natura Silesiae Superioris. 2009;12:33–44.

133. Snowarski M. *Tricholoma aurantium* (Schaeff.) Ricken [Internet]. 2016 [cited 2016 May 12]. Available from: http://www.grzyby.pl/gatunki/Tricholoma_aurantium.htm

134. Snowarski M. *Tricholoma populinum* Lange [Internet]. 2016 [cited 2016 May 12]. Available from: http://www.grzyby.pl/gatunki/Tricholoma_populinum.htm

135. Kõljalg U, Abarenkov K, Nilsson RH, Larsson KH, Aas AB, Adams R, et al. SH440634.07FU [Internet]. UNITE Community; 2015 [cited 2016 Jun 16]. Available from: http://dx.doi.org/10.15156/BIO/SH440634.07FU

136. Jumpponen A, Egerton-Warburton LM. Mycorrhizal fungi in successional environments – a community assembly model incorporating host plant, environmental and biotic filters. In: Dighton J, White JF, Oudemans P, editors. The fungal community. Its organization and role in the ecosystem. 3rd ed. Boca Raton, FL: CRC Press, Taylor & Francis; 2005. p. 139–180. (Mycology; vol 23).

137. Bidartondo MI, Bruns TD, Blackwell M, Edwards I, Taylor AFS, Horton T, et al. Preserving accuracy in GenBank. Science. 2008;319(5870):1616–1616.

138. Schoch CL, Robbertse B, Robert V, Vu D, Cardinali G, Irinyi L, et al. Finding needles in haystacks: linking scientific names, reference specimens and molecular data for Fungi. Database. 2014;1–21. http://dx.doi.org/10.1093/database/bau061