

DOI: 10.5586/am.1124

Publication history

Received: 2019-01-06
Accepted: 2019-03-22
Published: 2019-12-05

Handling editor

Wojciech Pusz, Faculty of Life Sciences and Technology, Wrocław University of Environmental and Life Sciences, Poland

Authors' contributions

BG: field research, identification of the specimens, manuscript preparation; AK, AS, TS, PC: field research, identification of the specimens, correction of the manuscript; TP: field research, photographic documentation; GD: field research, photographic documentation, correction of the manuscript

Funding

This research has been financed with authors' private funds and cofinanced by the Bieszczady National Park in 2011 (field studies for Park protection plan). Publishing of the manuscript was covered by the statutory funds of the Institute of Forest Sciences, Warsaw University of Life Sciences – SGGW.

Competing interests

No competing interests have been declared.

Copyright notice

© The Author(s) 2019. This is an Open Access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by/4.0/), which permits redistribution, commercial and noncommercial, provided that the article is properly cited.

Citation

Gierczyk B, Kujawa A, Szczepkowski A, Ślusarczyk T, Pachlewski T, Chachuła P, et al. Macrofungi of the Bieszczady Mountains. *Acta Mycol.* 2019;54(2):1124. <https://doi.org/10.5586/am.1124>

ORIGINAL RESEARCH PAPER

Macrofungi of the Bieszczady Mountains

Błażej Gierczyk^{1*}, Anna Kujawa², Andrzej Szczepkowski³, Tomasz Ślusarczyk⁴, Tomasz Pachlewski⁵, Piotr Chachuła⁶, Grażyna Domian⁷

¹ Faculty of Chemistry, Adam Mickiewicz University in Poznań, Uniwersytetu Poznańskiego 8, 61-614 Poznań, Poland

² Institute for Agricultural and Forest Environment, Polish Academy of Sciences, Bukowska 19, 60-809 Poznań, Poland

³ Institute of Forest Sciences, Warsaw University of Life Sciences – SGGW, Nowoursynowska 159, 02-776 Warsaw, Poland

⁴ Naturalists' Club, 1 Maja 22, 66-200 Świebodzin, Poland

⁵ Independent researcher, Poland

⁶ Pieniny National Park, Jagiellońska 107B, 34-450 Krościenko nad Dunajcem, Poland

⁷ West-Pomeranian Nature Society, Wąska 13, 71-415 Szczecin, Poland

* Corresponding author. Email: hanuman@amu.edu.pl

Abstract

The Bieszczady Mts, a mountain range in SE Poland, is a hot spot of fungal richness and diversity in Poland. This paper summarizes 5 years of studies in the Bieszczady Mts, as well as previously published research. A total of 1,377 macromycetes taxa were found, including many (464) which were protected, red-listed, or very rare in Poland. Thirty-eight taxa (nine Ascomycota and 29 Basidiomycota) have been reported in Poland for the first time: *Agrocybe gibberosa*, *Auriporia aurulenta*, *Bolbitius variicolor*, *Bulgariella pulla*, *Chaetosphaerella phaeostroma*, *Clitocybe subspadicea*, *Clitopilus passeckerianus*, *Cortinarius anomalus* var. *subcaligatus*, *C. fervidus*, *C. flexipes* var. *inolens*, *C. sylvae-norvegicae*, *Cudoniella tenuispora*, *Entoloma bisporigerum*, *E. olorinum*, *E. poliopus* var. *parvisporigerum*, *E. sericeoides*, *Galerina caulocystidiata*, *Gymnopilus josserandii*, *Hymenoscyphus subferrugineus*, *Hypholoma olivaceotinctum*, *Inocybe queletii*, *Laccaria altaica*, *Lactarius romagnesii*, *L. rostratus*, *Mycena epipterygia* var. *atroviscosa*, *M. epipterygia* var. *candida*, *M. polygramma* f. *candida*, *Octavianina lutea*, *O. mutabilis*, *Pachyella violaceonigra*, *Panaeolus papilionaceus* var. *capitatocystis*, *Phaeocollybia jennyae*, *Psathyrella almerensis*, *Pyrenopeziza inornata*, *Scutellinia torrentis*, *Tricholoma basirubens*, *Tricholomopsis flammula*, and *Vibrissea decolorans*. For all new taxa, short descriptions based on the collected material have been provided.

Keywords

Bieszczady National Park; Ascomycota; Basidiomycota; diversity

Introduction**Study area**

The Bieszczady Mts are a mountain range located in Poland, Slovakia, and Ukraine making up the western part of the Outer Eastern Carpathians. They are part of the Beskidy Mts, a series of the mountain ranges lying between the Czech Republic and Ukraine. The Polish Bieszczady Mts are classified as the Western Bieszczady Mts and are part of the mesoregion of the Beskidy Lesiste located in the eastern part of Podkarpackie Province [1,2]. The Polish part of this range occupies an area of ca. 1,450 km² and is bounded by Polish-Ukrainian and Polish-Slovakian borders in the south and east, respectively; the Łupkowska Pass, Ośława valley, and the road between Szczawne and Czaszyn in the

west; and by the Leskie Foothills, the San River valley, and the line connecting N shore of the Victorini bay and the borderland village Michniowiec in the north (Fig. 1). This definition of the Bieszczady Mts also includes the Otryt and Ostre ranges. It is worth noting that the legend of “the wild Bieszczady” is still alive in Poland; therefore, many adjacent regions are often called “the Bieszczady Mts” (e.g., the Sanocko-Turczańskie Mts, Słonne Mts, or Przemyskie Foothills) for mainly commercial reasons. This misconception is reproduced in many books, scientific papers, websites, touristic folders, or popular tourist guides; however, these areas are not part of the Bieszczady Mts in terms of geology and physio-geography. The topography of the Bieszczady Mts has a characteristic system of straight ridges arranged from NW to SE, separated by deep valleys. The highest peak is Tarnica Mt (1,346 m a.s.l.), while the maximal denivelation is 700 m. The hydrological network is dense with numerous springs. Unlike the other parts of the Polish Carpatians, the Bieszczady Mts contain a high concentration of raised bogs, located mainly in the San and Wołosate valleys [1,3,4].

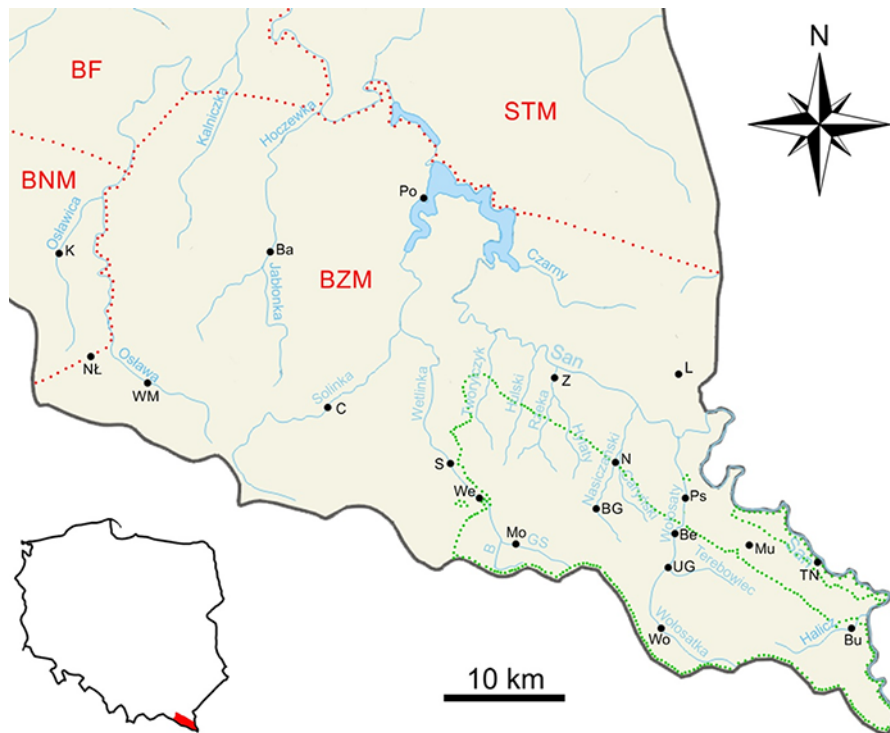


Fig. 1 Location of the area studied. Red dotted lines – borders of mesoregions (BZM – Bieszczady Zachodnie Mts; STM – Sanocko-Turczańskie Mts; BNM – Beskid Niski Mts; BF – Bukowskie Foothills). Green dotted lines – borders of the Bieszczady National Park. Black dots – selected villages (Ba – Baligród; Be – Bereżki; BG – Brzegi Górne; Bu – Bukowiec; C – Cisna; K – Komańcza; L – Lutowska; Mo – Moczarne; Mu – Muczne; NŁ – Nowy Łupków; Po – Polańczyk; Ps – Pszczeliny; S – Smerek; TN – Tarnawa Niżna; UG – Ustrzyki Górne; We – Wetlina; Wo – Wołosate; Z – Zatwarnica). Blue lines – major rivers and streams (B – Beskidnik; GS – Górna Solinka).

Approximately 80% of the Bieszczady Mts are covered by forests. The most widespread are beech forests (*Dentario glandulosae-Fagetum*, *Luzulo nemorosae-Fagetum*), growing between the foothill and lower montane zones (Fig. 2). The stream valleys and seeps are covered by alder forests (*Caltho-Alnetum*, *Alnetum incanae*; Fig. 3). Communities with sycamore dominate (*Sorbo-Aceretum carpaticum*, *Lunario-Aceretum*, *Phyllitido-Aceretum*, *Aceri-Fagetum*) the upper montane zone, boulders, and rock outcroppings often at the upper forest margins, northern shady slopes, and deep valleys. In bogs and wet meadows, miscellaneous damp shrubs and forests occur, e.g., *Salicetum pentandro-cinereae*, *Vaccinio uliginosi-Pinetum*, *Vaccinio uliginosi-Betuletum pubescentis*, or *Sphagno-Piceetum*. Natural coniferous mountain forests (*Abieti-Piceetum montanum*) are rare; however, artificial spruce and fir forests are quite common, e.g., in the upper San valley. A unique



Fig. 2 Carpathian beech forest (*Dentario glandulosae-Fagetum*) on the slopes of the Otryt mountain range, Bieszczady Mts (Aug 16, 2009). Photography by G. Domian.

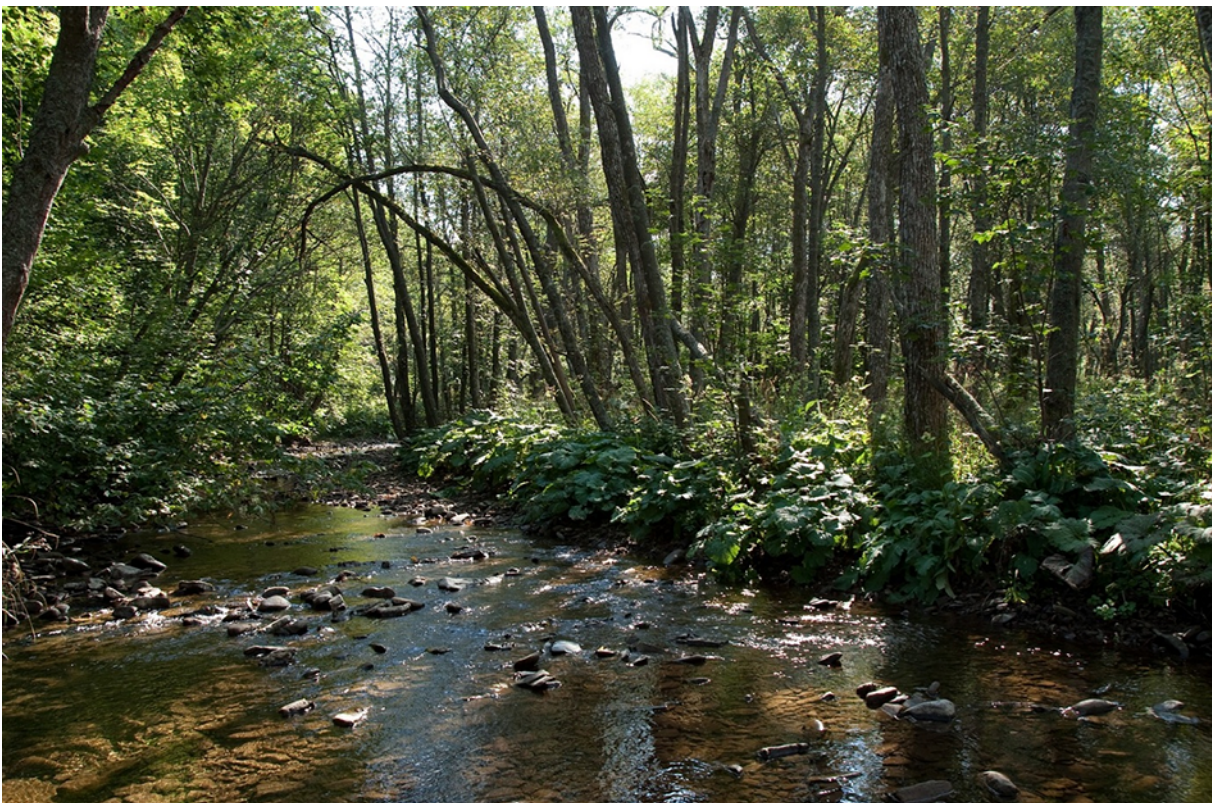


Fig. 3 Grey alder community (*Alnetum incanae*) in Wołosatka valley, Bieszczady Mts (Sep 2, 2011). Photography by K. Kujawa.

feature for the Bieszczady Mts are the shrub communities with green alder (Fig. 4), *Athyrio distentifoliae-Sorbetum alnetosum viridae*, *Pulmonario filarszkyanae-Alnetum viridis*, *Calamagrostis-Alnus viridis*, or *Salix silesiaca-Alnus viridis* in subalpine areas. Hornbeam forests are rare and represented only by *Tilio-Carpinetum*; additionally, common alder communities are extremely rare. The nonforest plant communities in the Bieszczady Mts were strongly influenced by the pasturage of sheep, goats, and horses in the past. Shepherding has resulted in the formation of unique landforms in the subalpine zone (above 1,200 m a.s.l.), called polonynas (Polish: *poloniny*; Fig. 5), which are characteristic of the Eastern Beskidy Mts. Over 40 plant communities have been described in the subalpine zone of the Polish Bieszczady Mts. In the lower montane zone, over 50 types of nonforest plant communities are present. Of these, raised bogs (*Oxycocco-Sphagneteta*; Fig. 6), poor fens (*Scheuchzerio-Caricetea*), and poor meadows with *Nardus stricta* are the most valuable [3,5].



Fig. 4 Green alder (*Alnus viridis*) shrubs near Tarnica Mt, Bieszczady Mts (Jul 17, 2006). Photography by R. Sobon.

The soils of the Bieszczady Mts are derived from the Carpathian Flysch Belt rocks. The most common soils are eutrophic and dystrophic loamy brown earths (cambisols), shallow initial soils (leptosols, regosols), and soils characteristic of moist habitats, such as river banks (fluviosols), bogs (histosols), or meadows (gleysols) [3]. From a mycological point of view, the major soil characteristic influencing the fungal diversity is their pH. The soils of Bieszczady Mts are, in general, acidic or neutral (pH = 5.5–7.0 in water) with low concentrations of carbonates [$\text{Ca}(\text{Mg})\text{CO}_3$]. This limits the number of fungal taxa, e.g., the calciphilous species of hypogeous or boletoid fungi do not occur in Bieszczady Mts.

Due to their unique character, and natural and cultural value, the Bieszczady Mts are protected. Over 290 km² are protected as the Bieszczady National Park (BdPN). Established in 1973, it has since been expanded a few times and is the third largest national park in Poland. The BdPN buffer zone is over 520 km². BdPN covers the most valuable parts of the Polish Bieszczady Mts. In 1992, the East Carpathian Biosphere Reserve was



Fig. 5 Subalpine zone (polonynas) on Kopa Bukowa Mt, Bieszczady Mts (Sep 10, 2011). Photography by K. Kujawa.



Fig. 6 Raised bog "Dzwiniacz" in the upper San valley, Bieszczady Mts (Aug 18, 2009). Photography by G. Domian.

established by the UNESCO. It is a transboundary protection project that includes parts of Poland, Ukraine, and Slovakia. The entire Polish section is located in the Bieszczady Mts and is almost 1,090 km² large. It includes the BdPN and two landscape parks: Ciśniańsko-Wetliński Landscape Park and San Valley Landscape Park. The Bieszczady Mts are also protected as two Natura 2000 areas: Special Protection Area (Bieszczady SPA, PLC180001) and part of the Basin of the Upper San Special Area of Conservation (PLH180021) [6,7]. Fourteen natural reserves have been established in the Bieszczady Mts: Cisy na Górze Jawor, Gołoborze, Hulskie im. prof. Stefana Myczkowskiego, Krywe, Nad Jeziorem Myczkowieckim, Olsza kosa w Stężnicy, Olszyna Łęgowa w Kalnicy, Przełom Oślawy pod Duszatynem, Przełom Sanu pod Grodziskiem, Sine Wiry, Śnieżycza wiosenna w Dwerniczku, Woronikówka, Zakole, and Zwieżło [6,8]. Moreover, seven landscape-nature complexes (Wieś Krywe, Młyn w Hulskim, Cerkiew w Hulskim, Cmentarz w Ruskiem, Młyn w Dwerniku, Wieś Smolnik, Cmentarz w Stuposianach) and 44 ecological sites have been established in the Bieszczady Mts [7].

Current state of mycological studies in the Bieszczady Mts

Highly diverse habitats and their largely natural character results an above average macromycete richness. The first mycological data from the Bieszczady Mts were published by Gumińska as a result of an 11-day trip of Polish mycologists (S. Czyżewska, S. Domański, B. Gumińska, M. Lisiewska, A. Nespiak, A. Skirgiełło, and W. Truszkowska) to the mountain range, in the vicinity of the village Wetlina [9]. The interesting results obtained from this trip inspired further studies by a group of scientists from various academic centers and specializing in different systematic groups. T. Majewski and W. Wojewoda joined the previous participants. Three excursions were made between 1960 and 1970, and their findings were published in four papers [10–13]. A preliminary red list of macromycetes of the Polish Carpathians was published in 1991, while a checklist of the corticioid fungi of this region was published in 1999 [14,15]. Both were based on earlier published data including those from the Bieszczady Mts. No further systematic mycological studies were conducted in the area of the Bieszczady Mts until 2008; however, some data have been published in many chorological or taxonomic papers and monographs (see references list). In 2008, Gierczyk and coworkers started a 5-year study of the mycobiota of the Bieszczady Mts. The first results (together with all available literature data) were published in 2009 [16]. In 2011, a protection plan for the BdPN was prepared by Kujawa et al.; however, it was not published. A short description of the characteristics of the mycobiota of the BdPN was prepared and published in the monograph on fortieth anniversary of the Park [17]. Selected results from this study have also been published by the participants of this project in papers on particular species or systematic groups [18–27]. Some species from the Bieszczady Mts have also been reported in the internet Database of Protected and Endangered Fungi (GREJ) (e.g., [28–34]). The diversity of lichenized or lichenicolous macromycetous fungal species (*Lichenomphalia*, *Multiclavula*, *Tremella*) have also been published in papers and monographs on the Bieszczady Mts lichen biota [35–42]. In last few years, two forestry science reports were published, containing lists of the observed fungi [43,44].

In the current paper, all available data on the Bieszczady Mts mycobiota have been reviewed and published, including the published reports and the authors' unpublished data.

Material and methods

Route studies were performed from 2008 to 2013. Every year, 3–5 weeks were devoted to exploration. Almost all types of habitats characteristic of the Bieszczady Mts were checked each season. The specimens collected were identified by standard methods used in fungal taxonomy, i.e., determination of micro- and macrocharacters using a binocular or optical microscopy. Standard staining techniques, including an aqueous ammonia solution, 10% KOH in water, Congo red in ammonia, Melzer reagent, sulfovanilin, aniline (cotton) blue in lactophenol or lactic acid, brilliant cresyl blue

in water, acetocarmine, or carbol fuchsin, were used. Macrochemical reaction tests included aqueous ammonia solution, 10% KOH in water, FeSO₄ in water, and guaiac resin in ethanol. Specimens were identified using the following general keys and atlases: *Funga Nordica* [45,46], *Nordic Macromycetes* [47–49], *Flora Agaricina Neerlandica* [50–55], *Röhrlinge und Blätterpilze in Europa* [56], *Die Nichtblätterpilze, Gallertpilze und Bauchpilze* [57], *Fungi of Switzerland* [58–63], *Pilzkompendium* [64–71], and *Microfungi on land plants* [72]. The following monographs and taxonomic papers were also used: *Agaricus* [73–75], *Amanita* [76,77], *Conocybe* and *Pholiotina* [78], *Crepidotus* [79], *Entoloma* [80,81], *Galerina* [82–85], *Gymnopilus* [86], *Helvella* [87], *Hemimycena* and *Xeromphalina* [88], *Hygrophorus* and *Hygrocybe* [89–91], *Inocybe* [92,93], *Lactarius* [94,95], *Peziza* [96], *Ramaria* [97], *Russula* [98,99], *Scutellinia* [100], *Tricholoma* [101,102], Boletales [103,104], Geoglossaceae [105–107], Strophariaceae [108,109], clavarioid fungi [110,111], jelly fungi [112,113], marasmioid fungi [114], hypogeous fungi [115], and gasteromycetes [116]. Ascomycota were also determined based on the keys, iconography, and descriptions provided in a DVD edition by Baral [117]. Taxa names follow *Funga Nordica* 2 [46] (except for a few taxa, as indicated in the species list) when available, otherwise names from the MycoBank Database [118] are used. The macrofungi group has been arbitrarily delimited as species forming sporocarps (basidiomata, ascomata) and stromata visible to the naked eye. In general, this overlaps with the concept accepted by the authors of *Nordic Macromycetes* [47–49], *Funga Nordica* [46], and *Fungi of Switzerland* [58–63], i.e., representatives of Boliniales, Chaetosphaeriales, Diaporthales, Hypocreales, Pleosporales, Rhytismatales, Sordariales, Taphrinales, Trichosphaeriales, and Xylariales have been included on the list. The checklist by Mirek et al. [119] has been used for the names of flowering plants and pteridophytes, while the checklist by Ochyra et al. [120] was used for the names of mosses. The distribution of species in Poland have been compiled based on checklists of Polish micro- and macromycetes [121–123], lichens and lichenicolous fungi [124,125], and the database of Polish mycological literature [126]. The threat categories were assigned according to “Red list of macrofungi in Poland” [127], and the protected species were indicated according to the Ministry of the Environment regulation from 2014 [128]. Dry specimens have been deposited in the Błażej Gierczyk private fungarium and the Fungarium of the Division of Mycology and Forest Phytopathology, Warsaw University of Life Sciences – SGGW (WAML). Geographic names from the touristic-toponymic map by Krukar [129] have been used.

Results

The complete list of macrofungi species found by the authors in the Bieszczady Mts together with the associated literature data has been supplied as supportive material (Appendix S1). Data is presented according to the following scheme: species name; threat category, species protection; LR: literature data (with synonymous names used by cited authors); PP: data included in the Bieszczady National Park Protection Plan (2011; unpublished); UP: unpublished data from the years 2008–2013. Notes: additional information and comments (doubts, misconceptions, errors, etc.); description of the taxa new to Poland.

For PP and UP records, localities, phenological information, habitats, and substrata have been reported. In the LR section, the paper by Gierczyk et al. [16] has been cited only if this paper provided original data.

Discussion

The available literature on the fungal diversity in the Polish Bieszczady Mts has been reviewed and the new data collected by the authors in the years 2008–2015 is presented. The current list of macrofungi species identified in the Bieszczady Mts includes 1,377 species, subspecies, varieties, and forms: 235 taxa of Ascomycota and 1,142 taxa of Basidiomycota (in the Bieszczady National Park 1,206 species: 196 of Ascomycota and

1,010 of Basidiomycota) comprising 30% of the total number of macromycetes known in Poland. A further 71 taxa are supported by dubious data (16 Ascomycota and 55 Basidiomycota). The number of taxa from the Bieszczady NP listed by Kujawa [130] is higher (1,304), because it includes some unpublished data on corticioid fungi collected by Dariusz Karasiński and some dubious data. This mycobiota richness makes the Bieszczady Mts the third richest region in macrofungi in Poland, after Białowieża Primeval Forest (ca. 2,000 known taxa) [131] and Kampinos NP (ca. 1,600 taxa) [132]. In comparison, 1,233 taxa of macrofungi have been reported from the Slovakian Poloniny National Park [133–135]. Unfortunately, the mycological data for Uzhanian National Park (Ukraine) are not available. The official website of the Nature Reserve Fund of Ukraine mentions a total of 66 fungal species from Uzhanian National Park [136]. Many taxa recorded in the Bieszczady Mts are very valuable (Tab. 1). Four species (*Hericium erinaceum*, *Hydnellum conrescens*, *Corticium polygonioides*, and *Skeletocutis odora*) are strictly protected and another 14 (*Bondarzewia mesenterica*, *Clavariadelphus pistillaris*, *Gomphus clavatus*, *Hericium alpestre*, *H. coralloides*, *Inonotus obliquus*, *Morchella conica*, *M. esculenta*, *Ptychoverpa bohemica*, *Sparassis brevipes*, *Strobilomyces strobilaceus*, *Tremiscus helvelloides*, *Verpa conica*, and *Xerocomus pelletieri*) are partially protected in Poland. Two hundred and ninety taxa recorded in the Bieszczady Mts are red-listed comprising 30% of all species in the Polish red list. In the current paper, 319 taxa not previously known to be present in the Bieszczady Mts are reported. They include 38 taxa (nine Ascomycota and 29 Basidiomycota) hitherto not known in Poland: *Agrocybe gibberosa*, *Auriporia aurulenta* (Fig. 7), *Bolbitius variicolor*, *Bulgariella pulla* (Fig. 8), *Chaetosphaerella phaeostroma*, *Clitocybe subspadicea*, *Clitopilus passeckerianus* (Fig. 9), *Cortinarius anomalus* var. *subcaligatus*, *C. fervidus*, *C. flexipes* var. *inolens*, *C. sylvae-norvegicae*, *Cudoniella tenuispora* (Fig. 10), *Entoloma bisporigerum*, *E. olorinum*, *E. poliopus* var. *parvisporigerum*, *E. sericeoides*, *Galerina caulocystidiata*, *Gymnopilus josserandii*, *Hymenoscyphus subferrugineus*, *Hypholoma olivaceotinctum*, *Inocybe*

Tab. 1 Rare, protected, and red-listed macrofungi in the Bieszczady Mts.

	Ascomycota	Basidiomycota	Total
Strictly protected species	0	4	4
Partially protected species	5	9	14
Red-listed species	15	275	290
Category Ex	0	4	4
Category E	1	82	83
Category V	4	63	67
Category R	10	115	125
Category I	0	11	11
Taxa rare in Poland (known from up to three contemporary localities)	44	147	191
Taxa known in Poland only from the Bieszczady Mts	20	57	77
Taxa with locus classicus in the Bieszczady Mts	0	2	2
Taxa not mentioned Polish on checklists of fungi	18	139	157
Indicator species of nature value of beech forests follow on European scale [137]	0	16	16
Species of special interest [139]	3	59	62
Class A	1	4	5
Class B	0	29	29
Class C	2	26	28



Fig. 7 Basidiomata of *Auriporia aurulenta* A. David, Tortič & Jelič from the Bieszczady Mts (Sep 5, 2011). Photography by K. Kujawa.



Fig. 8 Ascomata of *Bulgariella pulla* (Fr.) P. Karst. from the Bieszczady Mts (Aug 8, 2009). Photography by G. Domian.



Fig. 9 Basidiomata of *Clitopilus passeckerianus* (Pilát) Singer from the Bieszczady Mts (Aug 1, 2011). Photography by K. Kujawa.



Fig. 10 Ascomata of *Cudoniella tenuispora* (Cooke & Massee) Dennis from the Bieszczady Mts (Jun 2, 2015). Photography by T. Pachlewski.

queletii, *Laccaria altaica*, *Lactarius romagnesii*, *L. rostratus*, *Mycena epipterygia* var. *atroviscosa*, *M. epipterygia* var. *candida*, *M. polygramma* f. *candida*, *Octavianina lutea*, *O. mutabilis* (Fig. 11), *Pachyella violaceonigra*, *Panaeolus papilionaceus* var. *capitatoscystis*, *Phaeocollybia jennyae* (Fig. 12), *Psathyrella almerensis*, *Pyrenopeziza inornata*, *Scutellinia torrentis* (Fig. 13), *Tricholoma basirubens*, *Tricholomopsis flammula*, *Vibrissea decolorans* (Fig. 14). This makes Polish Bieszczady Mts a hot spot of fungal diversity, in both Poland and Europe. Sixteen taxa listed on the list of indicators of the nature value of beech forests in Europe [137] have been found in the Bieszczady Mts. This is higher than that reported for other beech forests of European importance including Poloniny National Park (Slovakia) [134,138], the forest with the hitherto highest value published (15). The number of the taxa designated as species of special interest (SSI), which are selected from wood-inhabiting fungi in European beech forests [139], is also high (62). Reported values of this parameter for other beech forests in Europe are lower varying from 23 (Poloniny National Park, Slovakia) to 51 (UNESCO World Natural Heritage Kellerwald-Edersee National Park, Germany) [134]. Many SSI species observed in the Bieszczady Mts are common within this area, e.g., *Hericium coralloides* or *Dentipellis fragilis*. Many other taxa selected by Slovakian mycologists as species of special interest during the study of beech forests in that country (e.g., *Antrodiella pallescens* or *Pereniporia narymica*) [140] have also been found in the Polish Bieszczady Mts. One should note that the evaluation systems proposed by Christensen et al. [137] and Ódor et al. [139] were based on Western and Southern European data, therefore need to be tested and adjusted for Central European forest conditions. The Bieszczady Mts are the only place where 77 taxa are found in Poland making it an important refuge of macrofungi. Another 114 taxa reported in the Bieszczady Mts are extremely rare in Poland and have only been found in three or fewer localities in this country. Its unique ecosystems (e.g., *Alnus viridis* communities or postpasture habitats) must be protected to preserve the macrofungi richness of this mountain range. The unusually high availability of forest biomass in the Bieszczady Mts region [141], the most important parameter determining the presence of many rare, wood-inhabiting fungi, should be especially emphasized. It is difficult to indicate the regions in the Bieszczady Mts with the highest mycological value. The most interesting findings have been made on the northern slopes, in humid stream valleys, e.g., Hylaty Valley or Górna Solinka Valley, and in places with high concentrations of large, dead tree trunks on the forest floor. One could expect further



Fig. 11 Basidiomata of *Octavianina mutabilis* E. Bommer & M. Rousseau from the Bieszczady Mts (Nov 29, 2011). Photography by P. Chachuła.

valuable findings, as many fungal groups (genera *Russula* and *Cortinarius*, corticioid and hypogeous fungi, small Ascomycota) are still undercollected and underrepresented on the current species lists. Moreover, although field work has been conducted throughout the Bieszczady Mts, the greatest emphasis has been placed on the study of the Bieszczady National Park mycobiota. In consequence, the northern and western parts of the Bieszczady Mts have only been cursorily studied. Analysis of data on the Poloniny NP has showed that 462 species of macrofungi known from the Slovakian part of the Eastern Carpathians have not been observed yet in the Bieszczady Mts. Some of these, for example fungi inhabiting old oak trees and logs (e.g., *Buglossoporus quercinus*), are unlikely to be collected in the Bieszczady Mts due to the absence of suitable habitats and substratum; however, most of these 462 taxa probably also grow on the Polish side of the border. Almost 1,840 macrofungi taxa are known from the Polish and Slovakian parts of the East Carpathian Biosphere Reserve.



Fig. 12 Basidioma of *Phaeocollybia jennyae* (P. Karst.) Romagn. from the Bieszczady Mts (Aug 2, 2011). Photography by K. Kujawa.



Fig. 13 Ascoma of *Scutellinia torrentis* (Rehm) T. Schumach. from the Bieszczady Mts (Aug 2, 2011). Photography by K. Kujawa.



Fig. 14 Ascomata of *Vibrissea decolorans* (Saut.) A. Sánchez & Korf (Jun 3, 2010). Photography by T. Pachlewski.

Acknowledgments

We thank Dariusz Karasiński, Kamil Kędra, Krzysztof Kujawa, Marek Snowarski, Michał Wójtowski, and Maciej Zalas for joint trips to the Bieszczady Mts. Our thanks also go to Tomasz Karabin for sharing with us data on the occurrence of some vernal Ascomycota in the vicinity of Krzywe village. We also thank Krzysztof Kujawa and Ryszard Soboń for sharing photographs. We wish to thank Beata Łyszkowska for providing assistance with linguistic correction and proofreading. Special thanks go to the management and staff of the Bieszczady National Park for help during field works.

Supplementary material

The following supplementary material for this article is available at <http://pbsociety.org.pl/journals/index.php/am/rt/suppFiles/am.1124/0>:

Appendix S1 Macrofungi of the Bieszczady Mountains – list of species.

References

- Kondracki J. Geografia regionalna Polski. Warszawa: PWN; 2002.
- Balon J, Jodłowski M. Regionalizacja fizycznogeograficzna Karpat Zachodnich – studium metodologiczne. In: Ziąja W, Jodłowski M, editors. Struktura środowiska przyrodniczego a fizjonomia krajobrazu. Kraków: Instytut Geografii i Gospodarki Przestrzennej Uniwersytetu Jagiellońskiego; 2014. p. 85–106.
- Górecki A, Zemanek B, editors. Bieszczadzki Park Narodowy – 40 lat ochrony. Ustrzyki Górne: Bieszczadzki Park Narodowy; 2016.
- Radwański K, Szymczak M, editors. Atlas Gór Polski. Sudety – Karpaty – Góry Świętokrzyskie. Warszawa: ExpressMap; 2008.
- Jasiewicz A. Rośliny naczyniowe Bieszczadów Zachodnich. Warszawa: Państwowe Wydawnictwo Naukowe; 1965. (Monographiae Botanicae; vol 20). <https://doi.org/10.5586/mb.1965.003>
- Mirek Z, Nikel A, Paul W, Wilk Ł, editors. Ostoje roślinne w Polsce. Kraków: Instytut Botaniki im. W. Szafera, Polska Akademia Nauk; 2005.
- Centralny rejestr form ochrony przyrody [Internet]. [cited 2018 Jun 5]. Available from: <http://crfop.gdos.gov.pl/CRFOP/>
- Rączkowski G, Walczak M, Smogorzewska M. Rezerваты przyrody w Polsce Południowej. Warszawa: Instytut Ochrony Przyrody; 2007.
- Gumińska B. Wycieczka mikologiczna w Bieszczady. Wiad Bot. 1959;3:135–136.
- Domański S, Gumińska B, Lisiewska M, Nespiak A, Skirgiełło A, Truszkowska W. Mikoflora Bieszczadów Zachodnich (Wetlina 1958). Monographiae Botanicae. 1960;10(2):159–237. <https://doi.org/10.5586/mb.1960.013>
- Domański S, Gumińska B, Lisiewska M, Nespiak A, Skirgiełło A, Truszkowska W. Mikoflora Bieszczadów Zachodnich. II. (Ustrzyki Górne, 1960). Monographiae Botanicae. 1963;15:3–75. <https://doi.org/10.5586/mb.1963.002>
- Domański S, Gumińska B, Lisiewska M, Nespiak A, Skirgiełło A, Truszkowska W. Mikoflora Bieszczadów Zachodnich. III. (Baligród, 1962). Acta Mycol. 1967;3(1):63–114. <https://doi.org/10.5586/am.1967.003>
- Domański S, Lisiewska M, Majewski T, Skirgiełło A, Truszkowska W, Wojewoda W. Mikoflora Bieszczadów Zachodnich. IV. (Zatwarnica, 1965). Acta Mycol. 1970;6(1):129–179. <https://doi.org/10.5586/am.1970.013>
- Wojewoda W. Grzyby kortycjoidalne polskich Karpat. Wiad Bot. 1999;43(3–4):19–30.
- Wojewoda W. Pierwsza czerwona lista grzybów wielkoowocnikowych (macromycetes) zagrożonych w polskich Karpatach. Studia Ośrodka Dokumentacji Fizjograficznej. 1991;18:239–261.
- Gierczyk B, Chachuła P, Karasiński D, Kujawa A, Kujawa K, Pachlewski T, et al. Grzyby wielkoowocnikowe Polskich Bieszczadów. Część I. Parki Narodowe i Rezerваты Przyrody. 2009;39(3):3–100.
- Kujawa A, Szczepkowski A, Gierczyk B, Ślusarczyk T, Chachuła P, Karasiński D. Grzyby wielkoowocnikowe w Bieszczadzki Parku Narodowym. In: Górecki A, Zemanek B, editors. Bieszczadzki Park Narodowy – 40 lat ochrony. Ustrzyki Górne: Bieszczadzki Park Narodowy; 2016. p. 199–210.
- Gierczyk B, Halama M, Kujawa A, Zalas M. *Pholiota limonella* – gatunek pomijany?

- Fragm Florist Geobot Pol. 2011;18(1):147–158.
19. Gierczyk B, Kujawa A, Pachlewski T, Szczepkowski A, Wójtowski M. Rare species of the genus *Coprinus* Pers. s. lato. Acta Mycol. 2011;46(1):27–73. <https://doi.org/10.5586/am.2011.003>
 20. Gierczyk B, Kujawa A, Szczepkowski A. New to Poland species of the broadly defined genus *Coprinus* (Basidiomycota, Agaricomycotina). Acta Mycol. 2014;49(2):159–188. <https://doi.org/10.5586/am.2014.020>
 21. Gierczyk B, Kujawa A, Szczepkowski A, Chachuła P. Rare species of *Lepiota* and related genera. Acta Mycol. 2011;46(2):137–178. <https://doi.org/10.5586/am.2011.010>
 22. Kudławiec B, Kujawa A, Ślusarczyk T, Gierczyk B. Nowe stanowiska gnojanki różowawej *Bolbitius coprophilus* (Peck) Hongo w Polsce. Przegląd Przyrodniczy. 2010;21(1):60–64.
 23. Kujawa A, Gierczyk B, Szczepkowski A, Karasiński D, Wołkowycki M, Wójtowski M. Ocena obecnego stanu zagrożenia gatunków z rodzaju *Geastrum* w Polsce. Acta Botanica Silesiaca. 2012;8:5–42.
 24. Ślusarczyk T. Nowe stanowiska grzybów z rodzaju zasłonak (*Cortinarius*) w Polsce. Przegląd Przyrodniczy. 2013;24(4):42–68.
 25. Szczepkowski A. *Sarcodontia crocea* (Polyporales, Basidiomycota) in Poland – distribution and decay ability in laboratory conditions. Pol Bot J. 2010;55(2):489–498.
 26. Szczepkowski A, Domian G, Kudławiec B, Kujawa A. Nowe stanowiska i nowe substraty suchogłównki korowej *Phleogena faginea* (Fr.) Link w Polsce. Chrońmy Przyrodę Ojczyzną. 2009;65(5):365–374.
 27. Szczepkowski A, Kujawa A, Halama M. *Volvariella bombycina* (Schaeff.) Singer in Poland: notes on its ecology, distribution and conservation status. Pol J Environ Stud. 2013;22(1):41–51.
 28. Kujawa A, Gierczyk B. Rejestr gatunków grzybów chronionych i zagrożonych. Część II. Podsumowanie roku 2006. Przegląd Przyrodniczy. 2007;28(3–4):3–70.
 29. Kujawa A, Gierczyk B. Rejestr gatunków grzybów chronionych i zagrożonych w Polsce. Część III. Wykaz gatunków przyjętych do rejestru w roku 2007. Przegląd Przyrodniczy. 2010;21(1):8–53.
 30. Kujawa A, Gierczyk B. Rejestr gatunków grzybów chronionych i zagrożonych w Polsce. Część IV. Wykaz gatunków przyjętych do rejestru w roku 2008. Przegląd Przyrodniczy. 2011;22(1):17–83.
 31. Kujawa A, Gierczyk B. Rejestr gatunków grzybów chronionych i zagrożonych w Polsce. Część VI. Wykaz gatunków przyjętych do rejestru w roku 2010. Przegląd Przyrodniczy. 2012;23(4):3–59.
 32. Kujawa A, Gierczyk B. Rejestr gatunków grzybów chronionych i zagrożonych w Polsce. Część VII. Wykaz gatunków przyjętych do rejestru w roku 2011. Przegląd Przyrodniczy. 2013;24(2):3–42.
 33. Kujawa A, Gierczyk B. Rejestr gatunków grzybów chronionych i zagrożonych w Polsce. Część VIII. Wykaz gatunków przyjętych do rejestru w roku 2012. Przegląd Przyrodniczy. 2013;24(4):10–41.
 34. Kujawa A, Gierczyk B, Ślusarczyk T. Rejestr gatunków grzybów chronionych i zagrożonych. In: Snowarski M, editor. Atlas grzybów Polski [Internet]. 2018 [cited 2018 Feb 20]. Available from: <http://www.grzyby.pl/rejestr-grzybow-chronionych-i-zagrozonych.htm>
 35. Kiszka J, Kościelniak R. Nowe i rzadkie gatunki porostów (Lichenes) w Bieszczadzkiem Parku Narodowym i jego otulinie. Część IV. Roczniki Bieszczadzkie. 2002;10:253–255.
 36. Kościelniak R. Tajemniczy świat porostów Bieszczadzkiego Parku Narodowego. Ustrzyki Górne: Bieszczadzki Park Narodowy; 2010.
 37. Kościelniak R. Porosty Bieszczadzkiego Parku Narodowego – stan obecny i przekształcenia w ostatnim półwieczu. Ustrzyki Dolne: Ośrodek Naukowo-Dydaktyczny Bieszczadzkiego Parku Narodowego; 2013. (Monografie Bieszczadzkie; vol 14).
 38. Kościelniak R, Betleja L, Baran D. *Multiclavula mucida* – epiksyliczny porost naturalnych lasów w Polsce południowo-wschodniej. Roczniki Bieszczadzkie. 2016;24:47–52.
 39. Kościelniak R, Kiszka J. Porosty torfowisk wysokich doliny górnego Sanu w Bieszczadzkiem Parku Narodowym. Roczniki Bieszczadzkie. 2004;12:39–49.
 40. Kościelniak R, Kiszka J. Porosty strefy wysokogórskiej Bieszczadzkiego Parku

- Narodowego – stan zachowania i zagrożenia. *Roczniki Bieszczadzkie*. 2006;14:123–133.
41. Kukwa M. New or interesting records of lichenicolous fungi from Poland III. *Herzogia*. 2005;18:37–46.
 42. Kukwa M, Czarnota P, Perz P. New or interesting records of lichenicolous fungi from Poland VIII. *Herzogia*. 2010;23(1):111–119. <https://doi.org/10.13158/hea.23.1.2010.111>
 43. Bartnik C, Wilczek AM, Szczybyło M. Grzyby wielkoowocnikowe w lesie gospodarczym i chronionym. *Studia i Materiały CEPL w Rogowie*. 2015;17(3):44–58.
 44. Kacprzyk M, Bednarz B, Kuźnik E. Dead trees in beech stands of the Bieszczady National Park: quantitative and qualitative structure of associated macrofungi. *Appl Ecol Environ Res*. 2014;12(2):325–344. https://doi.org/10.15666/aeer/1202_325344
 45. Knudsen H, Vesterholt J, editors. *Funga Nordica. Agaricoid, boletoid and cyphelloid genera*. Copenhagen: Nordsvamp; 2008.
 46. Knudsen H, Vesterholt J, editors. *Funga Nordica. Agaricoid, boletoid, clavarioid, cyphelloid and gasteroid genera*. 2nd ed. Copenhagen: Nordsvamp; 2012.
 47. Hansen L, Knudsen H, editors. *Nordic Macromycetes. Vol. 2. Polyporales, Boletales, Agaricales, Russulales*. Copenhagen: Nordsvamp; 1992.
 48. Hansen L, Knudsen H, editors. *Nordic Macromycetes. Vol. 3. Heterobasidioid, aphylophoroid and gasteromycetoid genera*. Copenhagen: Nordsvamp; 1997.
 49. Hansen L, Knudsen H, editors. *Nordic Macromycetes. Vol. 1. Ascomycetes*. Copenhagen: Nordsvamp; 2000.
 50. Bas C, Noordeloos ME, Kuyper TW, Vellinga EC. *Flora Agaricina Neerlandica. Critical monographs on families of agarics and boleti occurring in the Netherlands. Vol. 1*. Rotterdam: A. A. Balkema; 1988.
 51. Bas C, Noordeloos ME, Kuyper TW, Vellinga EC. *Flora Agaricina Neerlandica. Critical monographs on families of agarics and boleti occurring in the Netherlands. Vol. 2*. Rotterdam: A. A. Balkema; 1990.
 52. Bas C, Noordeloos ME, Kuyper TW, Vellinga EC. *Flora Agaricina Neerlandica. Critical monographs on families of agarics and boleti occurring in the Netherlands. Vol. 3*. Rotterdam: A. A. Balkema; 1995.
 53. Bas C, Noordeloos ME, Kuyper TW, Vellinga EC. *Flora Agaricina Neerlandica. Critical monographs on families of agarics and boleti occurring in the Netherlands. Vol. 4*. Rotterdam: A. A. Balkema; 1999.
 54. Noordeloos ME, Kuyper TW, Vellinga EC. *Flora Agaricina Neerlandica. Critical monographs on families of agarics and boleti occurring in the Netherlands. Vol. 5*. Lisse: A. A. Balkema Publishers; 2001.
 55. Noordeloos ME, Kuyper TW, Vellinga EC. *Flora Agaricina Neerlandica. Critical monographs on families of agarics and boleti occurring in the Netherlands. Vol. 6*. Boca Raton, FL: CRC Press; 2005.
 56. Horak E. *Röhrlinge und Blätterpilze in Europa*. Heidelberg: Elsevier; 2005.
 57. Jülich W. *Die Nichtblätterpilze, Gallertpilze und Bauchpilze. Aphylophorales, Heterobasidiomycetes, Gastromycetes*. Jena: VEB Gustav Fischer Verlag; 1984. [Kleine Kryptogamenflora; vol IIb(1)].
 58. Breitenbach J, Kränzlin F. *Fungi of Switzerland. Vol. 1. Ascomycetes*. Luzern: Verlag Mycologia; 1984.
 59. Breitenbach J, Kränzlin F. *Fungi of Switzerland. Vol. 2. Non gilled fungi. Heterobasidiomycetes, Aphylophorales, Gastromycetes*. Luzern: Verlag Mycologia; 1986.
 60. Breitenbach J, Kränzlin F. *Fungi of Switzerland. Vol. 3. Boletes and Agarics (Part 1). Strobilomycetaceae and Boletaceae, Paxillaceae, Gomphidiaceae, Hygrophoraceae, Tricholomataceae, Polyporaceae (lamellate)*. Luzern: Verlag Mycologia; 1991.
 61. Breitenbach J, Kränzlin F. *Fungi of Switzerland. Vol. 4. Boletes and Agarics (Part 2). Entolomataceae, Pluteaceae, Amanitaceae, Agaricaceae, Coprinaceae, Bolbitiaceae, Strophariaceae*. Luzern: Verlag Mycologia; 1995.
 62. Breitenbach J, Kränzlin F. *Fungi of Switzerland. Vol. 5. Boletes and Agarics (Part 3). Cortinariaceae*. Luzern: Verlag Mycologia; 2000.
 63. Kränzlin F. *Fungi of Switzerland. Vol. 6. Russulaceae*. Luzern: Verlag Mycologia; 2005.
 64. Ludwig E. *Pilzkompendium. Band 1. Abbildungen. Die kleineren Gattungen der Makromyzeten mit lamelligen Hymenophoren aus den Ordnungen Agaricales, Boletales*

- und Polyporales. Eching: IHW-Verlag; 2000.
65. Ludwig E. Pilzkompendium. Band 1. Beschreibungen. Die kleineren Gattungen der Makromyketen mit lamelligen Hymenophoren aus den Ordnungen Agaricales, Boletales und Polyporales. Eching: IHW-Verlag; 2001.
 66. Ludwig E. Pilzkompendium. Band 2. Abbildungen. Die größeren Gattungen der Agaricales mit farbigem Sporenpulver (ausgenommen Cortinariaceae). Berlin: Fungicon-Verlag; 2007.
 67. Ludwig E. Pilzkompendium. Band 2. Beschreibungen. Die größeren Gattungen der Agaricales mit farbigem Sporenpulver (ausgenommen Cortinariaceae). Berlin: Fungicon-Verlag; 2007.
 68. Ludwig E. Pilzkompendium. Band 3. Abbildungen. Die übrigen Gattungen der Agaricales mit weißem Sporenpulver. Berlin: Fungicon-Verlag; 2012.
 69. Ludwig E. Pilzkompendium. Band 3. Beschreibungen. Die übrigen Gattungen der Agaricales mit weißem Sporenpulver. Berlin: Fungicon-Verlag; 2012.
 70. Ludwig E. Pilzkompendium. Band 4. Abbildungen. Cortinariaceae (*Galerina*, *Hebeloma*, *Hebelomina*, *Inocybe*, *Phaeogalera*, *Cortinarius* Teil I mit den Untergattungen *Cortinarius*, *Dermocybe*, *Leproclybe*, *Phlegmacium*). Berlin: Fungicon-Verlag; 2017.
 71. Ludwig E. Pilzkompendium. Band 4. Beschreibungen. Cortinariaceae (*Galerina*, *Hebeloma*, *Hebelomina*, *Inocybe*, *Phaeogalera*, *Cortinarius* Teil I mit den Untergattungen *Cortinarius*, *Dermocybe*, *Leproclybe*, *Phlegmacium*). Berlin: Fungicon-Verlag; 2017.
 72. Ellis MB, Ellis JP. Microfungi on land plants. An identification handbook. Slough: The Richmond Publishing; 1997.
 73. Parra LA. *Agaricus* L. *Allopsalliota* Nauta & Bas. Part I. Alassio: Edizioni Candusso; 2008. (Fungi Europaei; vol 1).
 74. Parra LA. *Agaricus* L. *Allopsalliota* Nauta & Bas. Part II. Alassio: Candusso Edizioni s.a.s; 2013. (Fungi Europaei; vol 1A).
 75. Galli R. Gli *Agaricus*. Atlante pratico-monografico per la determinazione del Genere *Agaricus* L.: Fr. Milano: dalla Natura; 2004.
 76. Galli R. Le *Amanite*. Atlante pratico-monografico per la determinazione del Genere *Amanita* Pers. Milano: Edinatura; 2001.
 77. Kibby G. The genus *Amanita* in Great Britain. [publication place unknown]: [publisher unknown]; 2012.
 78. Hausknecht A. *Conocybe* Fayod. *Pholiotina* Fayod. Alassio: Edizioni Candusso; 2009. (Fungi Europaei; vol 11).
 79. Consiglio G, Setti L. Il Genere *Crepidotus* in Europa. Vicenza: A. M. B. Fondazione Centro Studi Micologici; 2008.
 80. Noordeloos ME. *Entoloma* s. l. Saronno: Libreria editrice Giovanna Biella; 1992. (Fungi Europaei; vol 5).
 81. Noordeloos ME. *Entoloma* s. l. Supplemento. Alassio: Edizioni Candusso; 2004. (Fungi Europaei; vol 5A).
 82. Smith AH, Singer R. A monograph on the genus *Galerina* Earle. New York, NY: Hafner Publishing Company; 1964.
 83. de Haan A, Walley R. Studies in *Galerina*. *Galerinae Flandriae* (1). Alassio: Edizioni Candusso; 2002. (Fungi Non Nelineati; vol 23).
 84. de Haan A, Walley R. Studies in *Galerina*. *Galerinae Flandriae* (2). Alassio: Edizioni Candusso; 2006. (Fungi Non Delineati; vol 33).
 85. de Haan A, Walley R. Studies in *Galerina*. *Galerinae Flandriae* (3). Alassio: Edizioni Candusso; 2009. (Fungi Non Delineati; vol 46).
 86. Holec J. The genus *Gymnopilus* (Fungi, Agaricales) in the Czech Republic. Acta Musei Nationalis Pragae, Series B – Historia Naturalis. 2005;61(1–2):1–53.
 87. Dissing H. The genus *Helvella* in Europe with special emphasis on the species found in Norden. København: Dansk Botanisk Forening; 1966. [Dansk Botanisk Arkiv; vol 25(1)].
 88. Antonín V, Noordeloos ME. A monograph of the genera *Hemimycena*, *Delicatula*, *Fayodia*, *Gamundia*, *Myxomphalia*, *Resinomycena*, *Rickenella* and *Xeromphalina* (Tribus *Mycenae* sensu Singer, *Mycena* excluded) in Europe. Eching: IHW-Verlag; 2004.
 89. Boertmann D. The genus *Hygrocybe*. Rodovre: The Danish Mycological Society; 1995. (Fungi of Northern Europe; vol 1).

90. Candusso M. *Hygrophorus* s. l. Alassio: Libreria Basso; 1997. (Fungi Europaei; vol 6).
91. Galli R. Gli Igrofori. Atlante pratico-monografico per la gereminazione delle Hygrophoraceae Roze ex Lotsy. Milano: Dalla Natura; 2012.
92. Kuyper TW. A revision of the genus *Inocybe* in Europe. I. Subgenus *Inosperma* and the smooth-spored species of subgenus *Inocybe*. Persoonia – Supplement. 1986;3(1):1–247.
93. Stangl J. The genus *Inocybe* in Bavaria. Burnley: Nuage Print And Copy; 2011.
94. Basso MT. *Lactarius* Pers. Alassio: Mykoflora; 1999. (Fungi Europaei; vol 7).
95. Heilmann-Clausen J, Verbeken A, Vesterholt J. The genus *Lactarius*. Mundelstrup: Svampetryk; 1998. (Fungi of Northern Europe; vol 2).
96. Hohmeyer H. Ein Schlüssel zu den europäischen Arten der Gattung *Peziza* L. Z Mykol. 1986;52(1):161–188.
97. Christan J. Die Gattung *Ramaria* in Deutschland. Eching: IHW-Verlag; 2008.
98. Sarnari M. Monografia illustrata del Genere *Russula* in Europe. Tomo Primo. Trento: A. M. B., Fondazione Centro Studi Micologici; 1998.
99. Sarnari M. Monografia illustrata del Genere *Russula* in Europe. Tomo Secondo. Trento: A. M. B., Fondazione Centro Studi Micologici; 2005.
100. Schumacher T. The genus *Scutellinia* (Pyronemataceae). Copenhagen: AiO Print Ltd.; 1990. (Opera Botanica; vol 101).
101. Riva A. *Tricholoma* (Fr.) Staude. Alassio: Edizioni Candusso; 1988. (Fungi Europaei; vol 3).
102. Riva A. *Tricholoma* (Fr.) Staude. Supplemento. Alassio: Edizioni Candusso; 2003. (Fungi Europaei; vol 3a).
103. Ladurner H, Simonini G. *Xerocomus* s. l. Alassio: Edizioni Candusso; 2003. (Fungi Europaei; vol 8).
104. Lannoy G, Estades A. Monographie des *Leccinum* d'Europe. La Roche-sur-Foron: Fédération Mycologique Dauphiné-Savoie; 1995.
105. Kučera V, Lizoň P. Geoglossaceous fungi in Slovakia III. The genus *Geoglossum*. Biologia. 2012;67(4):654–658. <https://doi.org/10.2478/s11756-012-0053-6>
106. Kučera V, Lizoň P, Kautmanová I. Geoglossaceous fungi in Slovakia: rare and new taxa for the territory. Biologia. 2008;63(4):482–486. <https://doi.org/10.2478/s11756-008-0077-0>
107. Ohenoja E. Occurrence of *Geoglossum*, *Trichoglossum* and *Microglossum* (Ascomycota, Leotiales) in Finland. Doc Mycol. 1995;25(98–100):285–294.
108. Holec J. The genus *Pholiota* in Central and Western Europe. Eching: IHW-Verlag; 2001. (Libri Botanici; vol 20).
109. Noordeloos ME. Strophariaceae s. l. Alassio: Edizioni Candusso; 2011. (Fungi Europaei; vol 12).
110. Corner EJH. A monograph of *Clavaria* and related genera. London: Oxford University Press; 1950.
111. Domański S. Basidiomycetes (Podstawczaki). Aphylophorales (Bezblaszkowe). Clavariaceae, Clavariadelphaceae, Clavulinaceae, Pterulaceae, Ramariaceae, Stephanosporaceae, Gomphaceae (II), Hericiaceae (II). Warszawa: Państwowe Wydawnictwo Naukowe; 1984. [Mała Flora Grzybów; vol 1(4)].
112. Reid DA. A monograph of the British Dacrymycetales. Transactions of the British Mycological Society. 1974;62(3):433–494. [https://doi.org/10.1016/S0007-1536\(74\)80060-4](https://doi.org/10.1016/S0007-1536(74)80060-4)
113. Wojewoda W. Podstawczaki (Basidiomycetes). Trzęsakowate (Tremellales). Uszakowate (Auriculariales). Czerwocogrzybowe (Septobasidiales). Warszawa: Państwowe Wydawnictwo Naukowe; 1977. [Grzyby (Mycota); vol 8].
114. Antonín V, Noordeloos ME. A monograph of marasmiod and collybioid fungi in Europe. Eching: IHW Verlag; 2010.
115. Montecchi A, Sarasini M. Fungi Ipogei d'Europa. Trento: A. M. B., Fondazione Centro Studi Micologici; 2000.
116. Sarasini M. Gasteromiceti epigei. Trento: A. M. B., Fondazione Centro Studi Micologici; 2005.
117. Baral HO, Maron G. In vivo veritas. Over 10,000 scans of fungi and plants (microscopical

- drawings, water colour plates, macro- and micrographs), with materials on vital taxonomy and xerotolerance [DVD edition]. 3rd ed. [publication place unknown]: published by the author; 2005.
118. Robert V, Stegehuis G, Stalpers J. The MycoBank engine and related databases [Internet]. 2005 [cited 2018 Feb 20]. Available from: <http://www.mycobank.org/>
 119. Mirek Z, Piękoś-Mirkowa H, Zając A, Zając M. Flowering plants and pteridophytes of Poland. A checklist. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences; 2002. (Biodiversity of Poland; vol 1).
 120. Ochyra R, Żarnowiec J, Bednarek-Ochyra H. Census catalogue of Polish mosses. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences; 2003. (Biodiversity of Poland; vol 3).
 121. Chmiel A. Checklist of Polish larger Ascomycetes. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences; 2006. (Biodiversity of Poland; vol 8).
 122. Mułenko W, Majewski T, Ruszkiewicz-Michalska M, editors. A preliminary checklist of micromycetes in Poland. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences; 2008. (Biodiversity of Poland; vol 9).
 123. Wojewoda W. Checklist of Polish larger Basidiomycetes. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences; 2003. (Biodiversity of Poland; vol 7).
 124. Czyżewska K, Kukwa M. Lichenicolous fungi of Poland. A catalogue and key to species. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences; 2009. (Biodiversity of Poland; vol 11).
 125. Fałtynowicz W. The lichens, lichenicolous and allied fungi of Poland. An annotated checklist. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences; 2003. (Biodiversity of Poland; vol 6).
 126. Kujawa A. Grzyby makroskopijne Polski w literaturze mykologicznej. In: Snowarski M, editor. Atlas grzybów Polski [Internet]. 2018 [cited 2018 Feb 25]. Available from: <http://www.grzyby.pl/grzyby-makroskopijne-Polski-w-literaturze-mikologicznej.htm>
 127. Wojewoda W, Ławrynowicz M. Red list of macrofungi in Poland. In: Mirek Z, Zarzycki K, Wojewoda W, Szelaż Z, editors. Red list of plants and fungi in Poland. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences; 2006. p. 54–70.
 128. Rozporządzenie Ministra Środowiska z dnia 9 października 2014 r. w sprawie ochrony gatunkowej grzybów. Journal of Laws of the Republic of Poland (Dziennik Ustaw), 2014 Oct 9, Item 1408.
 129. Krukar W. Bieszczady Wysokie. Bieszczadzki Park Narodowy [Map]. Krosno: Wydawnictwo "Ruthenus" Rafał Barski; 2007. Mapa turystyczno-nazewnicza 1:40,000.
 130. Kujawa A. Stan poznania różnorodności gatunkowej makrogrzybów w polskich parkach narodowych. Roczniki Bieszczadzkie. 2017;25:74–81.
 131. Kujawa A, Szczepkowski A, Gierczyk B, Ślusarczyk T. Ile gatunków grzybów rośnie w Puszczy Białowieskiej? Wystawy grzybów źródłem nowych danych. Sylwan. 2018;162(11):933–940.
 132. Gierczyk B, Szczepkowski A, Ślusarczyk T, Kujawa A. Contribution to the knowledge of mycobiota of the Kampinos National Park (Poland). Part 2. Acta Mycol. 2019;54(1):1116. <https://doi.org/10.5586/am.1116>
 133. Kuthan J, Adamčík S, Antonín V, Terray J. Houby Národného parku Poloniny. Košice: Správa národných parkov SR, Správa národného parku Poloniny; 1999.
 134. Langer E, Langer G, Popa F, Rexer KH, Striegel M, Ordynets A, et al. Naturalness of selected European beech forests reflected by fungal inventories: a first checklist of fungi of the UNESCO World Natural Heritage Kellerwald-Edersee National Park in Germany. Mycol Prog. 2015;14(11):102. <https://doi.org/10.1007/s11557-015-1127-y>
 135. Adamčík S, Christensen M, Heilmann-Clausen J, Walleyn R. Fungal diversity in the Poloniny National Park with emphasis on indicator species of conservation value of beech forests in Europe. Czech Mycol. 2007;59(1):67–81. <https://doi.org/10.33585/cmy.59107>
 136. Природно-заповідний фонд України [Pryrodno-zapovidnyy fond Ukrayiny] [Internet]. 2019 [cited 2019 Feb 27]. Available from: <http://pzf.menr.gov.ua/>
 137. Christensen M, Heilmann-Clausen J, Walleyn R, Adamčík S. Wood-inhabiting fungi as indicators of nature value in European beech forests. In: Marchetti M, editor. Monitoring and indicators of forest biodiversity in Europe – from ideas to operationality. Joensuu: European Forest Institute; 2005. p. 229–238. (EFI Proceedings; vol 51).

138. Langer E, Langer G, Striegel M, Riebesehl J, Ordynets A. Fungal diversity of the Kellerwald-Edersee National Park – indicator species of nature value and conservation. *Nova Hedwigia*. 2014;99(1–2):129–144. <https://doi.org/10.1127/0029-5035/2014/0201>
139. Ódor P, Heilmann-Clausen J, Christensen M, Aude E, van Dort KW, Piltaver A, et al. Diversity of dead wood inhabiting fungi and bryophytes in semi-natural beech forests in Europe. *Biol Conserv*. 2006;131(1):58–71. <https://doi.org/https://doi.org/10.1016/j.biocon.2006.02.004>
140. Adamčík S, Aude E, Bässler C, Christensen M, van Dort K, Fritz Ö, et al. Fungi and lichens recorded during the Cryptogam Symposium on Natural Beech Forests, Slovakia 2011. *Czech Mycol*. 2016;68(1):1–40. <https://doi.org/10.33585/cmy.68101>
141. Verkerk PJ, Fitzgerald JB, Datta P, Dees M, Hengeveld GM, Lindner M, et al. Spatial distribution of the potential forest biomass availability in Europe. *Forest Ecosystems*. 2019;6(1):5. <https://doi.org/10.1186/s40663-019-0163-5>