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Provisional list of the Ascomycota species from Kosovo with data on new records

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Abstract

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The mycobiota of Kosovo, especially fungi of the phylum Ascomycota, remains under-explored despite its ecological and biological importance. This study aims to assess the diversity and distribution of macrofungal species of the phylum Ascomycota in different ecosystems in Kosovo. Field work combined with laboratory analysis was conducted from 2017 to 2022, using standard mycological techniques for species identification. A total of 82 species have now been documented in Kosovo. Of these, 39 species have been previously reported in the scientific literature, and 43 species are new records, significantly enriching the knowledge of the diversity of fungi in Kosovo. Taxonomic analysis showed that these species belong to 56 genera, distributed in 34 families, 10 orders, six subclasses, five classes and one subphylum. The Helotiales and Pezizales orders had the highest diversity, with 12 and nine families, respectively. In contrast, the orders such as Xylariales and Hypocreales showed remarkable variation, while several other orders were represented by a single family. These results highlight the rich but under-explored diversity of Ascomycota in Kosovo and emphasise the importance of further research to support biodiversity conservation.

Keywords: distribution, diversity, fungi, habitats, macromycetes, taxonomy.

INTRODUCTION

The kingdom of Fungi is one of the largest groups of organisms, displaying enormous taxonomic diversity and playing a fundamental role in ecosystem functioning and maintaining a healthy environment. Currently, approximately 150 600 species of fungi have been officially documented according to the Species Fungorum (2024) database, but this number represents only a small fraction of the estimated 2 to 11 million species (Hawksworth & Lücking, 2017; Lücking et al., 2021; Baldrian et al., 2021). It is important to emphasise that species number estimates based on metabarcoding data are even higher. Wu et al. (2019) have assumed an even higher number of fungi species, 11.7–13.2 million. Ascomycetes are found in various habitats, including soil, plant surfaces and decaying organic matter in freshwater and marine environments (Hawksworth, 2001). Ascomycetes have a broad range of lifestyles, with some functioning as saprotrophs and as necrotrophic or biotrophic parasites of plants and animals, including humans (Boddy & Hiscox, 2016). In addition, certain ascomycetes have symbiotic relationships with other

organisms, forming lichens, which account for approximately 40% of described ascomycetes (Webster & Roland, 2007).

Located in south-eastern Europe on the Balkan Peninsula, Kosovo is known for its diverse natural resources and high biodiversity values (Hoxha, 2000). Approximately 44% of its total area, equivalent to 481 000 ha, is covered by forests (Tomter et al., 2013). However, human settlements and logging activities have led to irreversible degradation and loss of forest cover (Krasniqi, 1972). Despite extensive documentation of other groups of organisms in Kosovo (Krasniqi, 1972; Rexhepi, 1997, 2007; Millaku et al., 2013; Tomter et al., 2013; Ibrahimi et al., 2019), the diversity of macrofungi has received limited attention. Knowledge of macrofungal diversity in Kosovo has been limited until now, although more comprehensive studies have been conducted in recent years (Karadelev, 2018; Ramshaj et al., 2021, 2022).

This study aimed to investigate the diversity, distribution and taxonomic composition of macrofungal species within the phylum Ascomycota in Kosovo. Despite the favourable climate and diverse vegetation of the region, which are the main factors for the diversity of fungi, limited data exist for Ascomycota in this area. In this study, we aimed to document the known species of Ascomycota in Kosovo, to identify and record new species for the country, and to analyse the taxonomic structure of these species. By achieving these objectives, this study contributes to filling the knowledge gap on the fungal biodiversity of Kosovo and provides a basis for future research.

MATERIALS AND METHODS

Samples were collected from 36 localities between 2017 and 2022 (Fig. 1). Each sampled fungus was photographed before being carefully collected and wrapped in aluminium foil. The dried collections were placed in plastic bags and labelled with key information, including a brief description of the ecology of each fungal species identified, such as forest associations, habitat and substrate characteristics, geographical coordinates, altitude, date of collection and the name or names of the collectors. The collected specimens were deposited at the Herbarium of the Faculty of Mathematics and Natural Sciences, University of Pristina. Some specimens were also sent to the Institute of Forest Sciences, Hajnowka, Poland, where they are now part of their collection.

This study focused on researching the diversity and distribution of macrofungi species of the phylum Ascomycota within the territory of Kosovo. It aimed to provide a comprehensive overview of the diversity of this group. Collected specimens were identified according to the main monographs on this group of fungi (Hawker, 1954; Dennis, 1960; Moser, 1963; Breitenbach & Kränzlin, 1981; Hansen & Knudsen, 2000; Medardi, 2006). The nomenclature of the species was given according to the Index Fungorum (2024) and MycoBank (2024). The list of species recorded in Kosovo (Results section) was arranged alphabetically. Further explanations of the structure of the species list and the abbreviations used can be found in the introductory paragraph of this subsection.

RESULTS

During this study, 43 species were recorded for the first time in Kosovo, while 39 species were recorded in previous publications. Thus, a total of 82 species belonging to the phylum Ascomycota have been documented in the country so far. The registered species belong to one subphylum, five classes, 10 orders, 34 families and 56 genera. The order Helotiales showed the greatest richness, with 12 families. In addition, the Pezizales emerged as a prominent order with considerable diversity, consisting of nine families. Other important orders included the Xylariales, with four families, and the Hypocreales, with three families. In addition, several orders, namely the Tubeufiales, Teloschistales, Rhytismatales, Leotiales, Coronophorales and Chaetomellales, were represented by a single family each (Fig. 2).

The families with the highest species richness are Hypocreaceae and Hypoxylaceae, with seven species each, followed by Morchellaceae with six species. The families Diatrypaceae and Xylariaceae contain five species each. The families Erysiphaceae and Pezizaceae are characterised by four species. Families with three species include Discinaceae, Helotiaceae, Helvellaceae, Pyronemataceae and Sarcoscyphaceae. Gelatinodiscaceae, Mollisiaceae, Nectriaceae, Rhytismataceae, Rutstroemiaceae, Sclerotiniaceae

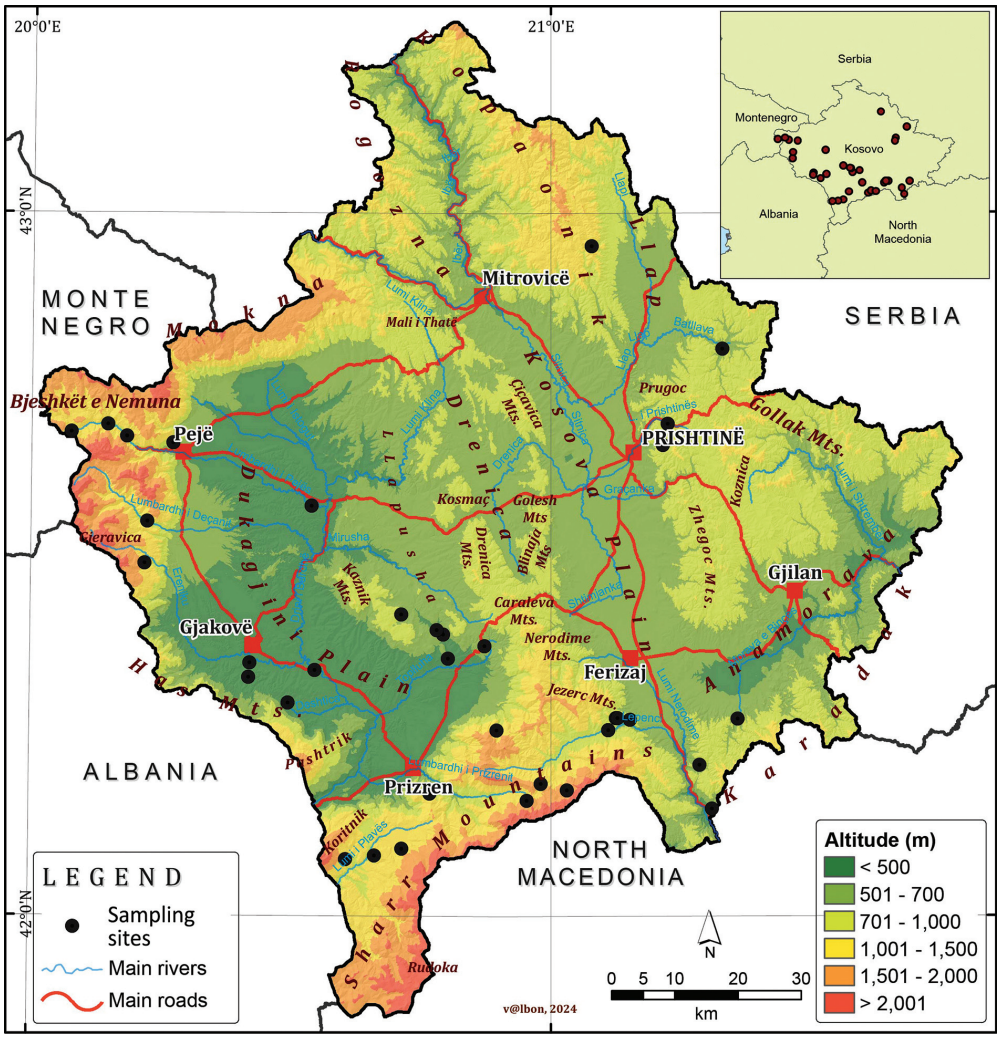


Fig. 1. Map of the fungi study sites in Kosovo.

and Tuberaceae all have two species. Finally, several families are represented by only one species: Bertiaceae, Caloscyphaceae, Cenangiaceae, Chlorociboriaceae, Clavicipitaceae, Graphostromataceae, Heterosphaeriaceae, Lachnaceae, Leotiaceae, Marthamycetaceae, Otideaceae, Pezizellaceae, Teloschistaceae, Tricladiaceae and Tubeufiaceae.

List of species

Species recorded for the first time in Kosovo are indicated by an asterisk (*). Information on collected specimen labels (locality, habitat, date of collection, geographical coordinates, altitude, names of collector(s), and identifiers and specimen number, if available) was provided. Summary information and publication references were added for species previously reported in Kosovo. The following abbreviations were used in the species list: BF – Besnik Fetiu; EM – Emri Murati; GK – Granit Kabashaj; GO – Granit Osaj; II – Ilze Irbe; KR – Katerina Rusevska; MTh – Matthias Theiss; MK – Mitko Karadalev; OF – Osman Fetoshi; PB – Pajtim Bytyqi; QR – Qëndrim Ramshaj; ST – Slavica Tofilovska; TJ – Tome Jovanovski; leg. (legitur) – collected; det. (determinavit) – identified; No. – specimen number.

* ***Acanthohelicospora scopula*** (Peck) Rossman & W.C. Allen. – Pejë: Kuqishtë, broad-leaved forest, on a branch of *Alnus glutinosa*, 20 November 2017, 42°40'54.3" N, 20°10'57.1" E, 850 m; leg. & det. EM, KR & MK (No. 2017/01).

* ***Aleuria aurantia*** (Pers.) Fuckel. – Suharekë: Mushtisht (Gradancë), beech forest, on leaf litter, sandy soil, 24 September 2022, 42°15'53.5" N, 20°53'41.5" E, 1084 m; leg. QR, det. QR, ST & MK (No. 2022/601).

* ***Ascocoryne cylichnium*** (Tul.) Korf. – Podujevë: Orllan, meadow, on dry branch of *Corylus avellana*, 2 November 2019, 42°48'29.3" N, 21°19'48.3" E, 690 m; leg. QR, OF & MK, det. QR & MK (No. 2019/273).

Ascocoryne sarcoides (Jacq.) J.W. Groves & D.E. Wilson. – was previously recorded in *Fagus sylvatica* forests in Prevalla, at an altitude of 1580 m, on a dry branch (Ramshaj et al., 2022).

Bertia moriformis (Tode) De Not. – was previously recorded in *Quercus cerris* and *Fagus sylvatica* forests in Semajë, Krushevc and Prevalla in 2017 and 2018, at altitudes of 850–1300 m, on dry branches and stumps (Ramshaj et al., 2021, 2022).

* ***Biscogniauxia nummularia*** (Bull.) Kuntze. – Junik, beech forest, on the bark of *Fagus sylvatica*, 15 April 2018, 42°30'06.28" N, 20°13'04.21" E, 1250 m; leg. II, LB & MK, det. MK.

* ***Caloscypha fulgens*** (Pers.) Boud. – Junik, beech forest, on leaf litter, 15 April 2018, 42°30'06.28" N, 20°13'04.21" E, 1250 m; leg. II, LB & MK, det. MK. Pejë: Kuqishtë, *Picea abies* forest, on rotten wood, 9 May 2022, 42°41'17.0" N, 20°04'33.0" E, 1170 m; leg. QR & GO, det. QR & MK (No. 2022/565).

Calycina citrina (Hedw.) Gray. – was previously recorded in beech forests in Brod and Prevalla in 2017 and 2019, at altitudes of 700–1150 m, on fallen branches of *Alnus glutinosa* (Ramshaj et al., 2022).

* ***Chlorociboria aeruginosa*** (Oeder) Seaver. – Podujevë: Orllan, meadow, on dead wood of *Salix* sp., 2 November 2019, 42°49'06.7" N, 21°19'50.8" E, 660 m; leg. QR, OF & MK, det. QR & MK (No. 2019/282).

* ***Claviceps purpurea*** (Fr.) Tul. – Suharekë: Peqan, wheat plantation, in the ear of wheat, 3 July 2019, 42°22'02.1" N, 20°48'04.6" E, 367 m; leg. QR, det. QR & MK (2019/329).

Cudoniella clavus (Alb. & Schwein.) Dennis. – Prizren: Prevallë, *Alnetum*, on fallen branch of *Alnus glutinosa*, 28 January 2018, 42°11'21.3" N, 20°58'47.5" E, 1100 m; leg. TJ, MTh, KR & MK, det. MK.

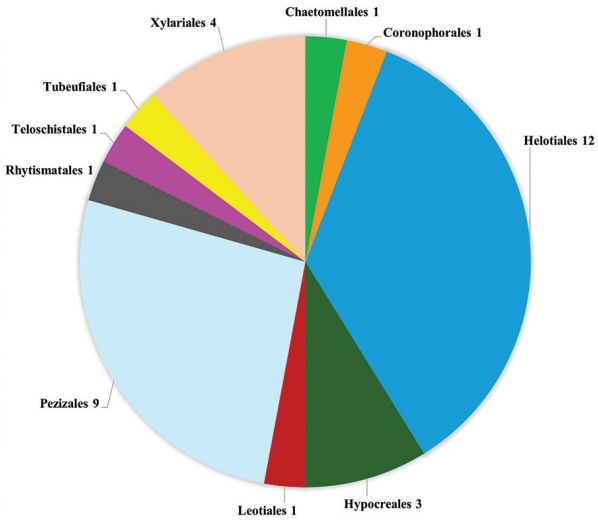


Fig. 2. Number of families in the orders of the phylum Ascomycota.

* ***Daldinia concentrica*** (Bolton) Ces. & De Not. – Prishtinë: Makoc, deciduous forest, on a cut tree trunk, 21 October 2020, 42°42'04.6" N, 21°13'26.6" E, 703 m; leg. BF, det. QR & MK.

* ***Diatrype bullata*** (Hoffm.) Fr. – Prishtinë: Germia Park, *Fagus sylvatica* forest, on a dry branch of willow, 19 May 2022, 42°40'16.0" N, 21°12'54.0" E, 790 m; leg. QR, det. QR & MK (No. 2022/555).

Diatrype disciformis (Hoffm.) Fr. – was previously recorded in *Fagus sylvatica* and *Populus* forests in Prevalla, Kuk and Brezovicë in 2019 and 2021, at altitudes of 1100–1687 m, on dry branches (Ramshaj et al., 2022)

Diatrype stigma (Hoffm.) Fr. – was previously recorded in *Quercus frainetto*, *Alnetum*, *Quercus pubescens* and *Carpinus orientalis* forests in Shushtë, Lirishtë, Semetisht, Breshancë, Grabanicë and Shkozë in 2017, 2018 and 2019, at altitudes of 419–700 m, on fallen and dry branches (Ramshaj et al., 2021). It was also recorded in mountain pasture in Rrenc and Krushevc in 2021, at an altitude of 1054 m, on a stump and dry branch of *Fagus sylvatica* (Ramshaj et al., 2022).

* ***Discina ancilis*** (Pers.) Sacc. – Pejë: Drelaj, *Alnetum,* on leaf litter, 16 April 2018, 42°41'55.1" N, 20°08'44.5" E, 985 m; leg. II, IB & MK, det. MK. Pejë: Kuqishtë, *Picea abies* forest, on rotten wood, 9 May 2022, 42°41'17.0" N,

20°04'33.0" E, 1170 m; leg. QR & GO, det. QR & MK (No. 2022/566).

* ***Discina geogenia*** Rahm ex Donadini. – Pejë: Kuqishtë, *Picea abies* forest, on leaf litter, 9 May 2022, 42°41'17.0" N, 20°04'33.0" E, 1170 m; leg. QR & GO, det. QR & MK (No. 2022/570).

* ***Disciotis venosa*** (Pers.) Arnould. – Rahovec: Xërxë, meadow, on leaf litter, 24 April 2022, 42°21'01.0" N, 20°32'45.0" E, 320 m; leg. QR, det. QR & MK.

* ***Dumontinia tuberosa*** (Bull.) L.M. Kohn. – Junik, beech forest, on rhizomes of *Anemone* sp., 15 April 2018, 42°30'06.28" N, 20°13'04.21" E, 1250 m; leg. II, LB & MK, det. MK.

* ***Encoelia furfuracea*** (Roth) P. Karst. – Pejë: Kuqishtë, *Picea abies* forest, on a dry branch of *Corylus avellana*, 9 May 2022, 42°41'17.0" N, 20°04'33.0" E, 1170 m; leg. QR & GO, det. QR & MK (No. 2022/575).

Erysiphe alphitoides (Griffon & Maubl.) U. Braun & S. Takam. – was previously recorded in a *Quercus cerris* forest in Gërlica, at an altitude of 800 m, parasitising oak leaves (Ramshaj et al., 2021).

* ***Erysiphe cruciferarum*** Opiz ex L. Junell. – Suharekë: Peqan, meadow, on leaves of *Convolvulus arvensis*, 10 August 2022, 42°21'59.3" N, 20°48'03.7" E, 362 m; leg. QR, det. QR & MK.

* ***Erysiphe necator*** Schwein. – Suharekë: Peqan, garden, on *Vitis vinifera* leaves, 28 August 2022, 42°22'04.1" N, 20°47'59.8" E, 365 m; leg. QR, det. QR & MK.

Eutypella alnifraga (Wahlenb.) Sacc. – was previously recorded in a beech forest in Prevalla, at an altitude of 1300 m, on a fallen branch of *Alnus glutinosa* (Ramshaj et al., 2022).

* ***Gyromitra ambigua*** (P. Karst.) Harmaja – Pejë: Kuqishtë, *Picea abies* forest, on leaf litter, 9 May 2022, 42°41'17.0" N 20°04'33.0" E, 1170 m; leg. QR & GO, det. QR & MK (No. 2022/569).

* ***Helvella acetabulum*** (L.) Quél. – Prishtinë: Germia Park, *Quercus pubescens* forest, on leaf litter, 19 May 2022, 42°40'26.3" N, 21°12'18.7" E, 650 m; leg. QR, det. QR & MK (No. 2022/556).

Helvella atra J. König. (Fig. 3 and Fig. 4) – was previously recorded on leaf litter in a *Quercus frainetto* forest in Smirë and Drenushë at an altitude of 750 m (Ramshaj et al., 2021).

Helvella lacunosa Afzel. – was previously recorded on leaf litter in a *Quercus frainetto* forest in Peqan at an altitude of 378 m (Ramshaj et al., 2022).

Heterosphaeria patella (Tode) Grev. – was previously recorded on herb stem in a beech forest in Prevalla at an altitude of 1150 m (Ramshaj et al., 2022).

Humaria hemisphaerica (F.H. Wigg.) Fuckel. – was previously recorded on leaf litter in beech forests in Mushtisht (Gradancë), at an altitude of 1084 m (Ramshaj et al., 2022).

Fig. 3. *Helvella atra* in the soil among leaf litter, Kosovo, Viti, 17 June 2017.. Photograph by M. Karadelev.

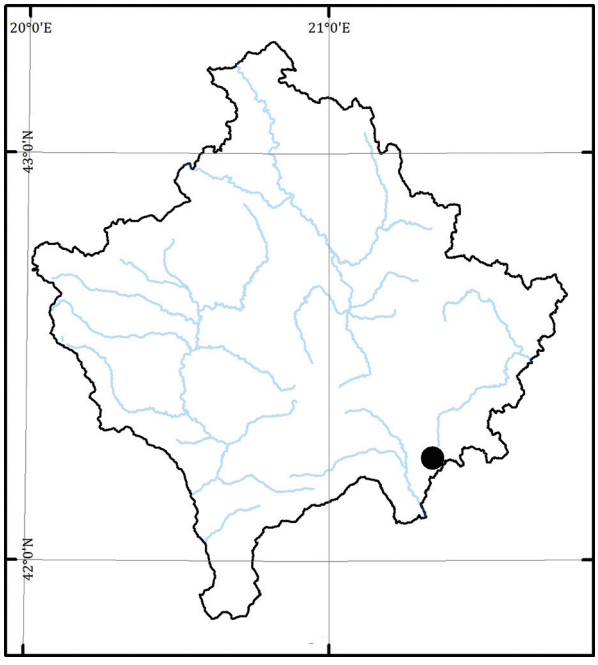


Fig. 4. Distribution of *Helvella atra* in Kosovo.

* ***Hymenoscyphus laetus*** (Boud.) Dennis. – Pejë: Drelaj, *Alnetum*, on rotten wood, 20 October 2017, 42°42'01.0" N, 20°06'53.2" E, 1020 m; leg. & det. EM, KR & MK.

* ***Hymenoscyphus serotinus*** (Pers.) W. Phillips. – Pejë, *Alnetum*, on fallen branch of *Alnus glutinosa*, 20 October 2017, 42°42'01.0" N, 20°06'53.2" E, 1020 m; leg. & det. EM, KR & MK.

Hymenoscyphus syringicolor Svrček. – was previously recorded in *Pinus heldreichii* forest, in Prevallë, at an altitude of 1550 m, on rotten wood of *Pinus heldreichii* (Ramshaj et al., 2022).

* ***Hypocrea gelatinosa*** (Tode) Fr. – Deçan, *Alnetum* and deciduous forest, on a fallen branch, 28 June 2019, 42°33'40.2" N, 20°13'23.4" E, 776 m; leg. & det. QR, ST, KR & MK (No. 2019/124).

Hypomyces chrysospermus Tul. & C. Tul. – was previously recorded in beech, *Quercus frainetto* in Mushtisht (Gradancë), Reqan and Peqan in 2022, at altitudes of 378–1084 m, on stipe and hymenium of *Boletus reticulatus, Boletus areus* and *Xerocomus submentosus* (Ramshaj et al., 2021).

Hypomyces hyalinus (Schwein.) Tul. & C. Tul. – was previously recorded in *Quercus pubescens* forests in Gorancë and Gllobоçicë, at an altitude of 900 m, parasitising the fruitbody of *Amanita vaginata* (Ramshaj et al., 2021, 2022).

Hypomyces lateritius (Fr.) Tul. & C. Tul. – was previously recorded in *Pinus nigra* plantings in Krivenik at an altitude of 700 m, parasitising the fruitbody of *Lactarius deliciosus* (Ramshaj et al., 2022).

Hypoxylon fragiforme (Pers.) J. Kickx f. – was previously recorded in *Pinus peuce* and *Abies alba* mixed with *Fagus sylvatica* forests in Mushtisht, Prevalla, Brezovicë and Krushevc in 2017 and 2021 at altitudes of 1150–1687 m, on dry branches of *Fagus sylvatica* (Ramshaj et al., 2022).

Hypoxylon fuscum (Pers.) Fr. – was previously recorded in *Quercus pubescens*, *Abies alba* mixed with *Fraxinus* sp., forests in Peqan, Semetishtë and Kuqishtë, at altitudes of 419–1142 m, on fallen and attached dry branches of *Corylus avellana* (Ramshaj et al., 2021, 2022).

Hypoxylon rubiginosum (Pers.) Fr. – was previously recorded in beech forests in Krushevc, at an altitude of 1150 m, on a stump of *Fagus sylvatica* (Ramshaj et al., 2022).

Hypoxylon seperans Lloyd. – Dragash: Rapçë, beech forest, on dry wood of *Fagus sylvatica*, 25 July 2021, 42°04'54.26" N, 20°36'21.31" E, 1227 m; leg. QR & PB, det. QR, ST & MK.

Jackrogersella multiformis (Fr.) L. Wendt, Kuhnert & M. Stadler. – was previously recorded in beech forests in Krushevc, at an altitude of 1150 m, on dry branches of *Fagus sylvatica* (Ramshaj et al., 2022).

Kretzschmaria deusta (Hoffm.) P.M.D. Martin. – was previously recorded in *Fagus sylvatica* forest and mixed forest of *Pinus peuce, Pinus alba* and *Fagus sylvatica* in Junik and Mushtisht (Gradancë), at altitudes of 861–1084 m, on dry branches of *Fagus sylvatica* (Ramshaj et al., 2022).

* ***Lachnum virgineum*** (Batsch) P. Karst. – Junik, beech forest, on rotten wood of *Fagus sylvatica*, 15 April 2018, 42°30'06.28" N, 20°13'04.21" E, 1250 m; leg. II, LB & MK, det. MK.

* ***Lanzia echinophila*** (Bull.) Korf. – Gjakovë: Gërqinë, chestnut forest, on a cone of fruit of *Castanea sativa*, 10 October 2020, 42°18'13.5" N, 20°29'40.8" E, 380 m; leg. QR & GK, det. QR & MK (No. 2020/423).

* ***Legaliana badia*** (Pers.) Van Vooren. – Suharekë: Biraqë, *Pinus nigra* forest mixed with *Quercus* tree, 3 April 2022, 42°23'06.4" N, 20°52'16.4" E, 650 m; on leaf litter; leg. QR, det. QR & MK (No. 2022/557).

* ***Leotia lubrica*** (Scop.) Pers. – Suharekë: Mushtisht (Gradancë), beech forest, on leaf litter, 24 September 2022, 42°15'53.5" N, 20°53'41.5" E, 1084 m; leg. QR, det, QR, ST & MK (No. 2022/621).

* ***Microstoma protractum*** (Fr.) Kanouse (Fig. 5 and Fig. 6). – Smirë and Drenushë, Kaçanik, *Alnetum*, on leaf litter, 17 June 2017, 42º15'09" E, 21º20'30" N, 750 m; leg. and det. MK. Prishtinë, Germia Park, beech forest, on leaf litter, 10 May 2022, 42°39'54.6" N, 21°13'12.8" E, 849 m; leg. QR, det. QR & MK.

Mollisia cinerea (Batsch) P. Karst. – was previously recorded in beech forests in Brezovicë, at an altitude of 1687 m, on rotten wood of *Fagus sylvatica* (Ramshaj et al., 2022).

* ***Morchella elata*** Fr. – Pejë: Kuqishtë, *Picea abies* forest, on leaf litter, 9 May 2022, 42°41'17.0" N, 20°04'33.0" E, 1170 m; leg, QR & GO, det. QR & MK.

* ***Morchella esculenta*** (L.) Pers. – Pejë: Kuqishtë,

Fig. 5. *Microstoma protractum* in the soil among leaf litter, Kosovo, Kaçanik, 1 April 2017. Photograph by M. Karadelev.

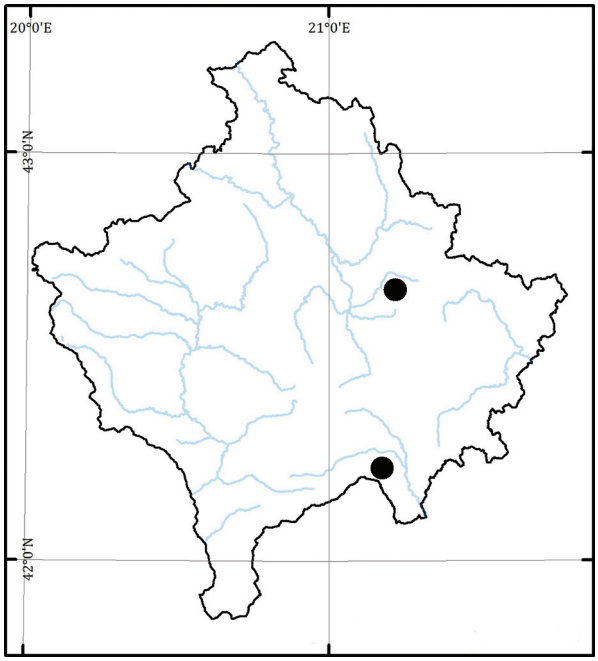


Fig. 6. Distribution of *Microstoma protractum* in Kosovo.

Picea abies forest, on leaf litter, 9 May 2022, 42°41'17.0" N, 20°04'33.0" E, 1170 m; leg, QR & GO, det. QR & MK (No. 2022/574).

* ***Morchella semilibera*** DC. – Mitrovicë: Kaçandoll, *Alnetum*, on leaf litter, 15 November 2017, 42°57'13.71" N, 21°04'40.53" E, 1130 m; leg. BM, det. MK.

* ***Nectria cinnabarina*** (Tode) Fr. – Podujevë: Orllan, meadow, on dry branch of *Carpinus orientalis*, 2 November 2019, 42°48'29.3" N, 21°19'48.3" E, 690 m; leg. QR, OF & MK, det. QR & MK (No. 2019/352).

* ***Neonectria coccinea*** (Pers.) Rossman & Samuels. – Prizren: Marash, deciduous forest, on the bark of a branch, 12 November 2021, 42°11'58.0" N, 20°45'05.0" E, 520 m; leg. QR, det. QR, ST & MK (No. 2021/496).

Otidea alutacea (Pers.) Massee. – was previously recorded on leaf litter in *Carpinus* forest mixed with *Quercus* sp. in Shkozë at an altitude of 660 m (Ramshaj et al., 2021).

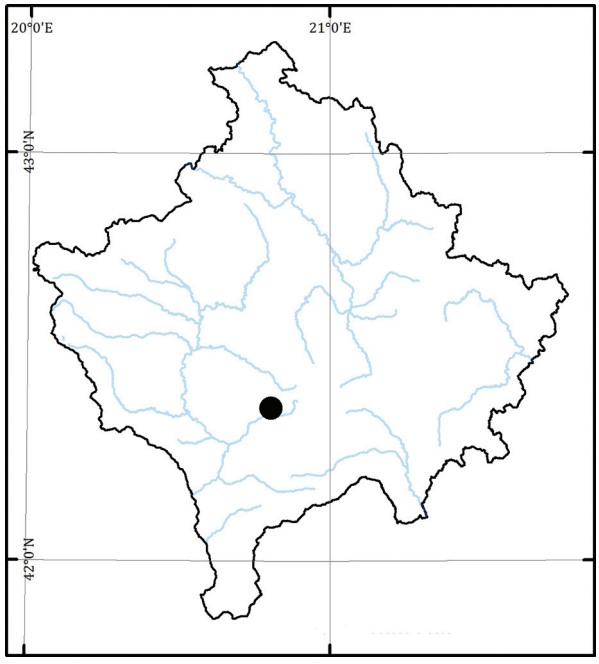
Paragalactinia succosa (Berk.) Van Vooren. – was previously recorded on leaf litter in *Quercus frainetto* forests between Smirë and Drenushë at an altitude of 750 m (Ramshaj et al., 2021).

Peroneutypa scoparia (Schwein.) Carmarán & A.I. Romero. – was previously recorded on oak bark in *Quercus pubescens* forests in Peqan at an altitude of 374 m (Ramshaj et al., 2021).

Peziza arvernensis Roze & Boud. – recorded on soil surface and decaying wood in *Quercetum frainetto-cerris* forests between Gorancë and Gllboçicë, at an altitude of 900 m (Ramshaj et al., 2021, 2022).

* ***Poronia punctata*** (L.) Fr. (Fig. 7) – Suharekë: Peqan, meadow, on pony droppings, 10 October 2021, 42°22'31.2" N, 20°48'16.7" E, 370 m; leg. QR, det. QR & MK.

Propolis farinosa (Pers.) Fr. – was previously recorded on a fallen branch in *Quercus cerris* for-



Fig, 7. Distribution of *Poronia punctata* in Kosovo.

ests in Gërlica at an altitude of 800 m (Ramshaj et al., 2021).

Rhytisma acerinum (Pers.) Fr. – was previously recorded on leaves of *Acer pseudoplatanus* in *Populus* forests in Kuk at an altitude of 1100 m (Ramshaj et al., 2022).

* ***Rutstroemia firma*** (Pers.) P. Karst. – Gjakovë: Gërqinë, chestnut forest, on a dry branch of *Castanea sativa*, 10 October 2020, 42°18'13.5" N, 20°29'40.8" E, 380 m; leg. QR & GK, det. QR & MK (No. 2020/424).

Sarcoscypha coccinea (Jacq.) Lambotte. – was previously recorded on a dry branch of *Robinia pseudoacacia* and a dry branch of *Pinus nigra* in *Quercus frainetto* and *Pinus nigra* forests in Peqan and Shkugëz in 2021 and 2022, at altitudes of 361–378 m (Ramshaj et al., 2022).

* ***Sarcoscypha jurana*** (Boud.) Baral. – Suharekë: Peqan, *Robinia pseudoacacia* forest, on fallen branch of *Robinia pseudoacacia*, 3 March 2019, 42°21'59.2" N, 20°48'09.1" E, 370 m; leg. QR, det. QR & MK (No. 2019/196).

* ***Sarcosphaera coronaria*** (Jacq.) J. Schröt. (Fig. 8 and Fig. 9). – Pejë: Koshutan, *Picea abies* forest, on leaf litter, 3 July 2022, 42°44'02.0" N, 20°05'37.0" E, 1480 m; leg. QR, det. QR, ST & MK (No. 2022/600).

* ***Sawadaea bicornis*** (Wallr.) Homma. – Suharekë: Peqan, meadow, on *Acer platanoides* leaves, 8 September 2022, 42°21'57.8" N, 20°48'05.8" E, 370 m; leg. QR, det. QR & MK.

* ***Sclerencoelia fascicularis*** (Alb. & Schwein.) Pärtel & Baral. – Suharekë, Peqan, *Quercus frainetto* forest, on a dry branch of *Corylus avellana*, 23 April 2021, 42°21'53.7" N, 20°48'04.5" E, 378 m; leg. QR, det. QR, ST & MK (No. 2021/530).

* ***Scutellinia scutellata*** (L.) Lambotte. – Pejë: Maja e Zezë, chestnut forest, on leaf litter, 29 June 2019, 42°40'22.0" N, 20°16'18.4" E, 699 m; leg. & det. QR, ST, KR & MK. Junik, beech forest, on leaf litter, 28 June 2019, 42°30'37.0" N, 20°13'20.7" E, 1015 m; leg. QR, ST, KR & MK. Dragash: Rapçë, beech forest, on rotten wood of *Fagus sylvatica*, 25 July 2021, 42°04'54.26" N, 20°36'21.31" E, 1227 m; leg. QR & PB, det. QR, ST & MK (No. 2019/157).

Tapesia fusca (Pers.) Fuckel. – was previously recorded on rotten wood of *Fagus sylvatica* in beech forests in Prevalla, at an altitude of 1300 m (Ramshaj et al., 2022).

Fig. 8. *Sarcosphaera coronaria* in soil among leaf litter, Kosovo, Pejë (Koshutan), 3 July 2022. Photograph by Q. Ramshaj.

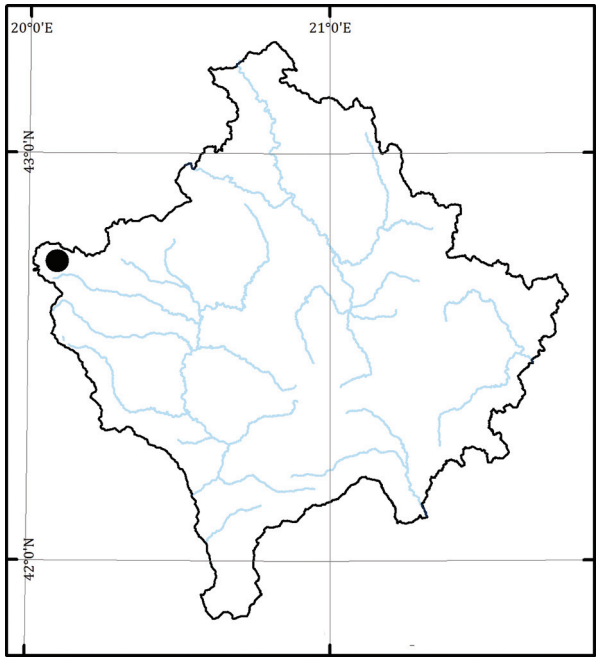


Fig. 9. Distribution of *Sarcosphaera coronaria* in Kosovo.

Trichoderma citrinum (Pers.) Jaklitsch, W. Gams & Voglmayr. – was previously recorded on oak bark in *Quercus cerris* forests in Semajë at an altitude of 850 m (Ramshaj et al., 2021).

* ***Trichoderma pulvinatum*** (Fuckel) Jaklitsch & Voglmayr – Junik, beech forest, on *Fomitopsis pinicola*, 28 June 2019, 42°30'37.0" N, 20°13'20.7" E, 1015 m; leg. QR, det. QR, ST, KR & MK (No. 2019/125).

Trichoderma viride Pers. – was previously recorded on a fallen branch in *Fagus sylvatica* forests in Prevalla at an altitude of 1300 m (Ramshaj et al., 2022).

* ***Tuber aestivum*** (Wulfen) Spreng. – Kaçanik: Semajë, *Alnetum*, in the soil, 31 May 2017, 42°16'58.0“ N, 21°07'35.0“ E, 850 m; leg. TJ, EM, KR & MK, det. KR & MK.

* ***Tuber borchii*** Vittad. – Kaçanik: Semajë, *Alnetum*, in the soil, 31 May 2017, 42°16'58.0“ N, 21°07'35.0“ E, 850 m; leg. TJ, EM, KR & MK, det. KR & MK.

Verpa bohemica (Krombh.) J. Schröt. – was previously recorded on leaf litter in broad-leaved forest, *Alnetum* and mixed forest of *Populus* and *Fagus* in Jabllanicë, Kaçandoll and Firza in 2017 and 2022, at altitudes of 416–1130 m (Ramshaj et al., 2022).

* ***Verpa conica*** (O.F. Müll.) Sw. – Elez Han: Dimcë, in *Alnus* stand on leaf litter, 11 March 2018, 42°09'12.71" N, 21°18'25.12" E, 500 m; leg. & det. MK. Pejë: Kuqishtë, *Abies alba* mixed with *Fraxinus* sp., on leaf litter, 9 May 2022, 42°41'34.0" N, 20°05'19.0" E, 1142 m; leg. QR & GO, det. QR & MK (No. 2022/563).

Xanthoria parietina (L.) Th. Fr. – was previously recorded on a dry branch of *Cornus mas* in *Quercus frainetto* forest in Peqan at an altitude of 378 m (Ramshaj et al., 2022).

Xylaria carpophila (Pers.) Fr. – was previously recorded on a fallen branch in *Fagus sylvatica* forests in Prevalla at an altitude of 1300 m (Ramshaj et al., 2022).

Xylaria hypoxylon (L.) Grev. – was previously recorded on rotten wood and leaf litter in *Fagus sylvatica* and mixed forests with *Pinus peuce* and *Abies alba* in Mushtisht (2017), Prevalla (2019), Qadrak (2020) and Brod (2021), at altitudes of 700–1370 m (Ramshaj et al., 2022).

* ***Xylaria longipes*** Nitschke – Deçan, *Alnetum* and deciduous forest, on leaf litter, 28 June 2019, 42°33'40.2" N, 20°13'23.4" E, 776 m; leg. & det. QR, ST, KR, & MK (No. 2019/175).

Xylaria polymorpha (Pers.) Grev. – was previously recorded on the trunk in *Alnus glutinosa* and *Fagus sylvatica* forests in Brod at an altitude of 700 m (Ramshaj et al., 2022).

Zeus olympius Minter & Diam. (Fig. 10 and Fig. 11). – was previously recorded on dry branches of living *Pinus heldreichii* in *Pinus heldreichii* forests in Prevalla at an altitude of 1600 m (Ramshaj et al., 2022).

Fig. 10. *Zeus olympius* on twigs of *Pinus heldreichii*, Kosovo, Prevallë, 1 June 2018. Photograph by M. Karadelev.

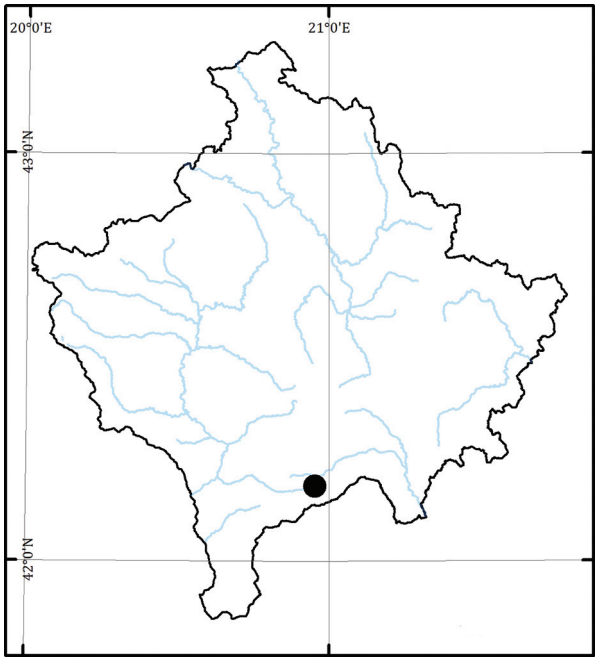


Fig. 11. Distribution of *Zeus olympius* in Kosovo.

DISCUSSION

The results of this research have significantly increased the knowledge of the diversity of Ascomycota fungi in Kosovo and the whole Balkan region. These results provide a basis for further mycological

and ecological studies of fungi in Kosovo and are important for conserving the mycobiota. During this study, five rare species, *Helvella atra*, *Microstoma protractum*, *Poronia punctata*, *Sarcosphaera coronaria* and *Zeus olympius* were recorded, which require specific conservation measures.

Helvella atra (Pezizales, Pezizomycetes) is a saprophytic fungus belonging to the group of fungi with a large apothecium (Fig. 3). It is a rare species in Europe (Breitenbach & Kränzlin, 1986; Jamoni, 2005). The species has been recorded in several countries of the Balkan Peninsula, but is rare and assessed as vulnerable in the Red List of Bulgaria (Gyosheva et al., 2006), Macedonia (Karadelev, 2020b) and Romania (Tănase & Pop, 2005). It is rare in Montenegro (Kasom & Miličković, 2006), but has been reported from several localities in Serbia (Savić, 2016; Savić et al., 2018). In Kosovo, this species has been recorded in a single locality (Viti) on a west-facing slope on the right side of the Morava e Binçës River valley. This area is characterised by shallow brown soils on schistose rocks, a continental climate with an annual air temperature of 8.6°C and annual rainfall of 800 mm (Pavičević et al., 1974; Pllana, 2015). The species is considered rare in Kosovo (Karadelev, 2018).

Another cup fungus of the Pezizales order is *Microstoma protractum*, which grows as a saprophyte mainly in forest soils. Since 2004, it has been a protected species in Poland and included in Poland's Red List of Macromycetes (Wojewoda & Ławrynowicz, 1986, 2006). Furthermore, *Microstoma protractum* has been classified as an endangered species in Slovakia (Lizoň, 2001). This species has also been considered vulnerable in Austria (Dämon & Krisai-Greilhuber, 2017) and Bulgaria (Gyosheva et al., 2006). In France, specifically in the Franche-Comté region, *Microstoma protractum* is critically endangered (Sugny et al., 2013). Records from North Macedonia confirm that *Microstoma protractum* is an endangered species in this region (Karadelev, 2020a). The occurrence of *Microstoma protractum* in Kosovo has only recently been confirmed. It was recorded growing in the leaf litter of deciduous trees on a northeast-facing slope in the upper sector of the Vellusha River in the Gërmia massif near Prishtina. Another record of this species was made in the vicinity of Kaçanik (Fig. 6). This locality is characterised by shallow brown soils on flysch sediments (Pavičević et al., 1974) and continental climate conditions with an annual air temperature of 9.6°C and 630 mm of annual rainfall (Pllana, 2015).

Poronia punctata (Xylariales) is an example of a coprophilous fungus that commonly colonises the aged dung of horses, ponies, donkeys and mules. Although less frequently, it has also been observed on the dung of cattle, especially cows (Matočec, 2000; Minter, 2006; Bignell & King, 2011; Edwards, 2015). In addition, sporadic occurrences of *Poronia punctata* have been recorded on the dung of sheep and elephants (Szczepkowski & Obidziński, 2016). In the Balkans, *Poronia punctata* has been assessed according to IUCN criteria in North Macedonia and has been classified as an endangered species (Rusevska, 2020). During this research, *Poronia punctata* was discovered for the first time in Kosovo, where it was only recorded in one locality (Peqan) on horse dung. The species was found on a south-facing slope in the middle sector of the Semetishti River valley. This area is characterised by alluvial-deluvial loamy soils, a continental climate influenced by the Mediterranean air masses, with an annual air temperature of 10.5°C and annual rainfall of 700 mm (Pavičević et al., 1974; Pllana, 2015). Comprehensive data documenting the distribution of *Poronia punctata* in European countries are currently lacking. However, the species has been included in red lists in several countries. The species is considered extinct in the Czech Republic (Holec & Beran, 2006) and Slovakia (Lizoň, 2001). Conversely, Bulgaria (Gyosheva et al., 2006) and Estonia (Saar et al., 2019) consider it a vulnerable species. It is classified as near threatened in Sweden, Great Britain and Romania (Gärdenfors, 2005; Evans et al., 2006; Tănase & Pop, 2005). It is listed as critically endangered in Ukraine (Heluta et al., 2022) and Croatia (Tkalčec et al., 2009). Furthermore, it has been proposed to include *Poronia punctata* in the preliminary Global Red List of Fungi and to place it in the category of species of least concern (Minter, 2014; Szczepkowski & Obidziński, 2016; Persiani & Ainsworth, 2020).

Sarcosphaera (Pezizales) is a monotypic genus represented by a single species, *Sarcosphaera coronaria*. It belongs to the group of cup fungi due to its distinctive cup-shaped fruiting body (Fig. 8). In North Macedonia, *Sarcosphaera coronaria* is classi-

fied as a vulnerable species (Karadelev, 2020c), while in Montenegro it is rare and proposed for protection (Branislav & Olgica, 2005). In Serbia, this species is strictly protected (Ivančević et al., 2012). The existence of specific threats to *Sarcosphaera coronaria* shows its status assessments in other European countries. It is classified as an endangered species in the Czech Republic (Holec & Beran, 2006), Bulgaria (Gyosheva et al., 2006), Estonia (Saar et al., 2019) and Slovakia (Lizoň, 2001). *Sarcosphaera coronaria* has recently been discovered in Kosovo, and only one locality is known in Koshutan (Pejë). The habitat is on an east-facing slope in the Rugova area of Mountains Bjeshkët e Nemuna (west of Kosovo), at an altitude of 1480 metres. The fungus was found in a stand of *Picea abies* on leaf litter (Fig. 8). The area is characterised by shallow brown soils on compact limestone, an alpine climate with a mean annual air temperature of 6.3°C and annual rainfall of 1080 mm (Pavičević et al., 1974; Pllana, 2015).

Zeus olympius belongs to the monotypic genus *Zeus* (Rhytismataceae, Rhytismatales). This species was discovered in 1987 when it was first collected from the iconic Mount Olympus in Greece (Minter et al., 1987). The fruit bodies of *Zeus olympius* are bright yellow discs that grow on the decaying wood of *Pinus heldreichii* H. Christ (Fig. 10). *Zeus olympius* has been recorded throughout the Balkan Peninsula. Stoykov et al. (2014) have reported its occurrence in Bulgaria, mainly on Mount Pirin, Mount Slavyanka and Mount Vitosha. Bulgarian mycologist Boris Asyov recorded this species in North Macedonia in September 2016, above Lake Ohrid, in Galičica National Park, where it was observed colonising dead leaves of *Ostrya carpinifolia* Scop. (Stoykov, 2020). Its populations in Greece are concentrated on Mount Olympus and Mount Pindus (Stoykov et al., 2014). The status of *Zeus olympius* according to IUCN criteria is currently unknown, as the assessment has not been completed for over a decade (RedList, 2014). In the southern part of Kosovo, this rare species has been recorded at an altitude of 1600 m in Prevalla, on steep slopes facing east and south-west, in the Oshlak area, in the Sharr Mountains. It is the only record of *Zeus olympius* in Kosovo. The site is characterised by browned rendzina soils on compact limestone, an alpine climate with an average annual air temperature of 5.5°C and annual rainfall of 1100 mm (Pavičević et al., 1974; Pllana, 2015). The species is associated with *Pinus heldreichii* stands (Karadelev, 2018).

This study has provided important information on the diversity, distribution and ecological characteristics of Ascomycota macromycetes in Kosovo. During the study, 43 new species of Ascomycota occurring in Kosovo were identified, and the total number of species more than doubled. The survey results are significant not only for the knowledge of the biodiversity of Kosovo, but also for information on the fungal species and their distribution in the whole region. The knowledge gained will be helpful in addressing conservation issues for some species and their habitats. Further research on the diversity of fungi in Kosovo is needed to identify the full diversity of Ascomycota and other groups of fungi.

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