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Biodiversity of fungal species from Tara Mountain (Serbia)

Original Article

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Abstract:

The Republic of Serbia is one of the few European countries without a national database of recorded fungal species, so documenting and publishing data on fungal diversity is of outmost importance for our country. The presence of fungal specimens of Tara Mountain was examined in the following localities: Mitrovac, Predov Krst, Kaludjerske Bare and Zaovine at each site in summer and autumn during 2021 and 2022. A total of 320 taxa of fungi were recorded during this period, 10 of them are included in the Serbian List of Protected Wild Species of Fungi: *Boletus edulis*, *B. reticulatus*, *Cantharellus cibarius*, *Craterellus cornucopioides*, *Hydnum repandum*, *Lactarius deliciosus*, *L. deterrimus*, *L. salmonicolor*, *Marasmius oreades* and *Russula cyanoxantha*, while three species: *Hericium flagellum*, *H. coralloides* and *Psilocybe serbica* are listed in the Serbian List of Strictly Protected Wild Specis of Fungi. Also, 38 species are indentified as an indicator species of old and preserved forests. The highest species diversity was founded in Mitrovac.

Key words:
mycological diversity, National Park Tara, fungi, indicator species

Apstrakt:

Biodiverzitet gljiva planine Tare (Srbija)

Republika Srbija je jedna od retkih evropskih zemalja koja nema nacionalnu bazu podataka o evidentiranim vrstama gljiva, pa je dokumentovanje i objavljivanje podataka o raznovrsnosti gljiva od izuzetnog značaja za našu zemlju. Istraživano je prisustvo plodnih tela gljiva planine Tare u leto i jesen tokom 2021. i 2022. godine na sledećim lokalitetima: Mitrovac, Predov Krst, Kaluđerske Bare i Zaovine. U ovom periodu evidentirano je ukupno 320 taksona gljiva, od kojih je 10 na listi zaštićenih divljih vrsta gljiva u Srbiji: *Boletus edulis, B. reticulatus, Cantharellus cibarius, Craterellus cornucopioides, Hydnum repandum, Lactarius deliciosus, L. deterrimus, L. salmonicolor, Marasmius oreades,* dok su vrste*: Hericium flagellum, H. coralloides* i *Psilocybe serbica* navedene u listi strogo zaštićenih divljih vrsta gljiva Srbije. Takođe, 38 vrsta je identifikovano kao indikatorske vrste starih i očuvanih šuma. Najveći diverzitet vrsta zabeležen je na lokalitetu Mitrovac.

Ključne reči:
mikološki diverzitet, Nacionalni park Tara, gljive, indikatorske vrste

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Introduction

Forests are among the most important terrestrial ecosystems, considering that they are the species-richest and are vital for sustaining life on Earth (Nilsson, 1992; Rydin et al., 1997; Gardenfors, 2000; Bravo-Oviedo et al., 2014). At the same time forests are one of the most endangered ecosystems on Earth due to various human activities like unsustainable use of wood, pollution, poor management, climate factors, etc. (Marchetti, 2004).

Fungi are a remarkably heterogeneous and diverse group of organisms present in nearly all ecosystems on our planet (Hood, 2006). They are of special significance in forest ecosystems, where they fulfill an array of vital functions and constitute an important part of their total biodiversity (Hawksworth, 2004). In forests, fungi are mainly present in soil where their mycelium makes up 89% of the total microbial biomass (Frankland, 1982). However, one of the most important groups of forest fungi are decomposers of dead and decaying organic matter - saprotrophs. This group of fungi is crucial for the functioning of forest ecosystems, as wood decomposition is decisive for nutrient cycling, carbon balance, and soil formation (Lonsdale et al., 2008). A particularly significant group of fungi that decompose dead wood are lignicolous fungi that decompose lignocellulosic matter as an underutilized natural resource (Karaman et al., 2012). Mycorrhizal

fungi are another important group of forest fungi. They provide plants with easier absorption of mineral substances, which increases their resistance to different abiotic and biotic stresses (drought, pollutants, pathogens, etc.) (Deacon, 2006). Also, fungi occur on living organisms as pathogens, and regulate population dynamics of different species (Fang et al., 2021; Bahram & Netherway, 2022).

Due to their sensitivity to human activities that reduce the naturalness and functionality of forest ecosystems, certain fungal species are used as indicators of old-growth forests, i.e. preserved, undisturbed, conservation-worthy forest habitats (Christensen et al., 2004). From a conservation point of view, old-growth forests are crucial for the survival of valuable, rare, and endangered species (Runnel & Lõhmus, 2017). Based on the presence of old-growth indicator fungal species, it is possible to prioritize protection and specific management of forest areas of high conservation value and at the same time to emphasize their importance and the importance of their protection and preservation (Christensen et al., 2004).

Considering the importance of forest ecosystems and the lack of biodiversity data on fungal species in Serbia, our research was focused on deepening the knowledge about the fungal diversity of Mountain Tara, which is located in western Serbia and represents a part of the Dinaric Alps, especially in the area of National Park Tara. Mt. So far, only a few papers related to the research on the diversity of macrofungal species in forest ecosystems of Mt. Tara have been published (Čolić, 1967; Karađić, 2006; Rakić, 2019; Jovanović et al., 2021; Rakić et al., 2022). In addition to this, several lignicolous and mycorrhizal fungal taxa from Tara Mt. have been examined for accumulation of heavy metals and radionuclides (Rakić et al., 2014). In our monitoring survey of fungal diversity of Mt. Tara, special four localities were selected. Furthermore, the diversity of old-growth indicator species such as *Hericium coralloides* (Scop.) Pers, *Ischnoderma benzoinum* (Wahlenb.) P. Karst., *Mucidula mucida* (Schrad.) Pat., *Pycnoporellus fulgens* (Fr.) Donk, *Sparassis crispa* (Wulfen) Fr., etc. have been detected.

Materials and Methods

Study area

The research was conducted in the National Park Tara, in four localities: Mitrovac, Kaludjerske Bare, Predov Krst, and Zaovine (**Fig. 1**). Site Kaludjerske Bare (43°54'22.4"N 19°31'30.8"E) is located in the southeastern part of Tara and represents one of the most famous tourist hot spots on the mountain. In this locality, forests of black and white pine, fir,

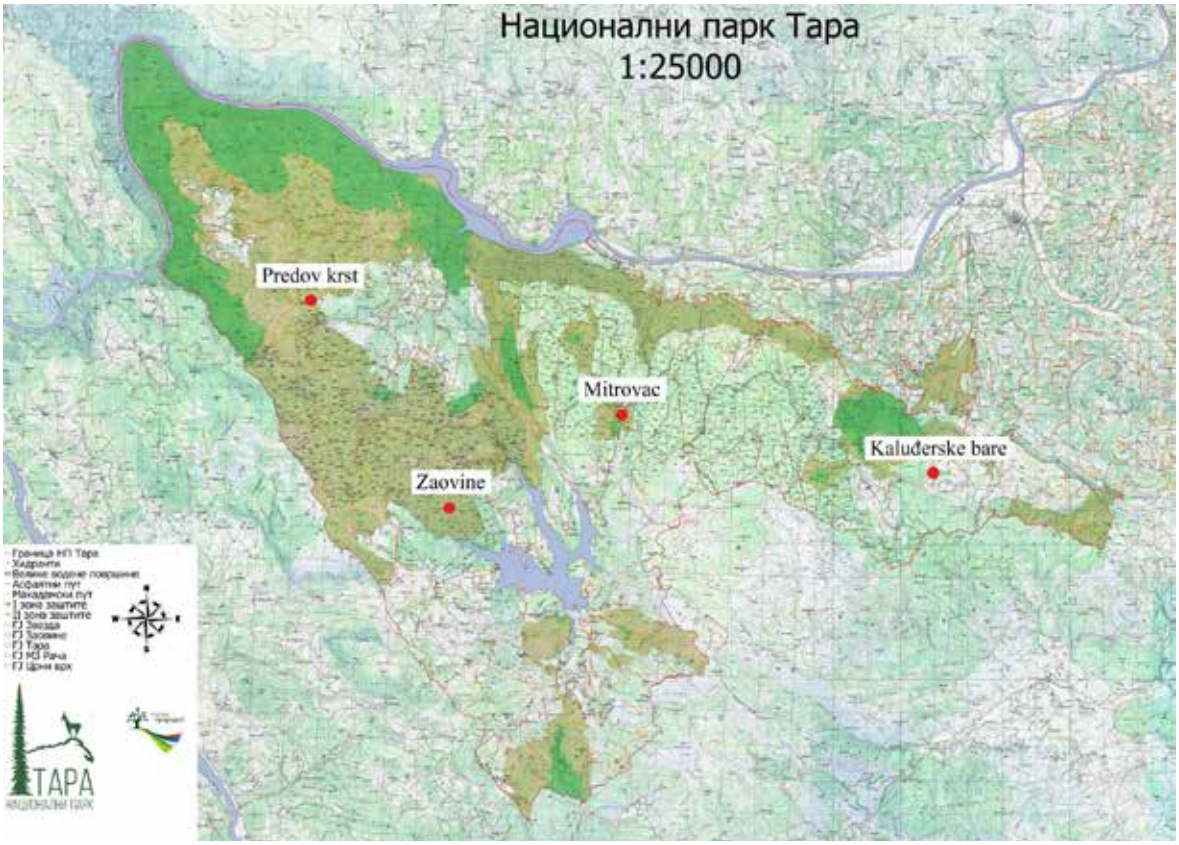

Fig. 1. Map of four investigated sites on Tara Mt.

and spruce grow on the limestone base. Predov Krst (43°56'28.4"N 19°18'34.3"E) is located in the most remote part of Tara, in the northwest. It is represented by the ridges surrounded by the Drina river. This is one of the best-preserved mountain areas in Serbia, with nature reserves which are refugees and one of the last habitats of the tertiary relic plant species - Serbian spuce (*Picea omorika* (Pančić) Purk). Mitrovac (43°55'16.4"N 19°25'25.9"E) is located in the central part of Mt. Tara, with specific geological, climate, and hydrological characteristics. It has preserved numerous sinkholes, a unique post-glacial peat bog, and primeval-type vegetation with one of the few remaining habitats of Serbian spuce. Site Zaovine (43°53'11.4"N 19°21'50.4"E) is located in the southern part of Tara Mountain, and represents area with mountainous character that includes the Zaovine village, the Zaovine lake and the canyon of river Beli Rzav „Sklopovi".

Data collection

Fungal diversity research was conducted during summer and autumn of 2021 and 2022. The fungal specimens were identified based on morphological (macroscopic and microscopic) descriptions on the Microscope Unit (Kern, OBN135). The identification of the species has been done according to specialized identification keys (Breitenbach & Kranzlin, 1984; Knudsen & Vesterholt, 2008; Uzelac, 2009; Aronsen & Læssøe, 2016; Læssøe & Petersen, 2019) by using standard reagents (KOH, $FeSO_4$).

The nomenclature of the species names is in accordance with the database of Index Fungorum (www.indexfungorum.org), and MycoBank (https://www.mycobank.org/). Representative specimens of fungal species were dried at 50 °C (Scholtes FP 955.3, Germany) and deposited within Fungarium of the ProFungi laboratory (BUNS Herbarium, Department of Biology and Ecology, Faculty of Sciences, University of Novi Sad) (https://www.pmf.uns.ac.rs/en/research/groups/profungi/). All specimens were recorded using the iNaturalist application (https://www.inaturalist.org/).

Results and discussion

A total of 320 fungal taxa were observed in four localities on Mt. Tara. Phylum Ascomycota is represented by 13 species that belong to 9 genera and 8 families with *Xylaria* as the most abundant genus represented by 3 species (**Tab. 1**). Phylum Basidiomycota is represented by 329 taxa, belonging to 136 genera and 69 families. The most diverse family in phylum Basidiomycota is Russulaceae with 37 taxa. Other representative families were: Tricholomataceae (25), Mycenaceae (21), Agaricaceae (19), Polyporaceae (17) and Boletaceae (15) (**Fig. 2**). The genus with the highest number of species is *Russula* with 20 taxa determined. One specimen from Phylum Mucoromycotina was recorded - *Spinellus fusiger* (Link) Tiegh. (**Tab. 1**).

Table 1. List of recorded fungal taxa

Taxa	Locality*	Indicator**	Functional group
Ascomycota			
Discinaceae			
Gyromitra infula (Schaeff.) Quél.	KB, Z		Sap
Gelatinodiscaceae			
Ascocoryne cylichnium (Tul.) Korf	M	Italy	Sap
Ascocoryne sarcoides (Jacq.) J.W. Groves & D.E. Wilson	M		Sap
Neobulgaria pura (Pers.) Petr.	M, PK		Sap
Helvellaceae			
Helvella atra J. König	M		Myc
Helvella crispa Sowerby	M, PK		Myc
Pezizaceae			
Peziza saniosa Schrad.	PK		Myc
Pezizellaceae			
Calycina citrina (Hedw.) Gray	M		Sap
Xylariaceae			

Xylaria hypoxylon (L.) Grev.	M, PK		Sap
Xylaria longipes Nitschke	M		Sap
Xylaria polymorpha (Pers.) Grev.	M, PK	Lithuania; Italy; Estonia	Sap
Basidiomycota			
Agaricaceae			
Agaricus essettei Bon	M, PK		Sap
Agaricus langei (F.H. Møller) F.H. Møller	M, PK		Sap
Agaricus sylvicola (Vittad.) Peck	KB, PK		Sap
Agaricus urinascens (Jul. Schäff. & F.H. Møller) Singer	KB		Sap
Chlorophyllum olivieri (Barla) Vellinga	M		Sap
Chlorophyllum rhacodes (Vittad.) Vellinga	M		Sap
Crucibulum laeve (Huds.) Kambly	KB		Sap
Cyathus striatus Willd.	PK		Sap
Cystodermella cinnabarina (Alb. & Schwein.) Harmaja	KB		Sap
Cystolepiota seminuda (Lasch) Bon	KB		Sap
Echinoderma asperum (Pers.) Bon	PK		Sap
Lepiota castanea Quél.	PK		Sap
Lepiota clypeolaria (Bull.) P. Kumm.	KB, M, PK		Sap
Lepiota cristata (Bolton) P. Kumm.	KB, M, PK		Sap
Lepiota ignivolvata Bousset & Joss. ex Joss.	PK, Z		Sap
Lepiota magnispora Murrill	KB		Sap
Macrolepiota mastoidea (Fr.) Singer	KB, Z		Sap
Macrolepiota procera (Scop.) Singer	KB, PK		Sap
Melanophyllum haematospermum (Bull.) Kreisel	Z		Sap
Amanitaceae			
Amanita battarrae (Boud.) Bon	KB		Myc
Amanita citrine Pers.	KB, M, PK		Myc
Amanita fulvoides Neville & Poumarat	KB		Myc
Amanita gemmata (Fr.) Bertill.	M		Myc
Amanita muscaria (L.) Lam.	KB, M, PK, Z		Myc
Amanita pantherina (DC.) Krombh.	KB, M, PK, Z		Myc
Amanita phalloides (Vaill. ex Fr.) Link	M		Myc
Amanita rubescens Pers.	KB, M, Z		Myc
Amanita vaginata (Bull.) Lam.	KB		Myc
Auriculariaceae			
Auricularia auricula-judae (Bull.) Quél.	PK		Sap

Auricularia mesenterica (Dicks.) Pers.	M	EU	Sap
Auriscalpiaceae			
Lentinellus flabelliformis (Bolton) S. Ito	M, PK		Par/Sap
Bankeraceae			
Sarcodon imbricatus (L.) P. Karst.	M, PK	Estonia	Myc
Boletaceae			
Boletus edulis Bull.	KB, M, PK		Myc
Boletus reticulates Schaeff.	M		Myc
Caloboletus calopus (Pers.) Vizzini	KB, M, PK		Myc
Chalciporus piperatus (Bull.) Bataille	Z		Par
Imleria badia (Fr.) Vizzini	KB, M		Myc
Leccinum albostipitatum den Bakker & Noordel.	KB		Myc
Leccinum aurantiacum (Bull.) Gray	KB, PK		Myc
Leccinum scabrum (Bull.) Gray	Z		Myc
Neoboletus luridiformis (Rostk.) Gelardi, Simonini &Vizzini	KB, M, PK		Myc
Suillellus luridus (Schaeff.) Murrill	PK		Myc
Suillellus queletii (Schulzer) Vizzini, Simonini & Gelardi	PK		Myc
Xerocomellus chrysenteron (Bull.) Šutara	KB, M, PK		Myc
Xerocomellus porosporus (Imler ex Watling) Šutara	M, PK		Myc
Xerocomellus pruinatus (Fr.) Šutara	KB, M		Myc
Xerocomus subtomentosus (L.) Quél.	M		Myc
Clavariadelphaceae			
Clavariadelphus pistillaris (L.) Donk	Z	Estonia	Myc
Cortinariaceae			
Cortinarius atrovirens Kalchbr.	KB, M		Myc
Cortinarius elegantior (Fr.) Fr.	PK		Myc
Cortinarius flexipes (Pers.) Fr.	KB, M		Myc
Cortinarius hercynicus (Pers.) M.M. Moser	Z		Myc
Cortinarius infractus (Pers.) Fr.	M		Myc
Cortinarius ohlone Bojantchev	KB		Myc
Cortinarius olivaceofuscus Kühner	M, PK		Myc
Cortinarius pseudodaulnoyae Rob. Henry & Ramm	M		Myc
Cortinarius salor Fr.	M		Myc
Cortinarius sanguineus (Wulfen) Gray	M		Myc
Cortinarius semisanguineus (Fr.) Gillet	M		Myc
Cortinarius trivialis J.E. Lange	KB, Z		Myc

Cortinarius violaceus (L.) Gray	M		Myc
Crepidotaceae			
Crepidotus applanatus (Pers.) P. Kumm.	M, PK		Sap
Cyphellaceae			
Baeospora myosura (Fr.) Singer	Z		Sap
Chondrostereum purpureum (Pers.) Pouzar	M		Par/Sap
Dacrymycetaceae			
Calocera cornea (Batsch) Fr.	M, Z		Par/Sap
Calocera furcata (Fr.) Fr.	M		Par/Sap
Calocera viscosa (Pers.) Fr.	M, PK		Par/Sap
Dacryobolaceae			
Postia ptychogaster (F. Ludw.) Vesterh.	KB		Par/Sap
Echinodontiaceae			
Amylostereum areolatum (Chaillet ex Fr.) Boidin	M		Par/Sap
Entolomataceae			
Clitopilus prunulus(Scop.) P. Kumm.	KB, M, PK, Z		Myc
Entocybe nitida (Quél.) T.J. Baroni, Largent & V. Hofst.	M		Sap
Entoloma hebes (Romagn.) Trimbach	KB		Sap
Entoloma lampropus (Fr.) Hesler	PK		Sap
Exidiaceae			
Guepinia helvelloides (DC.) Fr.	PK	Estonia	Sap
Pseudohydnum gelatinosum (Scop.) P. Karst.	KB, M, PK		Sap
Fomitopsidaceae			
Climacocystis borealis (Fr.) Kotl. & Pouzar	KB	Latvia	Par/Sap
Fomitopsis betulina (Bull.) B.K. Cui, M.L. Han & Y.C. Dai	M		Par/Sap
Fomitopsis pinicola (Sw.) P. Karst.	KB, M, PK	Yugoslavia	Par/Sap
Geastraceae			
Geastrum fimbriatum Fr.	PK	Lithuania; Estonia	Sap
Geastrum rufescens Pers.	KB	Lithuania; Estonia	Sap
Geastrum striatum DC.	PK	Lithuania; Estonia	Sap
Geastrum triplex Jungh.	KB, M	Lithuania; Estonia	Sap
Gloeophyllaceae			
Gloeophyllum abietinum (Bull.) P. Karst.	M		Par/Sap
Gloeophyllum odoratum (Wulfen) Imazeki	KB, M		Par/Sap
Gloeophyllum sepiarium (Wulfen) P. Karst.	M		Par/Sap

Gomphaceae			
Phaeoclavulina flaccida (Fr.) Giachini	KB		Sap
Ramaria aurea (Schaeff.) Quél.	M, PK		Myc
Ramaria stricta (Pers.) Quél.	PK		Sap
Gomphidiaceae			
Chroogomphus rutilus (Schaeff.) O.K. Mill.	KB, Z		Par
Hericiaceae			
Hericium clathroides (Pall.) Pers.	M		Par/Sap
Hericium coralloides (Scop.) Pers.	M	Great Britain; Lithuania; Central Europe; Europe; Latvia; Denmark; Estonia; Germany; Yugoslavia; Benelux	Par/Sap
Hericium flagellum (Scop.) Pers.	M	Central Europe; Yugoslavia	Par/Sap
Hydnaceae			
Cantharellus cibarius Fr.	M, PK		Myc
Clavulina coralloides (L.) J. Schröt.	M, Z		Myc
Clavulina rugosa (Bull.) J. Schröt.	M, Z		Myc
Craterellus cornucopioides (L.) Pers.	M		Myc
Craterellus tubaeformis (Fr.) Quél.	M		Myc
Hydnum repandum L.	KB		Myc
Hydnum rufescens Pers.	M		Myc
Hydnangiaceae			
Laccaria amethystine Cooke	KB, M, PK, Z		Myc
Laccaria bicolor (Maire) P.D. Orton	KB, Z		Myc
Laccaria laccata (Scop.) Cooke	KB, M, PK, Z		Myc
Hygrophoraceae			
Arrhenia spathulata (Fr.) Redhead	KB		Sap
Chrysomphalina grossula (Pers.) Norvell, Redhead & Ammirati	M	Czech Republic	Sap
Cuphophyllus pratensis (Pers.) Bon	KB		Sap
Hygrocybe chlorophana (Fr.) Wünsche	KB		Myc
Hygrocybe coccinea (Schaeff.) P. Kumm.	KB, M, Z		Myc
Hygrophorus agathosmus (Fr.) Fr.	KB		Myc
Hygrophorus capreolarius (Kalchbr.) Sacc.	M		Myc
Hygrophorus chrysodon (Batsch) Fr.	M		Myc
Hygrophorus cossus (Sowerby) Fr.	PK		Myc
Hygrophorus eburneus (Bull.) Fr.	KB, M, Z		Myc
Hygrophorus latitabundus Britzelm.	KB		Myc

Hygrophorus persoonii Arnolds	KB		Myc
Hygrophorus pudorinus (Fr.) Fr.	M		Myc
Hygrophoropsidaceae			
Hygrophoropsis aurantiaca (Wulfen) Maire	KB, M, PK		Sap
Hymenochaetaceae			
Phellinus pomaceus (Pers.) Maire	KB, M, Z		Par/Sap
Hymenogastraceae			
Galerina badipes (Pers.) Kühner	M		Sap
Galerina graminea (Velen.) Kühner	KB		Sap
Galerina hypnorum (Schrank) Kühner	M		Sap
Galerina marginata (Batsch) Kühner	KB, M		Sap
Gymnopilus penetrans (Fr.) Murrill	KB, M, PK, Z		Sap
Gymnopilus picreus (Pers.) P. Karst.	M		Sap
Gymnopilus sapineus(Fr.) Murrill	M		Sap
Hebeloma birrus (Fr.) Gillet	M		Myc
Hebeloma crustuliniforme (Bull.) Quél.	KB, M		Myc
Hebeloma sinapizans (Paulet) Gillet	KB		Myc
Psilocybe coronilla (Bull.) Noordel.	KB		Sap
Psilocybe serbica M.M. Moser & E. Horak	KB, M		Sap
Incrustoporiaceae			
Tyromyces chioneus (Fr.) P. Karst.	M		Par/Sap
Inocybaceae			
Inocybe geophylla P. Kumm.	M		Myc
Inocybe griseolilacina J.E. Lange	Z		Myc
Ischnodermataceae			
Ischnoderma benzoinum (Wahlenb.) P. Karst.	M, PK	Czech Republic; Yugoslavia	Par/Sap
Laetiporaceae			
Laetiporus sulphureus (Bull.) Murrill	M		Par/Sap
Lycoperdaceae			
Apioperdon pyriforme (Schaeff.) Vizzini	KB, M, PK	Italy	Sap
Bovista plumbea Pers.	KB		Sap
Bovistella utriformis (Bull.) Demoulin & Rebriev	KB		Sap
Lycoperdon echinatum Pers.	PK	Lithuania; Estonia	Sap
Lycoperdon excipuliforme (Scop.) Pers.	KB, PK, Z		Sap
Lycoperdon molle Pers.	M		Sap
Lycoperdon perlatum Pers.	KB, M, PK		Sap
Lycoperdon pratense Pers.	KB		Sap

Lyophyllaceae			
Asterophora lycoperdoides (Bull.) Ditmar	Z		Sap
Lyophyllum decastes (Fr.) Singer	PK		Sap
Tephrocybe rancida (Fr.) Donk	KB, M		Sap
Macrocystidiaceae			
Macrocystidia cucumis (Pers.) Joss.	KB, M		Sap
Marasmiaceae			
Crinipelliss cabella (Alb. & Schwein.) Murrill	KB		Sap
Marasmius oreades (Bolton) Fr.	KB, PK		Sap
Marasmius rotula (Scop.) Fr.	M, Z		Sap
Marasmius torquescens Quél.	M, PK		Sap
Megacollybia platyphylla (Pers.) Kotl. & Pouzar	KB, M, PK		Sap
Meripilaceae			
Meripilus giganteus (Pers.) P. Karst.	PK	Germany	Par/Sap
Meruliaceae			
Phlebia tremellosa (Schrad.) Nakasone & Burds.	M		Par/Sap
Mycenaceae			
Hemimycena lactea (Pers.) Singer	M		Sap
Hydropus marginellus (Pers.) Singer	M	Central Europe	Sap
Mycena aurantiomarginata (Fr.) Quél.	M		Sap
Mycena crocata (Schrad.) P. Kumm.	M, PK		Sap
Mycena epipterygia (Scop.) Gray	KB, M, PK		Sap
Mycena galericulata (Scop.) Gray	M, PK	Italy; European Union	Sap
Mycena galopus (Pers.) P. Kumm.	KB, M		Sap
Mycena haematopus (Pers.) P. Kumm.	KB, M, PK		Sap
Mycena lammiensis Harmaja	PK		Sap
Mycena maculata P. Karst.	M	Germany	Sap
Mycena pelianthina (Fr.) Quél.	KB		Sap
Mycena picta (Fr.) Harmaja	M		Sap
Mycena pterigena (Fr.) P. Kumm.	M		Sap
Mycena pura (Pers.) P. Kumm.	KB, M, PK, Z		Sap
Mycena rosea Gramberg	KB, M, PK		Sap
Mycena rosella (Fr.) P. Kumm.	M		Sap
Mycena sanguinolenta (Alb. & Schwein.) P. Kumm.	M		Sap
Mycena stipata Maas Geest. & Schwöbel	KB, M, PK		Sap

Mycena viridimarginata P. Karst.	M		Sap
Panellus stipticus (Bull.) P. Karst.	KB, M, PK		Sap
Prunulus diosmus (Krieglst. & Schwöbel) C. Hahn	KB		Sap
Omphalotaceae			
Collybiopsis confluens (Pers.) R.H. Petersen	KB, M, PK		Sap
Collybiopsis peronata (Bolton) R.H. Petersen	PK		Sap
Collybiopsis vaillantii (Pers.) R.H. Petersen	KB		Sap
Gymnopusan drosaceus (L.) Della Magg. & Trassin.	M		Sap
Gymnopus dryophilus (Bull.) Murrill	M		Sap
Gymnopus erythropus (Pers.) Antonín, Halling & Noordel.	KB		Sap
Gymnopus hariolorum (Bull.) Antonín, Halling & Noordel.	PK		Sap
Mycetinis alliaceus (Jacq.) Earle ex A.W. Wilson & Desjardin	KB, M, PK, Z		Sap
Mycetinis scorodonius (Fr.) A.W. Wilson & Desjardin	KB, M		Sap
Rhodocollybia butyracea (Bull.) Lennox	KB, M, Z		Sap
Rhodocollybia maculata (Alb. & Schwein.) Singer	KB		Sap
Rhodocollybia prolixa var. *distorta* (Fr.) Antonín, Halling & Noordel.	M		Sap
Paxillaceae			
Paxillus involutus (Batsch) Fr.	KB, M, Z		Myc
Phanerochaetaceae			
Bjerkandera adusta (Willd.) P. Karst.	KB, M, PK		Par/Sap
Phyllotopsidaceae			
Phyllotopsis nidulans (Pers.) Singer	M	Great Britain	Par/Sap
Pleurocybella porrigens (Pers.) Singer	M		Sap
Physalacriaceae			
Armillaria gallica Marxm. & Romagn.	KB, M		Par/Sap
Hymenopelli sradicata (Relhan) R.H. Petersen	KB, M, PK, Z		Sap
Mucidula mucida (Schrad.) Pat.	KB, M, PK	Germany	Par/Sap
Xerula pudens (Pers.) Singer	KB, PK, Z		Myc
Pluteaceae			
Pluteus cervinus (Schaeff.) P. Kumm.	KB, M, PK		Sap
Pluteus petasatus (Fr.) Gillet	PK		Sap

Pluteus pouzarianus Singer	PK		Sap
Podoscyphaceae			
Abortiporus biennis (Bull.) Singer	M		Par/Sap
Polyporaceae			
Cerioporus varius (Pers.) Zmitr. & Kovalenko	PK		Par/Sap
Coriolopsis gallica (Fr.) Ryvarden	M	Great Britain	Par/Sap
Cyanosporus caesius (Schrad.) McGinty	KB, M, PK		Par/Sap
Daedaleopsis confragosa (Bolton) J. Schröt.	KB, PK		Par/Sap
Daedaleopsis tricolor (Bull.) Bondartsev & Singer	M		Par/Sap
Fomes fomentarius (L.) Fr.	KB, M, PK	Italy; Germany; Yugoslavia	Par/Sap
Ganoderma applanatum (Pers.) Pat.	M, PK	European Union; Germany; Yugoslavia	Par/Sap
Ganoderma carnosum Pat.	M	Yugoslavia	Par/Sap
Ganoderma resinaceum Boud.	M		Par/Sap
Trametes cinnabarina (Jacq.) Fr.	M		Par/Saprothr
Trametes gibbosa (Pers.) Fr.	M, Z		Par/Sap
Trametes hirsuta (Wulfen) Lloyd	M, PK		Par/Sap
Trametes ochracea (Pers.) Gilb. & Ryvarden	PK		Par/Sap
Trametes pubescens (Schumach.) Pilát	KB, M, PK	Italy	Par/Sap
Trametes versicolor (L.) Lloyd	KB, M, PK		Par/Sap
Trichaptum abietinum (Pers. ex J.F. Gmel.) Ryvarden	KB, M, PK		Par/Sap
Trichaptum biforme (Fr.) Ryvarden	M, PK		Par/Sap
Psathyrellaceae			
Candolleomyces candolleanus (Fr.) D. Wächt. & A. Melzer (Fr.) D. Wächt. & A. Melzer	KB, M, PK		Sap
Coprinellus micaceus (Bull.) Vilgalys, Hopple & Jacq. Johnson	KB, M		Sap
Coprinopsis atramentaria (Bull.) Redhead, Vilgalys & Moncalvo	M		Sap
Panaeolus acuminatus (P. Kumm.) Quél.	KB		Sap
Pseudoclitocybaceae			
Pseudoclitocybe cyathiformis (Bull.) Singer	M	Czech Republic	Sap
Pycnoporellaceae			
Pycnoporellus fulgens (Fr.) Donk	M, PK	Latvia; Finland; Estonia; Yugoslavia	Par/Sap
Rickenellaceae			

Rickenella fibula (Bull.) Raithelh.	KB, M		Par
Rickenella swartzii (Fr.) Kuyper	KB, M		Par
Russulaceae			
Lactarius aurantiacus (Pers.) Gray	KB, M, Z		Myc
Lactarius blennius (Fr.) Fr.	KB, M, PK		Myc
Lactarius controversus Pers.	KB		Myc
Lactarius deliciosus (L.) Gray	KB, M, PK		Myc
Lactarius deterrimus Gröger	KB, M		Myc
Lactarius luridus (Pers.) Gray	M		Myc
Lactarius mairei Malençon	Z		Myc
Lactarius pallidus Pers.	KB, PK		Myc
Lactarius picinus Fr.	PK		Myc
Lactarius rubrocinctus Fr.	KB		Myc
Lactarius rufus (Scop.) Fr.	M, PK		Myc
Lactarius salmonicolor R. Heim & Leclair	KB, M, Z		Myc
Lactarius scrobiculatus (Scop.) Fr.	KB, M		Myc
Lactariustorminosus (Schaeff.) Pers.	KB		Myc
Lactarius uvidus (Fr.) Fr.	KB, PK	Czech Republic	Myc
Lactarius violascens (J. Otto) Fr.	KB		Myc
Lactifluus vellereus (Fr.) Kuntze	KB		Myc
Russula adusta (Pers.) Fr.	M, Z		Myc
Russula aeruginea Lindblad ex Fr.	PK		Myc
Russula atropurpurea (Krombh.) Britzelm.	KB, M		Myc
Russula badia Quél.	KB, M		Myc
Russula cessans A. Pearson	M		Myc
Russula chloroides (Krombh.) Bres.	KB, M		Myc
Russula cyanoxantha (Schaeff.) Fr.	KB, M, PK		Myc
Russula delica Fr.	M		Myc
Russula densifolia Secr. ex Gillet	M		Myc
Russula fellea (Fr.) Fr.	M		Myc
Russula fragilis Fr.	PK		Myc
Russula fragilis f. *violascens* (Secr. ex Gillet) Sacc.	M		Myc
Russula grata Britzelm.	M		Myc
Russula integra (L.) Fr.	KB, M, Z		Myc
Russula mustelina Fr.	M		Myc
Russula nobilis Velen.	M		Myc
Russula ochroleuca Fr.	M		Myc
Russula sardonia Fr.	KB		Myc
Russulas olaris Ferd. & Winge	KB		Myc
Russula torulosa Bres.	KB		Myc

Sarcomyxaceae			
Sarcomyxa serotina (Pers.) V. Papp	M		Sap
Schizophyllaceae			
Schizophyllum commune Fr.	M, PK, Z		Sap
Sparassidaceae			
Sparassis brevipes Krombh.	M	Yugoslavia	Sap
Sparassis crispa (Wulfen) Fr.	M	Finland	Sap
Squamanitaceae			
Cystoderma carcharias (Pers.) Fayod	KB, M		Sap
Stereaceae			
Stereum hirsutum (Willd.) Pers.	M, PK		Par/Sap
Stereum subtomentosum Pouzar	M, PK	Denmark; Yugoslavia	Par/Sap
Strophariaceae			
Hypholoma capnoides (Fr.) P. Kumm.	M		Sap
Hypholoma fasciculare (Huds.) P. Kumm.	KB, M, PK		Sap
Hypholoma lateritium (Schaeff.) P. Kumm.	KB, M		Sap
Kuehneromyces mutabilis (Schaeff.) Singer & A.H. Sm.	PK		Sap
Pholiota adiposa (Batsch) P. Kumm.	KB		Sap
Pholiota aurivella (Batsch) P. Kumm.	KB, M	Denmark; Benelux	Sap
Pholiota lenta (Pers.) Singer	M		Sap
Pholiota squarrosa (Vahl) P. Kumm.	M		Sap
Stropharia aeruginosa (Curtis) Quél.	KB, M, PK		Sap
Stropharia caerulea Kreisel	M, Z		Sap
Suillaceae			
Suilluscollinitus (Fr.) Kuntze	KB		Myc
Suillus granulatus (L.) Roussel	KB, PK		Myc
Suillus luteus (L.) Roussel	Z		Myc
Tremellaceae			
Tremella mesenterica (Schaeff.) Pers.	M		Par
Tricholomataceae			
Clitocybe dealbata (Sowerby) P. Kumm.	KB		Sap
Clitocybe fragrans (With.) P. Kumm.	KB, M		Sap
Clitocybe nebularis (Batsch) P. Kumm.	KB, M		Sap
Clitocybe odora (Bull.) P. Kumm.	KB, PK		Sap
Collybia cirrhata (Schumach.) Quél.	M		Sap
Infundibulicybe geotropa (Bull.) Harmaja	PK		Sap
Lepista nuda (Bull.) Cooke	KB, M		Sap
Leucocortinarius bulbiger (Alb. & Schwein.) Singer	KB, PK		Myc

	Leucocybe connata (Schumach.) Vizzini, P. Alvarado, G. Moreno & Consiglio	M		Sap
	Leucopaxillus gentianeus (Quél.) Kotl.	KB, PK		Sap
	Paralepista flaccida (Sowerby) Vizzini	M, Z		Sap
	Tricholoma album (Schaeff.) P. Kumm.	KB	European Union	Myc
	Tricholoma bufonium (Pers.) Gillet	M		Myc
	Tricholom equestre (L.) P. Kumm.	Z		Myc
	Tricholoma evenosum (Sacc.) Rea	KB		Myc
	Tricholoma fracticum (Britzelm.) Kreisel	KB		Myc
	Tricholoma fulvum (DC.) Bigeard & H. Guill.	KB		Myc
	Tricholoma imbricatum (Fr.) P. Kumm.	M		Myc
	Tricholoma portentosum (Fr.) Quél.	Z		Myc
	Tricholoma saponaceum (Fr.) P. Kumm.	KB, M		Myc
	Tricholoma saponaceum f. *ardosiacum* (Bres.) Bon	M		Myc
	Tricholoma sulphureum (Bull.) P. Kumm.	KB, M, PK	European Union	Myc
	Tricholoma terreum (Schaeff.) P. Kumm.	KB, M		Myc
	Tricholoma vaccinum (Schaeff.) P. Kumm.	KB, M, Z		Myc
	Tricholomopsis rutilans (Schaeff.) Singer	KB, M, PK		Sap
Mucoromycota				
Phycomycetaceae				
	Spinellus fusiger (Link) Tiegh.	M		Par

* Locality: KB – Kaludjerske Bare; M – Mitrovac; PK – Predov Krst; Z – Zaovine. Functional group: Sap – Saprotroph, Par – Parasite, Par/Sap – Parasite/Saprotroph, Myc – Mycorhizal
** Regions in which a specific fungal species is listed as an indicator species of old-growth forests: Benelux (Walleyn & Veerkamp, 2005); Central Europe (Blaschke et al., 2009); Czech Republic (Holec, 2003; Dvořák et al., 2017); Denmark (Heilmann-Clausen & Christensen, 2000); Estonia (Parmasto, 2001; Estonian Ministry of Environment, 2017); Europe (Christensen et al., 2004); European Union (European Commission, 2013); Finland (Kotiranta & Niemelä, 1993; 1996); Germany (Schmid & Helfer, 1999; Müller et al., 2007; Schmidt et al., 2012); Great Britain (Ainsworth, 2004); Italy (Blasi et al., 2010); Latvia (Ek et al., 2002); Lithuania (Andersson & Kriukelis, 2002); Yugoslavia (Tortić, 1998)

The highest number of species was recorded on site Mitrovac – 210 (**Fig. 3**). The most represented genera on site Mitrovac were *Mycena* (15), *Russula* (15), *Cortinarius* (8) and *Tricholoma* (7). Of the total documented species diversity, 92 taxa were recorded only on site Mitrovac. Within the localities Kaludjerske Bare and Predov Krst, 152 and 113 taxa were recorded, respectively. The least number of taxa were observed on site Zaovine – 48 taxa (**Tab. 1**).

The recorded taxa belong to four ecological categories. Saprotrophic fungi (141 taxa) are the most represented ecological group, followed by mycorrhizal fungi (124 taxa), parasite/saprotrophs (47 taxa), parasites (6 taxa), and mutualist (2 taxa) (**Fig. 4**). Saprotrophic fungi were dominant on all localities except Zaovine, where fungi from mycorrhizal ecological group stood out (**Tab. 1**).

Ten recorded species are on the list of Protected Wild Species of Plants, Animals, and Fungi (Annex II of the „Official Gazette of RS", No. 5/2010 and 47/2011) while three species are on the list of Strictly Protected Wild Species of Plants, Animals and Fungi (Annex I of the „Official Gazette of RS", No. 5/2010 and 47/2011) (**Tab. 2**).

Mitrovac is the most valuable locality for both protected (8 taxa: *Cantharellus cibarius, Craterellus cornucopioides, Lactarius salmonicolor, Boletus edulis, Lactarius deliciosus, Lactarius deterrimus, Russula cyanoxantha*), and strictly protected

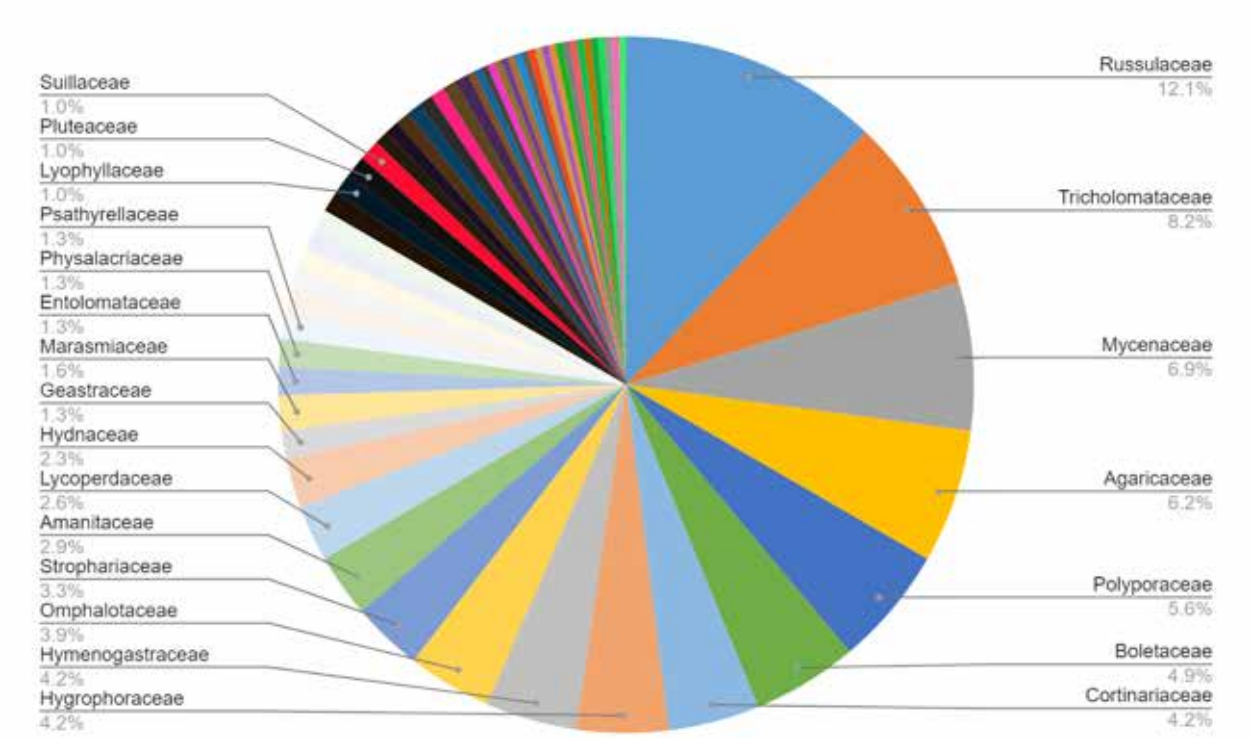

Fig. 2. Families of fungal species from the phylum Basidiomycota recorded in the monitoring of four locations at Mt. Tara during 2021/2022

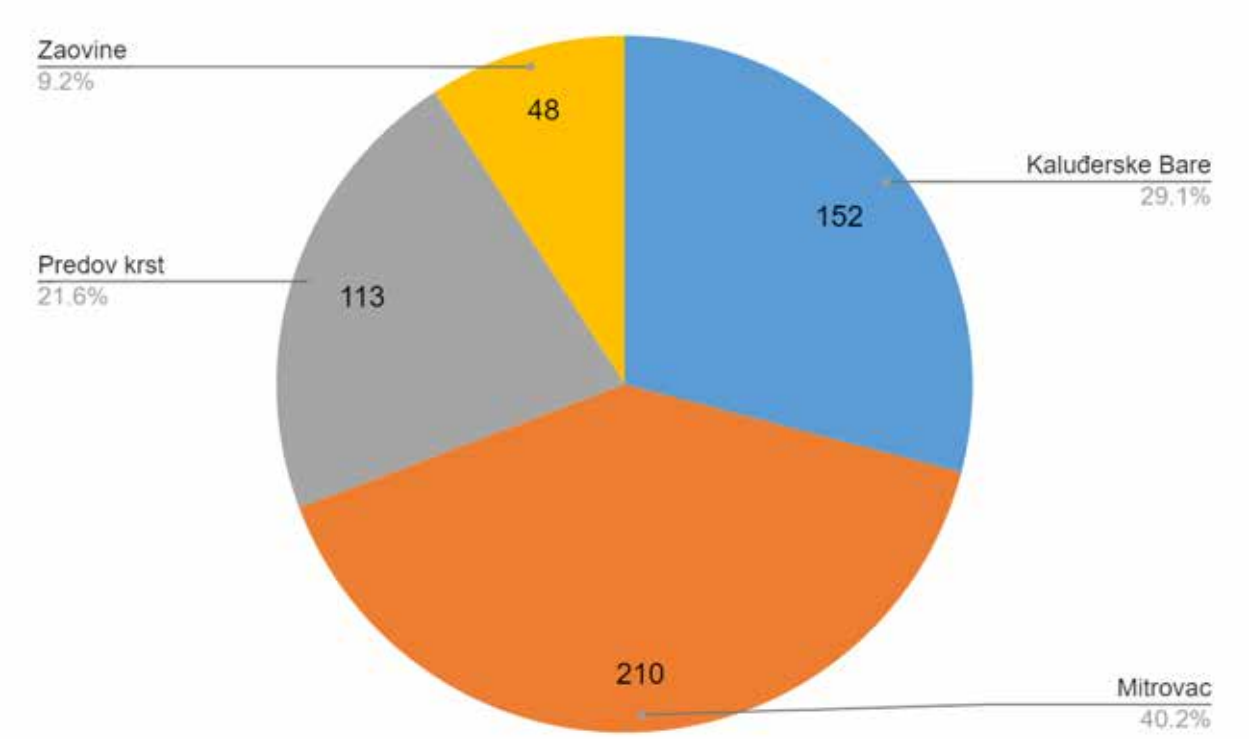

Fig. 3. Number (percent) of taxa per monitored locality

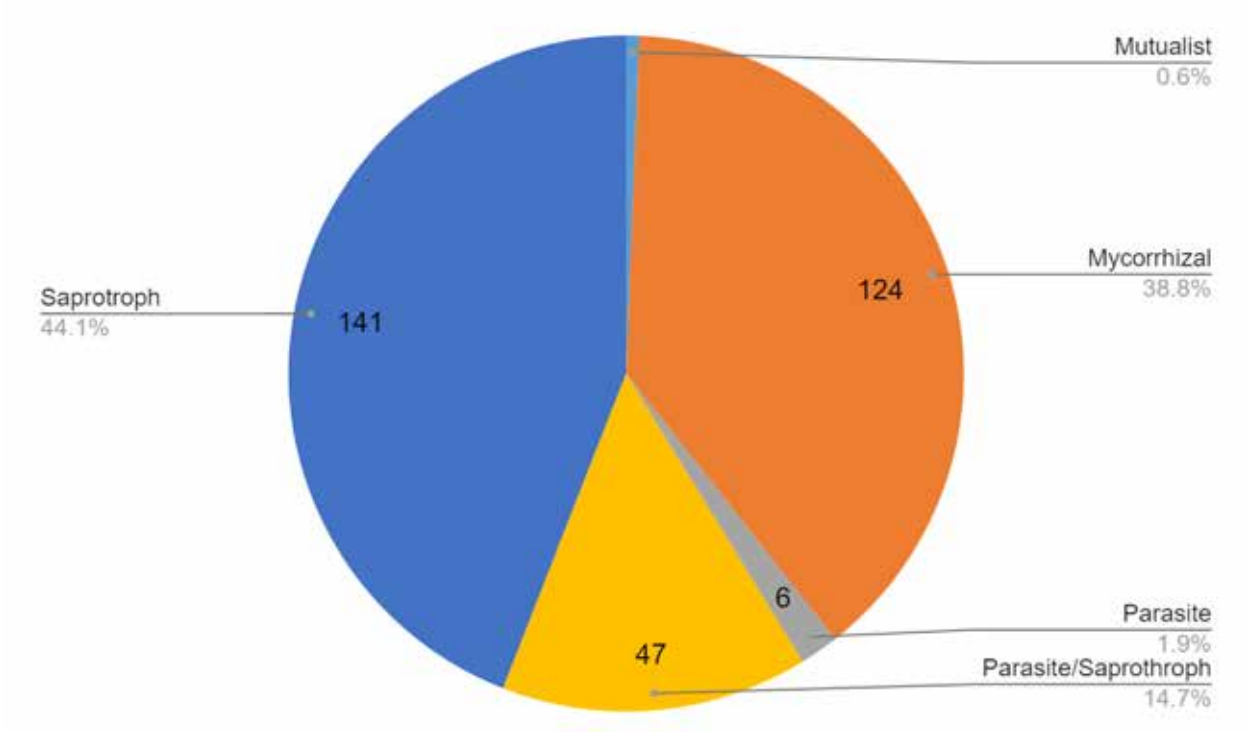

Fig. 4. Number (percent) of taxa per ecological category

fungi (3 taxa: *Hericium flagellum, Hericium coralloides, Psilocybe serbica*), and it's followed by site Kaludjerske Bare with 7 protected (*Hydnum repandum, Lactarius salmonicolor, Boletus edulis, Lactarius deliciosus, Lactarius deterrimus, Marasmius oreades, Russula cyanoxantha*) and 1 strictly protected species (*Psilocybe serbica*). On sites Predov Krst and Zaovine, no strictly protected species were recorded during the investigated period (**Tab. 2**).

Also, 38 indicator fungal species of old-growth forests and valuable forest sites were observed, which is 12% of the total species number. Recorded species were present on indicator lists of 14 different European regional units (**Tab. 1**). Highest number of recorded indicator species were from Estonian indicator lists (Estonian Ministry of Environment, 2017). *Hericium coralloides* is species with the highest number of occurrences on indicator lists, it occurred on 10 out of 14 lists analyzed in this work (**Tab. 1**). This species is considered as rare and as one of the representatives of undisturbed habitats with high conservation value (Christensen et al., 2004; Adamcik et al., 2007): Austria (Vulnerable - VU), Bulgaria (Vulnerable - VU), Croatia (Endangered - EN), Denmark (Near Threatened - NT), Estonia (Near Threatened - NT), Germany (Endangered - EN), Latvia (Vulnerable - VU), Macedonia (Near Threatened - NT), Netherland (Endangered - EN), Norway (Near Threatened - NT), Poland (Vulnerable -VU), Romania (Near Threatened - NT), Sweden (Near Threatened - NT), Switzerland (Vulnerable - VU) and Ukraine (Vulnerable - VU) (http://iucn.ekoo.se/). In this research *Hericium coralloides* was recorded only on site Mitrovac, which is also confirmed previously by Čolić (1967), Rakić (2019), and Jovanović et al. (2021).

The highest number of indicator species belong to the saprotrophic ecological category (18), followed by parasite/saprotrophic (15), and mycorrhizal category (5). For the majority of saprotrophic, and all the parasite/saprotrophic indicator species, a prerequisite for survival is the presence of large amounts of dead wood of different quality (dimensions and decay stage) (Holec et al., 2015). For fungi that are connected to woody substrate, it is generally considered that the most significant limiting factor for the survival of their populations is the presence of a suitable substrate (Lonsdale et al., 2008). However, Nordén et al. (2018) indicate that the connection of the habitat i.e. substrate (ecological continuity) is also a very important factor because for the species used as indicators, limiting factors for the survival of populations are also limited dispersion and establishment of individuals.

The greatest number of indicator species was recorded on site Mitrovac (28 of 210 taxa; 13,3%), but the greatest ratio between indicator and total recorded taxa was documented on site Predov Krst (18 of 113 taxa; 16%) (**Tab. 2**). These results indicate

Table 2. List of protected, strictly protected and indicator species

	Kaludjerske Bare	Mitrovac	Predov Krst	Zaovine
Protected species				
Boletus reticulatus Schaeff.		*	*	
Cantharellus cibarius Fr.		*		
Craterellus cornucopioides (L.) Pers.		*		
Hydnum repandum L.	*			
Lactarius salmonicolor R. Heim &Leclair	*	*		*
Boletus edulis Bull.	*	*	*	
Lactarius deliciosus (L.) Gray	*	*	*	
Lactarius deterrimus Gröger	*	*		
Marasmius oreades (Bolton) Fr.	*		*	
Russula cyanoxantha (Schaeff.) Fr.	*	*	*	
Total number:	7	8	5	1
Strictly protected species				
Hericium flagellum (Scop.) Pers.		*		
Hericium coralloides (Scop.) Pers.		*		
Psilocybe serbica M.M. Moser & E. Horak	*	*		
Total number:	1	3	/	/
Indicator species				
Apioperdon pyriforme (Schaeff.) Vizzini	*	*	*	
Ascocoryne cylichnium (Tul.) Korf		*		
Auricularia mesenterica (Dicks.) Pers.		*		
Chrysomphalina grossula (Pers.) Norvell, Redhead &Ammirati		*		
Clavariadelphus pistillaris (L.) Donk				*
Climacocystis borealis (Fr.) Kotl. & Pouzar	*			
Coriolopsis gallica (Fr.) Ryvarden		*		
Fomes fomentarius (L.) Fr.	*	*	*	
Fomitopsis pinicola (Sw.) P. Karst.	*	*	*	
Ganoderma applanatum (Pers.) Pat.		*	*	
Ganoderma carnosum Pat.		*		
Geastrum fimbriatum Fr.			*	
Geastrum rufescens Pers.	*			
Geastrum striatum DC.			*	
Geastrum triplex Jungh.	*	*		
Guepinia helvelloides (DC.) Fr.			*	
Hericium flagellum (Scop.) Pers.		*		
Hericium coralloides (Scop.) Pers.		*		
Hydropus marginellus (Pers.) Singer		*		
Ischnoderma benzoinum (Wahlenb.) P. Karst.		*	*	

Lactarius uvidus (Fr.) Fr.	*		*	
Lycoperdon echinatum Pers.			*	
Meripilus giganteus (Pers.) P. Karst.			*	
Mucidula mucida (Schrad.) Pat.	*	*		
Mycena galericulata (Scop.) Gray		*	*	
Mycena maculata P. Karst.		*		
Pholiota aurivella (Batsch) P. Kumm.	*	*		
Phyllotopsis nidulans (Pers.) Singer		*		
Pseudoclitocybe cyathiformis (Bull.) Singer		*		
Pseudoclitocybe cyathiformis (Bull.) Singer		*		
Pycnoporellus fulgens (Fr.) Donk		*	*	
Sarcodon imbricatus (L.) P. Karst.		*	*	
Sparassis brevipes Krombh		*		
Sparassis crispa (Wulfen) Fr.		*		
Stereum subtomentosum Pouzar		*	*	
Trametes pubescens (Schumach.) Pilát	*	*	*	
Tricholoma album (Schaeff.) P. Kumm.	*			
Tricholoma sulphureum (Bull.) P. Kumm.	*	*	*	
Xylaria polymorpha (Pers.) Grev.		*	*	
Total number:	12	29	18	1

that Mitrovac and Predov Krst are valuable preserved habitats for old - growth indicator (endangered and rare) species of fungi. The importance of preserved forests in terms of the ecosystem services they provide is enormous. The long and undisturbed development of these forests, together with the natural dynamics of the renewal and destruction processes, contributes to the emergence of a very high structural complexity (Franklin & Van Pelt, 2004). Structural complexity is reflected in the presence of a large number of different microhabitats (Kozák et al., 2018), which include dead wood, holes in wood, fruiting bodies of lignicolous fungi and other epiphytic structures, that at the same time represent a habitat for numerous different and important groups of organisms (Paillet et al., 2010). The structural complexity of old, preserved forests enables the neutralization of summer forest soil temperatures (Frey et al., 2016), thereby enabling the survival of species sensitive to climate change (Betts et al., 2018). Old preserved forests are more resilient, stable and adaptable than managed forests (Alberto et al., 2013; Watson et al., 2013).

Conclusion

Recent researches have shown the presence of a high species diversity on Mt. Tara, especially on the site Mitrovac which contains a great number of rare and endangered taxa. It is of great importance to preserve those habitats since they can present fungal biodiversity hot spots. However, in order to make the overall diversity picture more complete, it is necessary to carry out long-term monitoring.

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