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Taxonomic composition of macromycetes of Goygol National Park in Azerbaijan

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ABSTRACT

Question: What is the diversity and taxonomic structure of macrofungi in the Goygol National Park of Azerbaijan?
Locations: Goygol National Park, Azerbaijan.
Methods: field surveys, micromorphology studies follow Prance & Fechner (2017) using a microscope Axio Imager Vert. A1 Carl Zeiss, Germany; identification of species follow Arora (1986), Grunert & Grunert (2002), Horac (2005).
Nomenclature: www.indexfungorum.org, www.mycobank.org, www.worldfloraonline.org.
Results: The article provides information on the taxonomic composition and ecology of macromycetes, obtained on the basis of fungal samples collected in the territory of the Goygel National Park (Azerbaijan) in 2021–2024. About 130 specimens were newly collected, and 20 specimens kept in the herbarium were used for this study. The purpose of the study was to identify the diversity and taxonomic composition of fungi, as well as to determine the ecological groups of macromycetes in the study area. The work was carried out on the basis of the classical morphological approach (collection, processing of herbarium specimens, identification under a microscope according to the relevant literature). As a result, 80 species were identified belonging to 60 genera, 35 families of such orders as *Pezizales*, *Xylariales*, *Agaricales*, *Auriculariales*, *Boletales*, *Corticiales*, *Cantharellales*, *Geastrales*, *Hymenochaetales*, *Polyporales*, and *Russulales*. Among those, *Morchella elata* represents a new record for Azerbaijan. Based on the analysis of ecological groups, macromycetes were divided into three groups represented by 30 saprotrophs, 25 myco-rrhizal and 5 parasitic species. Some species (*Cerioporus squamosus*, *Fomes fomentarius*, *Laetiporus sulfureus*, and *Pleurotus ostreatus*) can behave as saprotrophs or parasites. Rare and threatened mushroom species (*Agaricus campestris*, *Coprinus comatus*, *Laccaria laccata*, *Lycoperdon perlatum*, and *Leccinum scabrum*) were identified according to the IUCN Red List categories. Studying the macrofungal diversity of Goygol National Park expands our understanding of fungi in the country and provides an opportunity to compare the diversity of the Lesser and Greater Caucasus within Azerbaijan. Recording the diversity of fungi is important along with elucidating their ecological role to suggest their sustainable use in the future.
Conclusions: The investigation of the macrofungal diversity of Goygol National Park broadens our understanding of the fungi found in the territory and provides an opportunity to compare the most mushroom-rich regions of the Greater and Lesser Caucasus in Azerbaijan. This will allow us to record and identify the diversity of fungal species and suggest ways to use them effectively in the future.

KEYWORDS
biodiversity, Caucasus, ecological groups, IUCN categories, morphology, mushrooms, mycorrhizal fungi, polypores

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INTRODUCTION

Fungi are one of the largest groups of heterotrophic eukaryotes and include organisms with different structures, starting from unicellular ones (Tedersoo *et al*. 2018, Antonelli *et al.* 2023, 2024, Niskanen *et al*. 2023). During the evolutionary process, spores and mycelia acquired a completely different morphology for adaptation to different substrates, and along with these morphological advantages, high metabolic capabilities led to the formation of a number of ecological groups within the fungal kingdom (Naranjo-Ortiz & Gabaldón 2019).

Fungi are widely distributed in different climatic zones of the world (arctic, temperate and tropical), and among them there are many cosmopolitan species. Despite all the research and the importance of biological collections providing information on fungal diversity, they remain largely incomplete (Hawksworth & Lücking 2017). It is estimated that more than 90 % of all fungal species have not yet been scientifically described (Niskanen *et al*. 2023, Antonelli *et al.* 2024). However, according to some assumptions, less than 10 % of the worldwide fungal diversity has been described so far (Nakarin *et.al*. 2022). Most of those belong to the true fungi that are classified within *Ascomycota* and *Basidiomycota*. These two main phyla are united by a number of features (dikaryotic mycelium, spore formation occurs by karyogamy and then meiosis) (Wijayawardene *et al*. 2018). A morphological approach is still preferred in classifying macromycetes and determining species status. In addition, in the last 20–30 years, electron microscopic and molecular-biological studies have been given great priority to investigate the status of cryptic species (Lücking *et al*. 2020).

Goygol National Park is located in the west of Azerbaijan, in the mountainous and foothill areas. The forests are mainly broad-leaved at an altitude of 1100–2200 m and are represented by very rich vegetation. About 80 species of trees and shrubs have been recorded in these mountain forests represented by mainly decidous species such as beech, oriental oak, Caucasian holly, sycamore, common cypress, broad-leaved birch, linden, and by conifer such as hook-shaped pine and Eldar pine (Gadzhiev *et al.* 1990, Babakishiyeva & Ibadullayeva 2021).

In recent years, the macrofungi of the mentioned area have been studied systematically. The aim of the current research is to investigate newly collected mushrooms and those stored in the herbarium, including associated plant species distributed on the territory, to determine and analyse their ecological groups according to the substrate and habitat where they are found as well as identify rare and threatened species.

MATERIAL AND METHODS

Specimens and area of collection. Samples were collected from Goygol National Park in 2021–2024. In total, 150 specimens were involved to the research. Specimens were collected in Maralgöl (40.378972° N, 46.312722° E), Goygol (40.408667° N, 46.318944° E), Ashigli village (40.537472° N, 46.329333° E), Toghanali village (40.442861° N 46.33025° E), Hajikand settlement (40.513583° N, 46.335444° E) within the Goygol National Park. During the field work, according to Mohapatra *et al.* (2015), photographs of each samples with different appearance were taken, macromorphological characteristics (structure, size, shape of the fruiting body, smell, taste, color change on the cut, the presence of a volva and ring, etc.) and a description of the collection site (host plant and other substrates) were recorded.

Microscopic studies. Micromorphological studies were performed using a microscope (Axio Imager Vert. A1 Carl Zeiss, Germany). Observed microscopic diagnostic parameters (spores, structure, color) were taken into account and appropriate measurements (40×) were made. For the assignment, both field records and macro- and micromorphological features were analyzed based on the available literature data, and recent taxonomic and nomenclatural innovations were taken into account (Dermek 1979, Breitenbach & Kränzlin 1984, Arora 1986, Grunert & Grunert 2002, Sadiqov 2007, Erdem 2018, Mustafabayli *et al.* 2021). All designated mushrooms were dried and deposited at the herbarium of the Institute of Botany (BAK). Fungal taxonomy and nomenclature were checked using informative data resources including Index Fungorum (http://indexfungorum.org/), MycoBank (http://www.mycobank.org/) and World Flora Online plant names (https://www.worldfloraonline.org/).

RESULTS AND DISCUSSION

Taxonomic composition. In general, 80 macromycete species belonging to 60 genera in 35 families, 12 orders of *Ascomycota* and *Basidiomycota* divisions (*Pezizales*, *Xylariales*, *Auriculariales*, *Agaricales*, *Boletales*, *Corticiales*, *Cantharellales*, *Geastrales*, *Gomphales*, *Hymenochaetales*, *Polyporales*, *Russulales*) were identified in Goygol National Park (TABLE 1).

TABLE 1. Taxonomic structure of the macromycetes recorded in the study area

Phyla	Order	Family	Genus	Species
Ascomycota	Pezizales	Morchellaceae	1	2
		Pezizaceae	1	1
	Xylariales	Xylariaceae	1	1
Basidiomycota	Agaricales	Agaricaceae	3	5
		Amanitaceae	1	3
		Clitocybaceae	1	1
		Cortinariaceae	1	1
		Crepidotaceae	1	1
		Entolomataceae	2	2
		Hydnangiaceae	1	1
		Hymenogastraceae	1	1
		Inocybaceae	1	1
		Lycoperdaceae	3	3
		Marasmiaceae	1	2
		Mycenaceae	2	2
		Omphalotaceae	1	1
		Physalacriaceae	2	2
		Pleurotaceae	1	1
		Pluteaceae	1	1
		Psathyrellaceae	4	5
		Schizophyllaceae	1	1
	Auriculariales	Auriculariaceae	1	1
	Boletales	Boletaceae	6	6
		Sclerodermataceae	1	1
	Corticiales	Corticiaceae	1	1
	Cantharellales	Hydnaceae	2	2
	Geastrales	Geastraceae	1	1
	Gomphales	Gomphaceae	1	1
	Hymenochaetales	Hymenochaetaceae	2	2
		Hirschioporaceae	1	1
	Polyporales	Polyporaceae	7	12
		Fomitopsidaceae	1	2
		Laetiporaceae	1	1
		Ganodermataceae	1	2
	Russulales	Peniophoraceae	1	1
		Russulaceae	2	8
Total	12	35	60	80

The phylum Ascomycota was represented by 4 species of 2 orders and 3 families, which include *Morchella conica*, *M. elata* (Pezizales, Morchellaceae), *Legaliana badia* (Pers.) (Pezizales, Pezizaceae) and *Xylaria longipes* (Xylariales, Xylariaceae). Of these, *M. elata* represents a new species for Azerbaijan (FIGURE 1).

Morchella elata Fr., Systema Mycologicum 2(1): 8. 1822 (FIGURE 1 a–c)

The cap is 2–6 (11) cm broad, 6–10 sm high, usually conical, oval or slightly irregular in shape, margins joined to the stalk. Pits and ridges usually vertically elongated or arranged in vertical rows, the surface inside the pits varies from pale brown to gray, darkens with age and may develop to yellow-brown, brown, greyish, olive-brown or even red-brown, sometimes becoming blackish as it develops. Interier hollow, sometimes flesh is fragile. Stalk 3–10(–15) cm long, 1–4 cm thick, the surface is white-cream white or rarely pinkish. The surface is sometimes grooved near the base. Asci 160–120 × 15–20 µm, 8 spors per askus. Spores 19–24(–30) × 11–15 µm, ellipsoidal, smooth, hyaline.

Specimen examined. Azerbaijan. **Goygol National Park**, alt. 1577.7 m, 40.4169° N, 46.3321° E. 25 April 2023 (BAK1783).

As is well known, *M. elata* is a highly polymorphic species with variations in appearance, such as shape, color and size. In Azerbaijan four species (*M. conica*, *M. esculenta*, *M. semilibera*, and *M. steppicola*) of the genus were recorded earlier (Sadiqov 2007). Also specimens identified as *M. hybrida*. which is currently synonymous with *M. semilibera* are deposited in BAK. Another morel species recorded in the country is *M. crassipes*, the status of which was unclear and most often considered a synonym of *M. semilibera*. Recent nuclear and mitochondrial studies at the subchromosomal level have shed light on the taxonomy of this mysterious fungus (Liu *et al.* 2020). In general, morels are recognized as one of the most valuable edible and medicinal mushrooms in the world and are collected en masse during the growing season.

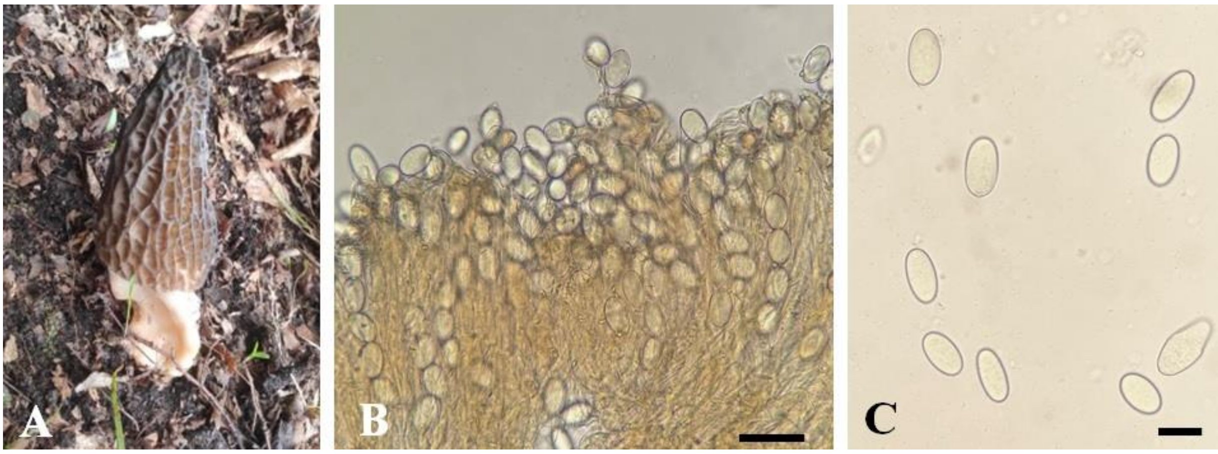

FIGURE 1. ***Morchella elata*: a – fruit body, b – asci, c – ascospores. Scale bars: B = 50 µm; C = 20 µm.**

Among the divisions, Basidiomycota was distinguished by the number of families and taxa. As observed, the order *Agaricales* dominates within Basidiomycota with 19 families (FIGURE 2). About 31 species belong to the *Agaricales* order. Several species belonging to the families *Agaricaceae* (5), *Psathyrellaceae* (5) and *Lycoperdaceae* (4) were recorded. The *Agaricaceae* was the most abundant in the number of species and included 3 species of the genus *Agaricus* L. (*Agaricus campestris*, *A. silvicolae-similis*, *A. spodophorus*), *Coprinus comatus* and *Lepiota cristata*. *Amanitaceae* represented by *Amanita rubescens*, *A. excelsa* var. *Spissa*, and *A. vaginata*. Two of five species of the family *Psathyrellaceae* belong to the genus *Coprinopsis* (*C. atramentaria*, *C. lagopus*), and the others were from the genera *Candolleomyces* (*C. candolleanus*), *Coprinellus* (*C. micaceus*) and *Psathyrella* (*P. spadiceogrisea*). The family *Lycoperdaceae* was represented by 3 species of the genera *Lycoperdon* (*L. perlatum*), *Calvatia* (*C. cyathiformis*) and *Bovista* (*B. plumbea*).

FIGURE 2. Some of macromycetes recorded in the Goygol National Park: a – *Coprinus comatus*, b – *Schizophyllum commune*, c – *Leccinellum pseudoscabrum*, d – *Suillellus luridus*, e – *Scleroderma citrinum*, f – *Fomitopsis betulina*, g – *Pallidohirschioporus biformis*, h – *Hymenopellis radicata*, i – *Coprinellus micaceus*, j – *Polyporus tuberaster*, k – *Ganoderma lucidum*, l – *Lactarius pyrogalus*, m – *Russula heterophylla*, n – *Russula delica*.

Two species each were identified in *Entolomataceae* (*Entoloma clypeatum*, *Pouzarella caldariorum*), *Marasmiaceae* (*Marasmius oreades*, *M. rotula*), *Physalacriaceae* (*Xerula megalospora*, *Hymenopellis radicata* and *Mycenaceae* (*Mycena galericulata*, *Panellus stipticus*. Familes such as *Clitocybaceae* (*Collybia nuda*), *Cortinariaceae* (*Cortinarius glaucopus*), *Crepidotaceae* (*Crepidotus cesatii*), *Hydnangiaceae* (*Laccaria laccata*), *Hymenogastraceae* (*Psilocybe coronilla*), *Inocybaceae* (*Pseudosperma rimosum*), *Omphalotaceae* (*Gymnopus erythropus*), *Pleurotaceae* (*Pleurotus ostreatus*), *Pluteaceae* (*Volvopluteus gloiocephalus*) and *Schizophyllaceae* (*Schizophyllum commune*) were represented by single species each.

A single species were recorded in the orders *Auriculariales* (*Auricularia mesenterica*), *Corticiales* (*Corticium roseum*), *Cantharellales* (*Cantharellus cibarius*), *Geastrales* (*Geastrum saccatum*) and *Gomphales* (*Ramaria pallida*).

The order *Boletales* was represented by the families *Boletaceae* and *Sclerodermataceae*. The family *Boletaceae* included six species of six genera (*Boletus edulis*, *Hortiboletus rubellus*, *Leccinellum pseudoscabrum*, *Leccinum scabrum*, *Suillellus luridus*, *Xerocomus subtomentosus*), and *Sclerodermataceae* family had only one species *Scleroderma citrinum*.

The order *Hymenochaetales* was represented by three species, *Phellinopsis conchata* and *Phylloporia ribis* of the family *Hymenochaetaceae* and *Pallidohirschioporus biformis* of the family *Hirschioporaceae*.

The order *Polyporales* ranks second with 17 species. The *Polyporaceae* family is superior in terms of the number of determined species including *Cerioporus squamosus*, *Daedaleopsis confragosa*, *D. tricolor*, *Fomes fomentarius*, *Lentinus arcularius*, *L. brumalis*, *Lenzites betulinus*, *Polyporus varius*, *P. tuberaster*, *Trametes gibbosa*, *T. hirsuta*, and *T. versicolor*. The family *Fomitopsidaceae* (*Fomitopsis pinicola* and *F. betulina* (= *Piptoporus betulinus*) and *Ganodermataceae* (*Ganoderma applanatum* and *G. lucidum*) were represented by two species each and *Laetiporaceae* was recorded with *Laetiporus sulphureus*.

Nine species of *Russulales* were identified. *Peniophora albobadia* (Schwein.) Boidin belongs to the *Peniophoraceae*, and the remaining eight species (*Lactarius mairei* var. *zonatus*, *L. pyrogalus*, *Russula aeruginea* , *R. cerolens*, *R. cremoricolor, R. delica*, *R. heterophylla*, and *R. xerampelina* belong to the family Russulaceae.

Ecological groups by substrate. All identified species were divided into three ecological groups: saprotrophs, mycorrhizal and parasitic fungi. The first of them is the largest, and 41 species (*Agaricus campestris, A. silvicolae-similis*, *Bovista plumbea*, *Calvatia cyathiformis*, *Candolleomyces candolleanus*, *Crepidotus cesatii*, *Coprinellus micaceus*, *Coprinopsis atramentaria*, *C. lagopus*, *Coprinus comatus*, *Entoloma clypeatum*, *Geastrum saccatum*, *Gymnopus erythropus, Xerula megalospora*, *H. radicata*, *Lepiota cristata*, *Collybia nuda*, *Lycoperdon perlatum*, *Panellus stipticus*, *Pouzarella caldariorum*, *Psathyrella spadiceogrisea*, *Legaliana badia, Stropharia coronilla*, *Marasmius oreades, Morchella conica, M. elata*, *M. rotula*, *Mycena galericulata*, *Volvopluteus gloiocephalus*, and *Xylaria longipes*) recided to this group. *Cerioporus varius, Corticium roseum, Fomitopsis pinicola, Lentinus arcularius, L. brumalis, Pallidohirschioporus biformis*, *Peniophora albobadia, Phellinopsis conchata*, *Polyporus tuberaster*, *Trametes hirsuta* and *T. gibbosa* classified as xylotrophs are also regarded as saprotrophic.

Mycorrhizal fungi included 26 species (TABLE 2). Most of them are associated with *Quercus macranthera*, *Fagus orientalis* and *Carpinus betulus*, which are common plant species in the study area. *Daedaleopsis confragosa, Fomitopsis betulina*, *Ganoderma applanatum*, *G. lucidum*, and *Phylloporia ribis* are exclusively parasitic species. The parasitic species collected during the study are mainly xylotrophs. Xylotrophs are known as facultative saprobes or facultative parasites. They live in symbiosis with trees and cause their destruction. Also, the ecology of some species may manifest itself differently. Polyporous fungi, known for their ecological role and special wood decomposition abilities, also show adaptation to a wide range of ecological niches (Pawłowicz *et al.* 2024).

TABLE 2. Mycorrhizal fungi used in this study and their host plants

Species names	Host plants
Agaricus silvicolae-similis	*Quercus petraea*
Agaricus spodophorus	*Fagus orientalis*
Amanita rubescens	*Carpinus orientalis*
Amanita vaginata	*Fagus orientalis*
Amanita excelsa var. *spissa*	*Carpinus orientalis*
Boletus edulis	*Fagus orientalis*
Cantharellus cibarius	*Quercus macranthera*
Clavulina cinerea	*Quercus petraea*
Cortinarius glaucopus	*Carpinus betulus*
Hortiboletus rubellus	*Fagus orientalis*
Laccaria laccata	*Fagus orientalis*
Lactarius mairei var. zonatus	*Quercus macranthera*
Lactarius pyrogalus	*Corylus*
Leccinellum pseudoscabrum	*Carpinus betulus*
Leccinum scabrum	*Betula pendula*
Pseudosperma rimosum	*Carpinus orientalis*
Ramaria pallida	*Quercus macranthera*
Russula delica	*Carpinus betulus*
Russula aeruginea	*Quercus petraea*
Russula cerolens	*Quercus macranthera*
Russula cremoricolor	*Quercus macranthera*
Russula heterophylla	*Quercus macranthera*
Russula xerampelina	*Pinus brutia*
Scleroderma citrinum	*Fagus orientalis*
Suillellus luridus	*Quercus macranthera*
Xerocomus subtomentosus	*Fagus orientalis*

Cerioporus squamosus, *Fomes fomentarius*, *Laetiporus sulfureus*, and *Pleurotus ostreatus* can grow as saprotrophs or parasites depending on the substrate and environment. *Schizophyllum commune* and *Trametes versicolor* are saprobic species, but can also act as a week parasite.

Symbiotrophic fungi, if the tree is vulnerable, take the opportunity to obtain nutrients, causing the wood to rot. These species are known as facultative saprobes or facultative parasites. They live in symbiosis with trees and cause their destruction. A number of other fungi, *Cerioporus varius*, *Daedaleopsis confragosa*, *Lenzites betulinus*, *Pleurotus ostreatus*, *Phylloporia ribis*, *Schizophyllum commune*, *Trametes gibbosa*, *T. hirsuta* and *T. versicolor* belong to the rot fungus group.

Mycorrhizal fungi may be invisible, but they provide enormous benefits to the climate. As climate change warriors, fungi help forests absorb CO_2 emissions, slowing the effects of global warming (Field *et al*. 2012, Hawkins *et al*. 2023). Mycorrhizal fungi play an important role in transporting carbon into soil systems. About 75 % of the earth's carbon is stored underground, and mycorrhizal fungi play a critical role in transporting carbon into soil food webs.

Among the species considered in this work, one species, *Ganoderma lucidum*, is listed in the third edition of the Red Book of Azerbaijan (2023). Few species such as *Agaricus campestris*, *Coprinus comatus*, *Lycoperdon perlatum* were published as Least Concern (LC), *Laccaria laccata* and *Leccinum scabrum* are proposed for the assessment according to the Global Fungal Red List Initiative (2022).

Temperature rase in some cases force plants and associated fungi to move to higher elevations or higher latitudes. The risk of species extinction increases with each level of warming, with far-reaching consequences for ecosystems. Ecosystem protection, management and restoration offer full mitigation potential for all natural solutions, including extinction threats.

As is known, mushrooms have played an important role in human civilization and today form an indispensable link, both from an environmental and economic point of view (Valvade *et al*. 2015, Bell *et al*. 2022, Navarro-Simarro *et al*. 2024). Fungi have been reported in ancient literature since the dawn of human civilization. As the most important non-green food found in the wild and grown indoors, mushrooms have attractive nutritional and medicinal properties. Research on mushrooms in Azerbaijan began in the middle of the last century, the diversity of which is still being explored (Sadiqov 2001, Mustafabayli *et al*. 2021, Alimammadova-Husiyeva & Aghayeva 2023). These studies are of some interest from the point of view of identifying diversity within the country, and studying their characteristics helps to identify the species with properties for use in various fields. Further research is planned to study biologically active compounds from species that have nutritional supplements and medicinal properties.

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РЕЗЮМЕ

Юсіфова, Я.А., Агаєва, Д.Н. (2025). Таксономічний склад макроміцетів Гейгельського національного парку (Азербайджан). *Чорноморський ботанічний журнал* 21 (1): 31–40. https://doi.org/10.32999/ksu1990-553X/2025-21-1-2

У статті наведено інформацію про таксономічний склад та екологію макроміцетів, отриману на основі 130 зразків, зібраних на території Гейгельського національного парку у 2021–2024 роках, та 20 зразків, що зберігаються в гербарії. Мета роботи – виявити видове різноманіття та встановити таксономічний склад грибів, а також визначити екологічні групи макроміцетів на території дослідження. Робота виконана на основі класичного морфологічного підходу (збір, обробка гербарних зразків, ідентифікація під мікроскопом з використанням відповідної літератури). У результаті дослідження ідентифіковано 80 видів, що належать до 60 родів, 35 родин таких порядків, як Pezizales, Xylariales, Agaricales, Auriculariale, Boletales, Corticiales, Cantharellales, Geastrales, Hymenochaetales, Polyporales та Russulales. Серед них *Morchella elata* є новим видом для Азербайджану. На основі екологічного аналізу макроміцети були розділені на три групи – сапротрофи (30 видів), мікоризні гриби (25 видів) та паразити (5 видів). Деякі види (*Cerioporus squamosus*, *Fomes fomentarius*, *Laetiporus sulfureus* і *Pleurotus ostreatus*) можуть поводити себе як сапротрофи або паразити. Рідкісні та зникаючі види грибів (*Agaricus campestris, Coprinus comatus, Laccaria laccata, Lycoperdon perlatum* і *Leccinum scabrum*) визначено відповідно до категорій Червоного списку МСОП. Вивчення різноманітності макроміцетів Гейгельського національного парку розширює наше розуміння грибів у країні та дає можливість порівняти різноманітність Малого і Великого Кавказу в межах Азербайджану. Дослідження різноманітності грибів разом із з’ясуванням їхньої екологічної ролі є важливим для збалансованого їх використання в майбутньому.

Ключові слова: біорізноманіття, гриби, екологічні групи, Кавказ, категорії МСОП, мікоризні гриби, морфологія, трутовики.