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ABSTRACT

of the dissertation submitted for the degree of Doctor of Philosophy

DIVERSITY AND BIOECOLOGICAL TRAITS OF PILEATED MUSHROOMS OF SHAKI DISTRICT OF AZERBAIJAN

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INTRODUCTION

Relevance and degree of development of the topic. Mushrooms are an important "*part of the organic world that surround us and a rich expression of biodiversity. These organisms represent many species of eukaryotes that can live in different environments and act as symbionts, endophytes, parasites or saprobes*"[1]. Science recognizes about 1000 species of pileated mushrooms, differing from each other in shape, size, color, smell and other characteristics. During evolution, these organisms have acquired remarkable abilities for high resistance to stressful conditions and adaptation to different environments. In recent years, the investigation of fungal diversity has been gaining importance all over the world as part of biodiversity documentation; based on research, regional floras or biotas are developed and monographs are published.

Pileated mushrooms make up a significant part of macromycetes due to the richness of their systematic composition and diversity of ecological groups. These mushrooms are found in various plant coenoses (forest, meadow, pasture, cropland, swamp, etc.) as well as in settlements, buildings, structures and even on wooden household items. Some mushrooms are actively involved in the decomposition of organic matter in the forest, causing degradation of biomass and in addition to clearing this soil of heavy loads, they also enrich it. Some species form mycorrhiza with woody plants, and during this time various ecological relationships are formed between plants and fungi. As for the importance of pileated mushrooms, in addition to edible and poisonous species, there are many more species used as raw materials in the medical industry.

"In the new bioeconomy, mushrooms play a very important role in solving important global problems"[2]. So, in addition to justifying themselves in increasing resource efficiency, they are used to convert

[1] Antonelli, A.The hiddeniniverse: adventures in biodiversity / – Chicago: The university of Chicago press, – 2022. – 256 p.

[2] Corbu, V.M. Current Insights in Fungal Importance – A Comprehensive Review / V.M. Corbu, I. Gheorghe-Barbu, A.Ș. Dumbravă. [et al.] // *Microorganisms,* – 2023. 11, – p. 1384.

residual and waste resources into renewable food and feed substitutes, to increase resistance to lifestyle diseases and antibiotics, to make agricultural plants more resistant to climate changes and "*as raw material for the production of new biological products"*[3].

Considering the above, the study of fungal diversity remains relevant. There are scientific works related to the study of the species composition of mushrooms belonging to different groups in different regions of the Republic. However, the pileated mushrooms of the Shaki district have been practically not studied. In the mycological herbarium of the Institute in totally 12 species (*Helvella acetabulum*, *Clitocybe odora*, *Coprinellus disseminatus*, *Gymnopus fusipes*, *Inosperma maculatum*, *Lepiota subgracilis*, *Pluteus cervinus*, *Neofavolus alveolaris*, *Russula foetens*, *R. minutula*, *Tuber aestivum*, *Imleria badia*) are kept. The study is significant in terms of studying and documenting the country's fungal diversity.

The object and subject of the research. As the object of research in the dissertation work, wild growing pileated mushrooms were selected and collected and 500 specimens were determined based on morphological traits. In addition, as the subject of research, preference was given to classical biological approaches, taking into account changes observed under the influence of environmental factors.

The purposes and objectives of the research. The purpose of the work is to study the diversity of pileated mushrooms of Shaki district, analyze their species composition and taxonomic status, and ecological groups, and also clarify rare, nutritionally important species for the area.

1. Determination of species composition and taxonomic status of pileated mushrooms of Shaki district;

2. Study of the ecological groups of pileated mushrooms, their analysis according to the substrate, determination of the host plants of mycorrhizal species;

[3] Lange T., Rasmussen M., Thygesen L.C. Assessing natural direct and indirect effects through multiple pathways // Am J Epidemiol. – 2014. 179(4), 513-8.

3. Investigation of distribution of pileated mushrooms in the study area depending on altitude and season;

4. Determination of rare species and development of recommendations for their conservation. Determination of the status of rare species that are important for conservation and identification of threats and development of the recommendations for their protection.

5. Determination of the nutritional and medical importance of pileated mushrooms based on the samples collected from the study area;

The methods of research. As research methods, preference was given to classical approaches, widely used in modern mycology. In addition to morphological studies, the ecological traits of the species were recorded and widely analyzed, taking into account factors such as environmental conditions, substrate, air temperature, soil type, distribution depending on height, etc. All species used in the study were herbarized and deposited accordingly. The obtained results were processed statistically.

The provisions of the dissertation presented for defense.

1. Pileated mushrooms found in the territory of Shaki district are represented by a rich variety of species belonging to different taxonomic groups;

2. The annual occurence frequency of pileated mushrooms varies depending on the season, being more intense in summer and autumn;

3. When determining the status of disputed species, the use a wide range of different approaches is necessary;

4. Development of a list of rare and endangered species and determination of dangers serves to protect biodiversity as a whole, while ensuring its conservation;

5. Investigation of food and medicinally important species serves to make suggestions on the ways of their using and ensures the formation of scientifically based proposals for the efficient use of potential species.

Scientific novelty of the research. Based on the 500 samples collected as a result of the research carried out in Shaki district,

155 pileated mushroom taxa including 151 species, 4 intraspecific taxa (i.t) were identified, their list and areas of occurence were specified, their ecological groups were determined taking into account the description of the environment and substrate, as well as modern knowledge, and the status of rare and nutritionally important species was assessed.

The studied species as a whole were classified within 12 orders, 40 families, and 84 genera belonging to the divisions Ascomycota (Pezizales) and Basidiomycota (Agaricales, Boletales, Cantharellales, Gomphales, Russulales, Thelephorales). Among the genera of mushrooms, *Morchella*, *Agaricus*, *Amanita*, *Boletus*, *Lactarius* and *Russula* are dominant genera by number of species. Of the species used in the study, 53 were new to Azerbaijan, and 90 new to the study area.

The species were identified as three ecological groups according to the substrate, that includes mycorrhizals (82 taxa, 52.9 %), saprotrophes (36 taxa, 23.22 %), xylotrophes (27 species, 17.41%), biotrophes (8 taxa, 5.17 %), caprotroph, carbontroph and mycoparasite (1 species each, 0.64%). Mycorrhiza stand out as the dominant group.

The attitude of mushroom taxa to light and humidity was studied, species growing in light places (8 species, 5.17 %),), shade-tolerant (9 species, 5.8 %) and shade-loving species were identified. Mushrooms were grouped into those growing in humid (24 taxa, 15.48 %) and moist (87 taxa, 56.1 %) areas.

Depending on the altitude, the distribution of pileated mushroom in the study area on five height above sea level was investigated, and it was found that the most mushroom species were distributed in the foothills (35) and the lower mountain belt (124), which confirms the general regularity. In the research conducted by season and months, more species were observed in summer (July, August) and autumn (October).

As a result of the research, 19 rare species for Azerbaijan were identified in the area, of which 16 species with CR and 3 species with EN categories were included in the III volume of the Red Book of RA. Additionally, 14 species are proposed for the next

edition.

The mushrooms of the study area were analyzed for their nutritional value, of which 20 (12.9 %) were of high quality, 11 (7.09 %) were edible and 27 (17.41 %) were poisonous (including 5 lethally toxic and 3 hallucinogenic).

Theoretical and practical significance of research. Since the climatic conditions in Shaki district are favorable for the development of mushrooms, taking into account the possibility of discovering new species for Azerbaijan on mycobiota, detailed information about the environment was also recorded when collecting samples. The innovations obtained resulted in the addition of 52 species and one variation (34.19 %) to the country's mycobiota, which will contribute to the writing of regional and taxonomic mycobiotas in the future.

The study of the ecological traits and trophic relationships of mushrooms in the research area allowed to determine the regularities of their distribution. Information about the areas of occurrence of food-important species and their existing usage possibilities has been collected. Investigation of the species composition, taxonomic structure, and other ecological characteristics of mushrooms will create opportunities for their systematic use in the future. The obtained results will enrich the information on mushroom diversity of the republic and will be used in the development of regional mycobiota and other popular-science resources, and maps on mushroom diversity and reserves.

Approbation of work. The results of the research work was presented in the international scientific symposium “International Caucasian Forestry Symposium” held in Turkey (Artvin, 2013), at the 5th International Scientific Conference “Innovative problems of modern biology” held at Baku State University (Baku, 2014), at the “I International Scientific Conference of Young Researchers" held at Baku Engineering University (Khirdalan, 2017), at the scientific conference “New Challenges in Botanical Research” dedicated to V.J.Hajiyev's 90th anniversary (Baku, 2018), in the scientific symposium dedicated to V.I. Ulyanishshev “The role of Academician V.I. Ulyanishshev in the development of mycological

research in Azerbaijan" (Baku, 2018), conference of Young Scientists and Students "Innovations in Biology and Agriculture to Solve Global Challenges" Dedicated to the academician J.Aliyev (Baku, 2019), at the conference "Ecology of fungi and fungi-like organisms: facts, hypotheses, trends" held at Yaroslavl State University (Yaroslavl, 2023).

The name of the institution where the dissertation work was performed. The research was carried out at the Department "Mycology and Primitive Plants" of the Institute of Botany of the Ministry of Science and Education of the Republic of Azerbaijan.

Structure of dissertation and its volume with characters. Dissertation work is 186 pages consisting of introduction, six chapters, result, conclusion, recommendation, 210 literature list and appendices. The dissertation includes 10 tables and 14 figures. The dissertation consisted of a total of 268623 characters, the Introduction section with the title page, table of contents and along with abbreviations and symbols 13840 characters, Chapter I, literature summary 45643 characters, Chapter II, material and method section - 10327 characters, the experimental part of the dissertation a total of 192450 characters, conclusion 3638, results 1981, recommendations 744 characters. The dissertation work is completed with 17 pages of Appendices.

CHAPTER I
LITERATURE SUMMARY

This chapter consisted of three sub-chapters. Sub-chapter 1.1. is dedicated to the detailed discussion of various views formed on the issues of systematics, such as the study of pileated mushrooms in the world, the history of the identification of diagnostic signs, the reasons for the formation of the main orders, etc., with reference to the literature, sub-chapter 1.2 - the history of accidental and planned study of pileated mushrooms in Azerbaijan, and sub-chapter 1.3. - information on the diversity of pileated mushrooms and their role in the ecosystem.

CHAPTER II
MATERIAL AND METHODS OF THE RESEARCH

2.1. Description of the study area. The research was conducted in Shaki district (2432.8 m^2) in 2014-2023. The district borders the Republic of Dagestan from the north, Gakh from the west, Oghuz and Gabala from the east, Yevlakh and Agdash districts from the south. The climate of the district is mild in winter, with little precipitation and warm in summer. The average amount of precipitation is around 700-1000 mm during the year. The annual number of sunny hours is 40% fall on the summer months and are more than 2300 hours. The abundance of water resources, soil types and vegetation provide favorable conditions for the development of pileated mushrooms here.

2.2. Collection of samples. The samples were collected, ensuring that they were fresh, ripe and *dried using "classical methods"*[4,5]. The growing areas of the mushrooms were determined during the field expeditions, and the GPS coordinates of the samples were taken. Mustafabey forest (GPS: 41º12' 09.06"N, 47º12'52.03"E, 820–930 m a.s.l.), Naringala (GPS: 41º15'33.14"N, 47º13'02.69"E, 1100 ± 50–70 m a.s.l.), Gala area (GPS: 41º12'15.17"N, 47º11'35.83"E, 770 ± 50–70 m a.s.l.), the proximity of Khan Yaylaghi (GPS: 41°13'54"N 47°13'35"E 1600 ± 50–70 m a.s.l.; 41°13'52"N 47°13'43"E 2100 ± 50–70 m a.s.l., etc.) were selected as the main research areas. During the field work, photographs of each sample were taken, macromorphological characteristics (fruit body's structure, size, shape, smell, taste, color changes when cut, presence of volva and annulus or ring, etc.) were recorded. Also, when separating the sporocarp from the substrate, attention was paid to the presence of rhizomorphs and their relationship with the substrate. Attention has been paid to signs such

[4] Ağayeva D.N. Mikologiyada tətbiq edilən klassik və müasir tədqiqat metodları. – 2011. – 207 p.

[5] Prance M., Fechner, N. Collecting and preserving fungi specimens, a manual. 2nd edition / M. Prance, N. Fechner – Brisbane: Department of Science, Information Technology and Innovation, – 2017. – 25 p.

as taste, smell, and color of the flesh of the fruit body, as well as color change after damage, juice flow and juice color.

2.3. Morphological studies. Microscopic and macroscopic characteristics, especially important diagnostic signs, are of great importance in the morphological determination of mushrooms. The pileus shape of the mushroom is one of the most noticeable signs that help in the identification process. In addition, the structure of the spore-bearing part on the fruit bodies (ascus, basidia, spore, cystidium, etc.) was investigated as the main object of research. During the research, attention was mainly paid to "*the size, shape and color of the pileus (cap), stalk, gill, appendages and derivatives, spores, basidia, cystidia and cystiols"*[6].

2.4. Determination of specimens. The specimens were examined in the laboratory for micromorphological features using a light microscope (Vert. A1, Carl Zeiss, Axion Imager, Göttingen, Germany). Although mainly distilled water is used for the preparations, Congo red was applied to make the microscopic structures of some mushrooms (basidia, cystidia, spores, etc.) more visible. A minimum of 20 measurements were obtained for each trait of taxa. The result of all measurements was calculated as the average denominator.

During the determination, both field records and macro- and micromorphological signs were analyzed based on literature data, and recent taxonomic and nomenclature innovations were taken into account. "*A number of determination keys*"[7,8] were used for the determination. The names of all taxa were checked against MycoBank and Index Fungorum databases, and in controversial matters, the most recent publications were preferred.

2.5. Bioecological approaches. The distribution of mushrooms was defined as altitudes of 670-2100 m above sea level and "*an*

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[6] Polemis, E., Identification and sustainable exploitation of wild edible mushrooms in rural areas / E. Polemis, G.I. Zervakis, M.L. Gargano // Technological Educational Institute of Thesally, – Larissa: – 2013. – p. 16–87.

[7] Грюнерт, Г. *Грибы* / Г. Грюнерт – Москва: Астрель, – 2002. – 287 с.

[8] Arora, D. Mushrooms demystified: A comprehensive guide to the fleshy fungi (2nd ed.) / D. Arora. – Berkeley: Ten Speed Press, – 1986. – 959 p.

analysis was carried out on five altitudes"[9,10]. Note that "*the season of sporocarp formation directly depends on the amount of precipitation and temperature*"[11]. Meteorological data were obtained from the data network on the Internet and analyzed according to relevant literature.

Collected species were evaluated on the GeoCAT[12] online program, criteria and categories were defined according to the "*latest guidelines of the International Union for Conservation of Nature (IUCN) Red List*"[13].

While studying the nutritional and medical importance of mushrooms, the data collected from the local population and "*literature data were mutually analyzed*"[14,15].

2.6. Deposits. All studied specimens were placed in the mycological herbarium (BAK) of the Institute of Botany, MSE RA (Appendix 1). Statistical calculations were made on each parameter, error (M±m), standard deviation (SD) were determined with arithmetic mean value. A number of calculations were made with the

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[9] Прилипко, Л.И. Растительный покров Азербайджана / Л.И. Прилипко. – Баку: Элм, – 1970. – 170 с.

[10] Mueller, G.M. Global diversity and distribution of macrofungi / G.M. Mueller, J.P. Schmit, P.R. Leacock [et al.] // Biodivers Conserv, – 2007. 16, – p. 37-48.

[11] Melanda, G.C.S. An overview of 24 years of molecular phylogenetic studies in *Phallales* (Basidiomycota) with notes on systematics, geographic distribution, lifestyle, and edibility / G.C.S. Melanda, A.G.S. Silva-Filho, A.R. Lenz [et al.] // – Front Microbiol, – 2021. 9(12), – 689374.

[12] GeoCAT Geospatial Conservation Assessment Tool: geocat.iucnredlist.org

[13] IUCN Standards and Petitions Committee. 2024. Guidelines for Using the IUCN Red List Categories and Criteria. version 16. Prepared by the Standards and Petitions Committee. ttps://www.iucnredlist.org/documents/RedListGuidelines.pdf

[14] Gogoi, I. Ethnomycological knowledge, nutritional and nutraceutical potential of wild edible macrofungi of Northeast India. / I. Gogoi, A. Borthakur, B. Neog // Studies in Fungi, – 2023. 8:12

[15] Hamza A, Mylarapu A, Krishna KV, Kumar DS. An insight into the nutritional and medicinal value of edible mushrooms: A natural treasury for human health. / Hamza A, Mylarapu A, Krishna KV, Kumar DS. // J Biotechnol. – 2024 Feb 10. 381, – p. 86-99.

help of the Microsoft Excel program, as well as "*appropriate literature was used*"[16].

CHAPTER III
TAXONOMIC ANALYSIS OF PILEATED MUSHROOMS

3.1. Taxonomic composition of pileated mushroom

The samples collected and analyzed from the territory of Shaki district belong to the Ascomycota and Basidiomycota divisions of the fungi kingdom. In total, 155 species and intraspecies taxa belonging to 13 orders, 40 families, 84 genera were identified (Table 1).

Table 1.
Taxonomic structure of macromycetes collected from the study area.

Phyla	Order	Family		Genus		Species	
		say	%	say	%	say	%
Ascomycota	*Pezizales*	6	15.38	6	7.14	14	9.05
Basidiomycota	*Agaricales*	17	43.58	41	48.5	62	40
	Boletales	4	7.69	18	21.2	31	20
	Cantharellales	1	2.57	2	2.38	4	2.6
	Geastrales	1	2.57	1	1.18	1	0.65
	Gomphales	2	5.12	2	2.38	3	1.9
	Hymenochaetales	1	2.57	1	1.18	1	0.65
	Phallales	1	2.57	1	1.18	1	0.65
	Polyporales	3	7.69	6	7.85	7	4.5
	Thelephorales	1	2.57	1	1.18	1	0.65
	Russulales	2	5.12	4	4.65	29	18.7
	Tremellales	1	2.57	1	1.18	1	0.65
Total		40	100	84	100	155	100

[16] Assyov, B. Stoykov D. Boletus bubalinus (Boletaceae). A new addition for the Bolete mycota of Bulgaria and the Balkans / B. Assyov, D. Stoykov // Institute of Biodiversity and Ecosystem Research. The Bulgarian Academy of Sciences, – 2011. 64(11), – p. 1583-1588.

Pezizales, Agaricales, Boletales, Russullales, Polyporalaes and families Agaricaceae, Boletaceae, Plyporaceae, genera Morchella, Agaricus, Amanita, Boletus, Lactarius, Russula are dominant in number of species.

3.2. Morphological description of taxa

A total of 151 species and 4 intraspecific taxa brief description, place of collection, date, substrate and deposit number to BAK are clearly given. (Figure 1).

Figure 1. Photos of some new species for Azerbaijan: 1. *Amanita strobiliformis*; 2. *Boletus aereus*; 3. *B. edulis* var. *arenarius*; 4. *Caloboletus radicans*; 5. *Calocybe gambosa*; 6. *Cantharellus subalbidus*; 7. *Clavariadelphus pistillaris*; 8. *Galerina marginata*; 9. *Hemileccinum depilatum*; 10. *Hydnellum concrescens*; 11. *Lactarius acerrimus*; 12. *Lactarius mairei*; 13. *Rubroboletus legaliae*; 14. *R. lupinus*; 15. *R. satanas*; 16. *Russula aurora* 17. *R. melitodes*; 18. *Tricholoma columbetta*.

51 species (*Agaricus porphyrizon*, *Amanita crocea*, *A. strobiliformis*, *Aureoboletus gentilis*, *A. moravicus*, *Auriscalpium vulgare*, *Boletus aereus*, *Caloboletus radicans*, *Calocybe gambosa*,

Cantharellus subalbidus, *Clavariadelphus pistillaris*, *Clavulina coralloides*, *Helvella atra*, *H. lacunosa*, *Hemileccinum depilatum*, *Hertzogia martiorum*, *Hortiboletus rubellus*, *Hydnellum concrescens*, *Inonotus obliquus*, *Phaeomarasmius erinaceus*, *Phallus ravenelii*, *Lactarius acerrimus*, *L. citriolens*, *L. evosmus*, *L. mairei*, *L. pyrogalus*, *L. semisanguifluus*, *Marasmius capillaris*, *Morchella rotunda*, *M. semilibera*, *Phlegmacium triumphans*, *Ramaria formosa*, *R. obtusissima*, *Rheubabariboletus armeniacus*, *Rubroboletus legaliae*, *R. lupinus*, *R. satanas*, *Russula aurea*, *R. aurora*, *R. heterophylla*, *R. melitodes*, *R. melliolens*, *R. velenovskyi*, *R. turci*, *Sarcosphaera coronaria*, *Scleroderma areolatum*, *Suillus collinitus*, *Tremella mesenterica*, *Tricholoma columbetta*, *T. batchii*), three taxa (*B. edulis* var. *arenarius*, *R. heterophylla* f. *adusta*, *S. luteus* f. *albus*) and for the study area 90 new taxa were identified. Recent taxonomic and nomenclature innovations have been taken into account when writing taxonomic units

CHAPTER IV
BIOECOLOGICAL TRAITS OF PILEATED MUSHROOMS

4.1. Ecological groups of pileated mushrooms

The collected samples were analyzed by ecological groups (saprotroph, biotroph, mycorrhizal and xylotroph) Ectomycorrhizal mushrooms and humus saprotrophs dominate in number of species (Table 2).

Table 2.

Dominant ecological fungal groups

Ecological groups	Number of species	%
saprotroph		
Humus saprotrofu	36	23.22
Kaprotrof	1	0.65
Karbontrof	1	0.65
	mycorrhizae	
Ectomycorrhizal	81	52.25
Arbuskular	1	0.65

Of the designated saprotrophes, those found in humus prevail. Most of the mycorrhizal species are ectomycorrhizal and are associated with a number of trees (*Quercus iberica*, *Carpinus betulus*, *Fagus sylvatica*) (Table 3). Ectomycorrhizal mushroom (80) are mainly representatives of the division Basidiomycota.

Table 3.
Distribution of mycorrhizal species on host plants.

Host plants	*Acer pseudoplatanus*	*Betula pendula*	*Carpinus betulus*	*Castanea sativa*	*Corylus avellana*	*Fagus sylvatica*	*Fraxinus exelsior*	*Picea pungens*	*Pinus brutia* subsp. *eldarica*	*Pinus sylvestris*	*Quercus iberica*	*Quercus macranthera*	*Taxus baccata*	*Ulmus minor*
Taxa number	8	4	50	9	24	48	5	1	4	17	53	26	5	3

Host plants of pathogenic and parasitic species have been investigated, and examples of this group are economically important species such as *Armillaria mellea* known as honey mushroom and root rotting *Gimnopus fusipes* (Table 3). In the table 4, the frequency of occurrence of mushrooms is expressed in numbers (1 – once, 2 – several times, 3 – often).

Table 4.
Biotroph mushrooms and their host plants

Mushroom species	Host plants												
	Acer	*Betula pendula*	*Carpinus betulus*	*Castanea sativa*	*Corylus avellana*	*Fagus sylvatica*	*Juglans regia*	*Morus alba*	*Populus*	*Prunus avium*	*P. cerasifera*	*Quercus iberica*	*Q. macranthera*
Armillaria mellea	1					2	3	3	1	3	1	1	
Ganoderma lucidum			2			1				2		1	1
G. applanatum			1						2				1
Gymnopus fusipes			3			2							
Fistulina hepatica				1									
Laetipous sulphureus				2	1							1	1
Inonotus obliquus		1											

Among the studied fungi, 27 taxa were identified as xylotrophs, which were also found in fallen dry branches, dried tree stumps (23), fallen pine cones (2), fallen dry pine bark (1), and dried oak leaves (1). The species of *Gomphidus roseus* was found together with mushrooms of the genus *Suillus* as mycoparasite.

4.2. Distribution of pileated mushrooms depending on altitude

In the study area, the analysis was carried out on five main altitudes: plain, foothills, lower mountain belt, middle mountain belt, upper mountain belt (Table 5). The frequency of occurrence of mushrooms on altitude, species diversity and also the occurrence of one species at one or more altitudes were analyzed. Distribution of mushroom taxa by altitudes was divided into two groups, those occurring only at one altitude and those occurring at two or more altitudes.

Table 5.
Distribution of mushrooms depending on altitude

Belts (m a.s.l.)	Taxon number
Plain (20-400)	7
Foothills (400-800)	32
Lower mountain belt (600-1000)	124
Middle mountain belt (800-1200 (1800))	20
Upper mountain belt (1800-2400)	16

Species such as *Morchella crassipes*, *M. rotunda*, *M. semilibera*, *Agaricus campestris*, *Macrolepiota procera*, *Lepista sordida*, *Lepiota subgracilis* were found only in plains, forests and other areas with an altitude of 20-400 m above sea level. *Tuber aestivum*, *Agrocybe praecox*, *Amanita strobiliformi*, *Flammulina velutipes*, *Pluteus pellitus*, *Phallus ravenelii* taxa are examples of mushrooms collected and determined only from the foothill zone with an altitude of 400-800 m above sea level. A total of 124 taxa were found in the lower mountain belt. *Sarcosphaera coronaria*, *Agaricus porphyrizon*, *Amanita verna*, *A. virosa* and etc. mushrooms were found in the areas surrounding the middle mountain belt. *Cerioporus varius*, *Lactarius citriolens*, *Lentinus brumalis*, *Postia tephroleuca* can be an example of species observed only in the upper mountain belt.

Agaricus porphyrizon, *Amanita crocea*, *Boletus edulis* f. *quercicola*, *Sarcosphaera coronaria* taxa are species collected and determined only from areas located at an altitude of 1600-1800 m above the middle mountain belt. *Cerioporus varius*, *Postia tephroleuca*, *Lactarius citriolens*, *Lentinus brumalis* are found in the upper mountain belt.

In addition to all this, a number of species have been found at two or more different altitudes: *Apioperdon pyriforme* were collected from the plains, foothills and lower mountain belt at the same time, *Helvella acetabulum*, *Morchella conica*, *Armillaria mellea*, *Butyriboletus pseudoregius*, *Caloboletus radicans*, *Coprinopsis atramentaria*, *Coprinus comatus*, *Echinoderma asperum*, *Ganoderma lucidum*, *Lactarius pyrogalus*, *L. zonarius*,

Lactifluus piperatus, *Lepiota cristata*, *Rubroboletus satanas*, *Russula olivacea*, *R. rosea*, *R. velenovskyi*, *Xerocomellus chrysenteron*, *Xerocomus subtomentosus* taxa were collected and determined from the foothills and lower mountain belts at the same time. *Morchella esculenta*, *Hymenopellis radicata* refers to macrofungi that are found in all three zones - foothill, lower mountain and middle mountain zones, which mostly cover the zones above 500-1700 m a.s.l., sometimes in the same season and sometimes in different seasons. *Flammulina velutipes* was found in different seasons in both the foothill and upper mountain belt. *Suillellus luridus*, *Trametes versicolor* macromycetes were found at altitudes ranging from 400 to 2400 m. *Amanita pantherina* and *Sarcoscypha coccinea* pileated mushrooms were found in the foothills, lower mountain, middle mountain and upper mountain belts. *Macrolepiota mastoidea*, *Lycoperdon umbrinum*, *Laetiporus sulphureus* species were found in a number of areas covering the lower, middle and upper mountain belts. Mycorrhizal mushrooms *Amanita rubescens* and xylotrophic macromycetes *Otidea onotica* are more common in the middle and upper mountain zones. *Amanita vaginata*, *Boletus aereus*, *B. edulis*, *B. edulis* var. *arenarius*, *Russula aurea*, *R. virescens* were found at altitudes of 600-1000 m and 800-1800 m above sea level. The growing possibilities of mushrooms at different heights is explained by their adaptation to different substrates (single or several), host plant associations, light, temperature, humidity demand.

4.3. Occurrence of pileated mushrooms by seasons

Mushrooms can be observed in all seasons, but a number of species can be observed in only one or two seasons (Figure 2). Some mushrooms, both as individual and as population, are found not only in one season, but also in different months of several different seasons. While only three species - *Lactarius deliciosus*, *Suillus granulatus* and *Sarcoscypha coccinea* are found in January and February, the number of species increases significantly in spring. Humus saprotrophic and mycorrhizal fungi such as *Morchella conica*, *M. esculenta*, *Polyporus subarcularius*, *Lactarius deliciosus*, *Sarcoscypha coccinea*, *Suillus granulatus*

was found in March, *Amanita vaginata*, *Boletus edulis*, *Morchella conica*, *M. crassipes*, *M. esculenta*, *M. rotunda*, *M. semilibera*, *Sarcoscypha coccinea* in April, *Amanita crocea*, *Auriscalpium vulgare*, *Bovista plumbea*, *Coprinopsis atramentaria*, *Helvella acetabulum*, *Hymenopellis radicata*, *Hypholoma fasciculare*, *Inosperma maculatum*, *Laetiporus sulphureus*, *Leccinellum pseudoscabrum*, *Lentinus brumalis*, *Lepista sordida*, *Morchella esculenta*, *Mycena crocata*, *Sarcosphaera coronaria*, *Suillellus luridus*, *Suillus granulatus*, *Tuber aestivum* in May. Mycorrhiza forming taxa dominate among pileated mushrooms found in the first month of summer (Figure 2).

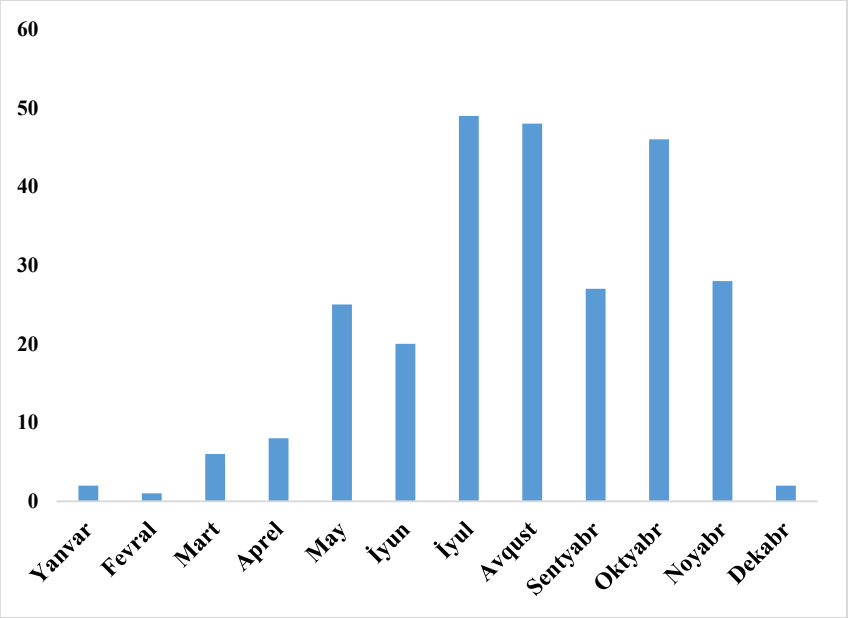

Figure 2. Seasonality in mushroom development.

The highest species diversity of mushrooms determined in the study area occurs in July (49 taxa) and August (48 taxa). Autumn can be considered the second season when mushrooms are most common. Thus, 27 species were identified in September, 46 in October, and 25 in

November. In December, the last month of the year and also the first month of winter, the mushroom species determined in connection with the cold weather were *Suillus granulatus* and *Tricholoma batschii*.

It should be noted that a number of mushroom species were encountered only in one month of the year. Of these, the following species were found only in one month of the year: *Polyporus subarcularius* in March, *Morchella crassipes*, *M. rotunda*, *M. semilibera* aprel, *Bovista plumbea*, *Clavulina coralloides*, *Helvella acetabulum* etc. in May, *Boletus edulis* f. *quercicola, Galerina marginata* in June, *Amanita phalloides*, *A. verna*, *Aureoboletus gentilis*, *Boletus edulis* f. *betulicola* etc. in July, *Amanita citrina*, *Geastrum saccatum*, *Fistulina hepatica* and etc. in August, *Agaricus sylvicola*, *Russula turci* in September, *Agaricus sylvicola*, *Apioperdon pyriforme*, *Echinoderma asperum* in October, *Chlorophyllum rhacodes*, *Clavulina cinerea*, *Flammulina velutipes* in November.

Also, a number of species were found in the study area in different years and in several seasons and months of those years. For example, among macromycetes found in five or more different months, *Amanita pantherina* and *Rubroboletus satanas* can be noted in summer and autumn (June, July, August, September, October), *Amanita vaginata* and *Boletus edulis* in spring, summer and autumn (April, June, July, August, September, October, November).

CHAPTER V
RARE AND ENDANGERED SPECIES

Among the species of mushrooms collected and identified in the study area, quite rare species were found. Of the collected and identified species, 19 were assessed according to the of IUCN categories and criteria and *Amanita crocea* – CR B2b(ii,iii,v), *A. pantherina* – CR C2a(i), *Auriscalpium vulgare* – CR C2a(i), *Phlegmacium triumphans* – CR C2a(i), *Ganoderma lucidum* – EN C2a(i), *Gomphidius roseus* – CR B2b(ii,iii,v), *Helvella crispa* – CR C2a(i), *Hemileccinum depilatum* – CR C2a(i), *Lactarius citriolens* – CR B2b(ii,v), *Lactifluus volemus* – EN C2(i), *Morchella semilibera* – CR B2b(ii,iii,v), *Ramaria formosa* – CR

C2a(i), *Rubroboletus legaliae* – CR B2b(ii,iii,v), *R. satanas* – CR B2b(ii,iii,v), *Russula aurea* – CR C2a(i), *R. virescens* – CR C2a(i), *Sarcosphaera coronaria* – CR B2b(ii,iii,v), *Tuber aestivum* – CR C2a(i), *Tricholoma batschii* – EN C2a(i) were included in "*Volume III of the Red Book of the Republic of Azerbaijan*"[17] (Figure 3).

Figure 3. Species included in 3rd volume of the Red Book of RA from the study area: 1. *Amanita crocea*, 2. *A. pantherina*, 3. *Auriscalpium vulgare*, 4. *Ganoderma lucidum*, 5. *Helvella crispa*, 6. *Lactarius citriolens*, 7. *Lactifluus volemus*, 8. *Morchella semilibera*, 9. *Phlegmacium triumphans*, 10. *Ramaria formosa*, 11. *Rubroboletus legaliae*, 12. *Tricholoma batschii*.

[17] Azərvaycan Respublikasının Qırmızı Kitabı. Nadir və nəsli kəsilməkdə olan flora növləri. [3 cilddə] / D.N. Agayeva, E.H. Mustafabayli. İmak mətbəəsi, – 3- cü nəşr. – 2023. Göbələklər, – s. 424-460.

In addition, *Amanita rubescens*, *Imperator rhodopurpureus*, *Lactarius acris*, *Leccinellum pseudoscabrum*, *Russula delica*, *R. olivacea* on the category EN and *Boletus edulis*, *Cantharellus cibarius*, *Lepista nuda*, *Morchella esculenta*, *M. rotunda*, *Rubroboletus lupinus*, *Tricholoma terreum* on the category CR were recommended for the next publication.

It should be noted that 15 of the studied species are included in the "Global Fungal Red List"[18], where *Agaricus campestris*, *Auriscalpium vulgare*, *Boletus edulis*, *B. reticulatus*, *Calocybe gambosa*, *Cantharellus subalbidus*, *Coprinus comatus*, *Gomphidius roseus*, *Suillus granulatus*, *S. luteus* species were included with the status "published", *Inonotus obliquus* species as "assessed", *Cantharellus cibarius* species "under assessment", and *Fistulina hepatica*, *Macrolepiota procera*, *Trametes versicolor* species as "proposed".

CHAPTER VI
SIGNIFICANCE OF PILEATED MUSHROOMS

6.1. Species distinguished by nutritional value

Mushrooms are a popular, low-calorie, cholesterol-free, high-value food with a number of important nutrients. The species collected from the study area were mainly grouped as edible and poisonous. However, it can be noted that these groups can be distinguished by several subgroups. About 20 mushrooms collected from the study area are high-quality edible mushrooms, of which *Agaricus campestris, Boletus edulis*, *B. edulis* var. *arenarius*, *Cantharellus cibarius*, *Flammulina velutipes*, *Imleria badia*, *Morchella conica*, *M. crassipes*, *M. esculenta*, *M. rotunda*, *Tuber aestivum* species are mass-collected depending on the season and used for food and medicinal purposes. Mushrooms such as *Amanita strobiliformis*, *Echinoderma asperum*, *Geastrum saccatum* can be shown as an example of macromycetes that do not have nutritional importance.

[18] The Global Fungal Red List Initiative: https://redlist.info/en/iucn/welcome

It was determined that 27 of the macromycetes collected and identified from the study area are poisonous: *Agaricus xanthadermus*, *Amanita citrina*, *A. pantherina*, *A. phalloides*, *A. rubescens*, *A. verna*, *A. virosa*, *Caloboletus radicans*, *Coprinopsis picacea*, *Deconica coprophila*, *Galerina marginata*, *Hebeloma sinapizans*, *Hypholoma fasciculare*, *Imperator rhodopurpureus*, *Inosperma maculatum*, *Lepiota cristata*, *L. ignivolvata*, *L. subgracilis*, *Mycena pura*, *Pseudosperma rimosum*, *Neoboletus erythropus*, *Otidea onotica*, *Ramaria formosa*, *R. obtusissima*, *Rubroboletus satanas*, *Scleroderma citrinum*, *Tricholoma terreum*. Of these, the species found in the study area such as *Amanita phalloides*, *A. pantherina*, *A. verna*, *A. virosa*, *G. marginata* are deadly poisonous mushrooms. Note that the main alkaloids causing more than 95% mortality are amatoxins, which are characteristic of several species of the genera *Amanita*, *Galerina*.

6.2. Medicinally important mushrooms

The beneficial effects of mushrooms on protecting health and treating certain diseases have been known since the beginning of history. Currently, *"there is information about nutrients obtained from mushrooms"* in the prevention of a number of diseases (hypertension, parkinson, stroke, tumor diseases)[19].

Many of the mushrooms collected and identified from the study area are used for the purpose of folk medicine both in the district area and in the territory of the Republic. A number of mushrooms such as poliporus (*Ganoderma applanatum*, *Fomes fomentarius*, *Laetiporus sulphureus* etc.), as well as morel (*Morchella conica*, *M. crassipes*, *M. esculenta*, *M. rotunda*, *M. semilibera*), shaggy ink cap (*Coprinus comatus*) are known and used spontaneously and sometimes purposefully by the local population. Another highly poisonous alkaloid found in the composition of deadly poisonous mushrooms is phalloidin (*A. phalloides*). The alkaloid psilocybin is found in a number of taxa of the genera *Deconica*, *Conocybe*, *Pluteus*, *Psathyrella*, *Psilocybe*

[19] Valverde, M.E., Hernández-Pérez, T., Paredes-López, O. Edible mushrooms: improving human health and promoting quality life // International Journal of Microbiology, – 2015. – p. 14.

and this substance mainly causes hallucinogenic intoxication. Some taxa of the genera *Amanita, Clitocybe*, *Inocybe*, *Inosperma* contain orellanine, an alkaloid that can cause gastrointestinal poisoning and, in rare cases, death. Examples of mushrooms with allergenic toxic coprine alkaloid collected from the area are *Coprinopsis atramentaria, Coprinus comatus*; this group of mushrooms is considered conditionally edible and causes serious poisoning when taken with alcohol.

CONCLUSION

The vast majority of knowledge underlying policies and actions aimed at the study of biodiversity is based on botanical and mycological collections, i.e. living and dried specimens (cultures) stored in herbariums. Based on these collections used for reference, new species are decided for a science or any research area.

The research carried out in Shaki district resulted in the study of a large number of pileated taxa, a total of 151 species and 4 intraspecific taxa belonging to 12 orders, 40 families, 84 genera were identified, of which 14 species is documented on the Ascomycota division, and 141 species and intraspecific taxa on the Basidiomycota division. The studied 53 species are new to Azerbaijan, and 90 species new to the research area.

Adequate knowledge of fungal diversity and their occurrence is essential for understanding the role of fungi in the ecosystem, for ecosystem management, optimal exploitation, and successful conservation. In the study, the ecological groups of pileated fungi were defined as saprotrophes (humus saprotroph, caprotroph, carbontroph), biotroph, mycorrhizal, xylotroph, and mycoparasite. Studies have revealed mycorrhizal fungi as the dominant group, which can be explained by the diversity of broadleaf plant species with which they are in association in the study area.

Although mushrooms do not need direct sunlight, it is a well-known fact that scattered sunlight affects the morphology of their fruiting bodies (pileus, stipe, derivatives), “the regulation of physiological and

biochemical processes and nutrient metabolism" in edible mushrooms"[20]. The attitude of mushrooms to light and humidity was investigated in the research work, species that grow mainly in meadows (*Bovista plumbea*, *Hertzogia martiorum* etc.) and arid places (*Sarcoscypha coccinea*) are assessed as light-loving species, and those growing in forest and shrub ecotopes are assessed as shade-tolerant (*Agaricus campestris*, *Amanita crocea*, *Coprinopsis atramentaria*, *Helvella acetabulum*, *H. atra*, *Morchella semilibera*, *Sarcoscypha coccinea* and etc.) and shade-loving (*Amanita phalloides*, *A. citrina*, *A. virosa*, *A. pantherina*, *Boletus aereus*, *B. edulis* var. *arenarius*, *Butyriboletus pseudoregius*, *Cortinarius triumphans*, *Lactarius deliciosus*, *Lactifluus volemus*, *Lepista nuda*, *Marasmius capillaris*, *Coprinus picacea*, *Tricholoma batschii*, *T. columbetta*, *Suillus granulatus*, *S. luteus* and etc.) species.

The occurrence of the studied species was monitored at five altitudes above sea level, and it was found that the most mushroom species were found in the foothills (35) and the lower mountain belt (124). By supporting general regularity, this fact can be explained mainly by host plant associations. Thus, 52.9% of the studied species are mycorrhiza forming taxa. The studies by season and month concluded that more species were observed in summer (July, August) and autumn (October), which can be explained by the optimal range of temperature and humidity for fungal development during these months.

As a result of the analysis of mushroom species collected from the area, 19 rare species were identified for Azerbaijan, based on IUCN guidelinse16 of which were classified as critically endangered (CR), 3 as endangered (EN). About 14 species were proposed for the next edition. Of the studied species, 15 (9.67 %) are published in the database of the Global Fungal Red List.

Since ancient times, the nutritional and medical importance of mushrooms has attracted great interest, they have been used raw or cooked, and even used in traditional medicine to prevent or treat

[20] Marim, R.A. Lentinus crinitus response to blue light on carbohydrate-active enzymes / R.A. Marim, K.V. Avelino, M.I. Wietzikoski Halabura. [et al.] //Bioscience Journal, – 2020. 36 (3), – p. 924-931.

certain diseases. Of the mushrooms analyzed for the nutritional value, 20 were identified as high quality, 11 as edible, 27 as poisonous (including 5 deadly poisonous and 3 hallucinogenic). According to their medical importance, mushrooms are grouped according to the biologically active substances they contain and the diseases they are used for. Results achived are very important for revealing fungal richness of the country along with their introduction and the preparation of recomendations of their rational use.

RESULTS

1. İn the territory of Shaki district 155 pileated mushrooms being 152 species and 3 intraspecific taxa were identified, their list and occurrence areas were specified. It was determined that dominant orders are Agaricales (62 species, 40 %), Boletales (32, 20.6 %), Russulales (28, 18.06 %), Pezizales (13, 8.38 %), and families are Morchellaceae (5, 3.22 %), Agaricaceae (15, 9.67 %), Boletaceae (27, 17.41 %), Russulaceae (28, 18.06 %), and genera are *Russula* (16, 10.32 %), *Lactarius* (12, 7.74 %), *Amanita* (9, 5.8 %), *Morchella*, *Agaricus*, *Boletus* (each of them 5 species, 3.22 %).
2. Of the species involved in the study, 53 species and intraspecific taxa are new to the mycobiota of Azerbaijan, and 90 are new to the study area.
3. The attitude of fungal taxa to light and humidity was studied, they are characterized as species growing in light places (8, 5.16 %), shade-tolerant (9, 5.8 %) and shade-loving species.
4. Mushrooms were bioecologically analyzed, mycorrhizae (ectomycorrhizae 81 taxa, 52.2 %, arbusculyar 1 species, 0.65 %) are dominant. Saprotrophes (humus saprotroph – (36 species, 23.2%, caprotrophe, carbontroph – 1 species each, 0.65 %), xylotrophe (27 species, 17.4%), biotroph (7 species, 4.52%) and micoparasite (1 species, 0.65 %) were also noted.
5. The distribution of mushrooms was studied depending on the

altitude, and it was found that the most mushroom species are distributed in the foothills (35 taxa, 22.58 %) and middle mountain zones 124 taksa, 80 %), which is explained by the specific growing season of the species, substrate, temperature, etc.

6. For Azerbaijan 19 rare species were identified, of which 16 species are included in CR and 3 species in EN categories of the IUCN to the III edition of the Red Book. Another 14 species are proposed for the next edition. Of these taxa, 15 have international conservation status.
7. The studied mushroom species were analyzed for their nutritional and medical importance. According to the nutritional value, 20 of taxa were identified as high quality, 11 as edible and 27 as poisonous, including 5 lethally toxic and 3 hallucinogenic. According to the medical importance, 3 species are used in gastrointestinal, 1 species in lung, 3 species in diabetes, and 4 species in tumor diseases.

RECOMMENDATIONS

1. The species discovered as a result of the research conducted in the Shaki district of Azerbaijan enrich the knowledge of the country about fungal diversity and their biological characteristics, and integration of the collected specimens in the mycological herbarium and their documentation serves as a reference for future research. These data enable the development of systematic and regional mycobiota, manuals, and maps on diversity and reserve.
2. Identification of nutritionally and medically important mushroom species in the study area paves the way for the development of scientifically based programs for their effective use in the future. The knowledge collected about edible and poisonous species serves to inform the population, and it is considered advisable to prepare atlases and books with photos in this direction.

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