

Diversity and Systematic Assessment of Macrofungi in Himachal Pradesh with Reference to Edibility, Conservation Status (Endangered, Rare, Common), Presence of nanoparticles and Frequency of Occurrence

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ABSTRACT

The present study is a cumulative effort to document the macrofungal diversity in twelve districts of Himachal Pradesh, India, with special emphasis on edibility, frequency, and conservation status of fungal species. The field surveys conducted from 2023 to 2024 yielded a rich macrofungal collection across diverse habitats, which included forests, fields, and riparian zones. The morphological and ecological surveys revealed an abundant fungal association that was most varied in Shimla, Sirmour, Spiti, and Chamba districts. The most common species found were *Schizophyllum commune* and *Trametes versicolor*, which indicate their accommodation and ecological breadth. The research points to the dominance of non-edible species in the majority of districts, emphasizing the necessity of awareness among people regarding mushroom safety as well as the bioprospecting value of wild fungi. Conservation classification highlighted a number of endangered and rare species, notably in Kinnaur, Kangra, and Hamirpur, highlighting the ecological vulnerability and urgency of conservation in these areas. The results provide important information on the taxonomy, ecology, and potential medicinal and biotechnological applications of macrofungi, and lay the foundation for future ecological and conservation planning in the Western Himalayas.

Key words: Macrofungi, Species, Conservation, Medicinal, Wild, Common, rare, Endangered.

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Introduction

Fungi are a diverse group of eukaryotic organisms that are employed in a number of industrially significant, medicinal, and ecological uses. Fungi are neither plants nor animals nor other microorganisms and form the kingdom of fungus. These organisms are distinguished from the photosynthetic organisms because of the varied mechanism of nutrient acquisition that follows enzymatic digestion of organic matter [1]. The kingdom consists of organisms such as mushrooms, which are macroscopic, whereas there exist unicellular animals such as yeasts and multicellular molds. Fungi degrade organic matter, recycle nutrients, and exist in mutualistic association with plants. With these roles, they play a significant role in ecosystem function [2].

They have a major impact on human life by serving as a source of food, being fermentation agents, and yielding medicines such as penicillin. Besides the positive, there are dangerous effects fungi have on humans and the environment. For instance, but fungi are opportunistic pathogens and are causative agents of several diseases in animals, plants, and humans [3]. The fungal cell's cell wall contains chitin and consists of a complicated life cycle that involves sexual and asexual reproduction. Such features of fungi have allowed them to survive and reproduce in various conditions, ranging from soil to water and even to extreme habitats of salt or concentration of heat [4]. Their biochemical potential and ecological adaptability underscore their importance in scientific research and use, including the cleaning up of

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environments. The class of fungi involving visible naked fruiting fungal bodies is categorized as macrofungi. It typically consists of shelf fungi, puffballs, and mushrooms - whose structures, such as these develop primarily responsible for spore production and dissemination, a fundamental mechanism in fungal reproduction [5]. Macrofungi are typically involved in a range of ecological processes including pathogenicity, mycorrhizal association between the plant and fungus, and detritivorous as well.

By degrading such highly complex organic matter as cellulose and lignin, macrofungi play a very important role in the nutrient cycling of the ecosystem [6]. Decomposition often allows recycling to the soil of nutrients such as nitrogen and phosphorus. Also, most macromycota are mycobionts. They have mutualistic relationships with plants, facilitating easier uptake of nutrients and water in return for carbohydrates, promoting plant health and ecological balance, as per a report [2]. Macrofungi also possess cultural and economic significance. They are used as food, and their medicinal values are in demand, particularly in contemporary pharmacology components such as polysaccharides and anticancer activity as well as traditional medicine [7]. The reason that, although there are advantages to some species, others are toxic and can lead to severe poisoning or even death if accidentally ingested requires further ecological and taxonomic studies [8]. Large groups of fungi known as macrofungi consist of coral fungi, mushrooms, brackets, and puffballs with other large macroscopic fruiting bodies that can be seen by the naked eye without a magnifying glass. Unique reproductive characteristics and ecological niches distinguish macrofungi from macrofungi. They were primarily basidiomycetes and ascomycetes. The fruiting characteristic is that in macrofungi, fruiting bodies are unique organs for the production and spread of spores. These provide a basis for taxonomy and show considerable variation in size, form, color, and texture

[5]. Two methods by which de-macrofungi have shown a variety of nutritional strategies are the breakdown of organic refuse and the recirculation of nutrients. symbiotic associations with plants enable them to take in nutrients and water. They gain their sustenance by feeding on living hosts, resulting at times in disease [6]. The major means of reproduction of macrofungi is by the formation of spores in their fruiting bodies, which may be wind, water, or animal dispersed. They possess asexual and sexual cycles of reproduction (via meiosis) [2]. Macrofungi fruiting bodies are shaped and formed in a variety of ways, such as spheric shapes like puffballs, shelving forms like bracket fungi, and caps and stems characteristic of mushrooms. The morphological variation within these fungi shows how they are suited to different ecological niches [8]. Macrofungi play a vital role in ecosystems. They decompose intricate organic material like cellulose and lignin by acting as decomposers. While some of the mycorrhizal macrofungi are pathogens and influence population dynamics, others are fertility agents of soil and agents of plant growth [7]. Many bioactive metabolites, varying from the enzymes of breakdown to secondary metabolites with toxic as well as therapeutic value are generated by macrofungi. They possess such features that they are useful in biotechnology, also pharmacy [5]. These are quite fascinating sets of ancient plants. Fungi large and clearly referred to as macrofungi whereas small and with naked eyes or unseen are microfungi. Mushrooms are also referred to as the general name of a macrofungus since it is part of the fruiting body of fungi. Fungi are like plant cells but this does not contain chlorophyll, which also differentiates them from a plant cell. These are typically conducted in a rainy season because this indicates moisture-loving organisms themselves.

Some of the previous work carried out by most of the researchers is given below: -

Study	Location	Fungal Species Identified	Key Findings
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Podaxis pislillaris identification	Kashmir Valley	<i>Podaxis pislillaris</i>	First mushroom identified from Kashmir Valley [9]
Fungal species in India	India	~27,000 species recorded	Around 850 species of mushrooms estimated by the end of the 20th century [10]
Macrofungi reference in ancient literatures	India, China, Greece, Rome	Various species	Mushrooms used for various purposes in ancient cultures [11].
Macrofungi study in Kampinos National Park (2015)	Poland	<i>Chondrostereum purpureum</i> , <i>Coniophora arida</i> , <i>Bjerkandera adusta</i> , <i>Cylindrobasidium e volvens</i> , <i>Stereum rugosum</i>	26 taxa found, mostly wood-decaying fungi. Most common species: <i>Chondrostereum purpureum</i> on black cherry trees [12].
Study in Hailugou Scenic Area	China	<i>Tricholomataceae</i> , <i>Russulaceae</i> families	29 lignicolous fungi, 74 edible, 15 medicinal, and 14 poisonous species identified [13].
Macrofungi itinerary in Pakistan	Pakistan	338 macrofungi species	338 species found across 114 genera, dominated by ectomycorrhizal symbionts with <i>Pinaceae</i> [14].
Diversity and medicinal value in Himalayan region (India)	Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Assam, West Bengal	<i>Amanita hemibaphla</i> , <i>Agaricus sp.</i> , <i>Ganoderma lucidium</i> , <i>Geopyxis majalis</i> , <i>Lactarius</i> , <i>Verpa bohemica</i>	Nutritional importance and ethnomycological aspects [15].

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Survey in Bharsar Region	Pauri Garhwal, Uttarakhand	<i>Cortinarius cf. distans</i> , <i>Gyroporus cf. cyanescens</i> , <i>Lactarius sp.</i> , <i>Hebeloma mesophaeum cf. var. longipes</i> , <i>Cantharellus cibarius</i> , <i>Hygrocybe</i> species	12 species from 10 genera, 12 varieties recorded [16].
Study in Western Kashmir Himalayas (2009-2010)	Western Kashmir Himalayas	<i>Agrocybe molesta</i> , <i>Coprinus plicatilis</i> , <i>Inonotus hispidus</i> , <i>Paxillus involutus</i> , <i>Psathyrella candolleana</i> , <i>Russula fragilis</i>	6 basidiomycetes recorded for the first time from Kashmir Valley [17].
Pyronemataceous macrofungi in Jammu & Kashmir (2012-2014)	Jammu and Kashmir	<i>Geopora arenicola</i> , <i>Peopora sepulta</i> , <i>Pulvinula convexella</i> , <i>Pulvinula miltina</i> , <i>Anthracobia macrocystis</i> , <i>Geopyxis majalis</i>	6 species, two new to India: <i>Geopora sepulta</i> and <i>Geopyxis majalis</i> [18].
Botanical Garden and Arboretum Study (Mangalore University)	Mangalore, India	<i>Clatharus delicatus</i> , <i>Entoona serrulatum</i> , <i>Tetrapyrgos nigripes</i> , <i>Russula adusta</i> , <i>Termitomyces microcarpus</i>	11 species reported, including new species for the region [19].
Nanda Devi Biosphere Reserve Study	Nanda Devi, Uttarakhand	<i>Geoglossaceae</i> , <i>Helvellaceae</i> , <i>Morchellaceae</i> , <i>Asteraceae</i> , <i>Araucariaceae</i> , <i>Clavariaceae</i> , <i>Ganodermataceae</i>	234 species, including 106 macrofungi and 128 lichens [20].
Gorakhpur District Macrofungi Study (2011-2014)	Gorakhpur, Uttar Pradesh	114 species from 33 families, <i>Agaricaceae</i> dominant	Most dominant family: <i>Agaricaceae</i> (18 species) [21].

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Doddanni Forest Study (Nilgiris)	Nilgiris, India	<i>Boletus edulis</i> , <i>Russula fragrantissima</i> , <i>Amanita muscaria</i> , <i>Tricholoma caligatum</i>	Multiple macrofungi recorded, including edible and medicinal varieties [22].
Pabbar Valley Wild Edible Mushrooms Study	Pabbar Valley, Himachal Pradesh	<i>Morchella sp.</i> , <i>Sparassis crispa</i> , <i>Cantharellus lateritius</i>	13 species identified, including saprophytic and mycorrhizal fungi [23].
Study in Hamirpur District	Hamirpur, Himachal Pradesh	<i>Tyromyces chioneus</i>	<i>Tyromyces</i> produces anti-HIV-1 compounds, identified for the first time with novel sesquiterpene molecules [24].
Ectomycorrhizal Fungi Study in Kinnaur District	Kinnaur, Himachal Pradesh	<i>Geastrum</i> , <i>Russula</i> , <i>Suillus</i> , <i>Boletus</i> , <i>Ramaria</i> , <i>Scleroderma</i>	Dominance of <i>Geastrum</i> in association with <i>Pinus gerardiana</i> roots [25].
Chlorolepiota Study in Solan District	Solan, Himachal Pradesh	<i>Chlorolepiota brunneotincta</i>	New species identified, unique due to browning flesh and stipe features [26].
Use of Wild Mushrooms in Kinnaur District	Kinnaur, Himachal Pradesh	<i>Sparassis crispa</i> , <i>Ramaria botrytis</i>	Local use of <i>Morchellaceae</i> mushrooms as food [27].
Sarkaghat Region Wood-Rotting Fungi Study	Sarkaghat, Mandi, Himachal Pradesh	<i>Auricularia</i> , <i>Polyporus</i> , <i>Xylobolus</i>	7 new species of wood-rotting fungi discovered [28].

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<p>Study on Bioactive Compounds (2012)</p>	Himachal Pradesh	<i>Lactarius</i> , <i>Laetiporus</i> , <i>Laccaria</i> , <i>Stropharia</i> , <i>Cortinarius</i>	65 samples collected from various ecological regions, highlighting bioactive compounds [29].
<p>Macrofungi Study in Hamirpur District</p>	Hamirpur, Himachal Pradesh	<i>Auricularia auricular-judae</i> , <i>Bovista pusilla</i> , <i>Daldinia concentrica</i> , <i>Ganoderma lucidium</i>	18 species identified, 12 first-time reports [30].
<p>Taxonomic Studies in Himachal Pradesh</p>	Himachal Pradesh	<i>Russula lepidicolor</i> , <i>Russula azurea</i>	<i>Russula lepidicolor</i> first reported from India in forests of <i>Cedrus deodara</i> [31].

Methods and methodology

Study site



Figure 1:-

<https://www.mapsofindia.com/maps/himachalpradesh/>

Material and methods :-

Field survey was conducted in year 2023-2024 to obtain samples of macrofungi from various places of districts of Himachal Pradesh including regions such as forests, fields, farms, roadsides, Waterfalls etc.

Method

Specimens were gathered from various places of H.P. Collection was done by cutting with sharp knife or by sawing. Hand lens was employed for fructification examination. Specimens were taken photographs at

the time of collection at the location with time, date, location altitude. Key observations about the specimens were noted at the time of collection such as colour, shape and size of fructification. Specimen collection was done along with the substratum

Drying of samples

Next step after the collection of specimens was drying of samples to be preserved and utilized for future lab work. The specimens were dried in sunlight and stored in cardboard/paper boxes. Fresh fleshy fructifications to be dried were placed over the blotting paper sheets. It was ensured during drying that hymenial surface should remain in upward position. On rainy days, on top of all, an electric drier was used to dry samples. To preserve, naphthalene balls were placed in a packet of specimens for insect or worm attack protection.

Results and discussion

Systematic studies conducted on macrofungi of twelve districts of Himachal Pradesh present enormous information concerning species distribution, edibility, frequency, and conservation status. Among all the districts, the most significant is Shimla with a highest number of fungal specimens (15%), which proves its diversified ecology and suitable place for fungal growth. Spiti (13%) and Sirmour (12%) follow next, showing great diversity. On the other hand, Bilaspur, Kinnaur, and Mandi shared the lowest 4% count of specimens each, suggesting reduced fungal diversity or less effort directed towards exploration in these areas.

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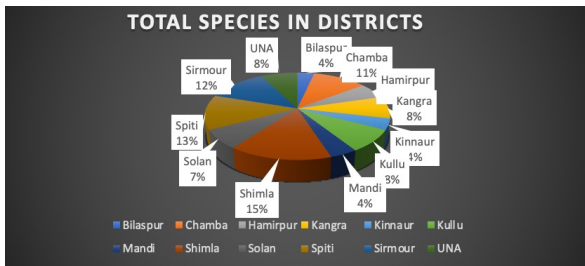


Figure 2: - Total species in all districts of Himachal Pradesh in percentage

It so falls in the case of edibility that the work highlights predominant presence of non-edibles in almost all districts. To put it, Chamba, Shimla, Sirmour, Solan, and Spiti accounted for a significant number of non-edible specimens while edible ones were quite low with being moderate only in Shimla, Chamba, and Sirmour. This pattern signals a need for public education about the safe use of mushrooms and potential toxicities, and potentially richness for bioprospecting of medically or industrially useful non-food fungi.

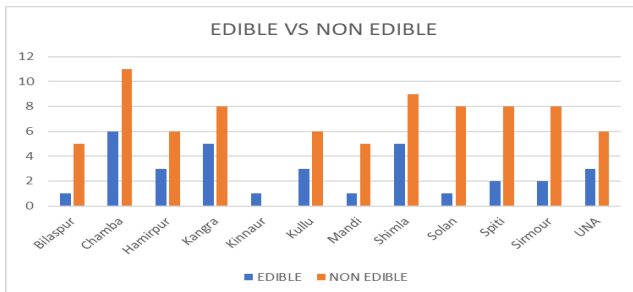


Figure 3: - This graph is depicting the total number of edible vs non edible species

With regard to occurrence frequency, the most frequent and widespread species within the districts are *Schizophyllum commune*, with 7 occurrences, then *Trametes versicolor* with 6 observations. *Trametes hirsute* and *Merulius tremellosus* are moderately frequent species. Others such as *Trametes gibbosa*, *Macrolepiota spp.*, and *Fomitopsis pinicola* are sampled only once and may be interpreted as either very rare or for very specialized niches. The unequal distribution infers the variation in microclimatic conditions and host that influence fungal biodiversity.

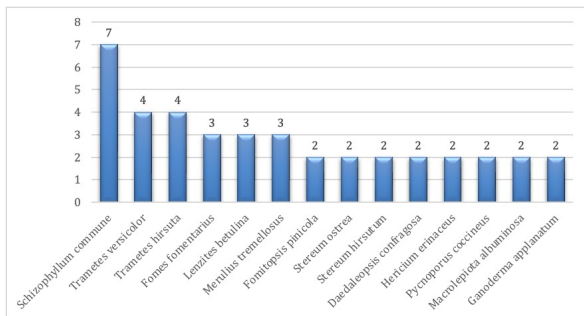


Figure 4: - This graph depicting the frequency of occurrence of species in different districts

The study also classifies species according to conservation status as common, rare, endangered, and threatened. Shimla, Sirmour, and Chamba have the largest number of common species, demonstrating their ecological value as hubs of fungal diversity. Spiti and Shimla also contain the largest numbers of rare species (7 each), highlighting the presence of unique or specialist fungi. The threatened and endangered species are relatively smaller in number, with one each of endangered and threatened species occurring in Kinnaur, Kangra, Hamirpur, and Bilaspur districts and hence these are priority areas to be conserved in the future. Interestingly, districts like Kinnaur, Kangra, and Hamirpur possess all four groups of fungi—common to endangered—and hence richness of biodiversity as well as vulnerability.

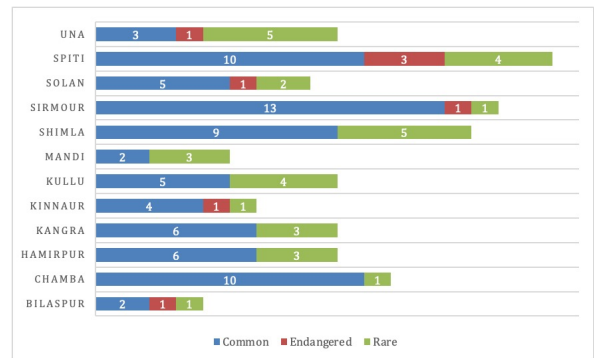


Figure 5:- This graph is depicting the rare, endangered and common species in the districts.

Species-by-district records also support the findings above. A well-tabulated list plots every species, their distribution and edibility status. For example, *Pleurotus pulmonarius*, *Macrolepiota procera*, and *Suillus grevillea* are very edible mushrooms of Sirmour and Chamba, while Una's *Amanita bisporigera* and Chamba's *Lepiota castanea* are very toxic and must not be eaten. Some of them, such as *Ganoderma applanatum* and *Trametes versicolor*, though inedible, have some medicinal properties, which add to the pharmaceutical and ecological significance of this study. Overall, the data draws attention to the fungal wealth of Himachal Pradesh, though uneven, with some districts like Shimla, Sirmour, Chamba and Spiti being of future research, conservation and sustainable utilisation potential. Dominance of local hotspots by endemic and threatened species demands urgent conservation measures along with habitat reservation. The study not only charts the Fungal richness but also provides a scientific rationale for ecological, pharmaceutical,

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and Community-level utilization of macrofungi in the region.

Distribution of Nanoparticle-Related Fungi by District

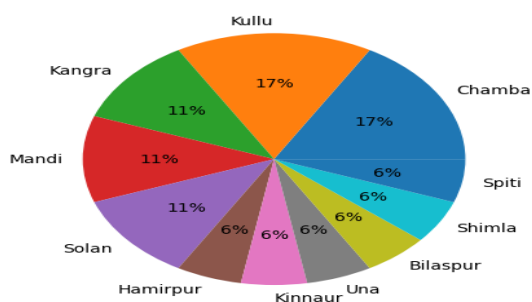


Figure 6:- This picture showing the distribution of nanoparticle-related fungi occurrences by district

Analysis of the fungal database showed that out of the total recorded number of fungal species, which was 142, there are only 8 recorded species that are cited in scientific literature for their potential in synthesizing nanoparticles through myco-nanotechnology. The recorded species include *Pleurotus ostreatus*, *Pleurotus pulmonarius*, *Pleurotus tuber-regium*, *Lentinula edodes*, *Ganoderma applanatum*, *Schizophyllum commune*, *Inonotus obliquus*, and *Trametes versicolor*. The three classes of fungi are the most researched because of their enzymes, proteins, and other metabolic compounds that have the potential for reducing metal ions for the synthesis of nanoparticles such as silver, copper, zinc, and gold nanoparticles. Fungi are seen as the most promising bio factories for the synthesis of nanoparticles because of their large biomass and capacity for accumulating metal ions in their cell walls. Within the present dataset, the occurrence of these nanoparticle-associated fungi was recorded 18 times in the districts of Himachal Pradesh. The highest occurrence of these nanoparticle-associated fungi was recorded in the districts of Chamba and Kullu with three records each, followed by the districts of Kangra, Mandi, and Solan with two records each, while the districts of Hamirpur, Kinnaur, Una, Bilaspur, Shimla, and Spiti recorded only one record each for the occurrence of these nanoparticle-associated fungi. From the present results, the districts of Chamba and Kullu have been identified as the major hotspots for the occurrence of these fungi with potential nanoparticle-producing capability, thereby emphasizing the importance of these districts in the context of the role of these fungi in the ecosystem.

Discussion

The present detailed survey of macrofungi in twelve districts of Himachal Pradesh re-establishes the high

fungal richness of this region and also records the ecological as well as conservation importance of the species. The results substantiate and add to the available studies on the Western Himalayas, bringing into light much useful information on distribution of the species, their edibility, frequency, and conservation status. Shimla district's predominance at 15% of the total fungal specimens collected is a reflection of its diverse habitat and favourable climatic conditions for the development of fungi. This concurs with another report who showed Rich macrofungal diversity in different eco-sites of Himachal Pradesh indicates the ecological richness of the area. Likewise, the Spiti and Sirmour districts have 13% and 12%, of samples respectively also confirmed the high macrofungal diversity in the area. The Finding of the study that a higher percentage of non-edible species in most districts, particularly Chamba, Shimla, Sirmour, Solan, and Spiti, underlines the urgent need for public the awareness about mushroom consumption. This is in agreement with the other report, who documented various macrofungi in Palampur, both edible and non-edible, and their impacts on the local residents [33]. *Schizophyllum commune*, the most widespread among them, being recorded from seven districts, and *Trametes versicolor* with six records, indicate their wide distribution and adaptability. The findings agree with the observations of another researcher in Kishtwar High Alt. National Park, where some macrofungal species exhibited wide ecological amplitudes [34]. It was further noticed that categorization of species according to their conservation status showed the highest number of common species in Shimla, Sirmour, and Chamba districts, hence defining them as biodiversity hotspots. The occurrence of seven rare species in Spiti and Shimla, each one of them possessing seven such species, highlights the uniqueness of their fungal flora. The findings are in agreement with other researcher, that documented the ectomycorrhizal fungi of *Pinus gerardiana* from Kinnaur district, highlighting specialised fungal associations of particular habitats [35]. Documenting species such as *Pleurotus pulmonarius*, *Macrolepiota procera*, and *Suillus grevillea* as common edible mushroom of Sirmour and Chamba stands in support of the effort other researcher, which also stressed the importance of taxonomy research to the conservation and sustainable utilisation of wild macrofungi [32]. Conversely, the identification of poisonous

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species like *Amanita bisporigera* from Una and 3. *Lepiota castanea* from Chamba emphasizes the pressing need for accurate species identification to prevent potential health hazards. On a general level, 4. the findings of this research are useful to the knowledge of macrofungal diversity of Himachal Pradesh, its high-biodiversity regions, abundance of inedible and toxic species, and the need for conservation measures. These findings are important 6. in informing sustainable practice application and recommending future research and conservation efforts.

Conclusion

The scientific investigation of macro fungi in every one of the twelve districts of Himachal Pradesh has 8. experienced a highly skewed but rich fungal diversity. Regions such as Shimla, Sirmour, Chamba, and Spiti emerged as hotspots of biodiversity and had an ample number of common and rare species, while Bilaspur, 9. Kinnaur, and Mandi had relatively few specimens with classes of endangered species. Prevalence of fungi with non-culinary and medicinally useful species at district level reflects the ecological and pharmaceutical significance of mycoflora of the area. 10. Furthermore, the occurrence of rare, endangered, and threatened spp. in ecologically sensitive districts like Kinnaur and Kangra reflects the necessity for an immediate conservation measure and habitat protection. This study does not only enhance our understanding of the fungal diversity of Himachal Pradesh but also Provides a critical reference point for future ecological studies, sustainable collection, and Macrofungal resource conservation in the Himalayas.

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Abbreviations

1. HIV-1 – Human Immunodeficiency Virus type 1
2. spp. – Multiple species
3. H.P – Himachal Pradesh
4. etc-et cetra
5. Alt.-altitude