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# Investigate of Global Comparison of Fungal Diversity by Ecosystem

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## Abstract

The thesis focuses about the wide variety of fungi and their functions in the environment in terrestrial ecosystems. It explores how fungi, as heterotrophic organisms, adapt and thrive in various environments by acquiring nutrients through extracellular digestion and absorption. The study delves into the morphological adaptations of fungi, such as the development of hyphae, rhizomorphs, and spores, which aid in nutrient acquisition and survival during nutrient-scarce periods. Overall, this research provides a comprehensive analysis of the ecological importance of fungi, emphasizing their adaptability, diversity, and essential functions within ecosystems, particularly in the Chhatarpur district, which hosts a rich a wide range of fungal species that are involved in area's biodiversity and ecological health.

**Keywords:** Global Comparison, Fungal Diversity, Ecosystem, development

## Introduction

In response to this absorptive mode of nutrition, fungi have evolved a characteristic growth habit and adaptive morphological structures. Hyphae, strands, rhizomorphs, haustoria, appressoria and traps all aid the fungus in obtaining and absorbing nutrients. Resistant structures such as chlamydospores and sclerotia provide mechanisms for enduring periods when nutrients are in short supply or when the physical environment becomes limiting. Except for aquatic fungi that produce zoospores, the most common means of reproduction in fungi is by the production of large number of non-motile spores at the surface of the substrate where they can be carried to new environments by wind, splashing rain drops or animals. Many fungi have evolved structures such as stroma and fruiting bodies that aid in this dispersal.

These morphological features of fungi particularly the types of sexual and asexual spores, have traditionally been used as criteria in fungal taxonomy and classification, although these features are now supplemented by physiological and biochemical criteria.

Fungal physiology relates to the study of phenomena in fungi and the underlying fundamental process that control these phenomena. The phenomenological component of fungal physiology has its origin somewhere in antiquity the fundamental component did not arise until by the middle of the nineteenth century. Advances in Microbiology, Biochemistry and Molecular biology over the past hundred years have given direction and impetus to both the phenomenological and fundamental aspects of fungal physiology.

An understanding of fungal nutrition and of the ways nutrients function at the biochemical level offers a means of controlling the activity of these organisms, thereby maximizing their beneficial effects and minimizing harmful ones. In addition, fungi serve as ideal experimental organisms for studying the biochemical bases for certain types of developmental and physiological processes because the metabolism of fungi is not additionally complicated by the presence of photosynthesis. Such information may be important not only to Fungal physiologists but also to Mycologists, Plant pathologists, Microbiologists and others.

More research on live fungus is being conducted than in the past. Part of the reason for this might be the growing interest in the fungi's industrial potential and the greater recognition of fungi as important disease producing agents of plants and animals and as destroyers of fabrics and other cellulosic materials of commercial importance. This has increased the interest in the cultivation of the fungi.

## Literature review

Naranjo-Ortiz, Miguel et al. (2019) [1]. The chitinous cell wall and lack of phagotrophy define the fungal kingdom as a heterotrophic eukaryotic organism. Although there are many types of fungus, the fact that certain of them may grow eternally as a cylinder of multinucleated cells (hypha) is a key component of their evolutionary success. Fungi have built a universe of interactions with other living species and won several ecological niches with their physical characteristics and exceptionally high metabolic diversity. In this review, we take stock of the most important ecological and evolutionary forces that have shaped fungal diversity. As one of the most significant evolutionary shifts in this kingdom, territorialization will be examined first after that before moving on to an examination of the and evolution of zoosporic lineages. We provide a novel model for fungal territorialization that takes ice conditions into account as a transitional gap between the sea and the recently deposited soil, adding to the list of possible explanations. Next, we'll delve into the primary ecological connections that fungus have with other creatures, including protozoans, mammals, plants, and other fungi. We'll also look at how certain fungi, including lichens, black fungi, and yeasts, adapted to inhabit specific ecological niches. In order to comprehend the ecological variety of fungi, we approach this review from an evolutionary and comparative-genomics standpoint. Our last point is that genome-enabled inferences are crucial for imagining believable stories and situations about significant changes.

Kumar, Vinit et al. (2021) [2]. Adaptation, migration, replacement, or extinction are some of the outcome's nature of the relationships between living things and the places they inhabit that are accelerated by climate change. Fungi and other microbes in marine ecosystems are particularly vulnerable as a result of global warming on these systems' ecological functioning. Marine fungi are actively involved in and have adapted to a wide variety of ecological processes. The intricate relationships between fungi and their environment have been the subject of several investigations into the dynamics of fungal evolution and adaptation. Nevertheless, there has yet to be a comprehensive assessment of how marine fungus have adapted to the changing environment. We have looked at how fungi like *Aspergillus terreus* and Hortaeawerneckii have adapted to life in the water, and how this can lessen the severity of certain climate change's most detrimental impacts on marine life. In order to provide light on the adaption process, we delve into the ecology, evolution, and impacts of climate change on marine fungus. An examination of the ways in which marine fungi have adapted will provide light on the process of evolution and its far-reaching consequences for the field.

Amend, Anthony et al. (2019) [3]. As parasites and mutualists, terrestrial fungus influence populations of macro-organisms and are crucial to the functioning of food webs and the cycling of nutrients. Despite estimates ranging from $1.5 million to more than 5 million different types of fungi worldwide, it is very probable that less than 10% of fungus have been discovered up to this point. Only over 1,100 species have been found only in marine habitats, indicating that very little amount of all Several different kinds of animals have been named with a connection to the ocean. Fungi, however, have been discovered in almost every marine environment studied, from the ocean floor to deposits kilometers below. Marine sediment fungi are believed to participate actively in the process of biological carbon pumping, phytoplankton population cycles, and sediment chemistry. Corals, sponges, plants, and algae are just a few examples of the marine creatures that have fungal infections or commensals. Despite the variety of these eukaryotic organisms and the many roles they play in marine environments, very little is known about them or the ecological tasks they provide Ocean Research Institute in Massachusetts - Woods Hole hosted a Marine Fungi Workshop in May 2018, which gave rise to this viewpoint. Here we lay out what little understood on the variety and role of marine fungi, as well as the many unanswered concerns about these topics, in relation to the geochemical cycles and the current level of scientific understanding.

Saikkonen, Kari other people. (2015) [4]. Interest in the position has been on the rise of phyllosphere fungus in soil processes and how they affect ecosystem functioning during the last decade. The present little is known about the interaction between foliar soil-dwelling fungus and nitrogen cycling is quickly reviewed here. Endophytes may influence nutrient availability, creatures that control the rate of litter breakdown and the quality of plant litter, according to recent research. But there is a lot of variation in the outcomes that have been produced so far. We try our best to draw connections between these findings and the state of ecological knowledge, and life-history strategies of endophytic fungal organisms, while also drawing attention to overarching principles and information gaps. And lastly, we propose research questions that may be answered by testing in the future.

Singh, Ravindra et al. (2018) [5]. The exquisite art and magnificent artwork of the Khajuraho people are famous all over the world. The Chhatarpur district in the Indian state of Madhya Pradesh is home to this stunning location. Out of 84 temples, 21 are still standing today. Discoloration and an unsightly appearance are caused by the temple's unrestricted exposure to the environment. Research on the temple has shown that several types of fungus and higher plant life, such as weeds and grasses, are responsible for its degradation and destruction. Isolated many species of fungi, including *Aspergillus niger*, *Alternativa alternata*, *Aspergillus sickle* cell, *Aspergillus chitridium*, *Fumigates* sp., *Curvularia lunata Rhizopus nigricans*, *Fusarium oxysporum*, *Mucor infectus* sp., and others. Flora in this study were identified and their similarity, dissimilarity index, and frequency were calculated. These macroflora include *Beorhaavia diffuse*, *Amaranthus viridis*, and *Auria scandence*, *Bothriocephalus*, *Valerian root*, Cynodondactylon, *Oxalis trifolia*, *Indigofera* sp., *Ficus religiosa*, *Ficus benghalensis*, and *Euphorbia hirta* among others. The layout and diversity of the temples of Khajuraho's southern group and their eastern counterparts were the primary foci of the current study endeavour.

## Materials and Methods

Samples were typically stored for a few weeks or months prior to being processed in the lab because of how remote the arctic areas are. The fact that several research looked at different substrates is also important to mention.

**Sample:** All 125 locations, which ranged from seminatural woods and grasslands to underclaimed land, had soil samples taken. The accompanying material included specific details on the locations of each facility. information with respect to latitude and longitude. At every location There was a 10 x 10 m area drawn out, and five soil samples were taken. were taken and mixed, with depths ranging from 0 to 20 cm and diameters of 10 cm. To remove boulders and plant debris, the allowed to dry naturally for three weeks at room temperature before being passed through a 2-mm sieve. soils were allowed to air-dry at ambient temperature for three weeks before being sieved through a 2-mm screen.

## Substrates from which fungi were obtained

Fungi found in the polar areas by molecular and cultural approaches contained species linked to both live things and dead organic residue, according to the analysis. Bioinert matter, which includes materials produced by living creatures and inert biosphere activities, is the substrate from which most species were separated. While inorganic substances predominated on certain bioinert substrates, organic ones were less common. There were separate groups for airborne fungus and substrates affected by human activity. Fungal species that were not found on other materials were added to the general list for each substrate category.

## Experiment using a microcosm of plastispheres

Due to its widespread usage and ease of detection for the microcosm experiment, polyethylene was used as the plastisphere substrate. To remove the sorbed chemicals, 10 micrometers thick PE film was bought at the neighbourhood store, sliced parts measuring 5 x 5 mm and placed in a solution of methanol for a week. Before incubation, the micro-fragments were sterilized in a UV Clean Bench for 15 minutes and dried in a fume hood. The microcosms were cultured at 25 °C for 180 days with a 60% water-holding capacity after 500 g of soil and 1000 micro-fragments were introduced to a 1-L sterilized glass jar. Our prior research 50, 51 informed the selection of the microplastic concentration.

## Results

Figure 1 shows that the fungus dataset included 2332 samples obtained from 41 separate sampling operations that were conducted on land, in water, and in the air. Due to the predicted variability of the datasets, there is a considerable variation in sampling effort, yet this dataset is nonetheless vast. Out of all the dataset with the highest number of samples (1130) was the coastline dataset, followed by the marine dataset with 924 samples, the terrestrial dataset with 800 samples with the less extensive records on freshwater with 154 samples for rivers and 246 samples for lakes. With an average of 57 fungal taxa per sample, terrestrial environments definitely had the largest number of species per observation. Figure 1C shows that the greatest Shannon diversity varied considerably ($p<0.001$, ANOVA) across the five habitats, with terrestrial ecosystems having a value of 2.75, freshwater ecosystems ranging from 1.6-1.26, and marine systems ranging from 0.59-0.51. The results of our study lend credence to the idea that the variety of fungus found in terrestrial ecosystems is greater than in aquatic ones, albeit this conclusion might be skewed due to the dearth of comprehensive data on fungi in aquatic environments. Although it is not always the case, a recent transect study in the Sargasso Sea that included both oligotrophic and estuarine waters found there were no notable variations in terms of fungal diversity. In marine environments Oceanic locales usually have the lowest fungal diversity, whereas surface waters and areas close to the shore usually have the most.

We analysed environmental factors shared by all ecosystems, which we collected from a public database. We examined measuring environmental factors such as temperature, latitude, and salinity for the various habitats (Figure 1D-F) to comprehend the impact of environmental parameters on fungal diversity. By narrowing our attention to the 18S rRNA V4 region, we were able to determine Alpha diversity, inverse Simpson, and the Chao estimator are relevant concepts. Still more proof of the diversity findings was provided by these (Supplementary Figure S1). Figure 1D and Supplementary Figure S5A show that alpha diversities were highest in terrestrial systems, rising between 8.2 and 19.7 °C before falling as the temperature approached 30 °C. The rivers, on the other hand, showed the greatest diversity in temperatures ranging from 1.3 to 7 °C. Figure 1E and Supplementary Figure S1B show that river communities had the greatest diversity at 0 salinity, while marine fungal communities showed an increase in diversity up to 37 salinities. Contrary to what was previously thought, the greatest variety of terrestrial fungi was found near 50 ◦N. As one would expect, fungal communities, marine bacteria, and phytoplankton diversity all show declines with rising latitude (Figure 1F, Supplementary Figure S1C), and this trend is consistent with the overall trend of marine fungal diversity decreasing towards high latitudes.

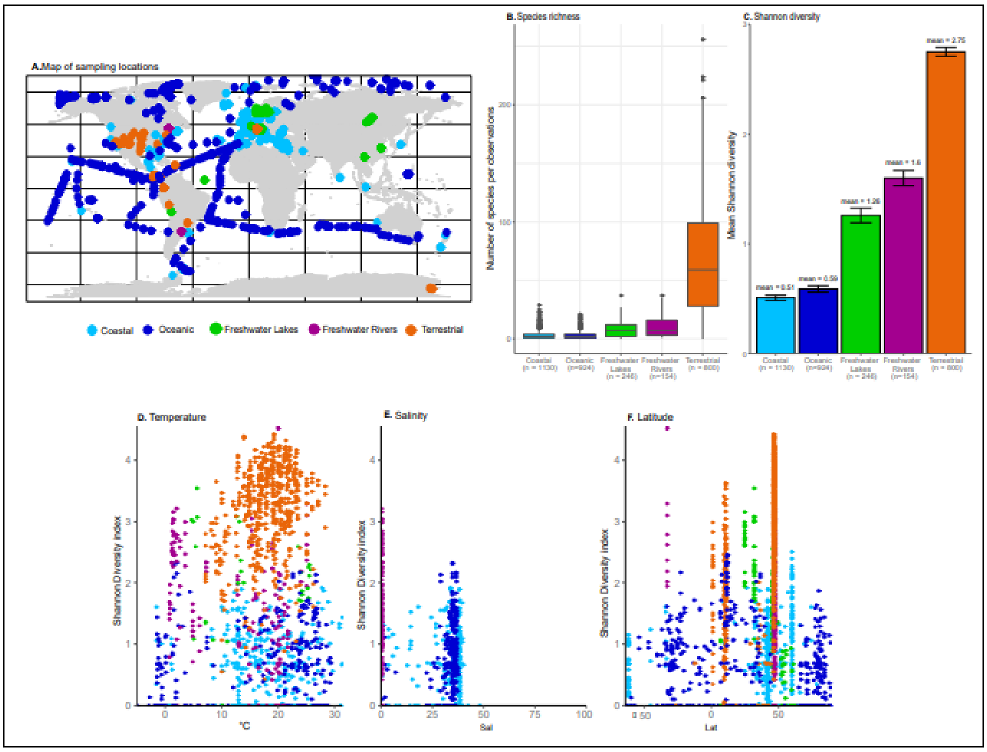
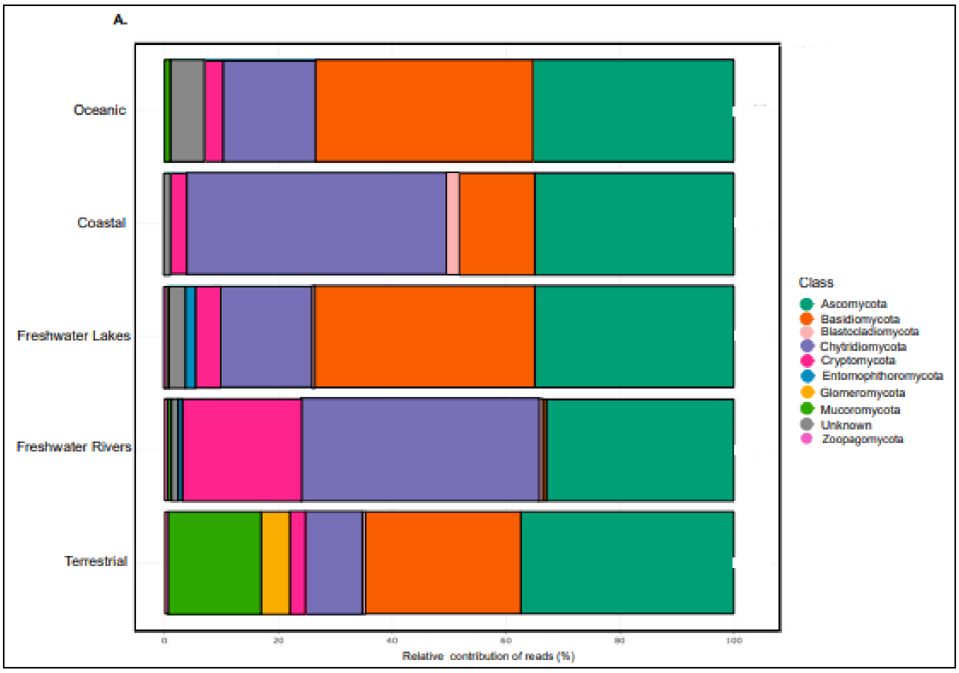


**Fig 1:** Locations of sampling from 41 campaigns and expeditions where fungal ASVs (A). Species richness by ecosystem (B), Shannon diversity by ecosystem (C), temperature (°C) as a measure of Shannon diversity (D), salinity as a measure of Shannon diversity (E), and latitude as a measure of Shannon diversity (F).

Ecosystem-Based Fungal Communities We went a step further and identified the primary factors that influence fungal variety across a range of settings. Most fungal taxa belonged to the Ascomycota, Basidiomycota, and *Chytridiomycota families*. environments, whereas Cryptomycota accounted for 16.7 percent of all freshwater river fungal species. Glomeromycota (4.8%) and Mucoromycota (16.6%) both made significant contributions to terrestrial populations. Fungi that have not been formally categorised (termed 'Unkn') also played an important role in all environments, namely in aquatic environments, including freshwater rivers (1.4%), lakes (3.2%), coastlines (0.9%), and oceans (5.8%). While there hasn't been a lot of research comparing our relative abundances to those of other studies across different habitats, the major subphyla and class contributions found are consistent with those of other soil, marine, and freshwater datasets. The communities' taxonomic makeup varied considerably among environments, as seen use the 'Adonis' function in R for Analysis of Variance Using Distance Matrices." Moreover, PCA provided additional confirmation of this.



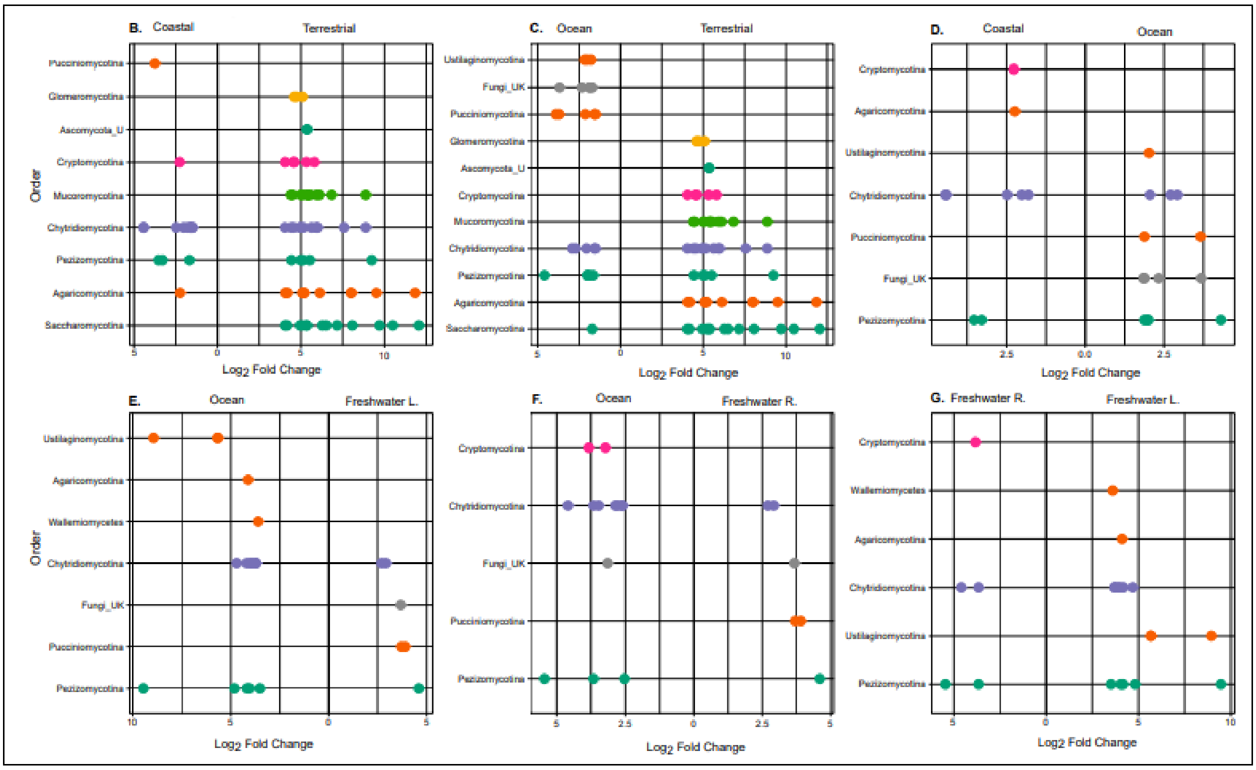


**Fig 2:** Ecosystem read contributions according to fungal class annotation, as shown in From A to G The variation in fungal order by ecology was brought to light using Deseq2 Analysis. The largest log2 fold changes are shown for each comparison. Take note of how the Log2 Fold change differs for each comparison.

To bring attention to the variations in fungal order by ecology, Deseq2 Analysis was carried out. Here we can see the most significant log2 fold changes for every comparison. Figure 2 shows that there is a change in Log2 Fold depending on the taxonomic rank. We also ran the same study using ASVs that were unique to genera although we warn that the differences between genera should be interpreted with caution since it is hard to identify genera from 18S rRNA gene sequencing.

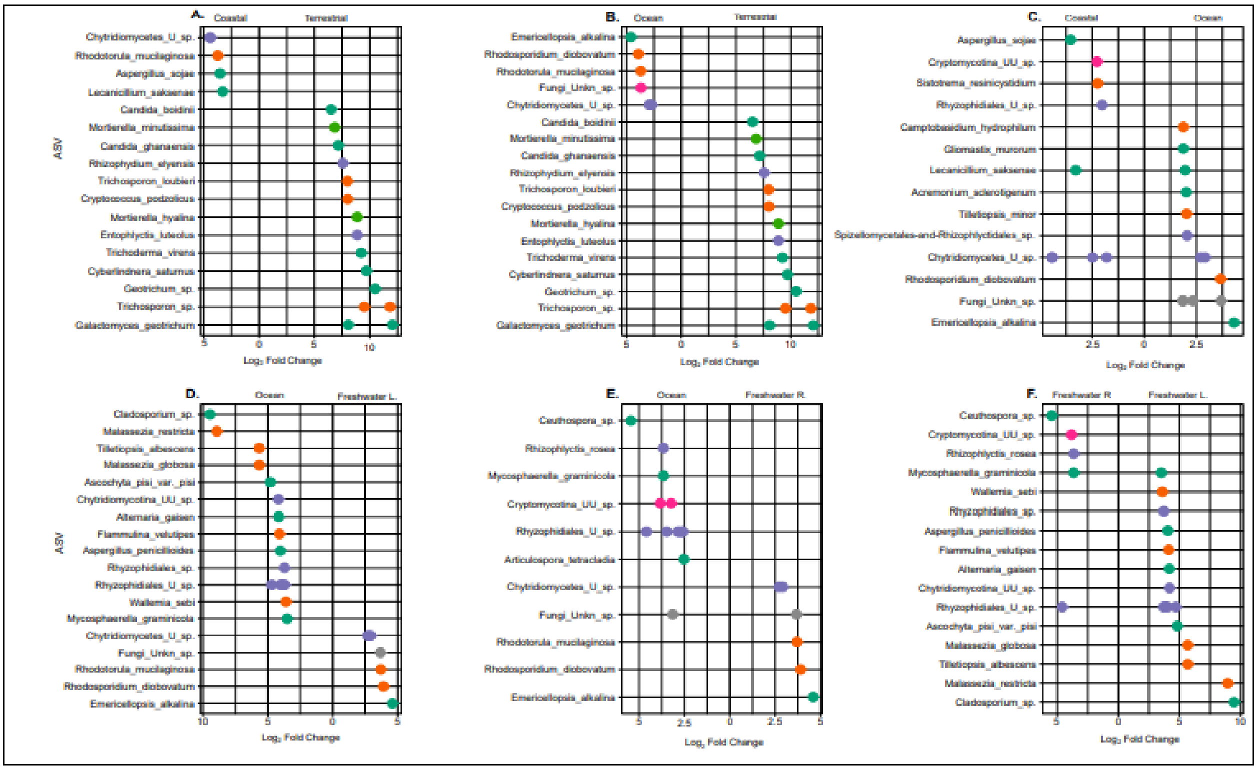


**Fig 3:** From A to F The variations in ASVs by ecology were brought to light using Deseq2 Analysis. The largest log2 fold changes are shown for each comparison. Keep in mind that the Log2 Fold change varies across comparisons.

Pucciniomycotina, Cryptomycotina, and Agaricomycotina were the subphyla from coastal datasets that differed most significantly (as measured by the most significant alterations (log2 fold)) seen in terrestrial communities. Subphyla Ustilaginomycotina and Pucciniomycotina, as well as unclassified fungus, exhibited the greatest log2 fold changes compared to terrestrial communities in ocean datasets. Prior research has located all of these in marine and coastal areas Seas devoid of oxygen in the Arabian Species of marine smut fungus belong to the Ustilaginomycotina family. When it comes to sea habitats, Pezizomycotina and Agaricomycotina are the most common types of fungus symbionts found in sponges. Cryptomycotina and Agaricomycotina were more important in distinguishing coastal communities from marine ones than Pucciniomycotina and Ustilaginomycotina. Additionally, it has been shown that agaricomycotina are linked to seaweeds in coastal waters.

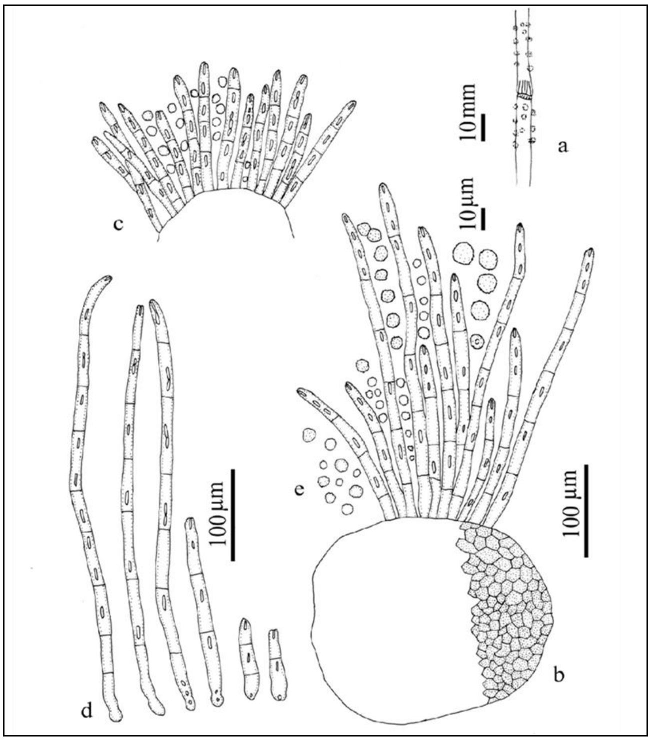
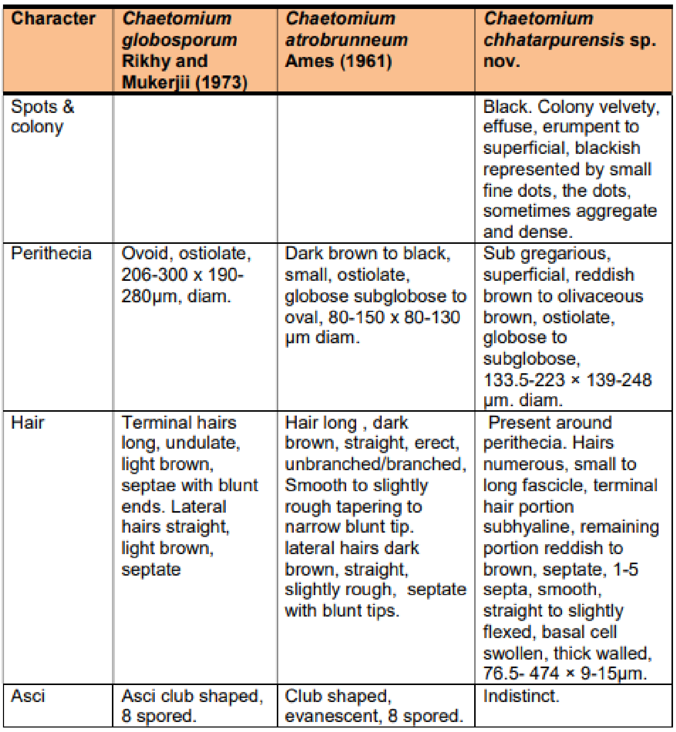


**Fig 4:** Camera lucida drawing of *Chaetomium chhatarpurensis* (holotype, AMH-9742); a - Symptoms; b - Perithecia with hairs; c - A part of perithecia; d - Hairs; e - Conidia; a=10 mm, b=100 µm, and e=10 µm are the scale bars.

**Table 1:** Comparative study of *Chaetomium chhatarpurensis* sp. Nov. with allied species.



| **Character** | ***Chaetomium globosporum* Rikhy and Mukerjii (1973)** | ***Chaetomium atrobrunneum* Ames (1961)** | ***Chaetomium chhatarpurensis* sp. nov.** |
|---|---|---|---|
| Spots & colony | | | Black. Colony velvety, effuse, erumpent to superficial, blackish represented by small fine dots, the dots, sometimes aggregate and dense. |
| Perithecia | Ovoid, ostiolate, 206-300 x 190-280µm, diam. | Dark brown to black, small, ostiolate, globose subglobose to oval, 80-150 x 80-130 µm diam. | Sub gregarious, superficial, reddish brown to olivaceous brown, ostiolate, globose to subglobose, 133.5-223 × 139-248 µm. diam. |
| Hair | Terminal hairs long, undulate, light brown, septae with blunt ends. Lateral hairs straight, light brown, septate | Hair long , dark brown, straight, erect, unbranched/branched, Smooth to slightly rough tapering to narrow blunt tip. lateral hairs dark brown, straight, slightly rough, septate with blunt tips. | Present around perithecia. Hairs numerous, small to long fascicle, terminal hair portion subhyaline, remaining portion reddish to brown, septate, 1-5 septa, smooth, straight to slightly flexed, basal cell swollen, thick walled, 76.5- 474 × 9-15µm. |
| Asci | Asci club shaped, 8 spored. | Club shaped, evanescent, 8 spored. | Indistinct. |

According to the literature review, the species in issue has been likened to *Chaetomium globosporum* and C. *atrobrunneum*. Wheat leaf and cauliflower have been found to harbour C. *Globosporum*, whereas C. *atrobrunneum* has been found on a variety of hosts and substrates.

Based on the critical observations of the species shown in Table 1, it is clear that there is a marked difference between the author's collection and the similar species. in terms of size, structure, and ascospores (verruculose). There are only a few commonalities, however. As a result, this taxon necessitates its extinction as a separate species.

## Conclusion

This research focusses on the systematics of fungi that grow in various habitats in the forest region of Chhatarpur (M.P.). These habitats include adjacent grasslands, fields, roadsides, wastelands, and the areas immediately around rivers, rivulets, streams, lakes, canals, and other patches of vegetation. Aside from foliaceous fungi, additional components such as fruit, bark, stem, root, etc., have also been gathered for the purpose of investigation. All through the year, fungal specimens have been collected and surveyed at regular intervals to research various types of fungal variety. In order to stain and observe fungus, lacto-phenol cotton blue (LPCB) was used. Using a variety of eyepiece and objective combinations, the intriguing formations were subjected to thorough taxonomic studies and their Camera Lucida drawings were created. The prepared slides were also used for their microphotographs.

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