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Macrofungal Abundance and Diversity in Adventist University of the Philippines

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ABSTRACT

Macrofungi are a diverse group of fungi that form visible fruiting bodies. These eukaryotic and robust organisms are integral to the ecosystem and human life. Fungi are actively involved in nutrient cycling, carbon sequestration, pollution degradation, and ecosystem restoration. Some species are utilized as food and medicine. This study taxonomically identified and analyzed the abundance and diversity of macrofungi in four areas of randomly selected quadrants in the Adventist University of the Philippines. A total of 28 macrofungal species were identified belonging to 13 families: Auriculariaceae, Dacrymycetaceae, Ganodermataceae, Marasmiaceae, Mycenaceae, Omphalotaceae, Physalacriaceae, Polyporaceae, Pluteaceae, Psathyrellaceae, Schizophyllaceae, Stereaceae, and Sarcoscyphaceae. The majority of the macrofungi identified belong to the order Polypolares. Among the 12 quadrants, quadrants 4, 5, 6, and 7 exhibited a moderate diversity index ($1 < H' \leq 3$). This study presents a pioneering work on macrofungi present in AUP. These results serve as reference baseline information on macrofungal abundance and diversity on campus. Maintaining the woodland habitats on the campus is crucial to conserving the diversity of macrofungi in AUP.

Keywords: macrofungi, diversity, abundance, ecosystem, AUP

INTRODUCTION

Fungi are eukaryotic living organisms that thrive in diverse substrates like soil and dead plant matter (Moore et al., 2023). One diverse and versatile group of fungi is macrofungi. Macrofungi form visible fruiting bodies belonging to the Ascomycota and Basidiomycota. They are non-motile organisms that have cell walls consisting of chitin. They are considered among the most successful soil inhabitants due to their metabolic and reproductive characteristics and ability to adapt to different environments (Sun et al., 2005). They are an integral part of the biogeochemical cycle and essential for maintaining ecological balance.

Macrofungi are consumed as food, supplements, and medicines and participate in nutrient cycling, carbon sequestration, pollution degradation, and ecosystem restoration (Lu et al., 2023). In agriculture, fungi play a significant role in maintaining soil fertility. Their role in the ecosystem includes breaking down nutrients into simpler forms to be readily available for other living organisms. Moreover, macrofungi can produce a wide variety of enzymes. They

break down dead organism debris like plants and animals, recycling their nutrients and returning them to the soil, thus regulating the balance of carbon and nutrients (Žifčáková et al., 2016). Not only do they play an essential role in soil fertility, but some are also consumed and used for the maintenance of health and the treatment and prevention of diseases (Nacua et al., 2018; Cababan et al., 2021).

Depending on various substrates and tree species compositions, macrofungi can be found in multiple habitats. Due to the favorable environment and profusion of flora, macrofungal species are more prevalent during spring and autumn rather than hot and dry seasons (Pilz & Molina, 2002). Fungal diversity is dependent on the diverse types of organisms found in an environment, such as plants and other animals (biotic factors), as well as levels of pH, moisture, temperature, salinity, and climate conditions (abiotic factors) (López-Bucio et al., 2015; Rouphael et al., 2015).

Ubiquitous in nature, roughly 1.5 million fungal species are observed worldwide, and only 70,000 fungi have been described and identified (Brazas et al., 2020). China has recorded 9,302 species of fungi, of which 1,789 are edible, 798 are medicinal, and 561 are both edible and medicinal (Li et al., 2015). Records from 2001-2021 showed that 2371 identified mushrooms in the Philippines were classified into 447 species, 193 genera, and 72 families (Dulay et al., 2023). However, habitat loss, environmental degradation, and overexploitation of the ecosystem are current challenges to the fungal populations. Furthermore, considering their significant roles and benefits, the need to assess the present status of macrofungi is indispensable. Some studies have already been conducted in various parts of the country, particularly in Luzon. However, many regions have yet to be explored, necessitating more taxonomic studies (Torres, 2020).

Studies on the abundance and diversity of macrofungi in different areas of the Adventist University of the Philippines (AUP) campus still need to be explored. The lack of fungal research creates a gap in our knowledge about these organisms' presence, habitats, abundance, and diversity on campus. This study identified the macrofungi species present in AUP and assessed their habitat, abundance, and diversity.

METHODS

SELECTION OF SAMPLING AREAS

The study was undertaken across various areas of AUP. The sampling site was partitioned into four distinct areas, each further subdivided into three quadrants. Fungal samples were collected from a randomly chosen area within these quadrants (10 x 10-meter plot). The precise location of each sampling site was photographed and accurately localized using the Global Positioning System (GPS) (Soriano et al., 2021).

The AUP campus sampling sites were divided into four areas, with the first area starting from the AUP parking lot beside the Registrar and the library building, going south towards the faculty homes at Daniel Dorm towards the east, including Eastern Dorm. Area 2 is from the AUP store; towards the south would include the ladies' dormitories and the faculty homes before arriving at Daniel Dormitory; towards the west is from the store until the apartment

buildings, including Gate 2. Area 3 is from the Public Safety Department going northward towards PIC and all the campsite areas. Area 4 is from the old golf course going northward, including the AUP gym, the AUP main gate, and the AUP Academy areas. All four areas were selected with a total of 12 quadrants. Quadrants 1 (Q1), 2 (Q2) and 3 (Q3) of Area 1 are located near the road, the shrubby woodland area near the Environmental Resources Management site, coming from Eastern dormitory towards Daniel Dormitory, with GPS coordinates of N 14°13.154' E 121°02.625', N 14°13.014' E 121°02.668' and N 14°13.017' E 121°02.704', respectively. Quadrant 1 (Q4) of Area 2 is beside the road, going towards Gate 2, near apartment A, with GPS coordinates of N 14°12.936' E 121°02.213'. Quadrant 2 (Q5), with a GPS coordinate of N 14°12.922' E 121°02.316', is located near Cadena Dormitory and in front of the AUP cafeteria. Quadrant 3 (Q6) of Area 3, with GPS coordinates of N 14°12.649' E 121°02.150', is located beside the area of the AUP water tank. Quadrant 1 (Q7) of Area 3, with GPS coordinates of N 14°13.231' E 121°02.494', is located towards the far side of the AUP campsite, beside the road where an intersection is located. Quadrant 2 (Q8) is also located beside the road with GPS coordinates of N 14°13.187' E 121°02.441', a few meters from Quadrant 1 (Q7) near Chrysanthemum Dormitory. Quadrant 3 (Q9) of Area 3 is located on the side of the campsite site with GPS coordinates of N 14°13.216' E 121°02.377'. Quadrant 1 (Q10) of Area 4, with GPS coordinates of N 14°13.121' E 121°02.265', is located beside the AUP gymnasium beside the road, where there is a woodland area. Quadrants 2 (Q11) and 3 (Q12) are located near the softball field area near the Talipapa, with GPS coordinates of N 14°13.113' E 121°02.199' and N 14°13.120' E 121°02.212', respectively.

COLLECTION OF FUNGI

The macrofungi samples were collected and documented. The whole fruiting body was collected and kept in a glass jar labeled with the ID code, date and time of collection, and the exact location. The habitats of macrofungi were also described. The macrofungal substrate, color, shape, and size of fruiting bodies were also recorded. Other morphological characteristics of the fungi, like the pileus surface features, gill attachment, stipe location, stipe surface color, and presence or absence of volva, were also noted.

PRESERVATION OF FUNGI

Each sample was promptly preserved to facilitate identification. For bracket specimens, preservation involved drying using silica gel beads desiccant. This method ensures the production of high-quality dried samples (Wang et al., 2017). Silica gel bead desiccant also allows long-term preservation (Karen et al., 2004). In contrast, fleshy fungi were preserved through pickling in vials using denatured alcohol (Brazas et al., 2020). This preservation method helps maintain the integrity of the specimens for future analysis and study.

IDENTIFICATION AND CHARACTERIZATION

The collected macrofungi samples were documented and subsequently identified based on their morphological characteristics and features. The identification process involved examining the macrofungi's morphological traits. Several reference materials were used to aid the initial identification process (Angeles et al., 2016; Brazas et al., 2020; Camp & Bal, 2022; Torres,

2020). Finally, the CLSU Center for Tropical Mushroom Research and Development certified and authenticated the samples.

ABUNDANCE AND DIVERSITY ANALYSES

The Shannon diversity index was used to express the abundance and diversity of fungi in AUP. Species richness (S) was determined by the number of fungal species in the collection site. Shannon-Wiener index (H') was calculated as: $H' = - \sum pi \ln pi$

Where H' = Shannon Weiner index, Pi is the relative abundance of the species in the area and is calculated as Pi = ni/N, ni = number of individuals of a species, and N = Total individuals of all species. The diversity criteria for interpretation are as follows: $H' \leq 1$= Low diversity; $1 < H' \leq 3$= Moderate diversity, and $H' \geq 3$ = High diversity.

RESULTS AND DISCUSSION

MACROFUNGAL TAXON AND SUBSTRATES

Table 1 shows the 28 different species of macrofungi observed and identified in AUP. Of these, 27 species belong to Phylum Basidiomycota from the family of Pluteaceae, Psathyrellaceae, Physalacriaceae, Omphalotaceae, Marasmiaceae, Mycenaceae, Schizophyllaceae, Auriculariaceae, Dacrymycetaceae, Polyporaceae, and Ganodermataceae. Only one species belonging to the Phylum Ascomycota of the family of Sarcoscyphacea was documented. The majority of the samples belong to the Order Agaricales and Polyporales.

Table 1
Taxonomy of Macrofungi

Phylum	Order	Family	Species
Basidiomycota	Agaricales	Pluteaceae	*Volvariella volvacea*
Basidiomycota	Agaricales	Pluteaceae	*Pluteus sp.*

Basidiomycota	Agaricales	Psathyrellaceae	*Coprinopsis micaceus*
Basidiomycota	Agaricales	Physalacriaceae	*Oudemansiella canarii*
Basidiomycota	Agaricales	Omphalotaceae	*Marasmiellus*
Basidiomycota	Agaricales	Omphalotaceae	*Marasmiellus palmivorus*
Basidiomycota	Agaricales	Marasmiaceae	*Gerronema keralense*
Basidiomycota	Agaricales	Mycenaceae	*Filoboletus manipularis*
Basidiomycota	Agaricales	Schizophyllaceae	*Schizophyllumcommune*
Basidiomycota	Auriculariales	Auriculariaceae	*Auricularia polytricha*
Basidiomycota	Dacrymycetales	Dacrymycetaceae	*Dacryopinax spathularia*
Basidiomycota	Polyporales	Polyporaceae	*Earliella scabrosa*
Basidiomycota	Polyporales	Polyporaceae	*Favolus acervatus*
Basidiomycota	Polyporales	Ganodermataceae	*Ganoderma applanatum*
Basidiomycota	Polyporales	Polyporaceae	*Polyporus sp.1*
Basidiomycota	Polyporales	Polyporaceae	*Polyporus sp.2*
Basidiomycota	Polyporales	Polyporaceae	*Hexagonia apiaria*
Basidiomycota	Polyporales	Polyporaceae	*Hexagonia sp.1*
Basidiomycota	Polyporales	Polyporaceae	*Hexagonia sp.2*
Basidiomycota	Polyporales	Polyporaceae	*Hexagonia tenuis*
Basidiomycota	Polyporales	Polyporaceae	*Lentinus sp.*
Basidiomycota	Polyporales	Polyporaceae	*Trametes gibbosa*
Basidiomycota	Polyporales	Polyporaceae	*Trametes hirsuta*
Basidiomycota	Polyporales	Polyporaceae	*Trametes ochracea*
Basidiomycota	Polyporales	Polyporaceae	*Trametes sp.*
Basidiomycota	Polyporales	Polyporaceae	*Trametes variegata*
Basidiomycota	Russulales	Stereaceae	*Stereum sp.*
Ascomycota	Pezizales	Sarcoscyphaceae	*Phillipsia sp.*

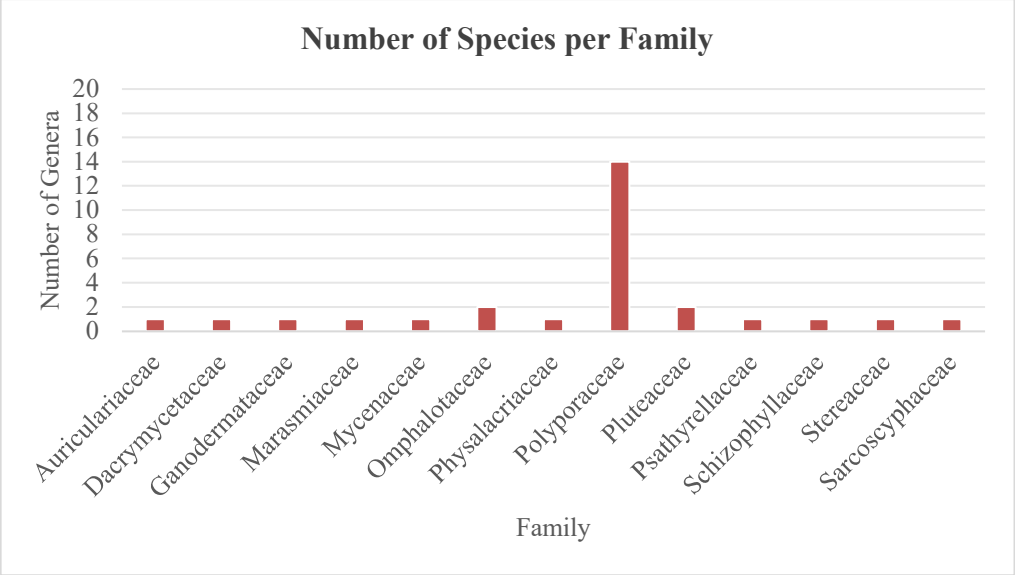

Figure 1. The number of macrofungi species per family.

Figure 1 shows the number of macrofungal species per family. Polyporaceae is the most diverse genera of all the documented macrofungi on campus, having a total of 14 genera, followed by the family Omphalotaceae and Pluteaceae, which have two genera. Among the identified families of macrofungi, most belong to wood-rotting macrofungi Sarcoscyphaceae, the only family belonging to Ascomycota. The families belonging to Basidiomycota include Polyporaceae, Ganodermataceae, Dacryomycetaceae, also known as jelly fungi, Auriculariaceae or ear fungi, Stereaceae or crust macrofungi, and Schizophyllaceae or split gill macrofungi among others (Tadiosa et al., 2021).

In four areas around the AUP campus, seven different macrofungi were collected in Area 1, 17 in Area 2, 8 in Area 3, and 8 in Area 4. Most macrofungi documented are from woodland habitats found in wood substrates such as rotten branches, logs, or dead fallen trees. These diverse production of macrofungi in different areas may be influenced by various factors such as undisturbed places, low temperature, and soil pH (Cababan et al., 2016). Polyporaceae is the most dominant species documented, which could be due to the abundance of wood substrate on which the macrofungi can grow. Furthermore, most macrofungi primarily encountered in woodland habitats are bracket and conk fungi, particularly those belonging to the Polyporaceae family (Cababan et al., 2016). Most macrofungi inhabit rotten woody substrates, indicating that most of the macrofungi found were saprophytic (Tadiosa et al., 2021).

MACROFUNGI RELATIVE ABUNDANCE

The results indicated that in Area 1 quadrant 1, with 36 individual macrofungi documented, 69.4% belong to *Polyporus sp.1*, as they most commonly thrive on woody substrate (Soriano et al., 2021). About 16.6% of the total macrofungi individuals documented comprise *Favolus acervatus*, and 13.8% are *Trametes sp*. They are found in a shrubby woodland habitat, and all three grow on separate rotten branches. All belong to bracket fungi, typically encountered all year round in woodland habitats (Cababan et al., 2016) because bracket fungi usually decompose rotten wood debris (Soriano et al., 2021).

Quadrant 2 results show that only one species of *Dacryopinax spathularia* macrofungi was documented growing on a rotten mango tree branch, which is also found in a shrubby woodland habitat. It is commonly seen growing on woody substrate, particularly on a rotten trunk or branch of dying trees (Angeles et al., 2016). However, because only one tree was found inside the quadrant, there was not enough rotting wood debris for other species of macrofungi to grow into.

Quadrant 3 has three species of macrofungi documented, with 80% of the ten total individual species recorded belonging to *Auricularia polytricha*, and 10% is composed of *Hexagonia sp.1* and 10% of Ganoderma applanatum. They are also found in a shrubby woodland habitat, where they were seen growing on woody substrates. The *Auricularia polytricha*, also called a jelly fungus, and the *Ganoderma applanatum,* which is a long-lived bracket fungus commonly grows on woody substrates in which they decompose hardwood trees (O'Reilly, 2022). Also, *Hexagonia sp.1,* like *G. applanatum,* is a bracket fungus that plays a vital role in decomposing wood waste in woodland habitats (Cababan et al., 2016).

Quadrant 4 of Area 2 is composed of eight species of macrofungi with a total of 40 individuals, of which 45.0% belong to *Filoboletus manipularis*, 17.5% from *Gerronema keralense*, 12.5% from *Marasmiellus palmivorus*, 10% from *Marasmeillus sp.,* 5.0% from *Oudemansiella canarii* and *Coprinopsis micaceus* and 2.5% from *Pluteus sp*. and 2.5% *Volvareilla volvacea*. The growth of these diverse macrofungal species is influenced by the wide variety of substrates such as rotten wood, trees, shrubs, and leaf litters (Brazas et al., 2020), as they were collected from a shrubby woodland habitat, where most of them are seen growing on woody substrates such as the *Pluteus sp*., *Coprinopsis micaceus, Oudemansiella canarii, Marasmiellus sp.,* and *Filoboletus manipularis*, while the other macrofungi species were found growing on leaf litter and soil substrates.

Quadrant 5 has six species with a total of 209 individuals, of which 48.8% belong to *Favolus acervatus*, 24.8% from *Polyporus sp.2*, 10% from *Hexagonia apiaria*, 8.6% from *Trametes variegata*, 7.1% from *Trametes gibbosa* and 0.4% from *Schizophyllum commune*. These macrofungi were collected in a woodland habitat. All of the macrofungi documented were seen growing on rotten wood substrates, such as a fallen dead tree, logs, and branches. Furthermore, many trees were found inside the quadrant that covered the ground, keeping it from being exposed to too much of the sun's heat. It prevents the increase in temperature that may cause a decrease in moisture and will negatively affect the growth of macrofungi (Laggui, 2019).

Quadrant 6 of Area 2 has three documented species with 25 individuals, of which 52% is composed of *Hexagonia sp.2*, 28% *Trametes ochracea*, and 20% *Trametes hirsuta*. These

species of macrofungi were collected on a rotten log in a habitat composed of small trees and banana plants near the water tank. However, without enough rotting wood substrate inside the quadrant, the species of macrofungi growing were limited. Also, the area where the quadrant is located was a route for people to pass by, which causes disturbance in the area that limits the growth of other species of macrofungi.

Quadrant 7 of Area 3 has five species documented with a total of 69 individuals, of which 30.4% is composed of *Phillipsia sp*., with 28.9% belonging to *Trametes variegata*, 28.9% from *Auricularia polytricha*, 8.7% from *Dacryopinax spathularia* and 2.9% from *Favolus acervatus*. In this area, only one mango tree is found inside the quadrant, with a plantation of pineapples. The species collected on woody substrates such as rotten branches, roots, and twigs, particularly on the rotten branches of a mango tree.

Quadrant 8 has two species with 32 individuals, of which 93.7% belong to *Auricularia polytricha* and 6.2% to *Lentinus sp*. Both grow on a rotten branch, with *Auricularia polytricha* growing on a single rotten branch with many individuals. The quadrant is in a grassy woodland habitat with trees growing far apart. It was observed that there was only a few rotten wood debris in the area, which limited the growth of other saprophytic macrofungal species.

Quadrant 9 has only one species of macrofungal documented, with a total of 11 individuals. The species was collected in a grassy habitat, growing on rotten coconut fruit. Similar to quadrant 2, with insufficient wood substrate. No other species of saprophytic macrofungi were seen growing in the quadrant.

Quadrant 10 of Area 4 has two documented species with eight individuals, of which 50% belong to *Earlilla scabrosa* and 50% to *Dacryopinax spathularia*. Both were found in a woodland habitat, growing on rotten branches and logs. However, with limited rotting woody substrates found in the quadrant, only two species of macrofungi were documented.

Quadrant 11 has two species documented with 26 individuals, of which 73% belong to *Hexagonia sp*.1 and 26.9% from *Hexagonia apiaria*. The quadrant is in a grassy woodland habitat with trees growing far apart. The macrofungi species were found growing on a few rotten tree branches. Only a few rotten wood debris were found in the area. Consequently, only a few species of macrofungi were found.

Quadrant 12 of Area 4 has four documented macrofungal species, with 161 total individuals, of which 70.8% is composed of *Schizophyllum commune*, 27.3% of *Stereum sp*. 1.2% of *Hexagonia tenuis*, and 0.6% of *Earliella scabrosa*. These saprophytic species of macrofungi were collected from rotten logs and branches found inside the quadrant, with *Schizophyllum commune* seen growing ubiquitously on a rotten log.

The majority of the macrofungi collected belong to the order Polypolares, a species of bracket fungi in which most of its species are saprophytic and commonly grow on stems, branches, and other woody substrate of dead trees to decompose and sustain their growth (Cababan et al., 2016). The abundance of trees in an area is one of the factors that contribute to macrofungal diversity. Furthermore, habitats with denser canopies, high trees, and shrubs appear to be inhabited more by macrofungi (Soriano et al., 2021). This contributes to the low

distribution of other species of macrofungi in some quadrants because not all quadrants have enough wood substrate for macrofungi to grow (Laggui, 2019).

DIVERSITY OF MACROFUNGI

Table 2 shows the number of species found in each quadrant, the number of individuals for each species, and the diversity of macrofungal species per quadrant.

Table 2
Shannon Weiner Diversity Index per Quadrant

Area	Quadrant	No. of Species	Abundance	Diversity (Shannon Weiner)	Diversity Criteria
	1	3	36	0.826	Low Diversity
1	2	1	6	0	Low Diversity
	3	3	10	0.639	Low Diversity
	4	8	40	1.6385	Moderate Diversity
2	5	6	209	1.3528	Moderate Diversity
	6	3	25	1.0183	Moderate Diversity
	7	5	69	1.349	Moderate Diversity
3	8	2	32	0.2337	Low Diversity
	9	1	11	0	Low Diversity
	10	2	8	0.6931	Low Diversity
4	11	2	26	0.5824	Low Diversity
	12	4	161	0.685	Low Diversity

Quadrant 1 of area 1 shows low diversity with a 0.82 diversity index with three total species of macrofungi documented. Quadrant 2 has no diversity, with a 0 diversity index indicating only one species exists. Because only one tree was found inside the quadrant, it lessened the number of rotting woody substrates for saprophytic macrofungi to grow. Quadrant 3 shows a low diversity index of 0.63, with three species of macrofungi documented, in an area with fewer trees and woody substrate for macrofungi to grow. Quadrant 4 of area 2 shows a slightly high diversity of macrofungi out of all the other quadrants. With a diversity index of 1.63, a total of eight species of macrofungi are documented, indicating a moderate diversity. Because of the high number of trees and shrubs found growing in the area and a few rotten furniture, such as wooden cabinet doors, it provides a wide variety of substrates, which includes soil, leaf litter, and rotten wood, for the diverse species of Basidiomycota macrofungi to grow into, in which majority of basidiomycetous macrofungi inhabits woody substrates, particularly rotten woods (Brazas et al., 2020). Another factor is that the quadrant is near the creek, which provides extra moisture and a cooler environment for the diverse macrofungal species to grow. Quadrant 5, with many trees growing in the area and near a creek, shows a moderate diversity (1.35 diversity index), registering six species of macrofungi. Quadrant 6 of area 2 records a

diversity index of 1.01, indicating moderate diversity, with three species of macrofungi documented growing on rotten logs.

Quadrant 7 of Area 3 has a moderate diversity, with a 1.34 diversity index. The area is located near the campsite, and within the quadrant are plantations of pineapple crops with a few trees, including a mango tree, wherein the macrofungi documented and collected are growing on rotten woody substrates such as branches and twigs. Quadrant 8 results in a 0.23 diversity index with a total of two species documented, indicating a low diversity in the quadrant. The habitat is grassy woodland, with trees far apart from each other, and only a few rotten branches were found inside the quadrant where the two species grow. Meanwhile, Quadrant 9 has a low diversity, with only one species of macrofungi documented. The habitat is characterized by coconut and mango trees surrounded by grasses. This area is also utilized as a camping site.

Because of the low species richness of trees present in the three quadrants of area 4, Quadrants 10, 11, and 12 show low diversity (0.69, 0.58, and 0.68). This study discovered that most of the macrofungi documented were saprophytic. Also, this explains the significant relationship between the species richness of trees and the existence and abundance of macrofungal species (Tadiosa et al., 2021). Furthermore, Basidiomycetous macrofungi thrive particularly in mountain ecosystems, where they get nourishment through rotten wood, branches, trunks, roots, and other debris of dying trees (Angeles et al., 2016).

The results imply that the variety of species of woody and other plant substrates in an area plays a significant role in the existence of the diverse species of Basidiomycetous macrofungi. A diverse woody substrate (Cababan et al., 2016) and a cooler and moist environment can also be attributed to the diversity of macrofungi species (Laggui, 2019). Quadrants 4, 5, 6, and 7 showed moderate diversity as these quadrants have abundant trees and shrubs and are located near bodies of water. Therefore, plenty of fallen branches, stumps, and rotten woods favor the growth of diverse macrofungal species (Laggui, 2012).

CONCLUSION, IMPLICATION, SUGGESTION, AND LIMITATIONS

A total of 28 macrofungi from 13 families have been documented, of which 12 are from the Phylum Basidiomycota, and only one is from the Phylum Ascomycota in predominantly woodland habitat. Many areas surrounding AUP exhibit low macrofungal diversity; Area 2 is the exception, with moderate macrofungal diversity. Polyporaceae is the most prevalent family out of 13 families with 14 genera. Macrofungi are crucial components of the ecosystem, primary agents of the decomposition of organic matter, participate in carbon, nitrogen, oxygen, and nutrient cycling, and are essential sources of food and medicines. Maintaining the woodland habitats on the campus is crucial to conserving the diversity of macrofungi that naturally occur in AUP. DNA analysis must be performed to further classify some macrofungi at the species level.

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