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Species Listing of Macrofungi in Brgy. Zabali, Baler, Aurora, Philippines

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Abstract. Macrofungi are often perceived as uncharismatic and, hence, are frequently neglected in scientific discussions on wildlife conservation. Several macrofungal studies have been conducted in various parts of the Philippines, most particularly in Luzon. This paper reports the species found in the ultramafic forests of Brgy. Zabali, Baler, Aurora, one of the key biodiversity areas of the Philippines. Particularly, the study aimed to observe the composition of macrofungi during the transition period towards the southwest monsoon (*habagat* season). An opportunistic sampling method was employed in the study across three collection periods from May to July 2025. We found that the forests of Brgy. Zabali support a diverse array of macrofungal species and are substantially influenced by precipitation. Polyporoid fungi were the dominant species during drier periods, while many fleshy fungi emerged much later, upon an increase in rainfall. A total of 105 specimens were collected, which are categorized under 1 class, 8 orders, 24 families, 39 genera, and 52 species. The family Polyporaceae recorded the highest number of distinct species among other families. Out of 52 species, only 19 were identified to the species level. The study also reports seven (7) newly recorded basidiomycetes in the Philippines, namely, *Calocera* sp., *Laetiporus* sp. *Marasmius* cf. *cladophyllus*, *Panus* c.f *similis*, *Phaeotremella* sp., *Phylloporia* cf. *alyxiae,* and *Scleroderma* sp. The absence of ascomycete representatives in the study may be attributed to poor timing and a relatively short collection period. Nevertheless, the results of this study provide valuable insights into the long-term monitoring and conservation of Philippine macrofungi.

Keywords: Macrofungal biodiversity; Sierra Madre Mountain Range; ultramafic forest; precipitation; Polyporaceae

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INTRODUCTION

Fungi, particularly macrofungi, play a crucial role in forest ecosystems as decomposers, symbionts, and nutrient cyclers (Soriano et al., 2021). Despite their ecological significance, many macrofungi remain underexplored, especially in various areas of the Philippines (Culliao et al., 2020). Recently, Niskanen et al. (2023) estimated the global number of fungal species to be approximately 2.5 million. Based on their assumptions, 92.5-95% of this figure remains undiscovered. This gap is highly evident in the Philippines, which currently holds about 400 validated species of macrofungi (Jacob et al., 2022). Furthermore, dela Cruz et al. (2024) reported that among these described species, only 142 macrofungi are novel to the country. Dela Cruz further attributes the lagging outputs of novel Philippine fungi to limited scientific resources, lack of experts, and the general lack of interest in the study of fungal taxonomy. The minimal discovery of new macrofungal species underscores an urgent need to address the gap in taxonomic and biodiversity studies. Despite these limitations, exploratory surveys of macrofungal diversity in the Philippines continue to yield important new records in various regions of the country (Bustillos et al., 2025; Nacua et al., 2018; Soriano et al., 2021).

Macrofungi are also valuable non-timber forest products (NTFPs) utilized as food and medicine by the indigenous peoples of the Philippines (Maslang et al., 2021). However, habitats of macrofungal resources could be under pressure, as studies have indicated that specific populations of important edible macrofungi are already in decline (Cao et al., 2021). In addition, many wild edible species face threats posed by climate change and by activities such as deforestation, which persists even within law-protected forest areas (Araza et al., 2021). This conservation crisis is compounded by the fact that fungi are being overlooked and dismissed as uncharismatic taxa (Barron, 2023; Stephenson et al., 2022). Consequently, it is imperative to recognize and monitor these organisms and highlight the preservation of the natural habitats that support macrofungal diversity.

In the province of Aurora, benchmark data began with Tadiosa (2011) who documented 107 species among 684 specimens collected from the Bazal-Baubo Watershed area. Dulay et al. (2025) expanded on this by amassing 121 species from different habitat types in Bazal, Maria Aurora, while Alfonso et al. (2026) recently recorded 86 species within three waterfall ecosystems in Mt. Mingan. Despite these regional efforts, the forest reserves of Aurora State College of Technology (ASCOT) in Brgy. Zabali, Baler, Aurora, remain underexplored. Notably, parts of Brgy. Zabali, which is situated within the Sierra Madre Mountain Range (SMMR), feature ultramafic soils, environments known to foster unique floral and microbial adaptations, yet whose fungal communities remain poorly understood (Bordez et al., 2016). The current study represents the first formal macrofungal assessment of this forest reserve. Finally, the findings of this research will contribute to the growing body of mycological knowledge in the Philippines and will provide useful data for long-term species monitoring.

The primary purpose of this research is to document the taxonomic composition and distribution of macrofungal species in the underexplored ASCOT forest reserves in Barangay Zabali, Baler, Aurora. Specifically, the study seeks to trace changes in macrofungal composition during the microclimatic transition into the southwest monsoon, evaluate substrate preferences, and establish a pure culture collection of viable local isolates for future biofunctional evaluation.

This investigation provides critical benchmark data on fungal community dynamics within a local ecosystem in Baler, Aurora, narrowing the extensive taxonomic knowledge gap regarding Philippine fungi. Documenting these macrofungi serves to elevate local conservation awareness, validate the ecological health of the study area, and safeguard potentially important wild fungal genetic resources against the escalating pressures of climate change and anthropogenic activities.

METHODS

General Description of Study Site

The sampling site is located at the northern portion of the forest reserve area of the ASCOT, Brgy. Zabali, Baler, Aurora, Philippines (marked at 15°45'00.2"N 121°34'58.0"E in Figure 1). The said area is categorized as ultramafic (Coracero & Malabrigo Jr, 2020), characterized by nutrient-deficient soils that exhibit high concentrations of minerals, such as nickel and magnesium (Galang et al., 2023; Galey et al., 2017). Despite these soil conditions, the forest reserve supports a diverse array of endemic trees, vines, shrubs, and lianas. Baler, Aurora experiences Climate Type IV, which is characterized by a relatively even distribution of precipitation throughout the year, with a more pronounced rainy season from November to January (Tolentino et al., 2016). Recorded data obtained from the Department of Science and Technology - Philippine Atmospheric, Geophysical, and Astronomical Services Administration (DOST-PAGASA) Baler Radar station revealed an increasing trend in precipitation throughout the collection period.

Sampling of Macrofungi

Permit to collect macrofungi was obtained from the officials of ASCOT, as they manage the study site. Forest rangers from the said institution assisted during the collection. Survey and collection of macrofungi were executed three times, each held at the beginning of the months May to July 2025 (May 2, June 2, and July 1). An opportunistic sampling method was employed in the study, during which the initial identification notes and the ecological data of each sample were recorded using field slips. Macrofungi were documented *in situ* and *ex situ* using a Canon PowerShot SX530 HS. Sample specimens were carefully selected from the substrate by hand or with a knife and then stored separately in paper bags to prevent excess humidity.

Figure 1. Map of the Philippines and location of study site (Notes: Yellow pin indicates sampling site in Brgy. Zabali, Baler, Aurora)

Morphological Identification of Macrofungi

Subsequent to the collection, specimens were taken into the Aurora Research Center for Oriental Fermentation (ARCOF) in ASCOT and were assigned initial identifications based on existing publications on global and Philippine macrofungi (Ryvarden, 2025; Tadiosa & Lubos, 2020; Tadiosa, 2011). The identifications were later validated by Dr. Rich Milton R. Dulay, Director of the Center for Tropical Mushroom Research and Development (CTMRD), Central Luzon State University (CLSU). To assess whether new records were observed, a thorough search was done by reviewing checklists of Philippine macrofungi (Dulay et al., 2023; Jacob et al., 2022; Pampolina et al., 2023) and recently published local species listings in Google Scholar using the search keywords “Philippines”, “macrofungi”, and “mushrooms”.

Isolation and Preservation of Specimens

Selected specimens were propagated using the tissue culture technique in which small portions of the sterile area of the basidiome were aseptically transferred into previously prepared potato dextrose agar (PDA) slants and incubated at room temperature. Following the isolation of cultures, all samples were oven-dried at 50 ºC for at least 24 hours or until they were cracker-dry. The dried specimens were then kept separately in glass jars, each containing a silica gel packet to absorb residual moisture, and stored in the fungal herbaria of ASCOT and CLSU.

Data Analysis

To determine the monthly species composition of macrofungi across the sampling period, the number of observed taxa in a given month was divided by the total number of macrofungal taxa recorded across the entire study, expressed as a percentage:

$$\text{Composition (\%)} = \frac{total\ number\ of\ macrofungi\ taxa\ observed}{total\ number\ of\ macrofungal\ taxa\ in\ entire\ sampling\ period}\ x\ 100$$

RESULTS AND DISCUSSION

Environmental and Ecological Factors Affecting Macrofungi

Since the collection period (May 2 to July 1) coincided with the onset of the southwest monsoon (*habagat*), a distinct increasing trend in precipitation was noted, with June receiving the highest amount at 103 mm (see Figure 2). Throughout this period, the recorded temperature in Baler fluctuated from 25 to 34.5 °C, while the relative humidity ranged from 72.8% to 93.1%. This shift in moisture and temperature created highly favorable conditions for fungal growth, resulting in a parallel increase in species composition over time; from 36.54% in May, to 55.77% in June, and peaking at 65.38% in July 2025 (see Table 1 and Figure 3).

This positive correlation between rainfall and macrofungal emergence aligns with the findings of Bustillos et al. (2025) in Nueva Ecija, Philippines, who demonstrated that macrofungal occurrence was positively correlated with precipitation from the months of May to July 2023. As Tadiosa (2025) explained, adequate moisture during the rainy season is a key element to drive the emergence of macrofungi, a phenomenon that Filipino mycologists take note of to schedule their mycological expeditions.

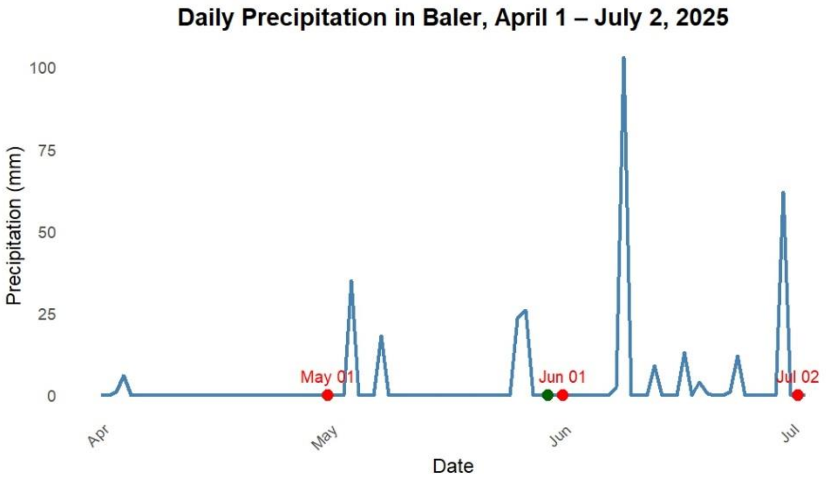

Figure 2. Precipitation trends in Baler, Aurora from April 1 to July 2. (Notes: Red dots indicate sampling periods. The onset of the SW monsoon is indicated by the green dot.)

Table 1. Temporal distribution and ecology of 52 macrofungi in Brgy. Zabali, Baler, Aurora.

Species	Collection Month			Substrate	Habit
	May	June	July		
Auricularia polytricha	—	—	•	Dead branch	Gregarious
Clavulinopsis sp.	—	—	•	Soil	Gregarious to Scattered
Coltricia cinnamomea	—	•	•	Soil	Gregarious
Calocera sp.	—	—	•	Dead branch	Gregarious
Fomitopsis sp. [a]	•	•	•	Dead stump	Solitary
Amauroderma sp. [a]	•	•	•	Soil	Solitary
Ganoderma sp. 1 [a]	•	•	•	Dead trunk	Gregarious
Ganoderma sp. 2	•	—	—	Dead wood	Solitary
Ganoderma sp. 3	—	—	•	Dead wood	Solitary
Sanguinoderma sp.	—	•	•	Soil	Solitary to Gregarious
Hygrocybe sp.	—	•	—	Soil	Solitary
Fulvifomes sp. [a]	•	•	•	Dead wood	Solitary to Gregarious
Hymenochaete rubiginosa	•	—	•	Dead trunk	Resupinate, Gregarious
Hymenochaete sp. 1	•	—	—	Dead trunk	Scattered
Phellinus sp.	•	—	—	Dead trunk	Scattered
Phylloporia cf. *alyxiae*	—	•	•	Live branch	Gregarious to scattered
Laetiporus sp.	•	—	—	Dead trunk	Solitary
Calvatia sp.	—	•	•	Soil	Gregarious
Lycoperdon sp.	—	—	•	Leaf litter	Solitary
Termitomyces sp. 1	—	•	—	Soil	Solitary
Termitomyces sp. 2	—	—	•	Soil	Gregarious
Marasmius cf. *cladophyllus*	—	—	•	Leaf litter	Gregarious
Marasmius cf. *crinis-equi*	—	•	•	Leaf litter	Solitary to Gregarious
Marasmius sp. 1	—	—	•	Leaf litter	Solitary to Gregarious
Mycena sp. 1	—	•	—	Leaf litter	Solitary to Gregarious
Mycena sp. 2	—	•	•	Leaf litter	Solitary to Gregarious
Panellus sp.	—	•	•	Dead trunk	Gregarious
Gymnopus sp.	—	—	•	Leaf litter	Gregarious
Cymatoderma sp.	•	—	•	Dead branch	Gregarious
Panus cf. *similis*	•	—	—	Leaf litter	Solitary
Phaeotremella sp.	—	•	—	Dead branch	Gregarious
Hohenbuehelia sp.	—	—	•	Dead trunk	Gregarious
Pleurotus djamor	—	—	•	Dead branch	Solitary
Earliella scabrosa	—	•	—	Dead trunk	Gregarious
Coriolopsis caperata	•	—	—	Dead branch	Gregarious

Hexagonia hydnoides	•	—	—	Dead trunk	Gregarious
Hexagonia tenuis [a]	•	•	•	Dead branch	Gregarious to scattered
Lentinus sajor-caju [a]	•	•	•	Dead branch, trunk	Gregarious to scattered
Lentinus tigrinus [a]	•	•	•	Dead branch	Gregarious to scattered
Microporus xanthopus	—	•	•	Dead branch	Gregarious
Trametes sanguinea	—	—	•	Dead branch	Solitary
Trametes sp. *1*	•	—	—	Dead branch	Gregarious
Trametes sp. *2*	—	•	—	Dead trunk	Gregarious
Fuscoporia sp.	—	•	—	Dead trunk	Gregarious
Psathyrella sp.	—	•	—	Leaf litter	Solitary
Schizophyllum commune	—	—	•	Dead branch	Gregarious
Table 1. (cont.)					
Scleroderma sp. 1	—	•	•	Dead branch	Solitary to Gregarious
Scleroderma sp. 2	—	•	•	Soil	Solitary
Nigroporus vinosus [a]	•	•	•	Dead trunk	Solitary to Gregarious
Stereum sp. [a]	•	•	•	Dead branch	Gregarious
Tremella fuciformis	—	•	—	Dead branch	Solitary
Unidentified	—	•	—	Dead stump	Solitary
Total:	19	29	34	[a] - *appeared in three collections*	
Composition (%)	36.54%	55.77%	65.38%		

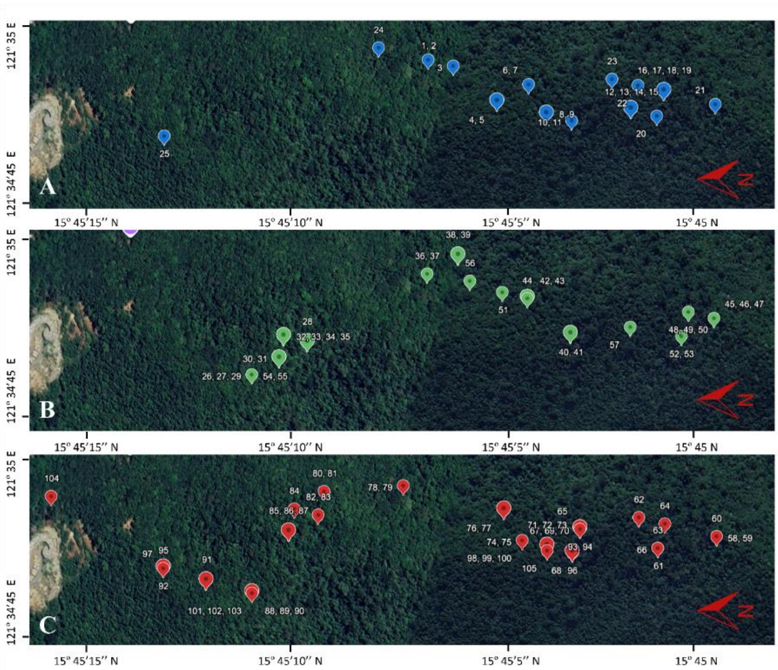

Figure 3. Distribution of macrofungi across three sampling periods. (Notes: A = May 2, 2025; B = June 2, 2025; C = July 1, 2025. Numbered pins mark the locations of specimens 1-105.)

The temporal and ecological distribution of these collected specimens is outlined in Table 1. Based on our findings, the most preferred substrate of macrofungi was decayed wood, followed by soil and leaf litter. Basidiomycetes are well adapted to sporulate on various wood substrates, from fallen logs to even small amorphous woody debris (Zmitrovich et al., 2023). Holec et al., (2020) emphasized that woody debris plays a critical role in maintaining macrofungal diversity, particularly in old-growth forests. Besides substrate availability, macrofungi are greatly influenced by access to canopy light and tree species composition (Pietras et al., 2025).

Unfortunately, anthropogenic disturbances were evident in the study area. Visible signs of poaching were noted, corroborating the report of Gallego (2024) that timber poaching and charcoal making remain the primary threats to the forests of Brgy. Zabali, Baler, Aurora. These activities diminish substrate availability, thus posing a severe risk to local macrofungal populations.

Taxonomic Distribution of Species

The taxonomic classification of the collected specimens is summarized in Table 2. A total of 105 macrofungal specimens were documented, all belonging to the class Agaricomycota. The specimens comprised 52 distinct species, which were further classified into 8 orders, 24 families, and 39 genera. Out of these species, nine were consistently sighted throughout all collection periods: *Amauroderma* sp., *Fomitopsis* sp., *Fulvifomes* sp., *Ganoderma* sp. 1, *Hexagonia tenuis*, *Lentinus sajor-caju*, *L. tigrinus*, *Nigroporus vinosus*, and *Stereum* sp. (refer to Table 1). The fruiting bodies of some representative species are shown in Figure 4.

Table 2. Taxonomic Classification of 52 species in Baler, Aurora

Class	Order	Family	Genus	*Species*
Agaricomycota	Agaricales	Clavariaceae	*Clavulinopsis*	*Clavulinopsis* sp. Overeem
		Hygrophoraceae	*Hygrocybe*	*Hygrocybe* sp. (Fr.) P. Kumm.
		Lycoperdaceae	*Calvatia*	*Calvatia sp.* Fr.
			Lycoperdon	*Lycoperdon* sp. *Pers.*
		Lyophyllaceae	*Termitomyces*	*Termitomyces* sp. R. Heim (1)
				Termitomyces sp. R. Heim (2)
		Marasmiaceae	*Marasmius*	*Marasmius* sp. Fr.
				Marasmius cf. *cladophyllus* Berk.
				Marasmius cf. *crinis-equi* F. Muell. ex Kalchbr.
		Mycenaceae	*Mycena*	*Mycena* sp. (Pers.) Roussel (1)
				Mycena sp. (Pers.) Roussel (2)
			Panellus	*Panellus* sp. P. Karst.
		Omphalotaceae	*Gymnopus*	*Gymnopus* sp. (Pers.) Gray
		Pleurotaceae	*Hohenbuehelia*	*Hohenbuehelia sp.* Schulzer
			Pleurotus	*Pleurotus djamor* (Rumph. ex Fr.) Boedijn
		Psathyrellaceae	*Psathyrella*	*Psathyrella* sp. (Fr.) Quél.
		Schizophyllaceae	*Schizophyllum*	*Schizophyllum* commune Fr.
		Incertae sedis	*Incertae sedis*	*Incertae sedis*
	Auriculariales	Auriculariaceae	*Auricularia*	*Auricularia polytricha* (Mont.) Sacc.
	Boletales	Sclerodermataceae	*Scleroderma*	*Scleroderma* sp. Pers. (1)
				Scleroderma sp. Pers. (2)
	Dacrymycetales	Dacrymycetaceae	*Calocera*	*Calocera sp.* (Fr.) Fr.
	Hymenochaetales	Hymenochaetaceae	*Coltricia*	*Coltricia cinnamomea* (Jacq.) Murrill
			Fulvifomes	*Fulvifomes* sp. Murrill
			Fuscosporia	*Fuscoporia* sp. Murrill
			Hymenochaete	*Hymenochaete* sp. Lév.
				Hymenochaete rubiginosa (Dicks.) Lév.
			Phellinus	*Phellinus* sp. Quél. 1886
			Phylloporia	*Phylloporia* cf. *alyxiae* Sheng H. Wu
	Polyporales	Fomitopsidaceae	*Fomitopsis*	*Fomitopsis sp.* P. Karst.
		Ganodermataceae	*Amauroderma*	*Amauroderma sp.* Murrill
			Ganoderma	*Ganoderma* sp. P. Karst. (1)
				Ganoderma sp. P. Karst. (2)
				Ganoderma sp. P. Karst. (3)
			Sanguinoderma	*Sanguinoderma* sp. Y.F. Sun, D.H. Costa & B.K. Cui
		Laetiporaceae	*Laetiporus*	*Laetiporus* Murrill
		Panaceae	*Cymatoderma*	*Cymatoderma elegans* Jungh.
			Panus	*Panus* cf. *similis* (Berk. & Broome) T.W. May & A.E. Wood

		Polyporaceae	*Coriolopsis*	*Coriolopsis caperata* (Berk.) Murrill
			Earliela	*Earliella scabrosa* (Pers.) Gilb. & Ryvarden
			Hexagonia	*Hexagonia hydnoides* (Sw.) M. Fidalgo
				Hexagonia tenuis (Fr.) Fr.
			Lentinus	*Lentinus sajor-caju* (Fr.) Fr.
				Lentinus tigrinus (Bull.) Fr.
			Microporus	*Microporus xanthopus* (Fr.) Kuntze
			Trametes	*Trametes* sp. Fr. (1)
				Trametes sp. Fr. (2)
				Trametes sanguinea (L.) Lloyd
		Steccherinaceae	*Nigroporus*	*Nigroporus vinosus* (Berk.) Murrill
	Russulales	Stereaceae	*Stereum*	*Stereum sp.* Hill ex Pers.
	Tremellales	Phaeotremellaceae	*Phaeotremella*	*Phaeotremella sp.* Rea
		Tremellaceae	*Tremella*	*Tremella fuciformis* Berk.
1 Class	8 Orders	24 Families	39 Genera	52 Species

Figure 4. Macrofungi of Brgy. Zabali, Baler, Aurora (Notes: A = *Laetiporus* sp.; B = *Scleroderma* sp.; C = *Tremella fuciformis*; D = *Calvatia* sp.; E = *Hygrocybe* sp.; F = *Clavulinopsis* sp.; G = *Amauroderma* sp.; H = *Auricularia polytricha*; I = *Calocera* sp.; J = *Sanguinoderma* sp.; K = *Marasmius* cf. *cladophyllus*; L = *Panus* cf. *similis)*

Among the documented taxa, Polyporaceae was the most species-rich family with 10 distinct species, followed by Hymenochaetaceae with seven. At the genus level, *Marasmius*, *Ganoderma*, and *Trametes* were the most diverse, yielding three (3) species each. In terms of frequency, *Sanguinoderma* sp. occurred most abundantly, with six (6) samples collected throughout the survey period.

The clear dominance of polypores observed mirrors previous macrofungal surveys across the Philippines, which frequently identify Polyporaceae as the prevailing group (Angeles et al., 2016; Baynosa et al., 2025; Brazas et al., 2020; Tadiosa, 2022). Preliminary studies in the Aurora region, particularly in the area of Bazal, likewise noted a significant representation of this family (Tadiosa, 2011). The widespread dominance may be attributed to their structural resilience. As noted by Sutjaritvorakul et al. (2017) polypores typically predominate over fleshy fungi because they tolerate environmental fluctuations better. Halbwachs et al. (2016) explained that macrofungi with a poroid hymenium can retain moisture for longer compared to gilled macrofungi, and are therefore more adapted to drier periods.

This structural advantage explains why *P. similis*, *L. sajor-caju*, and *L. tigrinus* were the only gilled species in the initial May collection, which was preceded by weeks of little to no rainfall in the weeks prior. The persistence of *Panus* and *Lentinus* spp. during dry intervals is driven by their distinct dimitic hyphal systems, which provide them with tough, leathery structures that minimize desiccation (Asif et al., 2024; Halbwachs et al., 2016; Ishaq et al., 2022).

Finally, after a thorough review of the taxonomic inventory of Philippine macrofungi, the study identified seven (7) macrofungal species that are newly recorded in the Philippines, namely, *Calocera* sp., *Laetiporus* sp. *Marasmius* cf. *cladophyllus*, *Panus* cf. *similis*, *Phaeotremella* sp., *Phylloporia* cf. *alyxiae,* and *Scleroderma* sp. This highlights the rich, untapped fungal resource of the country available for biotechnological and ecological research.

Interestingly, despite the diverse collection of macrofungi in Baler, Aurora, no ascomycetes were encountered. This absence may be attributed to a relatively short sampling period and poor seasonal timing for ascomycete fruiting bodies. Nevertheless, the researchers were able to successfully isolate six species into pure culture: *Amauroderma* sp., *Auricularia polytricha*, *Laetiporus* sp., *L. tigrinus*, L. *sajor*-caju, and *P. similis*. These isolates are currently maintained in the macrofungal culture collections of ASCOT and CLSU, serving as a biological repository for future studies in hopes of elucidating their potential functional and pharmacological properties.

The novelty of this study lies in its pioneering assessment of macrofungal populations strictly within a unique ultramafic forest pocket of the Sierra Madre Mountain Range. While many local surveys capture macrofungal biodiversity in protected forests and watersheds, this research specifically isolates specialized fungal adaptations to mineral-heavy, nutrient-deficient soils during a significant shift in climate. Furthermore, the identification of seven macrofungal species newly recorded in the Philippines demonstrates that this unique habitat acts as a refuge for previously undocumented mycoflora in the country.

By establishing the first formal inventory in this specific reserve, this study directly bridges regional data gaps for mycologists working across the Philippines and nearby countries. The successful cultivation of six pure isolates transitions the study from purely descriptive taxonomy to applied science, providing a foundational biological repository for future pharmacological and agricultural bioprospecting.

This research supports SDG 13 (Climate Action) and SDG 15 (Life on Land). By tracking the direct influence of precipitation trends on fungal emergence, the study advances our understanding of climate-driven ecosystem responses (SDG 13). Additionally, by indexing local macrofungi and highlighting the immediate risks that timber poaching poses to substrate availability, it directly contributes to the conservation, restoration, and sustainable management of threatened forest ecosystems (SDG 15).

CONCLUSION

In conclusion, this study has fulfilled its research objectives by documenting an array of 52 distinct macrofungal species from a collection of 105 specimens within the ultramafic forest reserves of ASCOT. The results confirm a progression in macrofungal species composition during the period of sampling, rising from 36.54% in May to 65.38% in July 2025, driven by increasing precipitation brought by the southwest monsoon. This study achieved its goals of expanding local biodiversity records with seven newly documented basidiomycetes for the Philippines and securing six viable cultures for future applications. To overcome the limitations of this study, future research should implement year-long sampling extending across both the distinct wet and dry seasons to capture the annual climate variations and to include other taxa potentially with a limited period of emergence. Finally, detailed soil-fungi correlation analyses are recommended to evaluate how specific concentrations of heavy metals in ultramafic substrates may influence the physiology and bioaccumulation of macrofungi.

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AUTHOR CONTRIBUTION STATEMENT

All authors contributed significantly to this study. JCR, RMRD, SPK, and RGR conceived and designed the research. Data collection was performed by JCR, OTBJ, and HPB. Literature review, data visualization, and data analysis were carried out by JCR, RMRD, SPK, AMDL, and RGR, who also provided substantial feedback during the drafting of the manuscript. All authors have read, approved, and agreed to be accountable for the final manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest regarding the publication of this paper

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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