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The Community Structure of Macroscopic Fungi in Arboretum and Lakeside Ecosystems: A Case Study in South Tangerang, Indonesia

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Abstract

This study aimed to evaluate the community structure (diversity, dominance, richness, and evenness indices) and the microclimate factors affecting the growth of macrofungi in arboretum and lakeside ecosystems. The research was conducted in South Tangerang, Banten, Indonesia, from September to December 2024. A species-specific survey method was used at two locations representing the arboretum and the area surrounding the lake. Results revealed that a total of 466 macrofungal individuals were found, representing nine species from the division of Basidiomycota. Two species, *Lentinus sajor-caju* and *Schizophyllum commune*, dominated the ecosystem. The diversity of macrofungi was classified as moderate, the dominance index as low, the richness index as poor, and the evenness index as low. Approximately 75% of the species were associated with decaying wood substrates, whereas the remaining species inhabited soil environments. Microclimatic variables, including air temperature, humidity, light intensity, and substrate pH, are key factors supporting macrofungal growth.

Keywords: Arboretum; Community structure; Diversity Index; Lakeside; Macrofungi; Microclimatic factors

Introduction

Indonesia is recognized as the second-largest mega-biodiversity hotspot in the world, home to approximately 25% of the planet's species across its diverse ecosystems (Risalba 2024). Its strategic location along the equator contributes to its tropical climate, which is characterized by high annual rainfall, elevated humidity, and abundant sunlight. These climatic conditions foster a wide range of ecosystems, from tropical rainforests to savannas, creating an ideal environment for numerous organisms, including fungi (Stallman *et al*. 2024).

Fungi are eukaryotic organisms that reproduce both sexually and asexually *via* spore production. They are characterized by the absence of chlorophyll and have cell walls composed of chitin and cellulose. As heterotrophic organisms, fungi obtain their nutrients by deriving substances from other living organisms (Suryani *et al*. 2020). As eukaryotic organisms, fungi can be classified into two size categories: microscopic fungi, which can only be observed under a microscope, and macroscopic fungi (or macrofungi), which are large enough to be seen with the naked eye (Nurhayat *et al*. 2021). Macrofungi are commonly used by humans as a source of food and medicine because of their nutritional and therapeutic properties (Wahyudi *et al*. 2012). Examples of edible fungi include ear mushrooms (*Auricularia auricula*) and white oyster mushrooms (*Pleurotus ostreatus*). In ecosystems, macrofungi play an essential ecological role as decomposers, as they can thrive on dead organic matter as saprophytes, thus contributing to nutrient cycling and the breakdown of organic materials (Annisa *et al*. 2017). In nature, macrofungi produce fruiting bodies that grow as saprophytes on dead or living tree trunks, leaf litter and soil (Noverita *et al*. 2018; Setiorini *et al*. 2018). These substrates are rich in compounds such as holocellulose (cellulose and hemicellulose), lignin, and other carbohydrates, which serve as energy sources for fungi (Setiyono 2004; Hamdiyati 2007). According to Wahyuningsih *et al*. (2022), tree trunks are particularly suitable substrates due to their high levels of lignin and cellulose (Wahyuningsih *et al*. 2022).

The arboretum and lakeside each reflect distinct semi-urban ecosystems are shaped by their unique vegetation and subtle differences in microclimate. The arboretum, with its dense tree canopy and shaded environment, creates a humid and sheltered habitat that favours fungal growth, whereas

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the lakeside area, being more exposed and open, provides drier and more fluctuating conditions for fungal growth. Although macrofungal diversity has been widely documented in natural forests and protected areas, relatively little is known about fungal communities thriving in green spaces shaped by human activity. It is essential for urban green zones to play a role in conserving biodiversity. Therefore, this study was conducted to assess the community structure, focusing on the diversity, dominance, richness, and evenness of macroscopic fungi in arboretum and lakeside ecosystems in South Tangerang, Indonesia, and to examine how local microclimatic factors affect their distribution and abundance.

Materials and Methods

Location and sampling procedure

The research was conducted at the arboretum and lakeside area around Universitas Terbuka, South Tangerang, Banten, Indonesia, from September to December 2024. This area lies between 6°20'16"S 106°45'35"E and 6°20'23"S 106°45'42"E for the arboretum and lakeside, respectively (Fig. 1).

Sampling locations were chosen based on the accessibility of the area and macrofungi occurrence. The sampling was carried out using the exploration method (Noerhandayani *et al*. 2021). The technique used was random sampling, which involved creating plots measuring 5 × 5 m^2, with 10 m between each plot (Sibuea 2017). Macrofungi were directly collected, and their characteristics, including shape, color, length of the stalk, diameter of the fruiting body and living substrate (soil, tree trunks, leaf litter, and other habitats), were recorded. The identification process followed the guidelines from Field Guide to Common Macrofungi in Eastern Forest and Their Ecosystem Functions (Ostry *et al*. 2011), A Little Field Guide to West Brisbane Fungi (Prance and Mcmullan-Fisher 2014), Mushrooms for Trees and People (Mortimer *et al*. 2014) and a guide to Missouri's edible and poisonous mushroom (Briggler 2018).

Pure cultures were obtained by isolating the collected mushroom samples. The steps for isolating macrofungi started by cleaning the surface of the samples, followed by sterilization with 70% alcohol. The samples were then longitudinally cut using aseptic techniques to collect spores from the interior (the part that had not been exposed to the environment to minimize contamination) using a sterile scalpel. The collected samples were placed in Petri dishes containing potato dextrose agar (PDA) medium. The samples in the Petri dishes were incubated at room temperature for 3-7 days. Mycelial growth on the PDA medium indicated that the sample had been purified (Fadhillah *et al*. 2019). The obtained pure culture was used for further research. The specimens were preserved for collection by creating a wet herbarium. The wet herbarium prepared by soaking the specimens in 70% alcohol (Oxi *et al*. 2024).

Fig. 1: Map of study area with scale 1:638,800,000

Environmental factors, such as air temperature, humidity, light intensity, and substrate pH, were measured to provide information related to the environmental conditions where macrofungi live.

Community structure measurements

The pameters measured in the present study included the relative abundance of macrofungi, diversity, dominance, richness and species evenness indices.

Relative abundance of macrofungi

Relative abundance (Pi) represents the proportion of a species within a community or sample of a community. The relative abundance (Pi) of each species was expressed as (Achacoso *et al*. 2016):

$$Pi = 1 + \frac{ni}{N} \times 100$$

Where: Pi = The relative abundance of each species
ni = The number of individuals of the same species
N = The total number of individuals for all species.

Diversity index

Macrofungal diversity was calculated using the Shannon-Wiener index (Achacoso *et al*. 2016; Baderan *et al*. 2021; Amrulloh *et al*. 2022; Fikri *et al*. 2023).

$$H' = \sum_{i=1}^{S} (\text{pi})(\ln pi)$$

Where: H' = Shannon-Wiener Diversity Index
ni = Number of individuals of the i-th species
N = Total number of individuals
i = Index for each species (1^{st}, 2^{nd}, ... Sth)
S = Total number of species (species richness) in the sample or community.

The range of diversity index values is classified as follows:
H' < 1 = Low diversity
1 ≤ H' ≤ 3 = Moderate diversity
H' > 3 = High diversity

Dominance index

The dominance of macrofungi was calculated using the Simpson index (Basyuni *et al*. 2018):

$$D = \sum_{i=1}^{s} \left(\frac{ni}{N}\right)\left(\frac{ni}{N}\right)^2$$

$$A = P\left(1 + \frac{r}{n}\right)^{nt}$$

Where: D = Simpson's dominance Index
ni = Number of individuals of the i-th species
N = Total number of individuals
s = Number of genera.

The range of dominance index values was classified as follows:
0.01 <D < 0.30 = Low dominance
0.31 < D ≤ 0.60 = Moderate dominance
0.61 < D ≤ 1.00 = High dominance

Richness index

The richness index was calculated using the Margalef Index Formula (Amrulloh *et al*. 2022):

$$R = \frac{S - 1}{Ln(N)}$$

Explanation: R = Specific Richness Index
S = Number of types
Ln = Natural logarithm
N = Total number of individuals.

The range richness index values were classified as follows:
R < 0.35 = Poor richness
0.35 < R ≤ 0.50 = Moderate richness
R > 0.50 = High richness

The species evenness index

The species evenness index was calculated using the Evenness Index Formula (Odum 1993; Amrulloh *et al*. 2022):

$$R = \frac{H'}{LnS}$$

Where: E = Specific evenness index
H' = Index of species diversity
S = Number of species
s = Number of genera

The range of species evenness index values can be classified as follows:
0.00 < D < 0.40 = Low evenness of species
0.40 < D ≤ 0.60 = Moderate evenness of species
0.60 < D ≤ 1.00 = High evenness of species

Data analysis

The data derived from the calculations were analysed descriptively to illustrate and characterize the sediment conditions based on the various parameters outlined earlier.

Results

Analysis of community structure of macrofungi

Based on research conducted across two different ecosystems, 466 microfungi were recorded, representing nine species. All identified species belonged to the division Basidiomycota and were classified within the families Ganodermataceae, Psathyrellaceae, Polyporaceae, Schizophyllaceae, Auriculariaceae and Phallaceae. In the arboretum, 460 individuals representing seven species were found, whereas at the lakeside, six individuals representing two species were recorded.

Table 1 lists the identified macrofungal species and their corresponding substrates. The majority of species were associated with decaying wood, indicating the importance of lignocellulosic material in supporting fungal growth. Only a few species, such as *Phallus* sp. and *Psathyrella* sp., were observed on soil.

Fig. 2 shows a clear difference in the number of macrofungal individuals recorded at the two sites, with 460 found in the arboretum and just 6 at the lakeside. This striking disparity suggests that environmental conditions in the arboretum, such as greater canopy cover, higher humidity, and an abundance of decaying wood, may be more suitable for fungal growth. On the other hand, the more exposed and drier conditions near the lakeside likely restricted macrofungal development.

The relative abundance of each species is detailed in Table 2. The arboretum ecosystem was dominated by *Lentinus sajor-caju* (43.6%) and *Schizophyllum commune* (38.0%), together comprising over 80% of all recorded individuals. In contrast, the lakeside was sparsely populated, with *Ganoderma* sp. 2 and *Phallus* sp. 2 found in very low numbers with 1.1% and 0.2%

Fig. 3 presents the images of the macrofungi observed during the study, helping to visually support the identification. The images show clear differences in features like cap shape, colour, and how each species grows on its substrate, making it easier to understand their diversity and appearance in the field. According to the Shannon–Wiener diversity index, the overall diversity of macrofungi was categorized as moderate (H' = 1.51). Diversity was moderate in the arboretum (H' = 1.48) and low at the lakeside (H' = 0.45), reinforcing the observation that the arboretum supports a wider variety of fungal species. The Simpson dominance index further emphasizes this difference. While the overall dominance was low (D = 0.29), the arboretum ecosystem exhibited high dominance (D = 0.72), indicating that a few species overwhelmingly dominated the community. In contrast, the lakeside showed low dominance (D = 0.29), suggesting a more balanced (though limited) species presence. Species richness, calculated using the Margalef index, was generally poor, with an overall richness value of 1.14. While the arboretum had a slightly better richness score (R = 1.14) compared to the lakeside (R = 0.55), both values suggest that only a few different species were present despite

Table 1: Species and substrate living from Macrofungi found at arboretum and lakeside ecosystems

Division	Family	Species	Substrate
Basidiomycota	Schizophyllaceae	*Schizophyllus commune*	Decaying wood
Basidiomycota	Auriculariaceae	*Auricularia* sp.	Decaying wood
Basidiomycota	Polyporaceae	*Lentinus sajor-caju*	Decaying wood
Basidiomycota	Ganodermataceae	*Ganoderma* sp. 1	Decaying wood
Basidiomycota	Phallaceae	*Phallus* sp. 1	Soil
Basidiomycota	Psathyrellaceae	*Psathyrella* sp. 1	Soil
Basidiomycota	Psathyrellaceae	*Psathyrella* sp. 2	Soil
Basidiomycota	Ganodermataceae	*Ganoderma* sp. 2	Decaying wood
Basidiomycota	Phallaceae	*Phallus* sp. 2	Soil

Table 2: The species relative abundance at arboretum and lakeside ecosystems

Species	Location founded	Number of Individuals	Relative abundance (%)
Schizophyllus commune	Arboretum	177	38.0
Auricularia sp.	Arboretum	33	7.1
Lentinus sajor-caju	Arboretum	203	43.6
Ganoderma sp. 1	Arboretum	8	1.7
Phallus sp. 1	Arboretum	3	0.7
Psathyrella sp. 1	Arboretum	25	5.4
Psathyrella sp. 2	Arboretum	11	2.4
Ganoderma sp. 2	Lakeside	5	1.1
Phallus sp. 2	Lakeside	1	0.2

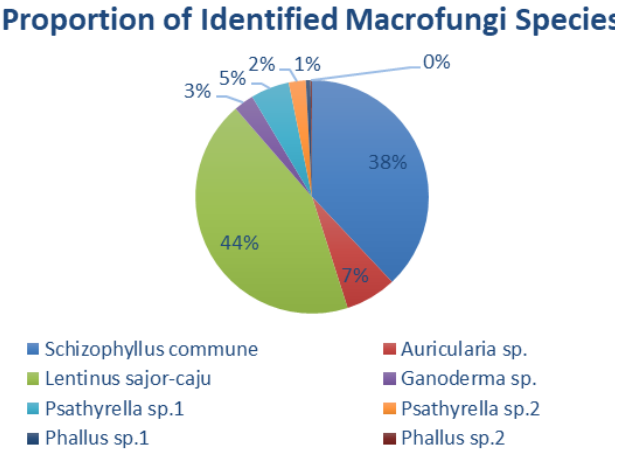

Fig. 2: Number of macrofungal individuals living in the arboretum and lakeside ecosystems

the relatively high number of individuals, especially in the arboretum. This may indicate that environmental conditions favoured the growth of certain dominant species, limiting the establishment of a more diverse fungal community. Evenness values were low in both areas. The overall evenness index was 0.25, reflecting the uneven distribution of individuals among species. This low evenness indicates low species distribution uniformity.

Table 3 summarizes the categories for diversity, dominance, richness and evenness indices for each location. The data confirm that the arboretum had higher diversity but was also characterized by species dominance and low evenness. The lakeside, in contrast, exhibited uniformly low values across all ecological indices.

Table 3: The category of Dominance (D), Richness (d) and Evenness (E) of Macrofungi at arboretum and lakeside ecosystems

Calculation	Arboretum	Lakeside	Combined
Diversity (H')	Moderate (1<H'<3)	Low (H'<1)	Moderate (1<H'<3)
Dominance (D)	Low (0.01<D<0.3)	Low (0.01<D<0.3)	Low (0.01<D<0.3)
Richness (R)	Poor (R<3.5)	Poor (R<3.5)	Poor (R<3.5)
Evenness (E)	Low (E<0.4)	Low (E<0.4)	Low (E<0.4)

Table 4: Environmental Parameters that Support Life of Macrofungi at arboretum and lakeside ecosystems

Environmental parameters	Arboretum	Lakeside
Air temperature (°C)	32.29 ± 1.77	33.8 ± 0.20
Air humidity (%)	70.26 ± 2.29	70.3 ± 2.42
Light intensity (lux)	3,928.08 ± 3,407.31	2,771.00 ± 2,783.31
Substrate pH	Decaying wood: 6.13 ± 0.26 Soil: 7.24 ± 0.14	Decaying wood: 6.00 ± 0.52 Soil: 6.80 ± 0.01

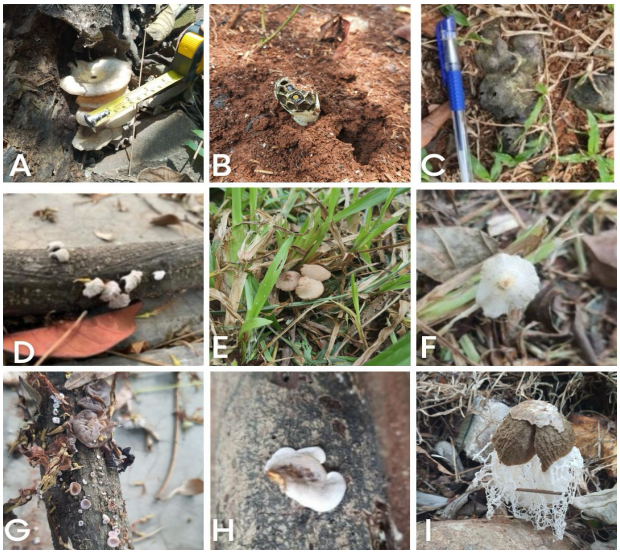

Fig. 3: Some species of macrofungi Found at arboretum and lakeside ecosystems
A. *Lentinus sajor-caju*, **B**. *Phallus* sp. 2, **C**. *Ganoderma* sp. 1, **D**. *Schizophyllus commune*, **E**. *Psathyrella* sp. 1, **F**. *Psathyrella* sp. 2, **G**. *Auricularia* sp., **H**. *Ganoderma* sp. 2, **I**. *Phallus* sp. 1

Effect of environmental factors on growth of macrofungi

Environmental measurements were conducted to assess the abiotic conditions influencing macrofungal distribution. Macrofungi inhabiting the combined ecosystems of the arboretum and lakeside were found to live in areas with an average air temperature of 32.85 ± 1.81°C, with the averaging 69.61 ± 2.27%. Light intensity ranged from 433 to 10,790 lux, with an average value of 3,415.07 ± 3,231.73 lux.

Table 4 provides a comparison of environmental parameters between the arboretum and lakeside ecosystems. While humidity and substrate pH were relatively similar, the arboretum showed lower temperatures and higher light intensity than the lakeside. The substrate pH of decaying wood and soil varied slightly between locations, with the

arboretum soil being more alkaline (pH 7.24) compared to the lakeside (pH 6.80). These variations in microclimatic conditions, particularly temperature, substrate type, and humidity, likely contributed to the differences in macrofungal abundance and diversity observed between the two different ecosystems.

Discussion

The diversity of macrofungi observed in the study area was moderate, with a diversity index of 1.54 ($1 < H' < 3$), indicating that the macrofungal community consisted of various types, with two species dominating the ecosystem: *Lentinus sajor-caju* with a relative abundance of 43.6% and *Schizophyllum commune* with a relative abundance of 38%. This dominance may be influenced by the preferred habitats of these species. *Lentinus sajor-caju* typically grows in clusters on dead and dying trees in rainforest. It exhibits a vase-like shape during the early fruiting stage, later resembling oyster mushrooms as it matures. Its annular ring is yellowish and attached to the stem, whereas the lamellate hymenophore is clearly visible on the underside of the cap. As it grows, the cap expands, the edges curl upward, and the surface becomes greyish, sometimes featuring white lines and scattered black spots. The cap margin was outwardly curved and wavy. Basidiospores are generally ellipsoid or occasionally near-subfusiform (Hermawan and Sari 2021).

Meanwhile, *Schizophyllum commune* forms a fan-shaped, fleshy, and elastic fruiting body with a cap diameter ranging from 1 to 4 cm. It is gray in color and attaches laterally to its substrate. The hymenophore, located on the underside of the fruiting body, is gilled, with distinctly folded and split gills earning it the common name "split-gilled fungi" (Padhiar *et al.* 2009).

Approximately 78% of the macrofungi were found within the arboretum, whereas the remainder were observed at the lakeside. Established around 2005 as a buffer zone, the arboretum hosts plant species collected from various regions of Indonesia. Over nearly two decades, the vegetation has developed a closed canopy, creating a humid microenvironment rich in substrates favourable for fungal growth. According to Trudell and Edmonds (2004), fungal diversity tends to be higher in habitats characterized by suitable soil moisture, abundant litter, and dense canopy cover, all of which help to maintain favourable humidity levels. Canopy cover plays a critical role in supporting macrofungal diversity by increasing substrate availability on the forest floor and promoting the retention of moisture. Litter, as an essential component of forest ecosystems, serves as the primary organic matter source for soil; its removal significantly impacts macrofungal diversity and growth (Joshi *et al*. 2022). The lakeside sampling area, located along the water's edge, exhibited a more open canopy and lower soil moisture levels, creating less favourable conditions for macrofungal development. Additionally, tree thinning has contributed to the decline of delicate and fragile fruiting bodies; however, the extent of this impact varies significantly depending on the season, fruiting patterns of macrofungi and degree of thinning (Luoma *et al*. 2004).

Approximately 75% of the macrofungi recorded in the study area were associated with decaying wood substrates. Decaying wood provides essential nutrients, such as cellulose, hemicellulose, and lignin, which support fungal growth. These compounds are broken down by extracellular enzymes secreted by fungi, enabling them to access the simpler molecules necessary for their development (Wahyuningsih *et al*. 2022). Hamdiyati (2007) further noted that tree trunks, which are rich in lignin and cellulose, serve as ideal substrates. The remaining 25% of macrofungi were found growing in the soil among the leaf litter and floor vegetation. As decomposers, mushrooms play a critical role in maintaining forest biodiversity by breaking down organic materials from plants into compounds that support their growth and development (Hasanuddin 2014).

The variation in macrofungal distribution observed across sites can be attributed to several environmental factors, including rainfall; substrate availability, consistently humid woodlands, and forest type (Talley *et al*. 2002). The moderate diversity observed is closely linked to environmental factors affecting fungal growth, such as humidity, temperature, light intensity, and substrate pH. Environmental factors, such as temperature, humidity, and substrate type, have been shown to significantly influence fungal colonization and infection severity (Alam *et al.* 2024), which aligns with our observations that substrate availability and microclimatic conditions shape macrofungal distribution patterns. Zikriyani *et al.* (2018) highlighted that temperature and relative humidity are particularly influential in fruiting body formation. During the study, the average air temperature recorded was 32.85 ± 1.81°C, a range suitable for macrofungal growth. Previous research suggests that optimal mushroom growth typically occurs within a relatively narrow temperature range of 20–24°C, accompanied by high humidity levels of around 80–90% (Immanuel and Oyedeji 2023). However, the observed diversity remained moderate rather than high, possibly because the prevailing temperatures slightly exceeded the optimal range for most macrofungi, which is typically 20–30°C. In addition to temperature, air humidity has a significant impact on macrofungal development. The measured average humidity was 69.61 ± 2.27%, which is lower than the typical range preferred by most macrofungi (80–97%) (Hasanuddin 2014), which are essential for maintaining water content and nutrient transport within cells (Nurzahra *et al*. 2025). Despite sporadic rainfall events during the sampling period, below-optimal humidity readings were likely influenced by data collection occurring during the dry season, when rainfall levels were considerably low. Data from the Indonesian Agency for Meteorology, Climatology, and Geophysics reported an average monthly rainfall of just 4.08 ± 9.46 mm in South

Tangerang, Indonesia, in September 2024, which is classified as low. Riastuti *et al*. (2018) emphasized that air and substrate humidity are significantly higher during the rainy season compared to the dry season, consequently affecting the development of fungal spores.

Conclusion

This study demonstrated that the diversity of macrofungi in the study area was moderate, with a diversity index of 1.54. The macrofungal community was largely dominated by *Lentinus sajor-caju* and *Schizophyllum commune*, which seemed to thrive under the site's environmental conditions, particularly where decaying wood was abundant. The arboretum, with its closed canopy and higher humidity, supported greater macrofungal diversity than the lakeside area, where open canopies and lower soil moisture limited fungal growth. Key microclimatic factors, such as air temperature, humidity, rainfall, substrate type, and canopy cover, significantly influence macrofungal distribution and diversity. These findings highlight the critical role of microhabitat conditions in shaping macrofungal communities and suggest that maintaining canopy cover and substrate availability is essential for supporting fungal diversity in forest ecosystems. However, the findings may vary seasonally, and further long-term monitoring is recommended to better capture the macrofungal dynamics.

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Author Contributions

HZ designed the study, collected and analyzed the data and wrote the manuscript. AA and NIA collected the data, interpreted the results and contributed to writing the manuscript. AJ reviewed and edited the manuscript. All authors contributed to and approved the final version of the submitted manuscript.

Conflict of Interest

All authors declare no conflict of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable to this paper.

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