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Diversity and Distribution of the Macroscopic Species of Fungi in the Forest Park of Pocut Meurah Intan, Aceh, Indonesia

[1]*Hendrix Indra Kusuma, [2]Essy Harnelly, [3]Zairin Thomy, and [4]Hilmina Itawarnemi

1. Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia*
2. Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia
3. Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia
4. Agrotechnology study program, Faculty of Agriculture, Universitas Teuku Umar, Meulaboh, Indonesia

*Correspondence email: hendrixkusuma@usk.ac.id

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Abstrak: Data mengenai keanekaragaman jamur makroskopik dari Tahura Pocut Meurah Intan masih belum tersedia secara luas yang mengakibatkan adanya kesenjangan dalam data dasar yang sangat penting untuk konservasi, pengelolaan wilayah, dan penjelajahan potensi biologis. Penelitian ini bertujuan untuk mengidentifikasi keragaman spesies jamur makroskopis yang terdapat di Tahura PMI dan menganalisa distribusinya berdasarkan tipe substrat dan kondisi habitat. Metode survei-eksplorasi dilakukan dengan mengikuti jalur pendakian yang tersedia. Sampel jamur yang ditemukan di lapangan didokumentasikan, diambil dan diawetkan, dan kemudian dianalisis morfologinya. Analisis data dilakukan secara deskriptif kualitatif dengan menyajikan distribusi spesies menurut kondisi habitat, jenis substrat, serta perbedaan antara musim hujan dan musim kemarau. Setiap kategori dipresentasikan dalam bentuk persentase dari total spesies yang teridentifikasi. Hasil penelitian menunjukkan bahwa sebanyak 123 spesies jamur makroskopik ditemukan, dengan dominasi dari ordo Agaricales (39%). Sebanyak 28 spesies memiliki potensi sebagai sumber pangan alternatif, sedangkan 17 spesies berpotensi sebagai bahan obat. Keanekaragaman tertinggi ditemukan pada habitat dengan vegetasi heterogen (85,37%), dibandingkan hutan homogen (21,95%) dan kawasan pertanian (16,26%). Kayu lapuk merupakan substrat utama tempat jamur tumbuh (56%), dan jumlah spesies lebih tinggi pada musim hujan dibandingkan musim kemarau. Temuan ini menunjukkan bahwa Tahura PMI merupakan habitat penting bagi jamur makroskopik dengan variasi distribusi yang dipengaruhi oleh perbedaan substrat dan kondisi lingkungan.

Kata kunci: keragaman spesies, jamur makro, Tahura Pocut Meurah Intan, komposisi jamur

Abstract: Data on the diversity of macroscopic fungi in Tahura Pocut Meurah Intan is still not widely available, resulting in a gap in basic data that is essential for conservation, area management, and exploration of biological potential. This study aims to identify the diversity of macroscopic fungal species found in PMI National Park and analyze their distribution based on substrate type and habitat conditions. An exploration survey method was used by following existing hiking trails. Fungal samples found in the field were documented, collected, preserved, and then analyzed morphologically. Data analysis was performed using descriptive qualitative methods,

presenting species distribution according to habitat conditions, substrate type, and differences between the rainy and dry seasons. Each category was presented as a percentage of the total identified species. 123 macroscopic fungal species were found, with a dominance of the order Agaricales (39%). A total of 28 species have the potential as alternative food sources, while 17 species have the potential as medicine. The highest diversity was found in habitats with heterogeneous vegetation (85.37%), followed by homogeneous forests (21.95%) and agricultural areas (16.26%). Weathered wood was the main substrate where fungi grew (56%), and the number of species was higher in the rainy season than in the dry season. These findings indicate that the PMI Nature Reserve is an important habitat for macroscopic fungi with variations in distribution influenced by differences in substrate and environmental conditions.
Keyword: diversity of species, macrofungi, Tahura Pocut Meurah Intan, fungal composition

1. Introduction

There are about 200,000 different species of fungi in Indonesia [1], however, there is no extensive research on the diversity of macroscopic fungi in its forest. Till date, data and literature on the diversity of macroscopic fungi are very limited, including the species found in Aceh area, especially in the Forest Park of Pocut Meurah Intan (*Tahura PMI*). Tahura PMI is located in Seulawah Agam forest area, which is about 70 kilometers from the capital city of Aceh (Banda Aceh) with an estimated area of 6,300 ha. The topography of this grand forest park is generally hilly; however, a small part is a lowland with the status of state forest and is located at the foot of Mount Seulawah Agam at an altitude of 500 to 1,800m above sea level. Furthermore, Tahura PMI has the ecosystem consisting of rivers, forests, grassland, and peatlands [2], which store a diversity of flora and fauna, including fungi.

Tahura PMI is a tropical rainforest characterized by a diverse array of vegetation, including woody trees, shrubs, and grasses. The balanced ecosystem of this region has created optimal habitat conditions for the development of fungi [3], however, in recent years, this area has experienced damage due to human behavior. The damages include logging, encroachment, and the conversion of forest into agricultural land has a great effect on the diversity of fungi from time to time. Furthermore, environmental changes resulting from tourism activities and regional management can also impact the viability of fungi, underscoring the necessity for comprehensive studies on their distribution.

The limited availability of scientific publications concerning the fungal community in Tahura PMI has led to a gap in fundamental data that is crucial for conservation, area management, and the exploration of biological potential. Previous studies have focused more on macro flora and fauna, while fungi have not received proportional attention. Consequently, it is necessary to collect data on the diversity of fungi species and their distribution found in this area. The objective of this study is to determine the diversity and distribution of macroscopic fungal species in Tahura PMI, Aceh, and to analyze their distribution based on substrate type and habitat conditions.

2. Research Method

a. Study Site

Sampling was conducted from October 2018 to April 2019 in the Tahura PMI. Geographically, it lies between 05°26'00''-05°26'60'' North Latitude and 95°44'80''-95°45'45'' East Longitude, which is administratively located in Saree, Aceh Besar Regency, Aceh Province. The exploration is carried out by following the existing hiking trail as shown in Figure 1.

b. Study Site

The explorative survey method is used for the collection of data, this includes the sampling techniques, in which the presence of fungi in the field is examined, documented, preserved, and analyzed. The photographs of the fruit bodies found were taken in their natural habitat and the character of the fungus was observed and recorded. Subsequently, the fruit bodies are cleaned using a sprayer and then placed in a bottle containing 70% alcohol. Furthermore, the Isolates from all species studied were then preserved in wet and dry form in the laboratory of Biology Department, Faculty of Mathematics and Natural Sciences, Syiah Kuala University. Data on the physical environmental condition were collected at each location where macro fungi were found. These include altitude, temperature, humidity, soil moisture, and pH, as well as the intensity of sunlight.

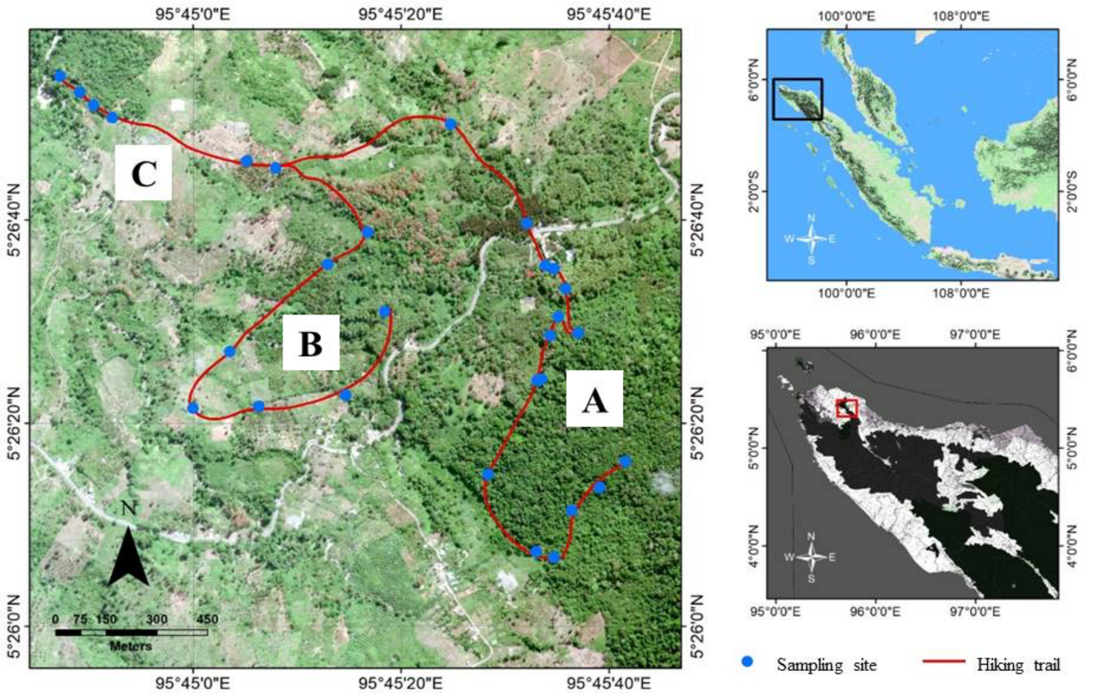

Figure 1. Map of Research Location (the red lines show the hiking trail while the blue dots is the location where the macrofungi were collected). Site A is a heterogeneous forest area with diverse vegetation that is characterized by giant trees with a wide canopy and many fallen branches. Site B is a homogeneous forest region dominated by *Pinus merkusii* with shrubs. Site C is a plantation area.

c. Study Site

The identification of specimen in the field begins by making a comparison with the published pictures. Its process was carried out on morphological characteristics, which include the colour of fruit body, the shape of hat (*pileus*), gill blades *(lamella*), stem (*stipe*), cup (*volva*), and ring (*annulus*). Subsequently, the morphological features were compared with the pictures contained in several identification books as well as cross-checking some relevant literature. These include *Instant Guide to Mushrooms and Other Fungi* [4]; *The Great Encyclopedia of Mushrooms* [5]; *Mushrooms of the Pacific Northwest* [6]; *Checklist of Fungi in Malaysia* [7]; *Wild Edible Fungi: A Global Overview of Their Use and Importance to People* [8]; *Mushroom for Trees and People: A Field Guide to Useful Mushrooms of the Mekong Region* [9]; *Edible and Poisonous Mushrooms of Canada* [10]; *Edible and Poisonous Mushrooms of the World* [11]; *The Pocket Guide to*

Mushrooms [12]; *Field Guide to Common Macrofungi in Eastern Forests and Their Ecosystem Functions* [13], and several other related literature sources that include books, journals, and representative online library materials.

d. Data analysis

The data obtained was analyzed using descriptive qualitative methods. Each species found was grouped based on family, substrate type, location of occurrence, and season of observation. The composition of dominant families was presented in percentage form, calculated from the number of species in each family compared to the total number of species found in Tahura PMI.

Fungal distribution was displayed based on habitat conditions, substrate type, and differences between the rainy and dry seasons. Each category was presented as a percentage of the total species found. All data were compiled and presented in tables and diagrams to illustrate patterns of occurrence, ecological trends, and taxonomic representation of fungi in an informative manner.

3. Results and Discussion

a. Composition and physical distribution of Macrofungi

The scientific name, division, family, growth substrate, and the benefit of macrofungi from Tahura PMI are shown in **Table 1**. The result shows that 123 species of macrofungi belong to 41 families, 14 orders, and 2 divisions, namely Ascomycotina (11%, 12 species) and Basidiomycotina (89%, 111 species).

Table 1. List of fungi identified from Tahura PMI with their substrate, benefits, and their distribution at the collection site.

Division	Family	No.	Species	Substrate	Benefits	Collection Site			Collection Time					
						A	B	C	Oct	Des	Jan	Feb	Mar	Apr
Ascomycota	Sarcoscyphaceae	1	*Cookeina tricholoma*	Soil, twigs	Edible, Medicinal	√	-	-	-	-	√	-	-	-
		2	*Cookeina sulcipes*	Soil, twigs	Edible	√	-	-	-	-	√	-	-	-
		3	*Sarcoscypha coccinea*	Soil, twigs	Nonedible	√	-	-	-	-	√	-	-	-
	Pezizaceae	4	*Peziza succosa*	Soil, litter	Medicinal	√	-	-	-	-	√	-	-	-
	Pyronemataceae	5	*Trichaleurina javanica*	Twigs, Litter	Nonedible	√	-	-	√	-		-	-	-
	Helotiaceae	6	*Bisporella citrine*	Stump, Logwood	Nonedible	√	-	-	√	-	-	-	-	-
	Xylariaceae	7	*Xylaria longiana*	Stump, Logwood	Nonedible	√	-	-	√	√	√	-	√	-
		8	*Xylaria hypoxylon*	Stump, Logwood	Nonedible	√	-	-	√	-	√	-	-	-
		9	*Xylaria pebleja*	Stump, Logwood	Nonedible	√	-	-	-	-	√	-	-	-
		10	*Xylaria tentaculata*	Stump, Logwood	Nonedible	√	-	-	-	-	-	-	√	-
		11	*Xylaria polymorpha*	Stump, Logwood	Nonedible	√	-	-	√	-	√	-	-	-
		12	*Daldinia concentrica*	Logwood, twigs	Nonedible	√	-	√	√	-	-	√	√	-
Basidiomycota	Tremellaceae	13	*Tremella foliacea*	Logwood, twigs	Nonedible	√	-	-	-	-	√	-	-	-
		14	*Tremella mesenterica*	Logwood, twigs	Edible	√	-	-	-	-	√	-	-	-
		15	*Tremella fuciformis*	Logwood, twigs	Edible, Medicinal	√	-	-	-	-	√	-	-	-
		16	*Tremellodendropsis tuberosa*	Soil	Nonedible	√	-	-	-	-	-	-	-	-
	Auriculariaceae	17	*Auricularia auricula-judae*	Logwood, twigs	Edible, Medicinal	√	-	√	√	√	√	√	-	-
		18	*Auricularia mesenterica*	Logwood, twigs	Edible	√	-	-	-	-	√	-	-	-
		19	*Auricularia delicata*	Logwood, twigs	Edible	√	-	-	√	√	√	√	-	-
		20	*Auricularia sp. 1*	Logwood, twigs	Edible	√	-	-	√	√	-	-	-	-

Division	Family	No.	Species	Substrate	Benefits	Collection Site			Collection Time						
						A	B	C	Oct	Des	Jan	Feb	Mar	Apr
	Exidiaceae	21	*Protohydnum sclerodontium*	Logwood, twigs	Nonedible	√	-	√	√	√	-	√	-	-
	Russulaceae	22	*Russula fragilis*	Soil	Edible	-	√	-	√	-	√	√	-	-
	Auriscalpiaceae	23	*Auriscalpium vulgare*	Pines cone	Nonedible	-	√	-	√	-	√	-	-	-
	Stereaceae	24	*Stereum hirsutum*	Logwood, twigs	Nonedible	√	-	-	√	-		-	-	-
		25	*Stereum ostrea*	Logwood, twigs	Nonedible	√	√	-	√	-	√	-	-	-
	Clavariaceae	26	*Clavulinopsis fusiformis*	Soil	Nonedible	√	-	-	√	-	-	-	-	-
		27	*Clavaria acuta*	Soil	Nonedible	√	-	-	√	-	-	-	-	-
	Hygrophoraceae	28	*Hygrocybe ceracea*	Soil, litter	Nonedible	√	-	-	√	-	-	-	-	-
	Marasmiaceae	29	*Baeospora myosura Singer*	Pines cone	Nonedible	-	√	-	√	√	-	-	-	-
		30	*Marasmiellus candidus*	Leaf litter, twigs	Nonedible	√	-	-	-	√	-	-	-	-
		31	*Marasmiellus nigripes*	Leaf litter, twigs	Nonedible	√	-	-	-	√	-	-	-	-
		32	*Marasmiellus ramealis*	Twigs	Nonedible	√	-	-	-	-	-	-	√	-
		33	*Marasmius rotula*	Leaf litter, twigs	Nonedible	√	√	-	√	-	-	-	-	-
		34	*Marasmius haematocephalus*	Leaf litter, twigs	Nonedible	√	√	-	√	-	-	-	-	-
		35	*Marasmius siccus*	Leaf litter, twigs	Nonedible	√	√	-	√	-	-	-	-	-
		36	*Marasmius oreades*	Leaf litter, twigs	Nonedible	√	-	-	-	-	-	√	√	-
		37	*Marasmius nummularius*	Leaf litter, twigs	Nonedible	√	-	-	√	-	-	-	-	-
		38	*Marasmius araucariae*	Leaf litter, twigs	Nonedible	√	-	-	-	-	-	-	-	-
		39	*Marasmius guyanensis*	Leaf litter, twigs	Nonedible	√	-	-	-	√	-	-	-	-
		40	*Marasmius sp. 2*	Leaf litter, twigs	Nonedible	√	-	-	-	√	-	-	-	√
		41	*Trogia infundibiliformis*	Twigs	Nonedible	√	-	-	-	-	-	-	√	-
	Agaricaceae	42	*Lepiota helveola*	Soil	Nonedible	√	-	-	-	-	-	-	√	-
		43	*Agaricus sp.*	Soil	Nonedible	√	-	-	√	-	-	-	√	-
		44	*Leucocoprinus sp.1*	Living tree	Nonedible	√	-	-	-	-	√	-	-	-
		45	*Leucocoprinus brebissonii*	Soil, litter	Nonedible	√	-	√	√	-	-	-	-	-

Division	Family	No.	Species	Substrate	Benefits	Collection Site			Collection Time					
						A	B	C	Oct	Des	Jan	Feb	Mar	Apr
		46	*Calvatia craniiformis*	Soil	Edible, Medicinal	-	-	√	√	-	-	√	√	-
	Mycenaceae	47	*Mycena rosea*	Soil	Nonedible	√	√	-	√	-	-	-	-	-
		48	*Mycena manipularis*	Twigs	Nonedible	√	√	-	-	-	√	-	√	-
		49	*Mycena vitilis*	Leaf litter, twigs	Nonedible	√	-	-	√	-	-	√	-	-
		50	*Mycena albicocapilaris*	Leaf litter, twigs	Nonedible	√	-	-	-	-	-	√	√	-
	Psathyrellaceae	51	*Parasola plicatilis*	Logwood	Nonedible	√	-	-	√	-	-	√	√	-
		52	*Coprinopsis fragilisimus*	Twigs	Nonedible	√	-	-	√	√	-	√	-	-
		53	*Coprinellus disseminatus*	Logwood	Nonedible	√	-	-	-	-	√	-	-	-
		54	*Flammulina velutipes*	Stump, Logwood	Edible	√	-	-	√	-	-	-	-	-
	Lyophyllaceae	55	*Termitomyces microcarpus*	Termites nest	Edible	√	-	-	-	-	-	√	-	-
		56	*Termitomyces umkowaan*	Termites nest	Edible	√	-	-	-	-	-	-	√	-
		57	*Termitomyces sp. 2*	Termites nest	Edible	√	-	-	-	-	-	√	-	-
	Physalacriaceae	58	*Oudimansella sp.*	Logwood, twigs	Nonedible	√	-	-	√	√	-	-	-	-
		59	*Cytotrama asprata*	Logwood	Nonedible	√	-	-	√	-	-	-	-	-
		60	*Cytotrama sp.*	Twigs	Nonedible	√	-	-	√	-	-	-	-	-
	Inocybaceae	61	*Inocybe rimosa*	Soil	Nonedible	√	-	-	√	-	-	-	√	-
	Nidulariaceae	62	*Cyathus striatus*	Twigs	Nonedible	√	-	-	-	-	-	-	√	-
	Schizophyllaceae	63	*Schizophyllum commune*	Logwood, Twigs	Edible, Medicinal	√	-	-	√	-	-	-	-	√
		64	*Lycoperdon perlatum*	Twigs	Edible, Medicinal	√	-	-	√	-	-	-	-	-
		65	*Lycoperdon echinatum*	Soil, litter	Medicinal	√	-	-	-	√	-	-	-	-
		66	*Lycoperdon pyriforme*	Twigs	Medicinal	√	-	-	-		-	-	-	√
	Amylocorticiaceae	67	*Plicaturopsis crispa*	Logwood	Nonedible	√	-	-	√	√	-	√	√	-
	Pterulaceae	68	*Pterula subulata*	Twigs	Nonedible	√	-	-	-	√	√	√	-	-
	Crepidotaceae	69	*Crepidotus sp.*	Twigs	Nonedible	√	-	-	-		√		√	-
	Cortinariaceae	70	*Gymnophillus sapineus*	Stump, Logwood	Nonedible	√	√	-	√	√	√	√	√	-
	Tricholomataceae	71	*Omphalina pyxidata*	Logwood, twigs	Nonedible	√	-	-	-	√		√	-	-
		72	*Omphalina sp.2*	Logwood, Twigs	Nonedible	√	-	-	-	√	√	-	-	-
		73	*Pleurotus ostreatus*	Logwood, twigs	Edible	√	-	-	-	-	-	√	-	√

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						A	B	C	Oct	Des	Jan	Feb	Mar	Apr
		74	*Pleurotus djamour*	Logwood, Twigs	Edible	√	-	-	-	-	-	√	-	√
		75	*Hebeloma albidulum*	Litter, Twigs	Nonedible	√	-	-	-	√	-	-	√	-
	Hymenochaetaceae	76	*Coltricia cinnamomea*	Soil, litter	Nonedible	-	√	-	-	√	-	-	√	-
		77	*Coltricia montagnei*	Soil, litter	Nonedible	-	√	-	-	√	-	-	-	-
		78	*Phellinus tremulae*	Logwood	Nonedible	-	√	-	-	-	-	-	-	-
		79	*Phellinus sp.*	Logwood	Nonedible		-	√	-	-	-	-	√	-
	Sclerodermataceae	80	*Scleroderma citrinum*	Soil	Medicinal	√	-	√	-	-	-	-	√	-
	Boletaceae	81	*Boletellus russellii*	Soil	Nonedible	√	√	-	-	√	-	√	-	-
		82	*Boletellus emodensis*	Soil	Nonedible	-	√	√	-	√	-	-	√	-
		83	*Boletus auripes*	Soil	Nonedible	-	√	-	-	√	√	-	-	-
		84	*Boletus edulis*	Soil	Edible	-	√	-	-	√	-	-	√	-
	Tapinellaceae	85	*Tapinella corrugata*	Soil	Nonedible	-		-	-	-	-	-	-	-
	Suillaceae	86	*Suillus luteus*	Soil	Edible	-	√	-	√	√	√	-	-	-
		87	*Suillus bovinus*	Soil	Edible, Medicinal	-	√	-	-	√	-	-	-	-
	Geastraceae	88	*Geastrum saccatum*	Soil	Nonedible	√	-	-	-	√	√	-	-	-
		89	*Geastrum quadrifidum*	Soil	Nonedible	√	-	-	-	-	-	-	√	-
		90	*Geastrum baculycristallum*	Soil	Nonedible	√	-	-	-	-	-	√	-	-
	Polyporaceae	91	*Polyporus alveolaris*	Logwood, twigs	Nonedible	√	-	-	-	-	-	√	-	-
		92	*Trametes versicolor*[a,b]	Logwood, Twigs	Medicinal	√	√	√	√	√	√	√	√	√
		93	*Trametes gibbosa*	Logwood, twigs	Nonedible	√	√	-	√	-	√	√	-	-
		94	*Trametes pubescens*	Logwood, twigs	Nonedible	√	-	-	√	√	-	-	-	-
		95	*Earliella scabrosa*[a]	Logwood, twigs	Nonedible	√	√	√	√	√	√	-	-	√
		96	*Hexagonia tenuis*[a,b]	Twigs	Nonedible	√	√	√	√	√	√	√	√	√
		97	*Pycnoporus sanguineus*	Logwood	Nonedible	√	√	-	-	-	-	√	-	-
		98	*Lenzites betulina*	Logwood	Nonedible	√	-	-	-	-	-	-	√	-
		99	*Tyromyces chioneus*	Logwood	Edible, Medicinal	√	-	-	-	-	-	-	√	-
		100	*Lentinus fasciatus*	Logwood	Edible	√	-	√	√	-	-	-	-	√
		101	*Lentinus sajor-caju*	Logwood	Edible	√	-	-	-	-	-	-	-	√
		102	*Lentinus polychrous*	Logwood	Edible	√	-	-	-	-	-	-	-	√
		103	*Lentinus roseus*	Logwood	Edible	√	-	-	-	-	-	-	√	-

Division	Family	No.	Species	Substrate	Benefits	Collection Site			Collection Time					
						A	B	C	Oct	Des	Jan	Feb	Mar	Apr
		104	*Lentinus squarosulus*	Logwood	Edible	-	√	-	-	-	-	√	-	-
		105	*Microporus xanthopus*	Logwood, twigs	Edible	√	√	-	√	√	-	√	√	√
	Ganodermataceae	106	*Ganoderma applanatum*[a]	Logwood	Medicinal	√	√	√	√	-	√	√	√	-
		107	*Ganoderma resinaceum*	Logwood	Medicinal	-	-	√	-	-	-	-	-	√
		108	*Ganoderma sp. 1*	Logwood	Medicinal	-	-	√	-	-	-	-	√	-
		109	*Amauroderma rude*	Soil	Nonedible	√	-	-	√	-	-	-	-	-
		110	*Amauroderma rugosum*	Soil	Nonedible	√	-	-	√	-	-	-	-	-
	Fomitopsidaceae	111	*Daedalea quercina*	Logwood	Nonedible	-	-	√	-	-	-	-	√	-
		112	*Ischnoderma resinosum*	Logwood	Nonedible	√	-	-	√	-	-	-	-	-
	Meruliaceae	113	*Clymacodon septentrionale*	Stump, Logwood	Nonedible	√	-	-	-	-	-	-	-	√
		114	*Cymatoderma elegans*	Twigs	Nonedible	√	√	-	√	-	-	-	√	-
	Gomphaceae	115	*Ramaria fennica*	Soil	Nonedible	√	-	-	√	-	-	-	-	√
		116	*Ramaria gracilis*	Soil	Nonedible	√	-	-	√	-	-	-	-	√
		117	*Ramaria formosa*	Soil	Nonedible	√	-	-	√	-	-	-	-	-
		118	*Ramariopsis kunzei*	Soil	Nonedible	√	-	-	√	-	-	-	-	-
	Thelephoraceae	119	*Thelephora ganbajun*	Litter, Soil	Edible, Medicinal	√	-	-	√	-	-	-	-	-
		120	*Thelephora cuticularis*	Soil	Nonedible	√	-		√	-	-	-	-	√
	Dacrymycetaceae	121	*Dacryopinax spathularia*	Logwood	Nonedible	√	-	√	-	-	-	√	-	-
		122	*Calocera cornea*	Logwood	Nonedible	√	-	-	-	-	-	-	-	√
		123	*Dacrymyces stillatus*	Logwood	Nonedible	√	-	-	-	-	-	-	√	-
Total						105	27	20	57	34	35	34	34	18
Composition (%)						85.37	21.95	16.26	46.34	27.64	28.46	27.64	27.64	14.63

Composition (%) = (total number of macrofungi occurred/total of macrofungal taxa) × 100.
(√) present; (–) absent.
[a] Species occurred in three collection sites.
[b] Species occurred in six collection months

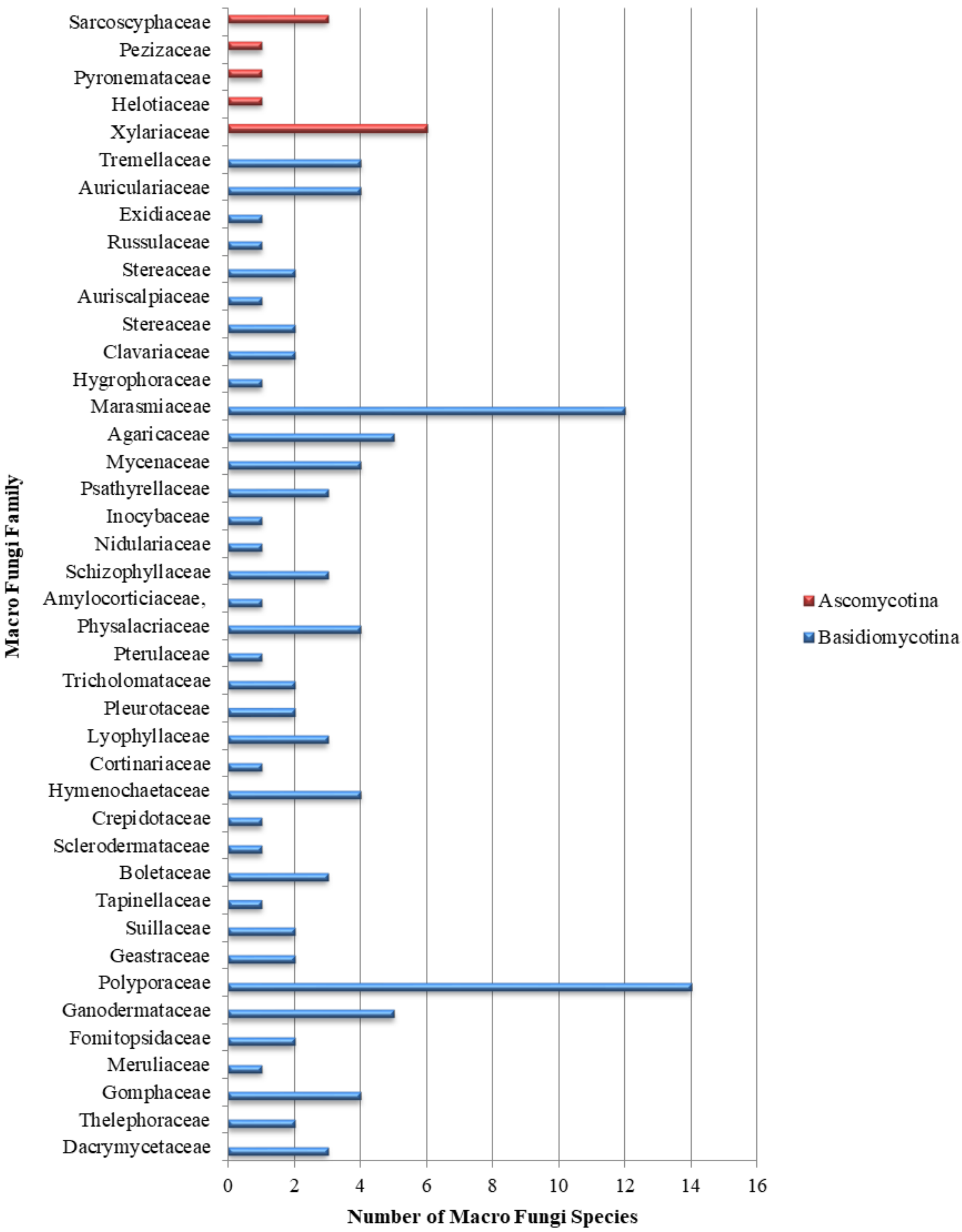

Figure 2. Number of Macro Fungi Species in Each Family Found in Pocut Meurah Intan Grand Forest Park, Saree, Aceh Besar Regency

Macrofungi from Tahura PMI were dominated by the Basidiomycota division with almost 90%, while the order level is dominated by Agaricales and Polyporales (39% and 21% respectively). The Agaricales, which are considered cosmopolitan fungi grow easily in a variety of habitats, from the Arctic to

Tropical. Meanwhile, some are confined to specific regions, and others grow in geographically dispersed areas [14]. This is similar to the Polyporales order, which possesses the ability to produce annual fruit bodies. The existence of these two orders was reported both dominate the Enggano Island and Bengkulu [15]. Within the family, Polyporaceae was discovered to be relatively high compared to other families in terms of macrofungi growth potential. This is evidenced by the huge number of fungus species (14) found at the research site. In addition, Marasmiaceae is the second most numerous family (12 species) in Tahura PMI (**Figure 3**). Similar findings which recorded the highest number of Polyporaceae species were also observed in the study in Malaysia and Philippines [16] [17].

Figure 3. Representation of macrofungi from (**a-f**) the Polyporaceae family and (**g-l**) the Marasmiaceae family found in Pocut Meurah Intan Grand Forest Park. a). *Polyporus alveolaris*, b). *Earliella scabrosa*, c). *Lentinus polychrous*, d). *Ganoderma resinaceum*, e). *Septentrionalis climacodon*, f). *Amauroderma rude*, g). *Marasmiellus candidus*, h). *Marasmius siccus*, i). *Marasmius araucariae*, j). *Mycena vitilis*, k). *Filoboletus manipularis* and l). *Trogia infundibiliformis*.

Fungi grow in two main habitats, ligneous (wood) and terrestrial (soil), which consist of different growth substrates. The terrestrial habitat contains debris, termite mounds, and nests, as well as soil surface, while the ligneous substrate consists of roots, stumps, logs, twigs, leaves, and dead twigs [18]. Generally, habitat and substrate are inseparable from fungi life, because it is the place where they grow, and it is a source of their nutrition. Several species show specificities in the choice of their growing habitat such as open areas with sufficient light, meanwhile, others prefer protected and woody habitats. A study reported that the diversity of the species of macrofungi is related to their habitat, which is mostly living on dead substrates or decaying wood debris [19].

The physical distribution of macrofungi at Tahura PMI was studied at three collecting sites. Collection site A had the largest percentage of macrofungi species composition (85.37 %) of the three collection locations, followed by collection site B (21.95 %). Meanwhile, collection site C had the lowest composition of all the collecting locations (16.26%). The high species composition at sites A and B can be attributed to the availability of massive forest litter as a substrate for growing macrofungi. Site A is a diversified woodland region with a large canopy and many fallen trees and branches. In contrast, Site B is a homogeneous woodland tract dominated by *Pinus merkusii* with shrubs. Previous research on Mount Merbabu National Park discovered the same phenomenon, finding that the diversity of macro mushroom species was larger in the mixed forest than in pine forests (80 and 30 species respectively) [20]. It is believed that *P. merkusii* leaf litter contains allelochemical substances such as phenols and flavonoids which can suppress the growth of macrofungi. Meanwhile, the low composition of macrofungi species at Site C in Tahura PMI was caused by habitat degradation caused by the community's agricultural activities. The presence of fallen trees as a cellulose-lignin-based substrate and an undisturbed ecosystem, according to an early study, is positively correlated with the composition of macrofungi species in an area [21]. Habitat degradation is a serious threat to fungal diversity [22]. Environments with sustainable forests, had the highest sporocarp abundance and the greatest morphotype richness, while degraded and modified forests had the lowest.

b. Fungi growth substrate and environment conditions in Tahura PMI

The macrofungi found in Tahura PMI grow on different substrates. They generally grow singly or scattered in large numbers or groups. From a total of 123 species found, 56%, 17%, and 22% grew on weathered wood, leaf litter, and soil respectively. Also, 5% grew on unique (rare) substrates, these include 3 species in termite nests (found in soil), 2 on pine conifer cones, and 1 in parasites on living trees (**Figure 4A**). Furthermore, several species of macrofungi grow on more than one substrate, however, the percentage was smaller than those on one (**Figure 4B**). Each fungus has a substrate preference; some species prefer growing media such as humus, litters of leaves, fruit, fallen and standing trees, as well as live tree bark or animal dung [23]. Additionally, different substrates usually result in the growth of various types of fungi. Based on our results, weathered wood is the dominant habitat for most species of macrofungi in Tahura PMI. A study reported that the macrofungi in an area experience succession, which involves changes in the composition of the community and is often related to the variation in the quality of the substrate on which they grow [24]. Additionally, during the decomposition stage of fallen large tree trunks has been observed that the fungus grows differently, some would develop in the early stages while others grow afterward [25].

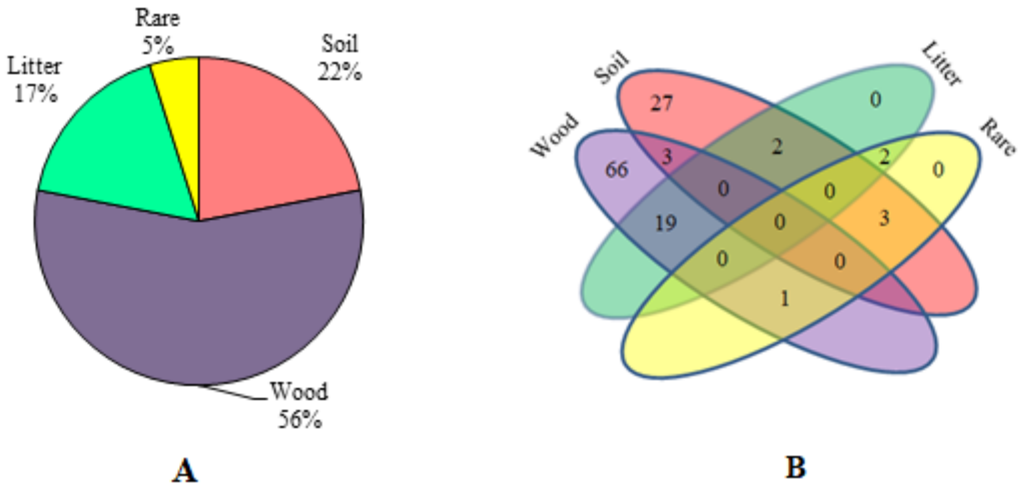

Figure 4. (A). Percentage of growing places and (B). Venn diagram analysis for the use of macrofungi substrate in Tahura PMI.

Each Macrofungi species is generally specific and require the characteristics of different environmental factors. Furthermore, the spread and growth of each macrofungi is determined by these environmental factors and each species are able to survive under some specific abiotic conditions that lies within a certain tolerance range suitable for the organism. The physical and chemical environmental factors measured in Tahura PMI are shown in **Table 2**.

Table 2. Conditions of Environmental Physical Factors in Tahura PMI.

No.	Environmental Physical Factors	Measurement Results	Unit
1	Air temperature	27.7-37.9	°C
2	Humidity	70-82	%
3	Soil pH	4.9-5.8	
4	Soil moisture	67-100	%
5	Light intensity	250-951	Lux

During the six-month sampling period in Tahura PMI, October-January had the highest macrofungi species composition (46.34%, 27.64%, and 28.46%, respectively), while February-April had the lowest (27.64%, 27.64%, and 14.63%). Changes in environmental conditions are responsible for this disparity. Tahura PMI experiences low temperatures and heavy humidity during the rainy season, which lasts from October 2018 to January 2019, whereas the hot dry season begins in February 2019. Several studies demonstrate that more macrofungi were found during the rainy season than it was during the dry season [24][26][27]. This is due to the fact that the production of fruiting bodies in macrofungi usually requires relatively high humidity and low temperatures [28]. The optimum temperature for fruit body development ranges from 10-18oC with humidity exceeding 80% [29]. Therefore, the distribution of macrofungi may vary depending on the climatic conditions at the time of collection and the particular area.

Factors such as geographic location, altitude, temperature, humidity, light, and surrounding flora greatly influence their growth and development. There are differences in the environmental factors measured at each sampling point in the Tahura PMI area, however, the conditions are still in the range of macrofungi growth. Furthermore, the ability of fungi to live in an area is strongly influenced by environmental factors, availability of substrate, vegetation, and human activities. From an ecological point of view, temperature, light, and water are the most important environmental factors. A significant increase in temperature also improves the activity of enzymes, which further affects the growth of fungi [29]. However, an excessive increase in temperature disrupts metabolic processes and terminates fungi growth. The optimum temperature required by fungi ranges between 15^{o}C-40^{o}C. Typically, fungi are known as organisms that require high humidity levels for their growth. Relative humidity affects the initiation of fruit body formation in fungi [30]. Moreover, relative humidity is between 95% and 100%, while maximum fruit body growth requires 50-75% of water content in the substrate.

The intensity of sunlight also has a significant effect on the temperature and the humidity of air in the location of macrofungi. Fungi require light for the formation of fruit bodies, and also for the pigmentation and formation of structures needed for the development of sexual and asexual reproduction [31]. Generally, high light intensity hinders the growth of fungi, because it inhibits the formation of structure for the reproductive organs and fungi spores. Furthermore, the magnitude of light intensity at a research location is strongly influenced by the vegetative cover of the plants in which the macrofungi grow.

Therefore, the optimum light intensity for fungi growth is between 380 and 720 Lux [1].

The presence of macrofungi is very important to humans and other organisms in the environment or habitat in which they grow. They live mainly as saprophytes, which act as decomposers of dead organic matter such as weathered wood and litter. Furthermore, the results of its decomposition are in the form of simple molecules, which is useful to the surrounding plants as a source of nutrition. In general, over 80% of the species found in the field act as decomposers of organic matter both in litter and on dead wood stems, branches, and twigs. Additionally, fungi grow well on rotten wood because they contain nutrients [32].

4. Conclusion

In summary, the macrofungal diversity in Tahura PMI is considerably high, as evidenced by the identification of 123 species, with Agaricales and Polyporales as the most dominant orders. A total of 28 species show potential as alternative food sources, while 17 species possess medicinal value. The greatest species richness was recorded in habitats with heterogeneous vegetation (85.37%), followed by homogeneous forests (21.95%) and agricultural zones (16.26%). Weathered wood served as the primary growth substrate for fungi (56%), and species richness was higher during the rainy season than in the dry season. The abundant presence of macroscopic fungi presents valuable opportunities for community-based socio-economic development. Therefore, comprehensive efforts are needed to document and conserve these biological resources, along with further research on species with medicinal potential in Tahura PMI.

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