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Species Composition of Macrofungal in Various Ecosystem in Badung Regency, Bali

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Abstract. Badung Regency is one of the administrative regions located in Bali Province with diverse ecosystems due to high topographic variations. This topographic heterogeneity affects the region's biodiversity, including the diversity of macrofungal. Macrofungi possess distinctive morphological features and potential uses, however, data regarding their diversity in this region remain insufficient. This research aims to assess the diversity of macrofungal across five ecosystem types (karst, mangrove, lowland, riparian, and highland ecosystems) in Badung Regency, Bali. The research was conducted from January to May 2025 using the belt transect method, with transect placement by purposive sampling. The results revealed that the composition of macrofungal species in Badung regency is comprised of 70 species, categorized in 43 genera and 26 families. Polyporaceae is the family with the highest number of species (18 species) which is dominated by the genus *Trametes* (eight species). The highland ecosystem in Jempanang recorded the highest species richness (39 species) and the highest diversity index (H'=3.00). On the contrary, the karst ecosystem in Ungasan exhibited the lowest species richness (three species) and diversity index (H'=0.60). The highest genus similarity index was observed between the lowland and riparian ecosystems (SI=59.26%). Conversely, the lowest was between karst and mangrove ecosystems (SI=0.00%). Environmental factors such as air temperature, air humidity, soil pH, soil temperature, soil moisture, and the presence of organic substrates are related to the occurrence and distribution of macrofungal across the research sites.

Keywords: Food Security; Home Gardens; Local Knowledge; LUVI.

I. INTRODUCTION

Indonesia is widely known as one of the mega-biodiversity countries in the tropical region. Biodiversity encompasses all variations in form/shape, appearance, number, and characteristics possessed by living things [1]. One of these biodiversity aspects is fungi. Fungi are eukaryotic organisms that play an ecological role as decomposers, mutualists, or pathogens with natural distribution in various habitats around the world [2]. Based on their size, fungi are divided into microscopic fungi or microfungi (small and should be observed by a microscope) and macroscopic fungi or macrofungi (large and easily distinguished by the naked eye) [3].

Macrofungi generally occupy ecosystems with a temperature range of 22—35 ºC and humidity ranging from 70—90% [3]. The type of ecosystem as the main habitat of macrofungal is the forest due to the high humidity levels, which results in it being easy for fungi to adapt [4]. In addition, altitude is also an important factor influencing the occurrence of macrofungal. The higher of the altitude, the lower the air temperature. Variations in altitude and temperature gradients influence macrofungal diversity and distribution by altering microclimatic conditions, particularly temperature and humidity, across ecosystems [5].

Badung Regency is one of the regencies in Bali that has diverse elevations and ecosystems. There are six subdistricts in Badung Regency, namely South Kuta, Kuta, North Kuta, Mengwi, Abiansemal, and Petang, each of with varying elevations and ecosystems. Subdistricts in the southern part, such as South Kuta, Kuta, and North Kuta with low elevations and long coastlines are dominated by coastal ecosystems such as mangroves, beach forest, and karst. The mangrove ecosystem in Nusa Dua, Subdistrict of South Kuta, is particularly interesting because it has a white sandy substrate, whereas most mangrove substrates in Bali are blackish sandy mud [6]. Furthermore, karst ecosystems are also only found in South Kuta, one of which is in Ungasan Village [6]. The Subdistrict Mengwi and Abiansemal have more varied elevations and are dominated by lowland forests with evergreen vegetation.

One of the villages in Abiansemal Subdistrict, the Bongkasa Pertiwi Village, has a riparian ecosystem that separates the terrestrial ecosystem from the river ecosystem. The Subdistrict Petang located in the northern part with the highest elevation in Badung Regency, dominated by evergreen highland forests [6].

The variation in landscape and ecosystems in Badung Regency will certainly affect the existing biodiversity, including the composition of macrofungal species. Therefore, research on macrofungal diversity is still limited. Some data on macrofungal in Bali are in the Jimbaran Hills, which obtained 20 species from the Basidiomycota Division [7], and in West Bali National Park, which obtained 22 species from the Basidiomycota Division [8]. Research in other locations, such as Kemujan Island (Central Java Province) with its mangrove forest vegetation, coastal vegetation, and parks, obtained 65 macroscopic fungal species from the Basidiomycota Division [9]. Meanwhile, in the Londerang Peat Protection Forest (Jambi Province) obtained 39 macroscopic fungal species from two divisions: Ascomycota and Basidiomycota [10].

In general, extensive research has been conducted on macrofungi, but still limited to their use as medicine and food ingredients. Meanwhile, primary data on the diversity remains insufficient, particularly in Badung Regency, Bali. So, this study aims to determine the diversity of macrofungal species and analyze the similarity index of macrofungal genera in five types of ecosystems in Badung Regency, namely karst, mangrove, lowland, riparian, and highland ecosystems. The results of this study are expected to be used as a reference regarding macrofungal diversity in Badung Regency, Bali.

II. METHODS

The research was conducted from January to May 2025 in five different ecosystem types in Badung Regency: mangroves (Benoa Village), karst (Ungasan Village), lowland evergreen forest (Mengwi Village), riparian (Bongkasa Pertiwi Village), and highland evergreen forest (Jempanang Hamlet, Belok Sidan Village) (Fig. 1). Sample management was carried out at the Plant Structure and Development Laboratory and the Plant Taxonomy Laboratory of the Biology Study Program, Faculty of Mathematics and Natural Sciences, Udayana University.

Research Procedure

Research Sampling

Sampling was conducted using the belt transect method as the sampling unit, with 1 km of total distance and 10 m width (the total distance was divided into several transects according to the conditions of the research location). The transect placement was carried out using purposive sampling based on ecosystem characteristics, prioritizing areas that were still natural and had the potential to be habitats for macrofungi. The starting point of the exploration was marked using GPS (Garmin 64s), then the tracking feature was activated to determine the exploration pattern and length of the exploration route.

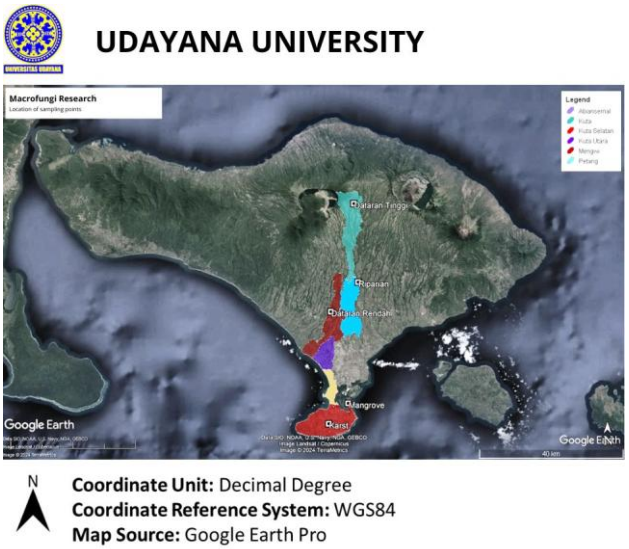


Fig.1. Sampling sites of macrofungal research

Each species of observed macrofungi was photographed and counted, followed by sample collection. Macrofungal samples were collected by picking the species and stored in paper envelopes or zip-lock bags. The paper envelopes/zip-lock bags were labelled with the collection number, collector's name, date of collection, and collection area. The samples were then stored in sample boxes. Further sample preparation was carried out at the Laboratory of Plant Structure and Development and Plant Taxonomy, in Biology Study Program, Faculty of Mathematics and Natural Sciences, Udayana University. Each macrofungal sample was completed with detailed records of the habitat type and substrate where the sample was found. The macrofungal substrates are classified as living tree, dead tree, detritus, and soil.

Measurement of Environmental Factors Affecting Macrofungi

Environmental factors were measured based on microclimate, namely air temperature, air humidity, light intensity, soil temperature, soil moisture, and soil pH. Measurements were taken at three points approximately 250 meters apart at each research location. Air temperature, air humidity, and light intensity were measured using a Lutron LM-8000A (Taiwan). Soil moisture and soil pH were measured using a Lutron PH-

220S soil tester (Taiwan). Soil temperature was measured using a soil thermometer.

Characterization and Identification of Macrofungi

The species characterization and identification were carried out at the Laboratory of Plant Structure and Development and Plant Taxonomy, Biology Program, Faculty of Mathematics and Natural Sciences, Udayana University. Comprehensive observation and documentation were done by showing the cap, lamellae, and stem. Subsequently, characterization was carried out by describing the organs of the fungi. Identification was referring to primary literature such as *The Mushroom Guide and Identifier* [11], *California Mushroom: The Comprehensive Identification Guide* [12], and *Mikologi: Ilmu Jamur* [13]. In addition, digital literature was also used through journal searches and related references.

Data Analyses

Diversity index

Data analyses in this research used the Shannon-Wiener Index of Diversity. The Shannon-Wiener Index of Diversity indicates the harmony, richness, and diversity of a species [14]. The formula for the Shannon-Wiener Index of Diversity is as follows:

$$H' = -\sum_{i=1}^{s} \left(\frac{ni}{N}\right) \left(\ln \frac{ni}{N}\right)$$

Description:

H'	=	Shannon-Wiener Index of Diversity
ni	=	Number of individuals of a species
N	=	Total number of individuals of all species

Similarity index

The Sorensen Index of Similarity is used to compare or determine the similarity of macrofungal species between research locations [15]. The species found in this research were very different, so the Sorensen Index of Similarity was calculated using genus data. The formula used is as follows:

$$IS = \frac{2C}{A+B} \times 100\%$$

Description:

IS = Sorensen Index of Similarity

A = Number of macrofungal genera at location A

B = Number of macrofungal genera at location B

C = Number of macrofungal genera in both locations

III. RESULTS AND DISCUSSION

Result

Species composition of macrofungal in Badung Regency Area

The results of research on macrofungal diversity show variations in each ecosystem. A total of 70 species of macrofungal were found in five ecosystems in Badung Regency, belonging to 43 genera, 26 families, and two divisions, namely Ascomycota and Basidiomycota. Macrofungal species from the Ascomycota division were only found in lowland, riparian, and highland ecosystems, consisting of eight species from five different genera and families (Table 1). In contrast, macrofungi from the Basidiomycota division were distributed across the five research ecosystems, consisting of 62 species belonging to 38 genera and 21 families (Table 2). Several macrofungal species found in Badung Regency are shown in Fig. 2.

In terms of species number, Polyporaceae is the family with the highest species diversity (18 species). Among these species, the genus *Trametes* is the most dominant with eight species. Another family with high species diversity is Ganodermataceae. In this research, only one genus from this family was found, namely the genus *Ganoderma* with a total of six species.

This research also found fungi from the genus *Auricularia*, which several of the species have been used as food (such as *Auricularia auricula* and *Auricularia delicata*). Cumulatively, there are four species from this genus, namely *Auricularia auricula*, *Auricularia delicata*, *Auricularia cornea*, and *Auricularia* sp. On the other hand, there are 14 families that have a low occurrence rate, represented by only one species.

The macrofungal families from the Basidiomycota division represented by a single species are Bankeraceae, Bolbitaceae, Dacrymycetaceae, Hymenochaetaceae, Omphalotaceae, Omphalinaceae, Schizophyllaceae, Strophariaceae, Stereaceae, and Tricholomataceae. At the species level, the species with the highest number of individuals were *Daldinia childiae* (112 individuals), *Marasmiellus candidus* (98 individuals), and *Stereum ostreata* (96 individuals). In this research, there were several species with only one individual, namely *Cymatoderma caperatum*, *Ganoderma* sp. 2, *Microporus* sp., *Mycena* sp., *Pecipes* sp., *Parasola* sp., and *Trametes* sp. 1.

Each ecosystem has a different species composition. The distribution of species numbers based on ecosystem type is summarized in Fig. 3. The order of ecosystems from lowest to highest species numbers is as follows: (1) karst ecosystems (3 species, 2 genera, 1 family); (2) mangrove ecosystems (5 species, 5 genera, 5 families); (3) lowland ecosystems (12 species, 12 genera, 10 families); (4) riparian ecosystems (17 species, 15 genera, 13 families); and (5) highland ecosystems (39 species, 26 genera, 19 families).

TABLE 1.
Composition of Macrofungi Species of the Ascomycota Division Found in Badung Regency, Bali

No	Species	Genus	Family	Location					Number of individuals
				K	M	LL	R	HL	
1	*Cookeina* sp.	*Cookeina*	Sarcoscyphaceae				P		20
2	*Cookeina tricholoma*	*Cookeina*	Sarcoscyphaceae					P	8
3	*Cordyceps tenuipes*	*Cordyceps*	Cordycipitaceae			P			2
4	*Daldinia childiae*	*Daldinia*	Amphisphaeriaceae					P	112
5	*Scutellinia scutellata*	*Scutellinia*	Pyronemataceae					P	25
6	*Xylaria cubensis*	*Xylaria*	Xylariaceae				P		35
7	*Xylaria longipes*	*Xylaria*	Xylariaceae				P	P	61
8	*Xylaria polymorpha*	*Xylaria*	Xylariaceae			P		P	47

Annotations: K=Karst; M=Mangrove; LL=Lowland; R=Riparian; HL=Highland

TABLE 2.
Composition of Macrofungi Species of the Basidiomycota Division Found in Badung Regency, Bali

No	Species	Genus	Family	Location					Number of individuals
				K	M	LL	R	HL	
1	*Auricularia auricula-judae*	*Auricularia*	Auriculariaceae		P	P	P	P	67
2	*Auricularia cornea*	*Auricularia*	Auriculariaceae					P	12
3	*Auricularia delicata*	*Auricularia*	Auriculariaceae					P	61
4	*Auricularia* sp.	*Auricularia*	Auriculariaceae					P	20
5	*Bolbitius* sp.	*Bolbitius*	Bolbitiaceae					P	40
6	*Collybia* sp.	*Collybia*	Tricholomataceae					P	34
7	*Coltricia* sp.	*Coltricia*	Hymenochaetaceae					P	2
8	*Coprinellus disseminatus*	*Coprinellus*	Psathyrellaceae			P			22
9	*Coprinellus micaceus*	*Coprinellus*	Psathyrellaceae				P		6
10	*Coprinellus* sp.	*Coprinellus*	Psathyrellaceae					P	14
11	*Coprinopsis lagopus*	*Coprinopsis*	Psathyrellaceae					P	6
12	*Coprinus* sp.	*Coprinus*	Agaricaceae				P		2
13	*Crinipellis* sp.	*Crinipellis*	Marasmiaceae					P	2
14	*Cymatoderma caperatum*	*Cymatoderma*	Panaceae		P				1
15	*Cyptotrama asprata*	*Cyptotrama*	Physalacriaceae					P	9
16	*Dacryopinax spathularia*	*Dacryopinax*	Dacrymycetaceae				P		40
17	*Favolaschia manipularis*	*Favolaschia*	Mycenaceae				P		15
18	*Favolaschia pustulosa*	*Favolaschia*	Mycenaceae			P			20
19	*Flammulina* sp.	*Flammulina*	Physalacriaceae					P	43
20	*Fomes fomentarius*	*Fomes*	Polyporaceae					P	10
21	*Ganoderma* sp. 1	*Ganoderma*	Ganodermataceae			P			3
22	*Ganoderma* sp. 2	*Ganoderma*	Ganodermataceae				P		1
23	*Ganoderma* sp. 3	*Ganoderma*	Ganodermataceae				P		7
24	*Ganoderma* sp. 4	*Ganoderma*	Ganodermataceae					P	4
25	*Ganoderma* sp. 5	*Ganoderma*	Ganodermataceae					P	7
26	*Ganoderma* sp. 6	*Ganoderma*	Ganodermataceae					P	5
27	*Gymnopilus* sp.	*Gymnopilus*	Strophariaceae					P	5
28	*Hemimycena* sp.	*Hemimycena*	Mycenaceae					P	55
29	*Laccaria* sp.	*Laccaria*	Hydnangiaceae					P	12
30	*Laccaria tortilis*	*Laccaria*	Hydnangiaceae				P		39
31	*Lentinus arcularius*	*Lentinus*	Polyporaceae				P		5
32	*Lentinus* sp.	*Lentinus*	Polyporaceae			P			15
33	*Lentinus tigrinus*	*Lentinus*	Polyporaceae					P	94
34	*Lepiota* sp.	*Lepiota*	Agaricaceae					P	3
35	*Lycoperdon* sp.	*Lycoperdon*	Agaricaceae					P	2
36	*Marasmiellus candidus*	*Marasmiellus*	Omphalotaceae			P			98
37	*Marasmius siccus*	*Marasmius*	Marasmiaceae				P	P	8
38	*Marasmius* sp. 1	*Marasmius*	Marasmiaceae		P				18
39	*Marasmius* sp. 2	*Marasmius*	Marasmiaceae			P			8

No	Species	Genus	Family	Location					Number of individuals
				K	M	LL	R	HL	
40	*Microporus* sp.	*Microporus*	Polyporaceae				P	P	1
41	*Microporus xanthopus*	*Microporus*	Polyporaceae				P	P	15
42	*Mycena* sp.	*Mycena*	Mycenaceae	P				P	1
43	*Oligoporus* sp.	*Oligoporus*	Polyporaceae		P			P	26
44	*Omphalina* sp.	*Omphalina*	Omphalinaceae				P	P	6
45	*Oudemansiella* sp.	*Oudemansiella*	Physalacriaceae				P		3
46	*Parasola* sp.	*Parasola*	Psathyrellaceae				P		1
47	*Pecipes* sp.	*Pecipes*	Polyporaceae					P	1
48	*Phellodon atratus*	*Phellodon*	Bankeraceae			P	P		13
49	*Pluteus* sp.	*Pluteus*	Pluteaceae			P			2
50	*Pseudofavolus* sp.	*Pseudofavolus*	Polyporaceae		P				3
51	*Pycnoporus sanguineus*	*Pycnoporus*	Polyporaceae	P					20
52	*Schizophyllum commune*	*Schizophyllum*	Schizophyllaceae		P				32
53	*Stereum ostreata*	*Stereum*	Stereaceae					P	96
54	*Trametes gibbosa*	*Trametes*	Polyporaceae	P					4
55	*Trametes* sp. 1	*Trametes*	Polyporaceae	P					1
56	*Trametes* sp. 2	*Trametes*	Polyporaceae			P			10
57	*Trametes* sp. 3	*Trametes*	Polyporaceae					P	9
58	*Trametes* sp. 4	*Trametes*	Polyporaceae					P	4
59	*Trametes* sp. 5	*Trametes*	Polyporaceae					P	3
60	*Trametes* sp. 6	*Trametes*	Polyporaceae					P	90
61	*Trametes versicolor*	*Trametes*	Polyporaceae					P	6
62	*Volvariella* sp.	*Volvariella*	Pluteaceae					P	2



Cookeina tricholoma | *Cordyceps tenuipes* | *Favolaschia manipularis*

Cordyceps tenuipes | *Coprinellus disseminatus* | *Cyptotrama asprata*

Figure 2. Several macrofungi species found in Badung Regency, Bali (yellow scale bar = 1 cm; red scale bar = 0.5 cm)

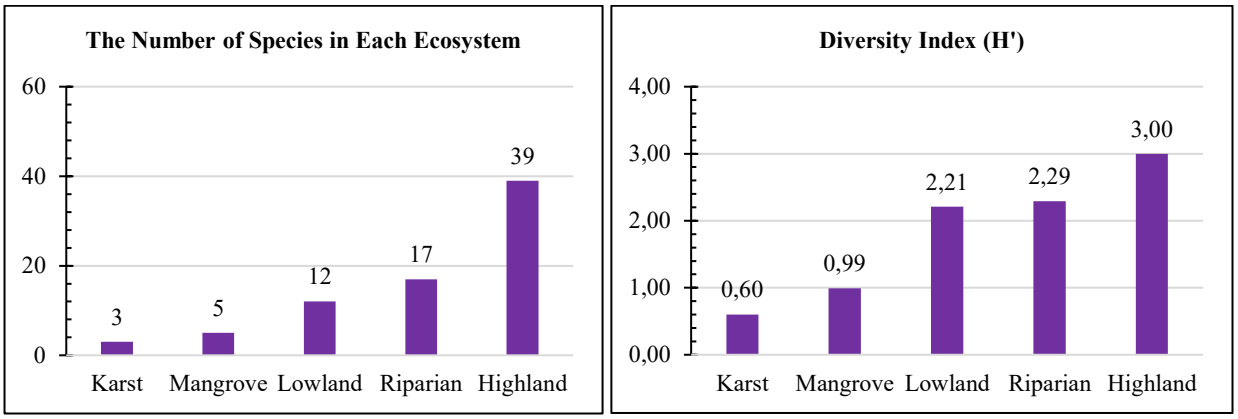


Figure 3. Number of macrofungal species in each ecosystem in Badung Regency (*left fig.*); macrofungal diversity index (H') values in each ecosystem in Badung Regency, Bali (*right fig.*)

Based on the Shannon-Wiener Index of Diversity (H') in Fig. 4, it was recorded that the species diversity index in each ecosystem in Badung Regency had low to moderate species diversity. The highland forest ecosystem in Jempanang Hamlet had the highest macrofungal species diversity (H' = 3.00); on the contrary, the ecosystem with the lowest diversity index value was the karst ecosystem in Ungasan Village (H' = 0.60).

Three ecosystems are classified as moderate, namely the lowland ecosystem in Mengwi Village (H' = 2.21), the riparian ecosystem in Bongkasa Pertiwi Village (H' = 2.29), the highland forest ecosystem in Jempanang Hamlet (H' = 3.00), and two ecosystems are classified as low, namely the mangrove ecosystem in Benoa Village (H' = 0.99) and the karst ecosystem in Ungasan Village (H' = 0.60).

Similarity Index

The analysis of the similarity index of macrofungal used the genus because, at the species level, results showed very different species compositions and required more detailed identification. The similarity index (SI) in this research was divided into five categories, namely SI < 20% (very low), 21-40% (low), 41-60% (medium), 61-80% (high), and >80% (very high).

Based on the research data, the genus similarity index value in the moderate category was found between lowland ecosystems and riparian ecosystems, which was 59.26%. The similarity index value in the low category was between riparian ecosystems and highlands (37.21%) and between lowland ecosystems and highlands (35.00%).

The similarity index value in the very low category was found between karst ecosystems and mangroves (0.00%), mangrove ecosystems and highlands (6.06%), karst ecosystems and highlands (6.67%), mangrove ecosystems and riparian ecosystems (10.00%), mangrove ecosystems and lowlands (11.76%), karst ecosystems with riparian ecosystems (11.76%), and karst ecosystems with lowlands (14.29%). Table 3 presents the similarity index values based on the composition of macrofungal genera across the five research ecosystems.

TABLE 3.
Similarity index values of macrofungal genera across five ecosystems in Badung Regency, Bali

	K	M	LL	R	HL
K					
M	0,00%				
LL	14,29%	11,76%			
R	11,76%	10,00%	59,26%		
HL	6,67%	6,06%	35,00%	37,21%	

Description:
K = Karst (0-3,35 m a.s.l.)
M = Mangrove (50-180 m a.s.l.)
LL = Lowland (217-312 m a.s.l.)
R = Riparian (258-350 m a.s.l.)
HL = Highland (1213-1293 m a.s.l.)

Environmental factors

Environmental factors in the ecosystems observed show varying environmental conditions (Table 4). Based on air temperature, the karst ecosystem has the highest temperature (33.70±1.82°C), while the highland ecosystem has the lowest temperature (24.97±1.00°C). The highest air humidity was found in the mangrove ecosystem, which was 78.90±3.60% and the karst ecosystem showed the lowest air humidity with 62.67±4.65%. Soil pH measurements in the karst ecosystem showed a pH of 7.00±0.50, and the highland ecosystem showed the lowest pH of 5.83±0.29. The highest soil moisture was found in the mangrove ecosystem, which was 54.17±14.43%, and the karst ecosystem had the lowest soil moisture, which was 14.58±3.61%. The karst ecosystem had the highest soil temperature, which was 32.67±0.58°C, and the highlands had the lowest soil temperature, which was 21.17±0.29°C. The karst ecosystem had the highest light intensity at 18600.00±1372.73 Lux, indicating minimal vegetation cover. On the contrary, mangroves had the lowest light intensity at 1261.33±1794.89 Lux, indicating high mangrove vegetation cover.

TABLE 4.
Environmental Factors at the Research Site

Environmental Parameters	Ecosystems				
	Karst	Mangrove	Lowland	Riparian	Highland
Air temperature (°C)	33,70±1,82	30,33±1,10	32,10±0,17	28,30±0,10	24,97±1,00
Air humidity (%)	62,67±4,65	78,90±3,60	65,87±3,33	78,83±0,38	66,97±2,40
Soil pH	7,00±0,50	6,27±0,46	6,83±0,06	6,00±0,00	5,83±0,29
Soil moisture (%)	14,58±3,61	54,17±14,43	33,33±7,22	41,67±7,22	47,92±18,04
Soil temperature (°C)	32,67±0,58	29,00±1,00	27,33±0,58	26,33±0,58	21,17±0,29
Light intensity (Lux)	18600,0 ±1372,73	1261,33±1794,89	1393,33±115,68	2463,33± 283,61	1764,00± 630,21

Environmental factors influence the characteristics of the substrate where fungi grow in each ecosystem. The macrofungal substrates found in this research were dead trees, soil, living trees, and detritus, with the number of species shown in Fig. 5. Dead tree substrates were the substrates with the highest number of species, namely 43 species. Thirteen species of macrofungal were found on living tree substrates. The fungi found on the roots of living trees are *Marasmius* sp. 2, and on the trunks of living trees are *Auicularia delicata*, *Collybia* sp., *Cymatoderma caperatum*, *Daldinia childiae*, *Flammulina* sp., *Fomes fomentarius*, *Ganoderma* sp. 5, *Hemimycena* sp., *Trametes gibbosa*, *Trametes* sp. 6, *Stereum ostreata*, and *Pseudofavolus* sp. A total of 9 macrofungal species were found on soil substrates, namely *Bolbitius* sp., *Crinipellis* sp., *Ganoderma* sp. 1, *Lentinus* sp., *Lepiota* sp., *Parasola* sp., *Phellodon atratus*, *Pluteus* sp., and *Volvariella* sp. The substrate with the lowest number of species was detritus, with six species: *Coprinellus* sp. on coconut fronds; *Favolaschia manipularis*, *Favolaschia pustulosa*, *Marasmiellus candidus*, *Marasmius* sp. 1 on coconut fibers; and *Cordyceps tenuipes* on dead tree roots. Dead trees (including dead wood) are also actually included in detritus, but are separated to facilitate its classification as a macrofungal substrate preference.

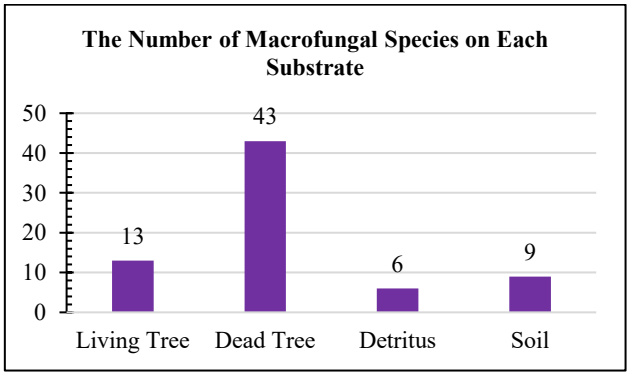


Figure 5. The number of macrofungal species on each substrate

Discussion

Species of Macrofungi

Macrofungi collected from the five research sites consisted of 70 species belonging to 43 genera and 26 families, dominated by fungi of the Basidiomycota division. In similar studies at other locations, the diversity of macrofungal species also tended to be dominated by the Basidiomycota division [16-18]. With a total of 70 species, this certainly indicates that the ecosystem in Badung Regency can support a wide variety of macrofungal species.

On the family level, Polyporaceae dominates the composition of macrofungal species in Badung Regency with 18 species. This family belongs to the order Polyporales, which is highly adaptable and has a hard and sturdy fruit body structure that allows it to survive in extreme weather conditions [19, 20].

On the genus level, *Trametes* and *Ganoderma* are the most found genera at the research site, with eight and six species, respectively. Both genera can adapt to a wide range of environmental conditions and have a high growth capability [21]. Fungi from the *Ganoderma* genus are widely known as one of the fungi with medicinal properties. The bioactive compounds contained in these fungi tend to be developed as an alternative medicines [22]. Besides *Ganoderma*, another fungus, such as *Trametes,* show pharmacological potential, one of which is the species *Trametes versicolor*. This fungus has wound healing, antidiabetic, antimicrobial, antifibrotic, neurotropic, and anti-inflammatory effects [23].

Daldinia childiae is the macrofungal species with the highest number of individuals (112 individuals), but it is concentrated on a single living tree. Several species of the genus *Daldinia* can survive in extreme environmental conditions such as burnt wood and dry habitats [24]. The species with the next highest number of individuals is *Marasmiellus candidus* (98 individuals). This may be because these fungi tend to grow in groups and easily adapt to their surroundings [25]. On the contrary, there are several species with only one individual each because these fungi grow solitarily, only grow under certain conditions, and have limited viability [26, 27].

In this research, the entomopathogenic fungus species *Cordyceps tenuipes* was found on tree roots. This fungus generally infects insects of the Lepidoptera family and colonizes roots [28]. In addition, there is also the fungus *Favolaschia manipularis*, which contains biolumi-

nescence. However, the bioluminescence of this fungus species was categorized as very dim [29].

Diversity Index

In this research, the highest index of macrofungal diversity was found in highland ecosystems. The highland ecosystem in Jempanang consists of forests and coffee agroforestry with dense canopy cover, resulting in low light intensity and creating conditions of lower temperature and high humidity. These conditions support macrofungal growth. Primary forests in highlands with dense vegetation cover and abundant substrate are known as an ideal habitat for fungi [14].

The lowest diversity index was found in karst and mangrove ecosystems. The karst ecosystem in Ungasan Village has low canopy cover, resulting in high light intensity reaching the ground surface. This condition contributes to a decrease in air and soil humidity, which can inhibit the growth and reproduction of macrofungi, particularly in the formation of spores and other reproductive structures. The highly porous nature of karst rock also accelerates groundwater loss, creating dry conditions [30]. Environments with limited availability of decaying wood, low humidity, and high light exposure do not support the survival of most macrofungal species. Therefore, only three fungi species were identified in this study. These three species belong to the Polyporaceae family, which is known to have a higher tolerance to extreme environmental conditions [19]. Different stresses are found in mangrove ecosystems, which are influenced by tidal movement, causing macrofungi to grow only on substrates that are not submerged, such as trunks and prop roots above the highest tide line. Temperatures in this ecosystem also tend to be high, and the humidity remains high due to limited air circulation under the dense tree canopy. This affects macrofungal growth and spore dispersal [17, 31].

Similarity Index

The results of the calculation of the similarity index (SI) value of the genus between ecosystems in Badung Regency varied greatly, but none were in the high similarity range (Table 3). The highest IS value (medium category) was recorded between lowland and riparian ecosystems (59.26%), which could be due to similar altitude and environmental conditions. The very low SI was found between karst and mangrove ecosystems (0.00%), mangrove and highland ecosystems (6.06%), and karst and upland ecosystems (6.67%), indicating very different genus compositions. Species similarity decreases with the transition from mountainous to lowland areas [32]. The composition of macrofungi tended to be similar in vegetation of the same altitude, but changed significantly in vegetation with a greater difference in altitude. This indicates the high turnover of macrofungal communities as altitudinal changes affect microhabitats [33].

Environmental Factors

The air temperature in the five ecosystems is within the range that allows fungi to grow, which is between 24.97±1.00°C (highlands) to 33.70±1.82°C (karst). Soil temperature in the five ecosystems was in the range of 21.17±0.29 (highland) to 32.67±0.58 (karst). The maximum air temperature for macrofungal growth ranges from 30-40°C with an optimum temperature of 20-30°C [34]. Although not within the optimum range, fungal species can still be found in karst and lowland areas. This is due to the adaptability of some species to higher ecological ranges, particularly those in the family Ganodermataceae and Polyporaceae.

The presence of macrofungi positively correlates with air humidity. Air and soil humidity for macrofungal growth is in the range of 70-90% which is strongly related to rainfall [35, 36]. Air humidity allows macrofungal hyphae to spread over the substrate surface. The availability of water in the environment around the fungus is very important in maintaining the balance of water content in cells and plays a role in transport [14]. Macrofungal growth is influenced by total rainfall, which directly correlates with air and soil moisture [37]. On the other hand, air and soil moisture can naturally decrease, which is generally caused by an increase in temperature and light intensity, which triggers evaporation [36].

In this research, the karst ecosystem had the highest light intensity (18600.00 ± 1372.73 Lux) and the lowest light intensity in the mangrove ecosystem (1261.33 ± 1794.89 Lux). In general, fungi grow optimally at low light intensity. High light intensity inhibits fungal growth by suppressing the formation of macrofungal reproductive structures [14, 30]. The lower the percentage of sunlight, the lower the temperature in the area and the higher the percentage of humidity [38], impacted a very low number of macrofungal species occurring in karst ecosystems.

Soil pH value can affect macrofungal growth indirectly, because it affects the availability of nutrients needed [39]. The five research locations fall within the appropriate pH range for macrofungal growth, namely pH 5.83 (highland) to pH 7.00 (karst). Fungi can generally alive in the pH range of 4-9, and optimum conditions at pH 5-6. In general, the optimum pH range for fungi tends to be in the acidic range, which indicates the availability of organic matter and the ongoing decomposition process [14].

In addition to these factors, the type of substrate also affects the growth of fungi. Habitat and substrate are inseparable from the life cycle of macrofungi, as they

serve as sites for macrofungal growth and provide essential nutrients. Habitat conditions that contain suitable sources of carbohydrates, cellulose, and lignin can affect the development of macrofungal fruiting bodies [7]. In this research, dead trees were the dominant substrate supporting macrofungal growth. This is because macrofungi require nutrients from substances contained in wood, such as cellulose, hemicellulose, lignin, and other cell contents [40, 41]. Macrofungal communities are also associated with the presence of dead tree and a high volume of forest litter. In general, high volumes of dead tree are considered a key feature of natural forests, and wood-dwelling fungi are often used as good indicators of high-value ecosystems [42]. Dead trees provide specific ecological niches that support macrofungal development and the formation of fruiting bodies [43].

The highland ecosystem in Jempanang Hamlet is dominated by forest cover so that a relatively larger amount of dead tree is found. This is due to the fall of branches or old trees that produce organic matter in the form of rotting trunks and branches on the forest floor. In contrast, the karst ecosystem in Ungasan Village has sparse vegetation so that only a small amount of dead wood is found. This is due to the thin soil type and average temperature ranging from 28-32°C, so it tends to be drier, which causes limited availability of organic matter [44, 45]. In the mangrove ecosystem in Benoa Village, there are large trees, but the decomposition process is faster due to the high humidity and tides, so the accumulation of dead wood above the water tends to be very limited. Fungi can grow on a variety of substrates, such as moist forest leaf litter with little exposure to sunlight or on tree trunks that provide plenty of nutrients [46].

Fungi can grow on living trees, especially on old trees, because of the cork tissue that lines the tree trunk. Cork tissue (periderm) is a tissue formed by the activity of cork cambium (phellogen) that divides inward and outward. Phellogen that divides inward will form phelloderm, which is a living tissue, outward phellogen forms a layer of phellem, which is a dead tissue. Phellem then accumulates and forms a structure known as stem bark [47]. This structure is a suitable habitat for certain fungi, namely *Auricularia delicata*, *Collybia* sp., *Cymatoderma caperatum*, *Daldinia childiae*, *Flammulina* sp., *Fomes Fomentarius, Ganoderma* sp. 5, *Hemimycena* sp., *Marasmius* sp. 2, *Pesudofavolus* sp., *Stereum ostreata, Trametes gibbosa*, and *Trametes* sp. 6.

IV. CONCLUSION

The species composition of macrofungi in various ecosystems in Badung Regency, Bali consisted of 70 species belonging to 43 genera, 26 families, and two divisions, namely Ascomycota and Basidiomycota, dominated by the Polyporaceae family. The ecosystem with the highest macrofungal species diversity value is the highland forest ecosystem in Jempanang Hamlet (H' = 3.00), indicating a moderate category. On the contrary, the ecosystem with the lowest diversity index value is the karst ecosystem in Ungasan Village (H' = 0.60), indicating a low category. The similarity index value of the genus between lowland and riparian ecosystems obtained the highest value (59.26%), including in the moderate category. Conversely, the lowest similarity index is between karst ecosystems and mangroves (0.00%). Environmental factors, namely air temperature, air humidity, soil pH, soil temperature, soil moisture, and light intensity, as well as the presence of organic substrates, have an impact on the presence of macrofungi at the research site.

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