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Diversity and Taxonomy of Basidiomycetous Fungi at the Northeastern Side of Quezon Protected Landscape, Southern Luzon, Philippines

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Abstract: The present study was conducted primarily, to determine the diversity of basidiomycetous fungi and their taxonomy, in the northeastern side of Quezon Protected Landscape, bordering the municipalities of Pagbilao, Padre Burgos and Atimonan in Quezon province, Southern Philippines. Ten quadrats measuring 10 m × 15 m with an interval of 50 m were established from a transect line set up from the baseline to the peak of the landscape. Species of basidiomycetous fungi were pre-identified in the field. Substratum, form, texture, size, color and other noteworthy characteristics were recorded during the time of collection. Confirmation of identities was done using published textbooks, literature and consultation with mycology expert. A total of 863 individuals of basidiomycetous fungi were collected and identified belonging to 19 different families, 31 genera and 53 species. Polyporaceae family has the highest number of species representing 30% of the total number of individuals documented. Most of the species belong to *Hexagonia* and *Polyporus* genera. The current research revealed that most of the substrates used by these fungal organisms are woody substrate, specifically rotten woods. The results of Shannon-Wiener diversity index showed that the area has a high basidiomycetous fungal diversity. There was also a high species richness of these fungal organisms, but there was a low dominance and the species were not evenly distributed in the area. As this area is open for hikers, it is recommended that a continuous monitoring of the macrofungi community be done for sustainability and conservation.

Key words: Atimonan, basidiomycetous, diversity, *Hexagonia*, macrofungi, northeastern side, Quezon Protected Landscape, Polyporaceae.

1. Introduction

Fungi are eukaryotic organisms which are historically included in the plant kingdom. However, because they lack chlorophyll and are distinguished by unique structural and physiological features, they have been separated from plants and are clearly distinguished from all other living organisms, including animals, by their principal modes of vegetative growth and nutrient intake, such digestion of organic matter externally before absorbing it into their mycelia [1]. Fungi are able to secrete enzymes that are capable of breaking down virtually all classes of plant compounds. Thus, fungi can decompose substrates such as fresh plant litter and some structural materials (e.g., lignin, chitin and keratin) that are initially almost inaccessible to other decomposers [2]. Moreover, fungi account for a large fraction of the soil

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microbial biomass, as they contribute to about 60%-90% of the microbial biomass in forest soils and to 50% in grassland soils. Fungi have extensive hyphae networks, which make it possible to acquire carbon (e.g., from forest litter) and nutrients (e.g., from mineral soil) from different locations. Mycorrhizae are symbiotic associations between fungi and plant roots. Based on conservative estimates, approximately 95% of all vascular plant species have the potential to form this mutualistic association with mycorrhizal fungi [3].

Due to these characteristics, fungi are very diverse in nature. According to Nacua *et al.* [4], there are approximately 1.5 million fungal species found in the whole wide universe, of which only 70,000 have been described and identified. This accounts for only a small percent of these organisms that need to be discovered, described and recorded. It is quite important to study their diversity and taxonomy in different parts of the world before these organisms would vanish in the earth. Loss of diversity is a problem at least as large for fungi as for plants and animals, but fungi are not usually a high profile group. Red Lists are being constructed for fungi using International Union for the Conservation of Nature categories, though use of criteria for plants and animals is not always straight forward [5].

Four large phyla comprise these organisms such as Basidiomycota, Ascomycota, Deuteromycota and Zygomycota. Of these phyla, macrofungi which are the focus of the present study, belong to either Basidiomycetes and Ascomycetes that were characterized by easily observable structures of the produced spores that form either above or underground [6].

Philippines is one of the mega diverse countries in the world, but only few researches on fungal diversity and taxonomy have been conducted in the area. Some of the studies were conducted in Mt. Palay-Palay Mataas na Gulod National Park [7, 8], Taal Volcano Protected Landscape in Tagaytay [9], Mt. Apo in Mindanao [10], Mt. Malinao, Albay [11], Mt. Makiling Forest Reserve, Laguna [4, 12-14], Puncan, Carranglan, Nueva Ecija [15], Sierra Madre Mountain Range, Cagayan province [16] and Bazal-Baubo Watershed, Aurora province [17]. The present study was conducted in the northeastern part of Quezon Protected Landscape (Quezon National Park) of the Municipalities of Pagbilao, Padre Burgos and Atimonan in Quezon province, Philippines, and primarily aimed to determine the diversity of macrofungi, specifically the basidiomycetous fungi and their taxonomy in this area. The park is situated north of the narrowest section of Luzon in Quezon province, located about 164 km (102 miles) Southeast of Metro Manila with coordinates 13°59′22″ N, 121°48′59″ E.

Knowing the different species of Basidiomycetes and its classification will help one to understand their functions and role in the ecosystems and categorize species to organize the diversity of life in the environment. This study presents the different species of basidiomycetous fungi with their classifications which is very important in this present time since fungi are affected by habitat loss, pollution, climate change and other environmental factors, so the local government can implement protection and conservation program for these fungi.

2. Materials and Methods

2.1 Study Site

Quezon Protected Landscape (Fig. 1) is a tropical rainforest under the protection of the Department of Environment and Natural Resources-Protected Areas and Wildlife Bureau, University of the Philippines Center for Integrative and Development Studies and Conservation International Philippines. It is geographically located 13°59′22.308″ N latitude and 121°48′59.0508″ E longitude and is 366 meters above the sea level (masl). The protected rainforest is 983.0765 ha, a tropical rainforest that spans five barangays of Quezon namely: Silangang Malicboy in

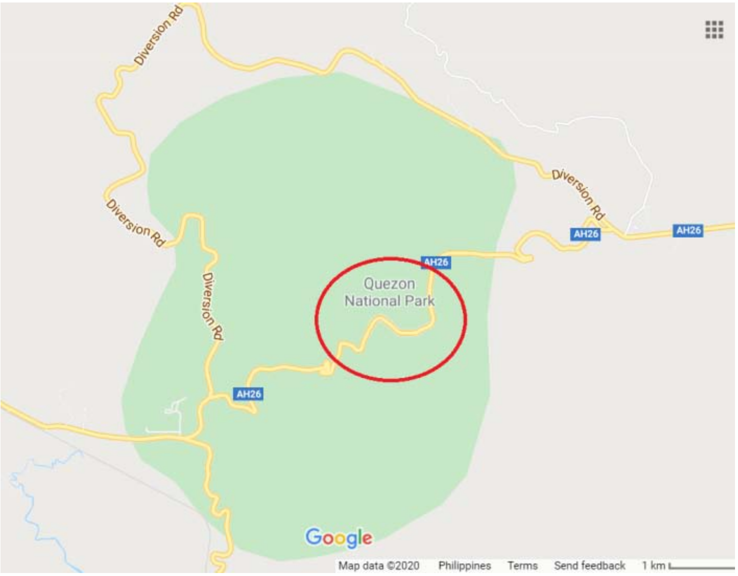

Fig. 1 Map showing the location of the study site.

Pagbilao, Sipa and Hanguiwin in Padre Burgos and Sta. Catalina and Malinao Ilaya in Atimonan.

2.2 Collection and Documentation of Fungi

Transect line and quadrat methods were used in the field samplings [18]. Ten quadrats were established in the identified transect line of study site that were set up from the baseline to the peak of northeastern part of Quezon Protected Landscape. Each quadrat has a size of 10 m × 15 m with an interval of 50 m in between.

Species found in each quadrat were pre-identified in the field. All basidiomycetous fungi were photographed in their natural habitat using a Canon DS126231 (DC 8.1 V) camera. Coordinates of each fungus were recorded through the use of global positioning system (GPS) [7]. Substratum, form, texture, size, color and other noteworthy characteristics were recorded during the time of collection. Samples of each species were collected, tagged, placed in a clean plastic and brought to the De La Salle University-Dasmariñas laboratory for proper identification and classification. Fragile and fleshy specimens were preserved in denatured alcohol and kept in vials and woody specimens were immediately air dried.

2.3 Identification and Classification of Fungi

Collected specimens were thoroughly analyzed using the macroscopic and microscopic attributes of the fruiting bodies [19]. Proper identification and classification was made by comparing the collected specimens with photos presented in the handbook on mushroom [20], National Audubon Society Field Guide to North American Mushrooms [21] and consultation with expert in the field of mycology.

2.4 Measurement of Basidiomycetous Fungal Diversity

Basidiomycetous fungal diversity was computed using Shannon-Wiener diversity index (H') [14]. This is to measure the species abundance and richness in the area. Only those species of fungi found within the transect were included for the computation of the diversity.

3. Results and Discussion

3.1 Taxonomy and Substrate of Collected Basidiomycetous Fungi

A total of 863 individuals of basidiomycetous fungi were collected from the area after field sampling using a transect with 10 quadrats. These were identified belonging to 19 different families, 31 genera and 53 species (Table 1). Polyporaceae family has the highest number of species representing 30% of the total number of individuals documented, most of which belong to the genera *Hexagonia* and *Polyporus*. The abundance of *Hexagonia* and *Polyporus* fungi could be attributed to the amount and diversity of coarse woody debris which they use as substrate [22]. The second highest number of individuals belongs to the Mycenaceae family which represents 26% of the total number of individuals collected, of which most of the genera belong to *Mycena* (Table 1). Fig. 2 represents samples of basidiomycetous fungi collected from the Northeastern Side of Quezon.

Fungi depend on a wide variety of substrates including soil, rotten wood, leaf litter, trees, shrubs, dead grass, etc., but the current study shows that basidiomycetous fungi mostly use woody substrates most especially rotten woods. These rotten woods have a crucial role in a forest biodiversity [23]. Some of the fungi degrade the cellulose in woods making cavities that would eventually decompose the woods [24]. Polypores and other white-brown-rot fungi are considered as the most important wood decomposer [25].

3.2 Diversity of Basidiomycetous Fungi

In Table 2, fifty-three (53) species of basidiomycetous fungi were identified using books and guides of fungi identification. Shannon-Wiener index was used to determine the diversity of the basidiomycetous fungi [14]. The computed value was 4.15 which is such a high value indicating that the northeastern part of the Quezon Protected Landscape has a high basidiomycetous fungal diversity. The genera with the highest number of individuals were obtained by the species *Hebeloma mesophaeum* (107) representing 12% of the total number of collected individuals showing that this is the most abundant or the most dominant species in the area. These dominant fungal species are probably the densest and the important decomposers [26] in this area. This was followed by the *Polyporus* sp. which has total number of 89 representing 10.3% of the total number of fungal individuals. The study also revealed that there was a high species richness of these fungal organisms.

Shannon-Wiener index is given by the following formula:

$$H' = -\sum[(pi) \times ln(pi)] \quad (1)$$

where N = number of individuals; pi = proportion of total sample represented by species i; S = number of species = species richness; $H_{max} = \ln(S)$ = maximum diversity possible; E = evenness = H/H_{max}.

Therefore:

H' = 4.14883944 or 4.15;

$H_{max} = \ln(S) = \ln 53 = 3.970292$ or 3.97;

E = 4.15/3.97 = 1.04534 or 1.05;

Shannon diversity (H) = 4.14883944;

Evenness = 1.05

For species richness (using Margalef's index (M)) [27]:

$$d = (S - 1)/\ln(N) \quad (2)$$

where d = Margalef's diversity index; S = total number of species; N = number of individuals.

Therefore:

$d = (53 - 1)/\ln 863 = 7.691835838$.

3.3 Effect of Relative Humidity in the Growth of Fungi

In the present study, relative humidity ranges from 78% to 100% and there was a number of basiodiomycetous fungal species found in each quadrat as presented in Table 3. Sixty-four (64) species were documented in the entire transect line, but since two or more quadrats share the same species, a total of 53 species were identified. This shows that a high relative humidity positively influenced the growth of a variety of fungal species. Fungi can grow quickly in moist or humid conditions because these are two of the fundamental requirements for fungal growth. Similarly, increased concentration of spores of basidiomycetous fungi like *Ganoderma* spores is associated with the high level of humidity such as 70% [28]. Aside from relative humidity, there are other factors that would contribute to the growth of fungi in an environment such as wind and temperature. Wind speed affects the distribution of basidiomycetous spores, such that if the wind speed is increased, the spores are also distributed at a fast rate. In addition, an increase in temperature enhances the growth of fungal populations [29].

Table 1 Taxonomy, substrate and the number of individuals per family of the collected basidiomycetous fungi.

Taxa	Substrate	Number of individuals
Agaricaceae		
Coprinus niveus (Pers. Fr.)	Soil	3
C. stercoreus (Fr., Epicrisis)	Rotten wood	1
Leucocoprinus fragilissimus (Berk. & M.A. Curtis)	Leaf litter, decayed plant matter	2
Subtotal		6
Auriculariaceae		
Auricularia auricula (Bull.) J. Schrot	Trees and shrubs	49
A. polytricha (Mont.) Sacc.	Rotten wood	29
Subtotal		78
Bolbitiaceae		
Conocybe tenera (Schaeff.)	Dead grass, decayed woods, and dung	7
Panaeolus papilionaceus (Bull. ex Fries) Quelet	Wood and pastures	11
Subtotal		18
Cortinariaceae		
Cortinarius sp.	Soil	1
Subtotal		1
Crepidotaceae		
Crepidotus variabilis (Pers.) P. Kumm.	Dead twigs of broad-leaved trees	42
Subtotal		42
Entolomataceae		
Entoloma cetratum (F.) M. M. Moser	Grasses and woods, can form mycorrhizal relationships	8
Subtotal		8
Fomitopsidaceae		
Daedalea ambigua (Berk)	Wood	6
Subtotal		6
Ganodermataceae		
Ganoderma applanatum (Pers.) Pat.	Wood	3
G. lucidum (Curtis) P. Karst.	Wood	1
Subtotal		4
Hygrophoraceae		
Hygrocybe nitida (Berk. & M.A. Curtis)	Rotten wood	4
Subtotal		4
Hymenochaetaceae		
Phellinus igniarius (L.) Quel.	Trunk of trees	16
P. punctatus (Fr.) Pilat.	Trunk and branches of trees	5
Subtotal		21
Hymenogastraceae		
Hebeloma mesophaeum (Pers.) Quel.	Soil	107
Subtotal		107
Marasmiaceae		
Crinipellis scabella (Alb. & Schwein.)	Leaf litter, soil	2
Marasmius haematocephalus (Mont.) Fr.	Rotten wood and soil	1
M. scorodonius (Fr.) A. W. Wilson and Desjardin	Soil and leaf litter	3

(Table 1 to be continued)

Taxa	Substrate	Number of individuals
Marasmius sp.	Soil and leaf litter	17
Subtotal		23
Mycenaceae		
Favolaschia pustulosa (Jungh.) Kuntze	Wood	1
Mycena acicula (Schaeff.) P. Kumm.	Wood	8
M. alcalina (Pers.) Gillet	Branches of tree and rotten log or wood	60
M. cinerella (P. Karst.)	Soil, leaf litter and similar detritus	20
M. clavularis (Batsch) Sacc.	Bark of trees	52
M. fibula (Fr.) Kuhner	Bark of trees and leaf litter	9
M. galericulata (Scop.) Gray	Rotten wood and soil	3
M. galopus (Pers.) P. Kumm.	Leaf litter	1
M. pura (Pers.) P. Kumm.	Wood and soil	3
M. vulgaris (Pers.) P. Kumm.	Leaf litter, soil and wood	69
Subtotal		226
Polyporaceae		
Earliella scabrosa (Pers.) Gilb. & Ryvarden	Trunk of trees, rotten wood and soil	20
Favolus alveolaris (DC.) Quel	Branches and twigs of hardwoods and dead hardwoods	1
Hexagonia glaber (P. Beauv.) Ryvarden	Rotten wood	7
H. nitida Durieu & Mont.	Rotten wood	12
H. tenuis (Hook.) Fr.	Branches and twigs of trees	4
Lentinus velutinus Fr.	Soil and leaf litter	21
Microporus affinis (Blume & T. Nees) Kuntze	Wood, rotting wood and trunk of trees	2
M. xanthopus (Fr.) Kuntze	Woody substrate	24
Polyporus badius (Pers.) Schwein.	Wood substrate esp. decaying woods	1
Polyporus sp. 1	Woody substrate	53
Polyporus sp. 2	Woody substrate	89
Poria sp.	Wood	20
Trametes ochracea (Pers.) Gilb & Ryvarden	Decaying logs and woods	1
T. versicolor (L.) Lloyd	Decaying woods	8
Subtotal		263
Psathyrellaceae		
Coprinellus micaceus (Bull.) Gray	Soil and woody substrate	1
Subtotal		1
Russulaceae		
Lactarius piperatus (L.) Pers.	Woody substrate	5
L. plumbeus (Bull.) Gray	Woody substrate	3
Subtotal		8
Schizophyllaceae		
Schizophyllum commune Fries	Decaying wood	3
Subtotal		3
Strophariaceae		
Stropharia semiglobata (Batsch) Quel	Decaying or leafy matter	1
Subtotal		1
Tricholomataceae		
Clitocybe dealbata (Sowerby) P. Kumm.	Grassy habitats/areas	1
C. gibba (Pers.) P. Kumm.	Soil and leaf litter	6
Trogia infundibuliformis Berk & Broome	Wood substrate	36
Subtotal		43
Total		863

Table 2 Diversity of basidiomycetous fungi collected.

	Species (*i*)	*N*	*pi*	*ln(pi)*	*piln(pi)*	(*-pilnpi*)	*pi*(*lnpi*)^2
1	*A. auricula*	49	0.0568	-2.8686	-0.1629	(0.1629)	0.1580
2	*A. polytricha*	29	0.0336	-3.3931	-0.1140	(0.1140)	0.0327
3	*C. dealbata*	1	0.0012	-6.7604	-0.0078	(0.0078)	0.0000
4	*C. gibba*	6	0.0070	-4.9687	-0.0345	(0.0345)	0.0003
5	*C. tenera*	7	0.0081	-4.8145	-0.0391	(0.0391)	0.0005
6	*C. micaceus*	1	0.0012	-6.7604	-0.0078	(0.0078)	0.0000
7	*C. niveus*	3	0.0035	-5.6618	-0.0197	(0.0197)	0.0000
8	*C. stercoreus*	1	0.0012	-6.7604	-0.0078	(0.0078)	0.0000
9	*Cortinarius* sp.	1	0.0012	-6.7604	-0.0078	(0.0078)	0.0000
10	*C. variabilis*	42	0.0487	-3.0227	-0.1471	(0.1471)	0.0995
11	*C. scabella*	2	0.0023	-6.0673	-0.0141	(0.0141)	0.0000
12	*Daedalia ambigua*	6	0.0070	-4.9687	-0.0345	(0.0345)	0.0003
13	*E. scabrosa*	20	0.0232	-3.7647	-0.0872	(0.0872)	0.0107
14	*E. cetratum*	8	0.0093	-4.6810	-0.0434	(0.0434)	0.0007
15	*F. pustulosa*	1	0.0012	-6.7604	-0.0078	(0.0078)	0.0000
16	*F. alveolaris*	1	0.0012	-6.7604	-0.0078	(0.0078)	0.0000
17	*G. applanatum*	3	0.0035	-5.6618	-0.0197	(0.0197)	0.0000
18	*G. lucidum*	1	0.0012	-6.7604	-0.0078	(0.0078)	0.0000
19	*H. mesophaeum*	107	0.1240	-2.0876	-0.2588	0.2588	1.6449
20	*H. glaber*	7	0.0081	-4.8145	-0.0391	(0.0391)	0.0005
21	*H. nitida*	12	0.0139	-4.2755	-0.0595	(0.0595)	0.0023
22	*H. tennis*	4	0.0046	-5.3741	-0.0249	(0.0249)	0.0001
23	*H. nitida*	4	0.0046	-5.3741	-0.0249	(0.0249)	0.0001
24	*L. piperatus*	5	0.0058	-5.1510	-0.0298	(0.0298)	0.0002
25	*L. plumbeus*	3	0.0035	-5.6618	-0.0197	(0.0197)	0.0000
26	*L. velutinus*	21	0.0243	-3.7159	-0.0904	(0.0904)	0.0124
27	*L. fragillisimus*	2	0.0023	-6.0673	-0.0141	(0.0141)	0.0000
28	*M. haemetocephalus*	1	0.0012	-6.7604	-0.0078	(0.0078)	0.0000
29	*M. scorodinius*	3	0.0035	-5.6618	-0.0197	(0.0197)	0.0000
30	*Marasmius* sp.	17	0.0197	-3.9272	-0.0774	(0.0774)	0.0066
31	*M. affinis*	2	0.0023	-6.0673	-0.0141	(0.0141)	0.0000
32	*M. xanthopus*	24	0.0278	-3.5824	-0.0996	0.0996	0.0186
33	*M. acicula*	8	0.0093	-4.6810	-0.0434	(0.0434)	0.0007
34	*M. alcalina*	60	0.0695	-2.6661	-0.1854	(0.1854)	0.2900
35	*M. cinerella*	20	0.0232	-3.7647	-0.0872	(0.0872)	0.0107
36	*M. clavularis*	52	0.0603	-2.8092	-0.1693	(0.1693)	0.1888
37	*M. fibula*	9	0.0104	-4.5632	-0.0476	(0.0476)	0.0010
38	*M. galericulata*	3	0.0035	-5.6618	-0.0197	(0.0197)	0.0000
39	*M. galopus*	1	0.0012	-6.7604	-0.0078	(0.0078)	0.0000
40	*M. pura*	3	0.0035	-5.6618	-0.0197	(0.0197)	0.0000
41	*M. vulgaris*	69	0.0800	-2.5263	-0.2020	0.2020	0.4411
42	*Paneolus papilionaceus*	11	0.0127	-4.3625	-0.0556	(0.0556)	0.0018
43	*P. igniarius*	16	0.0185	-3.9878	-0.0739	(0.0739)	0.0055
44	*P. punctatus*	5	0.0058	-5.1510	-0.0298	(0.0298)	0.0002
45	*P. badius*	1	0.0012	-6.7604	-0.0078	(0.0078)	0.0000
46	*Polyporus* sp.	53	0.0614	-2.7901	-0.1714	(0.1714)	0.1999
47	*Polyporus* sp.	89	0.1031	-2.2718	-0.2343	(0.2343)	0.9466
48	*Poria* sp.	20	0.0232	-3.7647	-0.0872	(0.0872)	0.0107

(Table 2 to be continued)

	Species (*i*)	*N*	*pi*	*ln(pi)*	*piln(pi)*	(*-pilnpi*)	*pi*(*lnpi*)^2
49	*S. commune*	3	0.0035	-5.6618	-0.0197	(0.0197)	0.0000
50	*S. semiglobata*	1	0.0012	-6.7604	-0.0078	0.0078	0.0000
51	*T. ochracea*	1	0.0012	-6.7604	-0.0078	(0.0078)	0.0000
52	*T. versicolor*	8	0.0093	-4.6810	-0.0434	(0.0434)	0.0007
53	*T. infundibuliformis*	36	0.0417	-3.1769	-0.1325	(0.1325)	0.0626
	Total	863	1.0000	-260.94	-3.204170	(3.2042)	4.14883944

Table 3 Relative humidity along the transect line per quadrat.

Quadrat	Relative humidity	Number of species documented
1	78%	14
2	92%	6
3	92%	6
4	92%	4
5	100%	3
6	100%	3
7	100%	4
8	100%	2
9	100%	9
10	100%	13
Total		64

Microporus xanthopus

Hebeloma mesophaeum

Auricularia polytricha

Leucocoprinus fragilissimus

Mycena alcalina *M. acicula*

Trametes versicolor *Ganoderma applanatum*

M. pura *Hexagonia glaber*

Fig. 2 Samples of basidiomycetous fungi collected from the northeastern side of Quezon Protected Landscape.

4. Conclusions

Quezon Protected Landscape is considered as a very high priority tropical rainforest in terms of biodiversity conservation. The current study accounted 863 individual specimens of basidiomycetous fungi at the northeastern part of Quezon Protected Landscape which belong to 19 families, 31 genera and 53 species. The protected forest harbors a high diversity of these fungi due to the wide range of available habitats such as rotten wood, leaf litter, grasslands and bark of trees. Though there is high diversity of basidiomycetous fungi at Quezon Protected Landscape, there is low dominance and evenness of them in the area. With this, there is still need of continuous monitoring of the macrofungi community for sustainability and conservation of Quezon Protected Landscape as this place is open for hikers.

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