Online ISSN: 2588-3526
Journal of Wildlife and Biodiversity

Volume 8(1): 298-307 (2024) (http://www.wildlife-biodiversity.com/)

Research Article

Assessment of macrofungi diversity in Perlis State Park, Perlis, Malaysia

Ag. Shaffie Ag. Ahmadni[1,2], Nura Adilla Shamsul Kamar[1], Muhamad Amir Hadi[1], Razak Terhem[1]*

[1]Laboratory of Forest Pathology and Tree Health, Department of Forestry Science and Biodiversity, Faculty of Forestry and Environment, Universiti Putra Malaysia, 43400 Serdang, Selangor
[2]Perlis State Forestry Department, Kilometer 2, Jalan Kaki Bukit, 01000 Kangar, Perlis
*Email: razakterhem@upm.edu.my

Received: 16 August 2023 / Revised: 29 September 2023 / Accepted: 26 October 2023/ Published online: 30 October 2023.

How to cite: Ag. Ahmadni, A.S., Shamsul Kamar, N.A., Amir Hadi, M., Terhem, R. (2024). Assessment of macrofungi diversity in Perlis State Park, Perlis, Malaysia, Journal of Wildlife and Biodiversity, 8(1), 298-307. **DOI**: https://doi.org/10.5281/zenodo.10206965

Abstract

Macrofungi play a diverse role in ecosystems, serving as decomposers, sources of food, and providers of medicinal benefits to humans for millennia. However, the status of macrofungi diversity in Perlis State Park is poorly understood. This study aims to identify the diversity of macrofungi species in Perlis State Park. Sampling was conducted using both opportunistic and selective approaches along a transect line comprising 10 trails during the rainy season between 2019 and 2023. Identification was based on the morphological characteristics of macrofungi. A total of 69 species of macrofungi were discovered, including 59 species from Basidiomycota and 10 species from Ascomycota. These species can be categorized into eight groups, namely Cup (2), Gill (20), Shelf and Bracket (16), Bolete (7), Coral (6), Jelly (6), Earthball and Puffball (4), and Tooth (4) fungi. Of the identified macrofungi species, 33 are confirmed to be edible. Additionally, three species from the Cordycipitaceae and Ophiocordycipitaceae families within the suborders of Ascomycota are entomopathogenic. Some microfungi fall under the category of 'Least Concern (LC)' according to the IUCN Red List. Our study highlights the importance of macrofungi diversity in Perlis State Park, which can be instrumental for conservation and educational purposes
Keywords: Ascomycota, Basidiomycota, Edible, Diversity, IUCN, Macrofungi

Introduction

Perlis State Park covers an area of 7,328.75 hectares and is situated in the northern part of Peninsular Malaysia. The park boasts rich biological resources, encompassing a wide range of plant and animal species, offering significant assets for the state of Perlis. These resources hold great economic potential in fields such as horticulture, medicinal plants, aesthetics, and urban forestry (Latiff et al., 2001). Perlis State Park is surrounded by mixed hill dipterocarp forests with sheer cliff walls and an extensive cave network (Wong, 2002). Its ecosystems, characterized by a predominance of limestone, were shaped by geographic and climatic factors, making Perlis State Park a rare conservation area. It is the only semi-deciduous forest in the nation, where a portion of the trees shed their leaves during the designated dry season (Rahimatsah and Osman, 2002). Perlis State Park serves as a sanctuary for numerous endangered and threatened species, with more than 600 species of plants, 70 species of mammals, 200 species of birds, and 35 species of reptiles thought to be currently present (Anuwar et al., 2020).

Macrofungi encompass both Basidiomycota and Ascomycota with visible spore-bearing structures, creating massive fructifications that are discernible without the aid of a microscope. These macrofungi can be categorized into three groups based on their ecological relationships: saprophytes, parasites, and symbiotic (mycorrhizal) species. While some terrestrial fungi are pathogens of plants or other fungi, the majority are either saprobes or mycorrhizal symbionts. Most of the time, macrofungi that fruit on woody substrates are saprobes or plant pathogens. The term "macrofungi" refers to fungi from various taxonomic families that produce conspicuous sporocarps, including "gilled fungi," "jelly fungi," "coral fungi," "stink fungi," "bracket fungi," "puffballs," "truffles," and "birds nest" fungi. Community diversity is a vital aspect of macrofungal diversity, contributing significantly to the overall diversity (Nafeesa Begum, 2021). Macrofungi play a crucial role in the decomposition of dead organic matter in the soil (Song et al., 2019) and are also utilized as bioindicators (Alem et al., 2021). Humans have used them in various ways for thousands of years (Oria-de-Rueda et al., 2008). Some macrofungi are sold in markets worldwide, serving as a significant source of revenue for rural areas (Pettenella et al., 2007) and providing food and shelter to other organisms (Jonsell & Nordlander, 2002).

However, the status of macrofungi is poorly understood. This group of organisms is well-established but rarely discussed in the scientific literature within Perlis State Park. The ecology and fundamental biology of fungal species, both known and unknown, remain poorly comprehended. Knowledge regarding their geographic distribution, host range, variety of life cycle stages, and community ecology is still insufficient. Thus, this study aimed to identify macrofungi species diversity in Perlis State Park.

Materials and methods

Study area

This study was carried out in Perlis State Park. There are 10 trails altogether which are Prince Denmark Trail (6.699053, 100.193653), Tok Jaafar Heritage Trail (6.681561, 100.187052), Tasik Meranti Trail 6.609154, 100.201461), Bukit Pelarit Trail 6.636685862411681, 100.18696810859039), Gunung Perlis Trail (6.711325, 100.205706), Gua Wang Burma Trail (6.710071, 100.208064), Bukit Bintang Trail 6.535491, 100.194192), Wang Panjang Trail (6.531311, 100.160467), Guar Jentik trail (6.520080, 100.183785), and Bukit Rongkit trail (6.694102, 100.186258). The sampling was conducted during the rainy season between the years of 2019 to 2023.

An opportunistic approach and a selective approach employing line transect sampling along trails were used to collect the data in this study on the variety of fungi. For the line transect sampling process, the fungus was sought within a 2 m radius. Fresh macrofungi samples were collected based on where their fruiting bodies were found on the substrates, primarily on dead trees, fallen rotten branches, and twigs. Pictures were taken for each specimen, showing the fungi from the top, side, and bottom. In all sampling plots, the presence of macrofungi fruiting bodies was consistently noted.

Morphology identification

The mushrooms were then categorized based on their macroscopic morphology using the proper monographs (Zoberi, 1972, Chang and Quimio, 1982, Tan, 1990, Pace, 1998, Wheeler, 2005, Lawrence and Harniess, 2007, Zainuddin et al., 2010, Lee et al., 2012, Læssøe, 2013, Jordan and, Lee, 2017, Tuah, 2018, Luangharn et al., 2021) to identify the macrofungal specimens' genus and species. Authors' names and current names for fungi species were retrieved from the Mycobank database (http://mycobank.org). Additionally, the criteria were utilized to evaluate the edibility of the fruiting bodies obtained from the study sites . Species that were listed in the literature as both edible and non-edible were categorized as non-edible. Non-edible species were those whose edibility has been questioned in the literature. Only species that were categorized as edible by a sizable portion of the literature studied were considered fungi. The list of red-listed macrofungi was used to determine the red-listed species (https://www.iucnredlist.org/). Only recordings that were already stated in the list and those that were recognized as genus were included in the final dataset.

Results

As a result, we identified macrofungi taxa in this study that are members of the two main suborders of the fungus kingdom: (i) Basidiomycota and (ii) Ascomycota. Table 1 lists all the families and genera of macrofungi collected in the study area. During the investigation of Perlis State Park, a total of 69 species of macrofungi were discovered, coming from 59 different Basidiomycota families and 10 from Ascomycota. There are 8 categories altogether which is cup, gill, shelf and bracket, bolete, coral, jelly, earthball and puffball, and also tooth fungi. Gill fungi had the largest macrofungi distribution in Perlis State Park (20 species) and were followed by Shelf and bracket fungi (16 species), and Bolete fungi (7 species). The macrofungi also have been stated with their edibility status, most of them are edible, 33 species are confirmed to be edible, and the others are non-edible and unknown. Among the species collected, there are also bioluminescence fungi that can emit light in the dark which is fungi from the genus Filoboletus and Mycena. There are also 3 species from the family of Cordycipitaceae and Ophiocordycipitaceae in the suborders of Ascomycota which is entomopathogenic. The IUCN list indicates the status of the species whether it is threatened to extinction or not. From the result, all the macrofungi found are not on the Red List of IUCN, and a few species are categorized as "Least concerned". Table 2, shows the total number of macrofungi collected according to their category in the studied area.

Table 1. List of Macrofungi collections by division and category at Perlis State Park.

Division	Category	Order	Family	Species	Edibility	IUCN Status
Ascomycota	Cup	Pezizales	Sarcoscyphaceae	*Cookeina sulcipes*	Yes	
Ascomycota	Cup	Pezizales	Sarcoscyphaceae	*Cookeina tricholoma*	Yes	
Ascomycota		Hypocreales	Cordycipitaceae	*Akanthomyces aranearum*	No	
		Hypocreales	Cordycipitaceae	*Cordyceps sp*	No	
		Hypocreales	Ophiocordycipitaceae	*Ophiocordyceps unilateralis*	No	
Ascomycota		Xylariales	Xylariaceae	*Xylaria longipes*	No	
Ascomycota		Xylariales	Xylariaceae	*Xylaria filiformis*	No	
Ascomycota		Xylariales	Xylariaceae	Xylaria hypoxylon	No	
Ascomycota		Xylariales	Xylariaceae	*Xylaria apiculata*	No	
Basidiomycota	Gill	Agaricales	Agaricaceae	*Agaricus arvensis*	Yes	
Basidiomycota	Gill	Agaricales	Amanitaceae	*Amanita obsita*	unknown	
Basidiomycota	Gill	Cantharellales	Cantharellaceae	*Cantharellus lateritius*	Yes	
Basidiomycota	Gill	Agaricales	Omphalotaceae	*Collybiopsis vaillantii*	Yes	
Basidiomycota	Gill	Agaricales	Psathyrellaceae	*Coprinellus disseminatus*	Yes	
Basidiomycota	Gill	Agaricales	Crepidotaceae	*Crepidotus sp.*	No	

Basidiomycota	Gill	Agaricales	Mycenaceae	*Filoboletus manipularis*	Yes	
Basidiomycota	Gill	Agaricales	Hygrophoraceae	*Hygrocybe sp*	Some	
Basidiomycota	Gill	Agaricales	Hygrophoraceae	*Hygrocybe cantharellus*	yes	
Basidiomycota	Gill	Agaricales	Hygrophoraceae	*Hygrocybe virgenea*	yes	
Basidiomycota	Gill	Agaricales	Omphalotaceae	*Marasmiellus candidus*	No	
Basidiomycota	Gill	Agaricales	Omphalotaceae	*Marasmiellus sp.*	No	
Basidiomycota	Gill	Agaricales	Marasmiaceae	*Marasmius siccus*	No	
Basidiomycota	Gill	Agaricales	Marasmiaceae	*Maramius sp.*	No	
Basidiomycota	Gill	Agaricales	Mycenaceae	*Mycena sp.*	No	
Basidiomycota	Gill	Agaricales	Mycenaceae	*Mycena manipularis*	No	
Basidiomycota	Gill	Agaricales	Physalacriaceae	*Oudemansiella sp*	Yes	
Basidiomycota	Gill	Agaricales	Psathyrellaceae	*Psathyrella splendens*	Yes	
Basidiomycota	Gill	Agaricales	Schizophyllaceae	*Schizophyllum commune*	Yes	
Basidiomycota	Gill	Agaricales	Lyophyllaceae	*Termitomyces sp.*	yes	
Basidiomycota	Shelf & Bracket	Polyporales	Ganodermataceae	*Amauroderma rugosum*	Yes	Least concern
Basidiomycota	Shelf & Bracket	Polyporales	Polyporaceae	*Coriolopsis polyzona*	Yes	
Basidiomycota	Shelf & Bracket	Polyporales	Meruliaceae	*Cymatoderma sp.*	Yes	
Basidiomycota	Shelf & Bracket	Polyporales	Polyporaceae	*Favolus brasiliensis*	Yes	proposed
Basidiomycota	Shelf & Bracket	Polyporales	Ganodermataceae	*Ganoderma applanatum*	No	
Basidiomycota	Shelf & Bracket	Polyporales	Ganodermataceae	*Ganoderma australe*	No	
Basidiomycota	Shelf & Bracket	Polyporales	Ganodermataceae	*Ganoderma lucidum*	Yes	
Basidiomycota	Shelf & Bracket	Polyporales	Ganodermataceae	*Ganoderma philippii*	No	
Basidiomycota	Shelf & Bracket	Polyporales	Ganodermataceae	*Ganoderma zonatum*	No	
Basidiomycota	Shelf & Bracket	Polyporales	Polyporaceae	*Microporus affinis*	Yes	
Basidiomycota	Shelf & Bracket	Polyporales	Steccherinaceae	*Nigroporus vinosus*	unknown	
Basidiomycota	Shelf & Bracket	Polyporales	Fomitopsidaceae	*Postia ptychogaster*	No	
Basidiomycota	Shelf & Bracket	Polyporales	Polyporaceae	*Pycnoporus sanguineus*	No	
Basidiomycota	Shelf & Bracket	Russulales	Stereaceae	*Stereum versicolor*	No	

Basidiomycota	Shelf & Bracket	Polyporales	Polyporaceae	*Trametes gibbosa*	No	
Basidiomycota	Shelf & Bracket	Polyporales	Polyporaceae	*Trametes menzeisii*	No	
Basidiomycota	Bolete	Boletales	Boletaceae	*Bolletus curtisii*	Yes	
Basidiomycota	Bolete	Boletales	Boletaceae	*Bolletus obscurecoccineus*	unknown	
Basidiomycota	Bolete	Boletales	Boletaceae	*Bolletus sp.*	Yes	
Basidiomycota	Bolete	Boletales	Boletaceae	*Pseudoboletus parasiticus*	yes	
Basidiomycota	Bolete	Boletales	Boletaceae	*Pulveroboletus icterinus*	yes	
Basidiomycota	Bolete	Sabellida	Serpulidae	*Serpula lacrymans*	No	
Basidiomycota	Bolete	Boletales	Boletaceae	*Strobilomyces strobilaceus*	yes (young)	
Basidiomycota	Coral	Russulales	Lachnocladiaceae	*Lachnocladium flavidum*	yes	
Basidiomycota	Coral	Gomphales	Lentariaceae	*Lentaria sp*	yes	
Basidiomycota	Coral	Gomphales	Lentariaceae	*Lentaria sp 2*	yes	
Basidiomycota	Coral	Agaricales	Pterulaceae	*Pterula sp.*	No	
Basidiomycota	Coral	Gomphales	Gomphaceae	*Ramaria sp.*	Some	
Basidiomycota	Coral	Gomphales	Gomphaceae	*Ramaria sp. 2*	Some	
Basidiomycota	Jelly	Auriculariales	Auriculariaceae	*Auricularia sp*	Yes	
Basidiomycota	Jelly	Dacrymycetales	Dacrymycetaceae	*Dacrymyces chrysospermus*	Yes	
Basidiomycota	Jelly	Tremellales	Phaeotremellaceae	*Tramella foliace*	yes	
Basidiomycota	Jelly	Tremellales	Tremellaceae	*Tremella mesenterica*	yes	
Basidiomycota	Earthball & puffball	Agaricales	Agaricaceae	*Calvatia sp.*	Yes	
Basidiomycota	Earthball & puffball	Agaricales	Agaricaceae	*Lycoperdon perlatum*	yes	Least concerned
Basidiomycota	Earthball & puffball	Boletales	Sclerodermataceae	*Scleroderma sinnamariense*	No	
Basidiomycota	Earthball & puffball	Agaricales	Agaricaceae	*Tulostoma sp.*	No	
Basidiomycota	Tooth	Agaricales	Clavariaceae	*Mucronella sp.*	Yes	
Basidiomycota	Tooth	Auriculariales	Exidiaceae	*Protohydnum sclerodontium*	unknown	

Table 2. The total number of fungi collected per category encountered in the studied area.

Category	Amount
Cup	2
Gill	20
Shelf & Bracket	16
Bolete	7
Coral	6
Jelly	4
Earthball & puffball	4
Tooth	2
Other ascomycete	8
Total	69

Discussion

Based on the macrofungi discovered in this study, encompassing both the Ascomycota and Basidiomycota divisions, a significant portion of these fungi plays a crucial role as decomposers in the forest ecosystem. Macrofungi serve as mutualistic symbionts and decomposers (Lutzoni et al., 2018; Ye et al., 2019), making them essential for sustaining biodiversity. They play a vital role in recycling organic matter, which is necessary for the growth and survival of various organisms, including humans (de Mattos-Shipley et al., 2016). Moreover, they are key players in the movement, storage, and release of essential nutrients such as nitrogen (N), phosphorus (P), and carbon (C) (Bortier et al., 2018; Ekblad et al., 2013). For instance, species within the genus Cookeina and Xylaria from the Ascomycota division, as well as Ganoderma and Microporus, which are often found on decaying wood, play significant roles as wood decomposers in the forest ecosystem. They are responsible for breaking down lignin and cellulose (Chepkirui et al., 2018). The prevalent fungi in this region belong to the Polyporaceae family, known for causing wood rot. We identified 16 species within the Polyporaceae family. Given the abundance of dead trees and logs in Perlis State Park, along with the high humidity and moisture content, polypores are likely to thrive on cellulose-rich substrates in such environments (Gilbert et al., 2002). The majority of these fungi belong to the category of white rot polypores, which primarily colonize dead wood and trees as their main substrate.

In the Basidiomycota division, primarily in the gill fungi category, species like Marasmius, Marasmiellus, Amanita obsita, and Termitomyces sp. were identified. Marasmius species are soil humus decomposers that grow on forest litter, while Mycena species are commonly found on the forest floor. The presence of both Cookeina sulcipes and C. tricholoma in pairs is indicative of a healthy forest ecosystem, as we did not encounter any of these species in disturbed areas. Furthermore, our study identified three species of entomopathogenic fungi, which have potential applications as biological control agents for insect pests in the agricultural and forestry sectors in Malaysia.

This study also unveiled 33 edible macrofungi (as described in Wei et al., 2022). Edible macrofungi are not only a source of essential minerals but are also considered nutritious foods (Seelan et al., 2015). Moreover, beyond their nutritional value, macrofungi may offer significant medicinal benefits. Zhang et al. (2021) highlight that edible macrofungi contain various bioactive components, including polysaccharides, dietary fiber, steroids, and polyphenols, which possess antioxidant, anti-tumor, and other physiological properties. However, it's worth noting that while some macrofungi may be edible, their taste might not be universally appealing, often influenced by their shape and size.

Additionally, our study identified two species of bioluminescent fungi in Perlis State Park, namely Filobelatus manipularis and Mycena sp. According to Chew et al. (2015), Malaysia is home to 15 species of bioluminescent fungi. The relatively small number of species discovered in this study, compared to Chew et al. (2015), could be attributed to our sampling period, which was limited to the rainy season.

Most of the macrofungi we assessed are not listed in the IUCN Red List, and some fall under the 'Least Concern' category. In the context of the International Union for Conservation of Nature (IUCN), a 'Least Concern' species is one that is considered not to be a primary focus of species conservation, as it remains abundant in the wild

Conclusion

The study reveals that the diversity of macrofungi in Perlis State Park serves as decomposers and plays a vital role in the forest ecosystem. The edibility of approximately half of the macrofungi species discovered in Perlis State Park could offer significant benefits to the rural communities surrounding the park, serving as a potential source of both food and income. These findings highlight that the diversity of macrofungi species in Perlis State Park reflects species richness and contributes to the overall stability of the forest ecosystem

Acknowledgements

We would like to thank the local community of Perlis for their support and also thank the Perlis Climbers, Perlis Hikers, Perlis Nature and Wildlife, and also Perlis Forestry Department staff for their support and help during the study.

References

Alem, D., Dejene, T., Oria-de-Rueda, J. A., & Martín-Pinto, P. (2021). Survey of macrofungal diversity and analysis of edaphic factors influencing the fungal community of church forests in dry Afromontane areas of northern Ethiopia. *Forest Ecology and Management*, *496,* 119391. https://doi.org/10.1016/j.foreco.2021.119391

Anuwar, N. A. A., Sobri, S. A., Hermawan, A., Hambali, K. A., Ismail, W. O. A. S. W., & Amini, M. H. M. (2020). The potential of eco-tourism: a narrative case study of Perlis state park, Malaysia. Journal of Critical Reviews, 7(15), 3070-3077.

Begum, N. (2021) *Diversity of Macrofungi*, Bhumi Publishing

Bortier, M. F., Andivia, E., Genon, J. G., Grebenc, T., & Deckmyn, G. (2018). Towards understanding the role of ectomycorrhizal fungi in forest phosphorus cycling : a modelling approach. *Central European Forestry Journal*, *64*(2), 79–95. https://doi.org/10.1515/forj-2017-0037

Chang, S. T. and Quimio, T. H. 1982. Tropical Mushrooms: Biological Nature and Cultivation Methods. Hong Kong: The Chinese University Press Hong Kong.

Chang, Y. S., & Lee, S. S. (2004). Utilisation of macrofungi species in Malaysia. Fungal Diversity, 15(2), 15-22.

Chepkirui, C., Yuyama, K. T., Wanga, L. A., Decock, C., Matasyoh, J. C., Abraham, W.-R., & Stadler, M. (2018). Microporenic Acids A–G, Biofilm Inhibitors, and Antimicrobial Agents from the Basidiomycete Microporus Species. *Journal of Natural Products*, *81*(4), 778–784. https://doi.org/10.1021/acs.jnatprod.7b00764

Chew, A. L. C., Desjardin, D. E., Tan, Y.-S., Musa, M. Y., & Sabaratnam, V. (2015). Bioluminescent fungi from Peninsular Malaysia—a taxonomic and phylogenetic overview. *Fungal Diversity*, *70*(1), 149–187. https://doi.org/10.1007/s13225-014-0302-9

de Mattos-Shipley, K. M. J., Ford, K. L., Alberti, F., Banks, A. M., Bailey, A. M., & Foster, G. D. (2016). The good, the bad and the tasty: The many roles of mushrooms. *Studies in Mycology*, *85*, 125–157. https://doi.org/10.1016/j.simyco.2016.11.002

Ekblad, A., Wallander, H., Godbold, D. L., Cruz, C., Johnson, D., Baldrian, P., Björk, R. G., Epron, D., Kieliszewska-Rokicka, B., Kjøller, R., Kraigher, H., Matzner, E., Neumann, J., & Plassard, C. (2013). The production and turnover of extramatrical mycelium of ectomycorrhizal fungi in forest soils: role in carbon cycling. *Plant and Soil*, *366*(1–2), 1–27. https://doi.org/10.1007/s11104-013-1630-3

Gilbert, G. S., Ferrer, A., & Carranza, J. (2002). Polypore fungal diversity and host density in a moist tropical forest. *Biodiversity and Conservation*, *11*(6), 947–957. https://doi.org/10.1023/A:1015896204113

Hanum, I. F., Osman, K., & Latiff, A. (2001). *Kepelbagaian Biologi Dan Pengurusan Taman negeri perlis: Persekitaran Fizikal Dan Biologi wang kelian*. Jabatan Perhutanan Negeri Perlis.

Jonsell, M., & Nordlander, G. (2002). Insects in polypore fungi as indicator species: A comparison between forest sites differing in amounts and continuity of Dead Wood. *Forest Ecology and Management*, *157*(1–3), 101–118. https://doi.org/10.1016/s0378-1127(00)00662-9

Jordan, P., & Wheeler, S. (2005). *The Complete Book of Mushrooms: An Illustrated Encyclopedia of Edible Mushrooms and over 100 delicious ways to cook them*. Lorenz.

Jordan, M. (2004). *The encyclopedia of fungi of Britain and Europe*. Frances Lincoln.

Læssøe, T. (2013). *Mushrooms & Toadstools: The Definitive Guide to Fungi*. Dorling Kindersley.

Lawrence, E., & Harniess, S. (2007). *Identification guides: British & European Mushrooms & other fungi*. Flame Tree Publishing.

Lee, S. S., Alias, S. A., Jones, E. B. G., Zainuddin, N. and Chan, H. T. 2012. Checklist of Fungi of Malaysia. Research Pamphlet No. 132. Forest Research Institute Malaysia

(FRIM), Institute of Ocean and Earth Sciences University of Malaya (IOES), Ministry of Natural Resources and Environment (MNRE), Malaysia. Selangor, Malaysia: Swan Printing Sdn.

Bhd.Lee, S. S. (2017). *A field guide to the larger fungi of Frim*. Forest Research Institute Malaysia.

Luangharn, T., Karunarathna, S. C., Dutta, A. K., Paloi, S., Promputtha, I., Hyde, K. D., ... & Mortimer, P. E. (2021). Ganoderma (Ganodermataceae, basidiomycota) species from the greater mekong subregion. Journal of Fungi, 7(10), 819

Lutzoni, F., Nowak, M. D., Alfaro, M. E., Reeb, V., Miadlikowska, J., Krug, M., Arnold, A. E., Lewis, L. A., Swofford, D. L., Hibbett, D., Hilu, K., James, T. Y., Quandt, D., & Magallón, S. (2018). Contemporaneous radiations of fungi and plants linked to symbiosis. *Nature Communications*, *9*(1), 5451. https://doi.org/10.1038/s41467-018-07849-9

Oria-de-Rueda, J. A., Martín-Pinto, P., & Olaizola, J. (2008). Bolete productivity of cistaceous scrublands in northwestern spain1. *Economic Botany*, *62*(3), 323–330. https://doi.org/10.1007/s12231-008-9031-x

Pace, G. (1998). *Mushrooms of the world: With 20 photographs and 634 full color illustrations of species and varieties*. Firefly Books.

Pettenella, D., Secco, L., & Maso, D. (2007). NWFP&S marketing: Lessons learned and new development paths from case studies in some European countries. *Small-Scale Forestry*, *6*(4), 373–390. https://doi.org/10.1007/s11842-007-9032-0

Rahimatsah, A., & Kasim, O. (2002). The administration and management of Perlis State Park. Forest Department of Perlis, Kangar, Perlis, Malaysia.

Song, J., Chen, L., Chen, F., & Ye, J. (2019). Edaphic and host plant factors are linked to the composition of arbuscular mycorrhizal fungal communities in the root zone of endangered *ulmus chenmoui* cheng in China. *Ecology and Evolution*, *9*(15), 8900–8910. https://doi.org/10.1002/ece3.5446

Seelan, J. S. S., Justo, A., Nagy, L. G., Grand, E. A., Redhead, S. A., & Hibbett, D. (2015). Phylogenetic relationships and morphological evolution in Lentinus , Polyporellus and Neofavolus , emphasizing southeastern Asian taxa. *Mycologia*, *107*(3), 460–474. https://doi.org/10.3852/14-084

Tan, T. K. (1990). *A guide to tropical fungi*. Singapore Science Centre.

Tuah, P. M., Atong, M., & Zahari, N. Z. (2018). *Wild fungi of sabah: A pictorial documentation*. Penerbit Universiti Malaysia Sabah.

Wei, Y., Li, L., Liu, Y., Xiang, S., Zhang, H., Yi, L., Shang, Y., & Xu, W. (2022). Identification techniques and detection methods of edible fungi species. *Food Chemistry*, *374*, 131803. https://doi.org/10.1016/j.foodchem.2021.131803

Wong,S.L. 2002. Plant life. The Pearl of Perlis. Perlis State Park. Forest Department Perlis

Ye, L., Li, H., Mortimer, P. E., Xu, J., Gui, H., Karunarathna, S. C., Kumar, A., Hyde, K. D., & Shi, L. (2019). Substrate Preference Determines Macrofungal Biogeography in the Greater Mekong Sub-Region. *Forests*, *10*(10), 824. https://doi.org/10.3390/f10100824

Zainuddin, N., Lee, S. S., Chan, H. T., & Thi, B. K. (2010). *A guidebook to the macrofungi of Tasik Bera. Kepong*: Forest Research Institute Malaysia.

Zhang, Y., Wang, D., Chen, Y., Liu, T., Zhang, S., Fan, H., Liu, H., & Li, Y. (2021). Healthy function and high valued utilization of edible fungi. *Food Science and Human Wellness*, *10*(4), 408–420. https://doi.org/10.1016/j.fshw.2021.04.003

Zoberi, M. H. (1972). *Tropical Macrofungi*. Palgrave Macmillan UK. https://doi.org/10.1007/978-1-349-01618-1