Fungi on the Southern Islands of Singapore

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ABSTRACT. Incidental collections of macroscopic fruiting bodies yielded 69 taxa of fungi from the Southern Islands of Singapore. While these represent only a snapshot of the probably commoner forms, they yielded several new records of species and genera, indicating the currently low knowledge base for fungi in Singapore and the opportunities for further discoveries and applications.

Keywords. Fungal diversity, Singapore macrofungi

Introduction

Perhaps best known for their edible fruiting bodies (‘mushrooms’), fungi are an astonishingly diverse kingdom with an estimated 2.2 to 6.2 million species worldwide (Hill, 2021), of which only 120,000 species (2% to 5%) have been named and described (Hawksworth & Lücking, 2017). These organisms are ancient, the earliest fungi having arisen between 760 million and 1.06 billion years ago (Watkinson et al., 2016). They come in diverse forms, some inhabiting plant tissues as endophytes (Hirsch & Braun, 1992), and others growing hyphae in soil or decomposing wood (Rodriguez & Redman, 1997). Two phyla, described below, typically have macroscopic fruiting bodies called mushrooms or toadstools. Others form symbioses consisting of three or more different taxa, namely algae, fungi, and cyanobacteria, which collectively are called lichens and grow mostly on the surfaces of rocks or trees (Nash, 2008).

The fungi are nature’s major decomposers and nutrient cyclers and serve several other ecological roles from forming plant mutualisms to causing diseases like rusts, smuts, and other infections (Watkinson et al., 2016). As decomposers, they serve an essential role in ecosystems, ensuring that nutrients from dead organic matter are broken down and released back into the environment (Boddy & Watkinson, 1995). Some soil fungi also help form underground mycelial networks, which have symbiotic relationships with plants to extract useful nutrients and minerals from the soil in exchange for plant sugars (Smith et al., 2003), and they can be crucial to the germination of orchids and the growth of many trees and other plants. Mycelial networks might also assist plants in communicating via chemical signals, which mycologists have cleverly referred to as the “wood wide web” (Wohlleben, 2016; Popkin, 2019). There are many poisonous and pathogenic fungi that could be rich sources of ideas for secondary compounds for medical and industrial purposes.

The largest phylum of fungi is the Ascomycota, containing about 64,000 (53%) of the named fungi. Sexually reproducing ascomycetes are characterized by the production of non-motile ascospores within a sac-like structure, but there are also asexual species lacking ascospores. Most fungi associating symbiotically as lichens are ascomycetes. Some are renowned foods (e.g., truffles) but much more important economically are yeasts used in the fermentation of beverages, cheeses and breads.

The second largest phylum of fungi is the Basidiomycota, with about 32,000 (26%) of the named fungi. Sexually reproducing basidiomycetes are characterized by the production of modified cells at the tips of hyphae, bearing tetrads of external meiospores. Traditionally, asexual species have been identified as basidiomycetes by their similarity to

sexually reproducing forms, but DNA analysis now gives much greater reliability in tracing relationships. Basidiomycetes include smuts, rusts and other parasitic forms in plants and animals. Some have long-lived fruiting structures (such as bracket fungi, polypores) and others are ephemeral with sporophytes lasting only a few hours or days (such as stinkhorns, lady's mantle).

These organisms are grossly understudied, especially in the tropics (Hawksworth et al., 1997; Lee, 2019; Hill, 2021). Mycology is challenging as many species are either microscopic, cryptic, or ephemeral, as is the case with their fruiting bodies (Wee, 2018), and investigators may not always have access to the means or expertise to identify fungi with molecular techniques (Watkinson et al., 2016). Scientific nomenclature for fungi is also in flux (Wu et al., 2019). On the advent of genetic sequencing, many taxonomic reorganizations of fungi that were formerly grouped in accordance with physical characteristics such as spore shape and colour occurred to the frustration of many budding mycologists (Watkinson et al., 2016). However, the rapid changes in mycology highlight the field's immense potential that should be tapped (Watkinson et al., 2016). Fungi, being the second most diverse group after insects, are a potential source of biological compounds that could have medical applications (Schulz et al., 2002; Müller et al., 2013), as well as a source of foods (e.g., alternative meats or mycoproteins), raw materials, and natural fertilizers (Barzee et al., 2021; Choong, 2022).

The earliest recorded fungal collections from the Southern Islands currently held in the Singapore Botanic Gardens' Herbarium (SING) were made by T.F. Chipp in 1919 on Pulau Blakang Mati, now known as Sentosa Island. He collected 32 specimens from 13 families and 24 taxa in a single day. Chipp's 1921 publication, "A List of the Fungi of the Malay Peninsula," includes many Singaporean species, among them those collected from Sentosa. No further fungal collections appear to have been made from the Southern Islands until now.

The fungi of Singapore present an exciting opportunity for the Southern Islands Biodiversity Survey (SIBS), as the conservation of fungal diversity is becoming an understated but growing concern for environmental science (Tsui et al., 1998; Lovelock & Ewel, 2005; Shi et al., 2019). Reporting the fungal diversity of the Southern Islands, combining incidental botanical survey findings of the SIBS and from past published and unpublished data, is timely and important for understanding what fungi we could be conserving on the Southern Islands. Furthermore, the fungal report could act as a baseline for future investigations into Singapore's mycobiota and help keep track of the fungal diversity at the time when the survey was conducted, with respect to the rapid ongoing changes to the islands such as urbanization, climate change and rising sea levels.

Materials and Methods

Between August 2020 and September 2022, a series of surveys were conducted as part of the Southern Islands Biodiversity Survey (Tan et al., 2025). During these trips, fungi visible to the naked eye were collected from eleven of the islands. Photographs of the substrate the fungal sample was growing on were taken, and sampled fruiting bodies were collected with the hyphae where possible. The fungi were then bagged and sent to the SING herbarium for vouchering, storage and identification. Many specimens were too old or deteriorated for vouchering and were documented photographically before being discarded. Fungi were not the main focus of the surveys, and the collections were not made by mycologists but were incidental to the general survey of higher plants.

Results

Fungi were found in various habitats, including rotten logs, dead wood, leaf litter, and soil. Many species were labeled as "common", indicating their widespread occurrence compared to mainland Singapore. The list included 69 taxa but definitive species names could only be attributed to 28 of them. A list of identifications is included in the annex.

Polyporaceae was the best represented family with 17 taxa (25% of the total), likely due to their longer-lasting fruiting bodies compared to those that emerge and decompose quickly. They allowed greater precision in assigning names (71% of Polyporaceae were named to species level, compared to 31% for all other fungal taxa).

Figure 1 shows the number of taxa recorded on each of 11 islands, ranging from one (Pulau Tekukor) to 29 (Pulau Sentosa). The mean number recorded per island was 8.4 taxa, but if Sentosa is set aside (because it includes the records by Chipp in 1919) the mean for the remaining ten islands was only 6.3 taxa each. Some species were identified as “in study", uncommon" or "new species/genera records for Singapore" and are currently under further study.

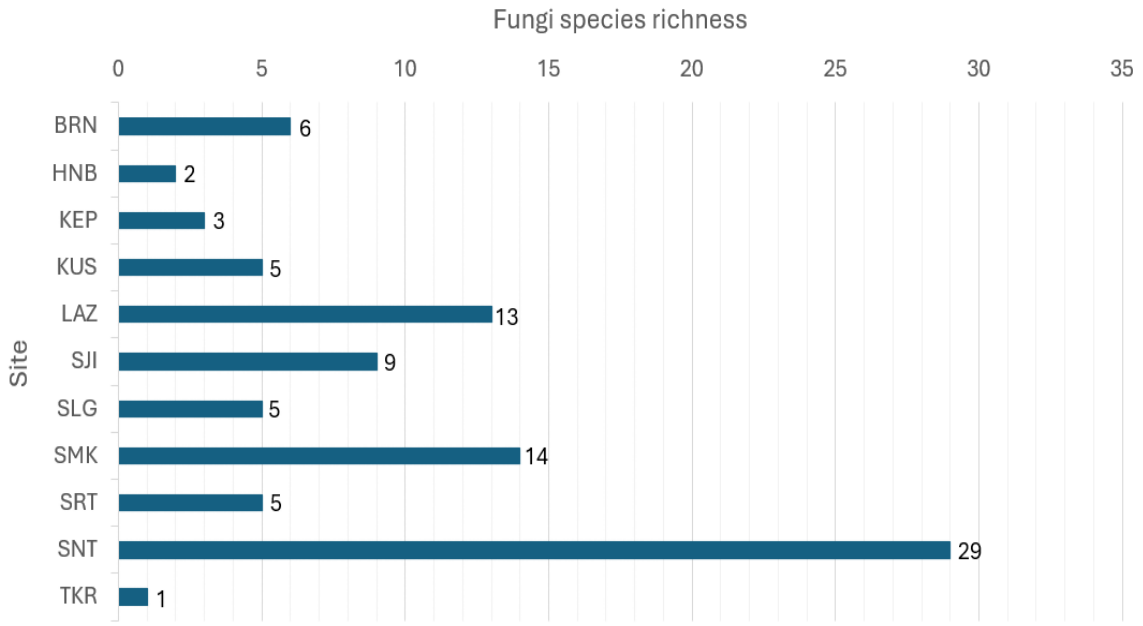


Figure 1. Number of fungal taxa observed on various Southern Islands of Singapore. Abbreviations: BRN (Brani); HNB (Hantu Besar); KEP (Keppel); KUS (Kusu); LAZ (Lazarus); SJI (St. John’s Island); SLG (Selegu); SMK (Semakau); SRT (Seringat); SNT (Sentosa); TKR (Tekukor).

Some species of interest are shown in Appendix 1.

Discussion

It is important to note that all fungal surveys provide a snapshot of diversity at a particular time due to the ephemeral nature of many fungal species. Chance, and the intensity and duration of surveys, are likely influences on the number of finds in the current survey. Therefore, the dataset cannot be used to draw definitive conclusions about ecological or geographical trends. The results are better regarded as an early initial survey of fungi in the Southern Islands, with a review of the relevant literature.

The results do begin to fill a knowledge gap in the fungal diversity of Singapore and could spur further interest. The survey was limited to fruiting bodies visible to the naked eye on the ground, on fallen timber and on tree trunks. There were no collections in soil, on leaf surfaces or in foam. Furthermore, there is limited literature available for review, not many experts in the field, and manpower or interest are limited as well.

These drawbacks can equally be seen as opportunities. There is scope for the use of microbiology and environmental DNA in soil, mangrove mud, humus, foliage and other specialized niches, and for exploration of marine fungi. Given the importance of fungi in pharmaceuticals and industrial processes, there can also be applications in conservation such as fungi that can assist in degrading plastics, microplastics and other hydrocarbons. With the importance of Singapore (and the waters surrounding the Southern Islands in particular) for international shipping and bunker fuels, and susceptibility to oil spills, the potential applications are not trivial.

Conclusion

This collection provides a valuable snapshot of fungal diversity on the Southern Islands. It highlights the importance of ongoing fungal surveys and documentation to enhance our understanding of the fungal diversity of the region.

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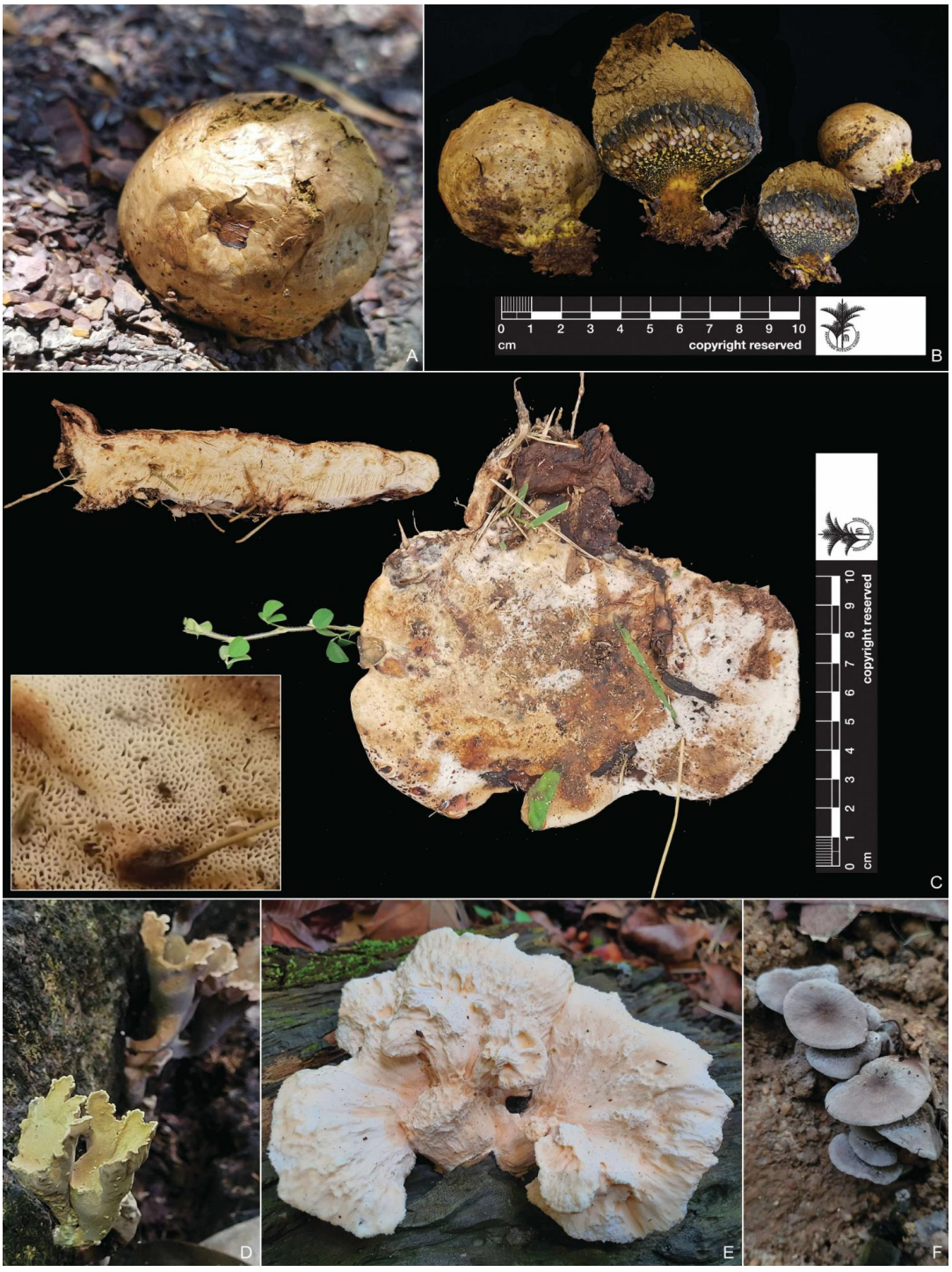
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Appendix 1. A. *Pisolithus alba* at Lazarus Island (voucher no. SL1589), credit: Lua H.K. **B.** Cross section of *Pisolithus alba* new species record published in Guide to Macrofungi in Singapore, credit: S.M.L. Lee. **C.** *Amylosporus* sp. (voucher no. SL1688), a soft poroid fungi, with spores that turn blue in Melzer's solution, new genus record (unpublished data), credit: S.M.L. Lee. C inset, showing pores of *Amylosporus* sp. credit: S.M.L. Lee. **D.** *Gomphus* sp. (voucher no. SL1902), in Sentosa, credit: S.M.L. Lee. new genus record (unpublished data). **E.** *Piptoporellus* sp. (voucher no. SL1899), in Sentosa, new genus record (unpublished data), credit: E. Wong. **F.** *Pseudobaeospora* sp. (voucher no. SL1969), in Sentosa, new genus record (unpublished data), credit: S.M.L. Lee.

Appendix 2. Locations of recorded Fungi from published and unpublished literature and Southern Islands Biodiversity Survey (SIBS) data. BRN = Pulau Brani, HNT = Pulau Hantu, KEP= Keppel Island, KUS= Kusu Island, LAZ = Pulau Sekijang Pelepah (Lazarus Island), SJI = Pulau Sekijang Benderah (St John's Island), SLG= Pulau Selegu, SMK = Pulau Semakau, SRT= Pulau Seringat, SNT = Pulau Blakang Mati (Sentosa Island), TKR= Pulau Tekukor.

Family	Scientific name	RDB3	IUCN	BRN	HNT	KEP	KUS	LAZ	SJI	SLG	SMK	SRT	SNT	TKR
Agaricaceae	*Agaricus* aff. *chiangmaiensis*	NL	NE					Y						
Agaricaceae	*Lepiota* sp "1"	NL	NE									Y		
Agaricaceae	*Lepiota* / *Agaricus* sp "2"	NL	NE				Y							
Agaricaceae	*Leucoagaricus lacrymans*	NL	NE								Y			
Agaricaceae	*Leucocoprinus birnbaumii*	NL	NE		Y									
Agaricaceae	*Leucocoprinus fragilissimus*	LC	NE					Y						
Agaricaceae	*Leucocoprinus* sp "1"	NL	NE										Y	
Agaricales	*Gerronema* sp "1"	NL	NE	Y										
Auriculariaceae	*Auricularia mesenterica*	LC	NE								Y			
Bondarzewiaceae	*Amylosporus* sp "1"	LC	NE				Y							
Clavariaceae	*Clavulinopsis* sp "1"	LC	NE										Y	
Dacrymycetaceae	*Dacryopinax spathularia*	LC	NE								Y			
Entolomataceae	*Entoloma flavidum*	LC	NE					Y						
Entolomataceae	*Entoloma* sp "1"	NL	NE	Y										
Entolomataceae	*Entoloma* sp "2"	NL	NE										Y	
Entolomataceae	*Entoloma* sp "3"	NL	NE										Y	
Entolomataceae	*Entoloma* sp "4"`	NL	NE										Y	
Entolomataceae	*Entoloma* sp "cuboid spores"	NL	NE					Y						
Fomitopsidaceae	*Piptoporellus* sp "1"	NL	NE										Y	
Fomitopsidaceae	*Rhodofomitopsis feei*	LC	NE							Y	Y		Y	

Appendix 2. Continuation.

Family	Scientific name	RDB3	IUCN	BRN	HNT	KEP	KUS	LAZ	SJI	SLG	SMK	SRT	SNT	TKR
Ganodermataceae	*Ganoderma* sp "1"	NL	NE						Y					
Gomphaceae	*Gomphus* sp "1"	NL	NE										Y	
Gomphaceae	*Ramaria* cf *zippelii*	NL	NE						Y					
Gomphaceae	*Ramaria* sp "1"	NL	NE						Y					
Hygrophoraceae	*Hygrocybe* sp "1"	NL	NE					Y						
Hymenochaetaceae	*Phylloporia* sp "1"	NL	NE				Y				Y			
Hymenochaetaceae	*Phylloporia* sp "2"	NL	NE								Y			
Hymenogastraceae	*Gymnopilus dilepis*	NL	NE			Y								
Hypoxylaceae	*Daldinia concentrica*	LC	NE						Y					
Marasmiaceae	*Hydropus anthidepas*	NL	NE	Y										
Marasmiaceae	Family Marasmiaceae sp "1"	NL	NE								Y			
Marasmiaceae	*Marasmius pellucidus*	LC	NE										Y	
Marasmiaceae	*Marasmius* cf *pellucidus*	NL	NE									Y		
Marasmiaceae	*Marasmius neotrichotus*	VU	NE		Y							Y		
Omphalotaceae	*Collybiopsis gibbosa*	NL	NE				Y							
Omphalotaceae	*Gymnopus* sp "1"	NL	NE										Y	
Omphalotaceae	Family Omphalotaceae sp "1"	NL	NE			Y								
Omphalotaceae	*Setulipes* sp "1"	NL	NE					Y						
Pleurotaceae	*Hohenbuehelia* sp "1"	NL	NE										Y	
Pluteaceae	*Pluteus* sp "1"	NL	NE										Y	
Polyporaceae	*Cubamyces menziesii*	LC	NE				Y							
Polyporaceae	*Earliella scabrosa*	LC	NE						Y					

Appendix 2. Continuation.

Family	Scientific name	RDB3	IUCN	BRN	HNT	KEP	KUS	LAZ	SJI	SLG	SMK	SRT	SNT	TKR
Polyporaceae	*Favolus acervatus*	LC	NE					Y		Y	Y			
Polyporaceae	*Favolus* sp "1"	NL	NE					Y						
Polyporaceae	*Favolus* sp "2"	NL	NE										Y	
Polyporaceae	*Hexagonia glabra*	NL	NE										Y	
Polyporaceae	*Hexagonia tenuis*	LC	NE						Y	Y	Y			
Polyporaceae	*Lentinus sajor-caju*	LC	NE					Y						
Polyporaceae	*Lentinus squarrosulus*	LC	NE										Y	
Polyporaceae	*Microporus xanthopus*	LC	NE	Y				Y		Y	Y		Y	
Polyporaceae	*Nigroporus vinosus*	NL	NE										Y	
Polyporaceae	*Polyporus* sp "1"	NL	NE						Y					
Polyporaceae	*Pseudofavolus tenuis*	NL	NE	Y		Y		Y				Y	Y	
Polyporaceae	*Pycnoporus sanguineus*	LC	NE						Y	Y	Y	Y		
Polyporaceae	*Trametes* sp "1"	NL	NE										Y	
Polyporaceae	*Trametes* sp "2"	NL	NE										Y	
Polyporaceae	*Truncospora ochroleuca*	LC	NE	Y							Y		Y	
Polyporales	Family Polyporales "1"	NL	NE										Y	
Polyporales	Family Polyporales "2"	NL	NE										Y	
Psathyrellaceae	*Psathyrella* sp "1"	NL	NE										Y	
Russulaceae	*Lactarius* sp "1"	NL	NE										Y	
Russulaceae	*Lactarius* sp "2"	NL	NE										Y	
Schizophyllaceae	*Schizophyllum commune*	LC	NE								Y			
Sclerodermataceae	*Pisolithus albus*	CR	NE					Y						Y

Appendix 2. Continuation.

Family	Scientific name	RDB3	IUCN	BRN	HNT	KEP	KUS	LAZ	SJI	SLG	SMK	SRT	SNT	TKR
Sclerodermataceae	*Scleroderma columnare*	VU	NE										Y	
Sclerodermataceae	*Scleroderma* sp "1"	NL	NE										Y	
Tricholomataceae	*Pseudobaeospora* sp "1" nov.	NL	NE										Y	
Xylariaceae	*Xylaria* sp "1"	NL	NE						Y					
Xylariaceae	*Xylaria* sp "2"	NL	NE								Y			