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Marine Fungi from Langkawi Island, Malaysia

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ABSTRACT Four hundred and fourty four marine fungi have been reported [11] which comprised of arenicolous, foliicolous, algicolous and manglicolous. Recent investigation has increased our knowledge of the diversity and occurrrence of marine fungi. Two aspects are addressed in this paper: i) manglicolous marine fungi distribution, ii) Comparison of the fungi recorded at Langkawi with other studied areas in Malaysia, host specificity and their biogeography. Seventy four lignicolous and manglicolous higher marine fungi were collected from various substrate of the North-East Langkawi Island. The most frequent fungi were *Dactylospora heliotrepha* Kohlm. & E. Kohlm., *Hypoxylon oceanicum* Schatz and *Leptosphaeria australiensis* (Cribb & Cribb) G. C. Hughes while *Sarvoyella lignincola* E. B. G. Jones & Eaton was frequently encountered. In the present study, we observed that the diversity of mangrove fungi is dependent on age of the mangrove materials, diversity of mangrove tree flora, host specificity and location of mangrove area. However, the total number of samples examined also determined the marine fungal diversity.

ABSTRAK Empat ratus empat puluh empat kulat marin telah dilaporkan [11] yang terdiri daripada kulat pada pasir, kulat pada daun, kulat pada alga dan kulat pada pokok bakau. Kajian yang dijalankan baru-baru ini telah menambahkan pengetahuan mengenai kepelbagaian dan kehadiran kulat marin. Dua aspek yang disenaraikan di sini ialah i) Taburan kulat marin dari pokok bakau, ii) perbandingan di antara kulat marin di Langkawi dengan kajian kulat marin yang lain di Malaysia, kespesifikan hos dan biogeografinya. Tujuh puluh empat kulat marin telah kutip daripada pelbagai substrat di Pulau Langkawi. Kulat yang paling kerap ditemui ialah *Dactylospora heliotrepha* Kohlm. & E. Kohlm, *Hypoxylon oceanicum* Schatz dan *Leptosphaeria australiensis* (Cribb & Cribb) G. C. Hughes manakala *Sarvoyella ligníncola* E. B. G. Jones & Eaton adalah kulat yang kerap dikira. Dalam kajian ini, kami telah memerhatikan kepelbagaian kulat dari bakau adalah bergantung kepada umur pokok bakau, kepelbagaian spesies pokok bakau, kespesifikan hos dan lokasi kawasan bakau. Walau bagaimanapun, jumlah sampel yang diperiksa juga menentukan kepelbagaian kulat marin tersebut.

(Marine fungi, frequency of occurrence, mangrove, diversity)

INTRODUCTION

Johnson and Sparrow [13] defined marine fungi as organisms with the ability to grow at certain seawater concentrations. However, Kohlmeyer *et al.* [21] stated that marine fungi cannot be defined strictly on physiological basis only and they used a broader ecological definition. They devided marine fungi into two groups: obligate marine fungi are those that grow and sporulate exclusively in marine or estuarine habitat; facultative marine fungi are those from freshwater or terrestrial milieus but able to grow in the marine environment'. Marine fungi can also be categorised on their ability to occupy specific habitats and substrata [21]. Marine fungi growing on submerged woody materials and driftwood are defined as lignicolous, while algicolous fungi occur on marine algae. Arenicolous fungi are associated with sand grains and foliicolous fungi are isolated from leaves immersed or shed in the marine environment. Marine fungi which are found on submerged parts of mangroves are called manglicolous fungi.

Fungi are the principle decomposer in the marine environment with an ability to produce enzyme capable of degrading the cell wall components of plant material including cellulose, hemicellulose and lignin [12]. They are not only inhabiting mangrove plants but also on seaweed, coral reef, shells, and other marine organisms. Within the intertidal zone there is a characteristic group of fungi that can tolerate harsh environmental conditions: high temperature, high salt concentrations, freshwater from rain and dessication [14]. They are able to inhabit and settle in the upper part of the intertidal region, producing sheath, pigmentation and appendages. This could account for the marine fungi to be the important decomposers of wood in the upper part of intertidal region as there are less marine borers in the harsh environment. However, there are limited information on the role of fungi in the degradation process throughout the whole marine environment.

Information on marine fungi is still in the cataloging phase. With an estimate of 1.5 million fungal species worldwide [5], less than 0.0001% marine fungi have been reported. Two hundred and nine taxa were recorded by Kohlmeyer *et al.* [20], Kohlmeyer *et al.* [21] recorded 321, while Hyde and Sharma [11] reported 444 taxa of higher marine fungi throughout the world. Jones and Mitchell [17] estimated there are ca 900 species of marine fungi. This indicates that studies of marine fungi still require further investigation. Alias [1] stated that the two possible reasons for the low number of marine fungi recorded are the method of isolation and the fact that large regions of the oceans still remain unexplored. Hence, the present study was undertaken to explore the richness and occurrence of higher marine fungi from various substrates, namely in Langkawi Island, Malaysia.

MATERIALS AND METHODS

A wide range of decaying driftwood, branches, stumps, prop roots and viviporous reproductive structures were randomly collected from selected coastal and mangrove trees of *Rhizophora apiculata* Blume, *Rhizophora mucronata* Lamk., *Xylocarpus granatum* König, *Ceriops* sp. Seven collection sites in the North-East Langkawi Island were chosen; located at North 6° 23' 19.8'', East 99° 53' 42.7'', Sungai Kilim, North 6° 24' 18.1'', East 99° 51' 13.0'' near Sungai Kilim Jetty, North 6° 25' 41.6'', East 99° 49' 53.4" near Sungai Kilim Jetty, North 0.6° 25' 41.6'', East 99° 49' 53.4", Sungai Kilim, North 0.6° 25' 41.6'', East 99° 49' 53.4" in Air Hangat, North 6° 25' 41.6'', East 99° 50' 20.6'', Sungai Itau, North 6° 28' 30.3'', East 99° 49' 43.1'', Pasir Panjang Beach, North 6° 24' 51.7'', East 99° 52' 21.0'', Sungai Banjar and North 6° 24' 20.2'', East 99° 51' 24.4'' in Tanjung Rhu.

Samples were placed in polythene bags and returned to the laboratory for examination and fungal identification. Surface mud and detritus were washed away using sterile sea water. Samples were then incubated in a sealed sandwich box with a layer of sterile damp tissue paper and kept at room temperature (28°C) for three months. Samples were kept moist by the periodic application of a fine aerosol spray of sterile sea water at regular intervals. Wood samples collected were examined under the compound microscope for the presence of ascomata, basidiomata, picnidia and conidia. Identification of higher marine fungi followed as in [3]. Isolation of marine fungi were made and kept in the Herbarium, University of Malaya.

RESULTS AND DISCUSSION

Of the 322 samples examined, 242 (75.2%) samples supported 74 taxa of fungi with a total of 425 fungal collections including 35 empty perithecia. Ascomycetes (86.5%) were the largest group encountered, followed by deuteromycetes (10.8%) and basidiomycetes (2.7%) which were 64, 8 and 2, respectively (Table 1). Twenty four unidentified species were recorded. The most frequent fungi were *Dactylospora heliotrepha* Kohlm. & E. Kohlm (7.9%) followed by *Leptosphaeria australiensis* (Cribb & Cribb) G. C. Hughes (7.7%), *Hypoxylon oceanicum* Schatz (7.7%), while *Sarvoyella longispora* E. B. G. Jones & Eaton (5.9%) was common. The percentage of colonization was 75.2% and the average number of fungi per sample was 1.2.

On the basis of percentage of occurrence, marine fungi observed in the present study can be grouped into very frequent (with 7% or more), common species (1-6%) and less frequent (< 1%) as summarised in Table 2. The majority of filamentous higher marine fungi occurring in the Langkawi Island were only rarely encountered (present at less than 1% occurrence). More than half of the marine fungi listed in Table 1 were found to be restricted to a single collection. A few of these were widely distributed at many locations in Langkawi Island e.g. *Leptosphaeria australiensis, Hypoxylon oceanicum, Hypoxylon* sp. 1, *Dactylospora heliotrepha* and *Verruculina enalia* (Kohlm.) Kohlm. & Volkm.-Kohlm.

Table 3 shows the total number of species and species specific to host collected from different mangrove species and coastal areas. A higher number of marine fungi were recorded from the mangrove trees than the coastal areas, with 60 and 29 species, respectively. The number of species found on each of the five substrates was also different in which 12 taxa were found on *Ceriops* sp., 48 on *Rhizophora apiculata*, 20 on *Rhizophora mucronata*, 23 on *Xylocarpus granatum* and 29 on driftwood. *Rhizophora apiculata* materials had the highest number of marine fungal species. Sixty seven of the samples examined were from *Rhizophora apiculata*. The lowest number of species found was from *Ceriops* sp. probably due to the small number of materials collected from this mangrove tree (26 samples examined). The common species on driftwood were *Hypoxylon oceanicum, Leptosphaeria australiensis, Quintaria lignalitis* Kohlm.) Kohlm. & Volkm.-Kohlm, *Dactylospora heliotrepha, Lautospora* sp. and *Savoryella longispora* while those from the mangrove area were *Leptosphaeria australiensis, Hypoxylon oceanicum, Dactylospora heliotrepha, Savoryella longispora* K. D. Hyde & E. B. G. Jones *Trichocladium achrasporum* (Meyers & Reynold) Dixon and Ascomycetes sp. 31.

Table 1. Marine fungi from Langkawi Island, Malaysia

Species	Location	% Occurrence
Ascomycetes (64 taxa)		
Aigialus grandis Kohlm. & Schatz	C	0.31
Aigialus mangrovei Borse	M	2.17
Aigialus parvus Schatz & Kohlm.	M	1.24
Aigialus sp. 1	C & M	4.04
Aigialus sp. 2	M	0.31
Ascocratera manglicola Kohlm	M	0.93
Caryosporella rhizophorae Kohlm	M	1.55
Coronopapilla mangrovei (K. D. Hyde) Kohlm. & E. Kohlm	C	0.31
Cryptosphaeria mangrovei K.. D. Hyde	M	0.93
Cryptovalsa mangrovei K. D. Hyde	M	0.62
Cucullosporella sp	M	0.31
Dactylospora heliotrepha (Kohlm. & E. Kohlm.) Hafellner	C & M	9.63
Dactylospora sp.	M	0.31
Eutypa bathurstensis K. D. Hyde & Rappaz	M	0.62
Eutypella naqsii K. D. Hyde	M	0.62

Halosarpheia abonnis Kohlm.	C & M	1.86
Halosarpheia minuta W. F. Leong	M	0.93
Halosarpheia ratnagiriensis Patil & Borse	C & M	2.17
Helicascus kanaloamus Kohlm.	M	0.31
Hypoxylon oceanicum Schatz	C & M	9.32
Hypoxylon sp. 1	C & M	3.73
Kallichroma tethys (Kohlm. & E. Kohlm.) Kohlm. & Volkm.-Kohlm.	M	3.42
Lautospora sp.	C & M	3.73
Leptosphaeria australiensis (Cribb & Cribb) G. C. Hughes	C & M	9.32
Leptosphaeria sp. 1	C & M	0.62
Leptosphaeria sp. 2	C	0.93
Leptosphaeria sp. 3	C	0.31
Lulworthia spp.	C & M	0.62
Lulworthia grandispora Meyers	C & M	0.93
Massarina ramunculicola K. D. Hyde	C	0.31
Massarina thallasiae Kohlm. & Volkm.-Kohlm.	C & M	3.11
Massarina velatospora K. D. Hyde & Borse	M	0.93
Massarina sp. 1	M	0.31
Phaeosphaeria sp. 1	C & M	1.86
Phaeosphaeria sp. 2	C	1.86
Quintaria lignalitis (Kohlm.) Kohlm. & Volkm.-Kohlm.	C & M	4.35
Rhizophila marina K. D. Hyde & E. B. G. Jones	M	1.55
Saccardoella mangrovei K. D.Hyde	C	1.24
Salsugenia ramicola K. D. Hyde	M	0.31
Savoryella lignincola E. B. G. Jones & Eaton	C	0.62
Savoryella longispora K. D. Hyde & E. B. G. Jones	C & M	7.14
Swampomyces sp.	M	1.55
Deuteromycetes (8 species)		
Cirrenalia pygmea Kohlm	M	2.48
Phoma sp. 1	C & M	1.24
Trichocladium achrasporum (Meyers & Reynold) Dixon	M	3.42
Trichocladium alopallonellum (Meyers & Moore)Kohlm. & Volkm.- Kohlm.	M	0.62
Xylomyces sp.	M	2.17
Deutero sp. 5	M	2.17
Deutero sp. 6	M	0.31
Deutero sp. 7	M	0.31
Basidiomycetes (2 species)		
Calathella mangrovei Jones and Agerer	M	0.62
Halochyphina villosa Kohlm and Kohlm.	M	2.17
Total	**390**	
Empty perithecia	**35**	
Total no. of individual	**425**	
No. of samples examined	**322**	
No. of samples colonized	**242**	
% colonization	**75.2%**	
Average no. of fungi per sample	**1.21**	
Total no. of fungi collected	**74**	

C- Occur at coastal area only M- Occur at mangrove area only C & M- Occur at both areas

Table 2. Frequency of occurrence of marine fungi in Langkawi Island

	Frequent (1-6%)	Less frequent (<1)
Dactylospora heliotrepha	*Quintaria lignalitis*	*Ascocratera manglicola*
Leptosphaeria australiensis	*Aigialus* sp. 1	*Halosarpheia minuta*
Hypoxylon oceanicum		*Leptosphaeria* sp. 2
Savoryella longispora	*Verruculina enalia*	*Lulworthia grandispora*
		Massarina velatospora
	Hypoxylon sp 1	SC sp. 1
		SC sp. 35
	Lautospora sp.	SC sp. 42
		SC sp. 3
	SC sp. 31	SC sp. 6
		SC sp. 17
	Kallichroma tethys	
		Calathella mangrovei
	Trichocladium achrasporum	*Cryptovalsa mangrovei*
		Eutypa bathurtensis
	Massarina thalassiae	*Eutypella naqsii*
	SC sp. 21	*Coronopapilla mangrovei*
		Cryptosphaeria mangrovei
	Cirrennalia pygmea	*Leptosphaeria* sp.1
	Aigialus mangrovei	*Lulworthia* sp.
	Deutero sp. 5	
	Halocyphina villosa	*Savoryella lignincola*
	Halosarpheia ratnagiriensis	
	Xylomyces sp.	*Trichocladium allopalonellum*
	Halosarpheia abonnis	
	Phaeosphaeria sp. 1	
	Phaeosphaeria sp. 2	
	Caryospora mangrovei	
	Rhizophila marina	
	Swampomyces sp.	*Aigialus grandis*
	Aigialus parvus	*Aigialus* sp. 2
	Saccardoella mangrovei	*Cucullosporella* sp.
	Phoma sp. 1	*Dactylospora sp.*
		Leptosphaeria sp. 3
		Helicascus kanaloamus
		Massarina ramuculicola
		Massarina sp. 1
		Salsugenia ramicola
		SC sp. 11
		SC sp. 12
		SC sp. 16
		SC sp. 18
		SC sp. 28
		SC sp. 30
		SC sp. 32
		SC sp. 34
		SC sp. 36
		SC sp. 37
		SC sp. 40
		SC sp. 41
		Deutero sp. 6
		Deutero sp. 7

Table 3. Total number of species and species specific to host collected from different mangrove species and coastal areas

	Rhizophora apiculata	***Rhizophora mucronata***	***Xylocarpus granatum***	***Ceriops* sp.**	**Coastal area**
Total species	**48**	**20**	**23**	**12**	**29**
Species specific to host	*Ascocratera manglicola*	*Caryosporella mangrovei*	*Massarina* sp.	SC sp. 36	*Aigialus grandis*
	Cucullosporella sp.	SC sp. 37	SC sp. 39	SC sp. 41	*Coronopapilla mangrovei*
	Cryptosphaeria mangrovei		SC sp. 40		*Leptosphaeria* sp. 2
	Cryptovalsa mangrovei		Deutero sp. 5		*Massarina ramunculicola*
	Eutypa bathurstensis				*Massarina velatospora*
	Eutypella naqsii				*Salsugenia ramicola*
	Helicascus kanaloanus				*Phaeosphaeria* sp. 2
	Saccardoella mangrovei				SC sp. 28
	Asco sp. 30				SC sp. 32
	Asco sp. 34				SC sp. 42
	Asco sp. 35				
	Deutero sp. 6				

RESULTS AND DISCUSSION

Cribb and Cribb [11] recorded the first manglicolous marine fungi. The first mangrove fungi to be described was *Metasphaeria australiensis* Cribb and Cribb (now placed in *Leptosphaeria australiensis* (Cribb and Cribb) G. C. Hughes) and was found on dead branches of *Avicennia marina* (Forsk.) Vierh. Var. *resinifera* (Forsk.) Cribb and Cribb [11] in Australia. Since then, many studies on marine fungi were investigated from other biogeographical locations by several workers [9, 19, 7, 21, 22, 14, 27, 23 and 24]. These studies showed that *Antennospora quadricornuta* (Cribb & J. W. Cribb) T. W. Johnson, *Dactylospora heliotrepha, Lulworthia grandispora, Lulworthia* sp., *Torpedospora radiata* Meyers, *Verruculina enalia, Halocyphina villosa* Kohlm & Kohlm., *Leptosphaeria australiensis, Hypoxylon oceanicum, Lignincola leaves* Höhnk, *Savoryella lignincola, Halosarpheia marina* (Cribb & Cribb) K. D. Hyde, *Kallichroma tethys* (Kohlm. & E. Kohlm) Kohlm. & Volkm.- Kohlm., *Massarina velatospora* K. D. Hyde & Borse, *Phoma* sp., *Cirrenalia pygmea* Kohlm., *Marinospora mangrovei* K. D. Hyde, *Aniptodera cheasapeakensis* Shearer & M. A. Mill, *Periconia prolifica* Anastasiou, *Swampomyces triseptatus* K. D. Hyde & Nakagiri, *Caryosporella rhizophorae* Kohlm. and *Trichocladium achrasporum* (Meyers & R. T. Moore) Dixon as common species in coastal and mangrove areas. In Malaysia, several studies were conducted by Jones *et al.* [18], Jones *et al.* [16], Tan *et al.* [25] and Alias *et al.* [3]. On the marine fungi from different geographical areas and showed that ascomycetes from different orders are the largest group of higher marine fungi occurring in the mangroves. The present study concurred that ascomycetes (86.5%) were found to be the most abundant fungi compared to deuteromycetes (10.8%) and basidiomycetes (2.8%).

Table 4 lists the frequent and common fungi in the present study and previous studies on marine fungi in Malaysia [2, 16, 18, 25], and shows that a number of fungi are commonly found. Hyde *et al.* [9] stated that the percentage of occurrence is used as an expression of the frequency of fungi on the substrata. Therefore, common or less frequent fungi can be ascertained. Alias *et al.* [3] documented *Hallocyphina villosa, Kallichroma tethys, Lulworthia grandispora, Hypoxylon oceanicum, Dactylospora heliotrepha,* *Verruculina enalia* and *Sarvoyella lignincola* as the most common marine manglicolous fungi reported from Morib, Kuala Selangor and Port Dickson. Similar results were obtained from the present study with *Dactylospora heliotrepha, Leptosphaeria australiensis* and *Hypoxylon oceanicum* being the most common species reported. *Zalerion varium* Anastasiou, *Leptosphaeria australiensis, Hypoxylon oceanicum, Savoryella lignincola, Dictyosporium pelagicum* (Linder) G. C. Hughes and *Trichocladium achrasporum* were the most common species in Hainan Island [27]. However, in Thailand, reported *Lulworthia grandispora* as the common species [8]. These differences could be due to the host specificity, type of substrates and location of the mangrove areas.

Results obtained from the present study indicate high diversity of marine fungi from the North-East Langkawi Island. Table 5 shows Sorenson and Diversity Index for North-East Langkawi Island and other locations in Malaysia as well as other countries. In comparison with other studied areas in Malaysia, Langkawi has the highest species diversity (11.73) compared to Morib (8.58), Kuala Selangor (8.28) and Port Dickson (10.62) [3], Sungei Geylang Patah (6.12) [18] and Pontian Besar (5.75) [25]. However, the diversity is lower compared to Kampung Sementa and Kuala Selangor (12.14) [16].

The similarity index could be used to measure how different or similar the variety of species found between habitats or samples. A comparison of similarity of species composition, using Sorenson Index of fungi found in the present study and other studies [3, 27 and 24] is shown in Table 5. Similarity coefficients show that the species composition of samples collected in the present study is very different from other areas, with relatively low indices, 0.05-0.4. These differences could be attributed to the total number of samples examined, host specificity and location of the mangrove areas.

Tan *et al.* [25] in their study of lignincolous marine fungi at different localities in Singapore, also found that the fungal species composition varied at different mangrove stands. [18], [7], [22] and [3] stated that the differences in the percentage of colonization, species diversity and average number of fungi per sample seen in this study, and those reported from the literature, can be attributed to several factors, e.g. position of the substrate on shore, mangrove tree species, environmental conditions and the nature and origin of the substrata examined.

[26] discussed the difficulty in determining the frequency of occurrence of marine fungi. Direct observation only allow us to identify fungi that sporulate while those present as mycelium may go undetected. The substrata collected in nature are not usually uniform, consisting of uneven length and diameter of wood, with or without bark. However, random collections of such substrata have allowed us to determine the fungal community in this ecosystem.

Fungi inhabiting the substrates of mangroves and coastal area are shown in Table 3. It has been known that marine fungi are not confined to one substrate only. However, a few species have been found to restrict to specific substrates. [21, 7, 22] suggested that some marine fungi are host specific but this remains to be determined [15, 7]. From this study, it is also shown that some marine fungi occur on a wide range of substrata while others only grow on specific timbers. In the present study, *Rhizophila marina* K. D. Hyde & E. B. G. Jones has been found to be restricted only on *Rhizophora apiculata* (Figure d). *Cryptosphaeria mangrovei* K. D. Hyde, *Cryptovalsa mangrovei* Abdel-Wahab & Inderb., *Eutypa bathurstensis* K. D. Hyde & Rappaz and *Eutypella naqsii* K. D. Hyde are new records for Malaysia. Decaying *Rhizophora apiculata* is a new host for *Eutypa bathurstensis* and *Eutypella naqsii*. *Eutypa bathurstensis* [10] and *Eutypella naqsii* [8] were found on intertidal wood of *Avicennia* sp. in Australia.

Marine fungi have special adaptation and ability to survive in harsh marine environment, particularly to dessication and settlement. These aspects were discussed by [18], [7], [14], [2]. Morphological character of ascomata, asci and ascospores of are unique in order to adapt in the marine environment. Marine fungi on the upper lever of intertidal region tend to be exposed to harsher temperature as well as variation in salinity. Generally, the ascomata tend to be immersed while some of them have carbonaceous walls to prevent from dessication, and some species have pigmented spores for the same purpose (Figures a, b, c, d). Many marine Ascomycota have spores with appendages and sheath for attachment and settlement (Figure e, f, g, h).

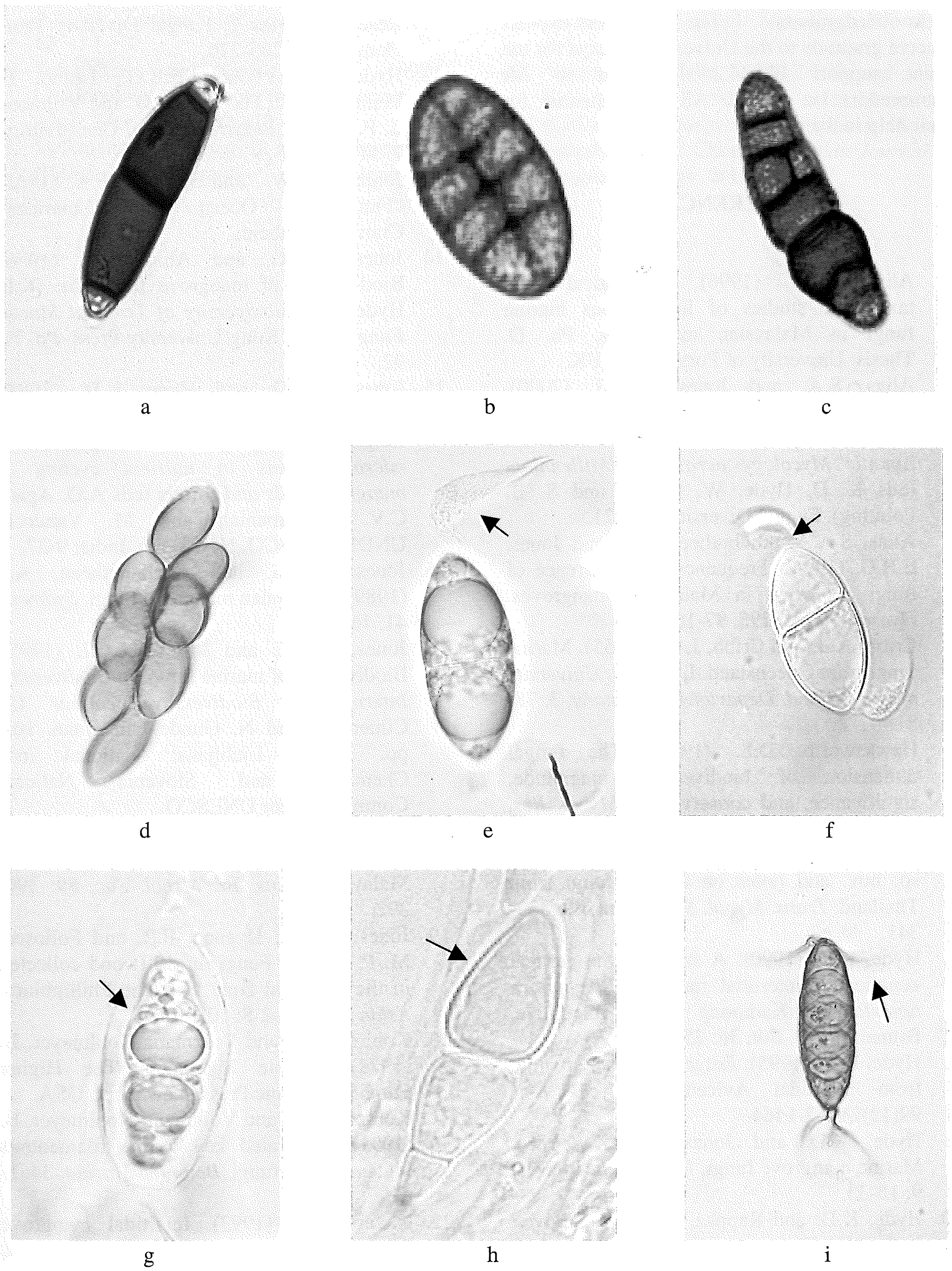
A number of mangrove areas in Langkawi Island are not thoroughly studied. Therefore, further investigations are needed to enhance the knowledge of marine fungi in Langkawi Island.

Table 4. Frequent and common marine fungi at different locations in Malaysia

Mangrove stand	Frequent fungi	Common fungi
Langkawi Island (Present study)	*Dactylospora heliotrepha* *Hypoxylon oceanicum* *Leptosphaeria australiensis* *Savoryella longispora*	*Kallichroma tethys* *Massarina thalassiae Trichocladium achrasporum* *Verruculina enalia*
Kuala Selangor (Alias, Kuthubutheen and Jones, 1995)	*Halocyphina villosa* *Leptosphaeria australiensis* *Kallichroma tethys* *Lulworthia grandispora*	*Marinosphaera mangrovei* *Phoma* sp. 1 *Eutypa* sp. *Ascocratera manglicola* *Dactylospora heliotrepha*
Morib (Alias, Kuthubutheen and Jones, 1995)	*Leptosphaeria australiensis* *Halocyphina villosa*	*Kallichroma tethys* *Hypoxylon oceanicum* *Phoma* sp. *Lulworthia grandispora* *Rhabdospora avicenniae*
Port Dickson (Alias, Kuthubutheen and Jones, 1995)	*Hypoxylon oceanicum* *Massarina ramunculicola*	*Leptosphaeria australiensis* *Kallichroma tethys* *Marinosphaera mangrovei* *Phoma* sp. 1 *Marinosphaera mangrovei* *Savoryella lignincola* *Halosarpheia ratnagiriensis* *Verruculina enalia* *Dactylospora heliotrepha*
Pontian Besar (Tan and Leong, 1992)	*Hypoxylon oceanicum* *Savoryella longispora* *Halocyphina villosa* *Trichocladium achrasporum*	*Savoryella lignincola* *Cytospora rhizophorae* *Massarina velatospora*
Kampung Sementa and Kuala Selangor (Jones and Kuthubutheen, 1989)	*Halocyphina villosa* *Kallichroma tethys*	*Hypoxylon oceanicum* *Lulworthia grandispora* *Halosarpheia marina*
Sungei Geylang Patah (Jones and Tan, 1987)	*Halocyphina villosa* *Hypoxylon oceanicum* *Savoryella paucispora* *Trichocladium achrasporum*	*Bathyascus* sp. *Cirrenalia basiminuta* *Aniptodera chesapeakensis* *Antennospora quadricornuta* *Mycosphaerella pneumatophore*

Table 5. Comparison of diversity and similarity index of marine fungi in Langkawi Island, other locations in Malaysia and other countries

Location	Diversity Index	Location	Similarity Index
Langkawi Island	12.02	Kuala Selangor (Alias *et al.*, 1995)	0.28
Kuala Selangor (Alias *et al.*, 1995)	8.25	Morib (Alias *et al.*, 1995)	0.29
Morib (Alias *et al.*, 1995)	8.58	Port Dickson (Alias *et al.*, 1995)	0.31
Port Dickson (Alias *et al.*, 1995)	10.62	Hainan (Vrijmoed *et al.*, 1996)	0.14
Pontian Besar (Tan and Leong, 1992)	5.73	India (Prasannarai *et al.*, 1999)	0.07
Kampung Sementa and Kuala Selangor (Jones and Kuthubutheen, 1989)	12.14		
Sungei Geylang Patah (Jones and Tan, 1987)	6.12		



Figures a-i. Light micrographs showing adaptations of marine fungi in Langkawi Island. Figs a-d showed marine fungi with pigmentation. From left, *Lignincola longirostris, Aigialus* sp. 2, *Phaeosphaeria* sp. 1 and *Rhizophila marina*.

Figures e-i. Sheath and appendage producing-spores (arrowed) of *Halosarpheia abonnis, Halosarpheia ratnagiriensis, Massarina thalassiae, Massarina velatospora* and Ascomycetes sp. 19, respectively.

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