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The diversity and distribution of polypores (Basidiomycota: Aphyllophorales) in wet evergreen and shola forests of Silent Valley National Park, southern Western Ghats, India, with three new records

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Abstract: The present study was conducted to document the diversity and distribution of polypores in wet evergreen and shola forests of Silent Valley National Park, Kerala State, in the southern Western Ghats, India. A combination of opportunistic and plot-based sampling was carried out in order to maximize the documentation of polypore distribution. The study was conducted throughout the entire study period of 2013–2015. Fifty-seven polypore species in 29 genera belonging to seven families were documented from the national park. The wet evergreen forest was enriched with 52 species whereas the shola forest harboured 20 polypore species. Fifteen species were found in both ecosystems while five species were exclusively found in the shola forest. The Polyporaceae was the dominant family with 30 species, followed by Hymenochaetaceae with 16 species, and Fomitopsidaceae and Meripilaceae with three species each. Ganodermataceae and Schizoporaceae made their presence with two species each while only one species was reported under family Meruliaceae. Among the polypores documented, 42 species were annuals and 15 were perennials. While analyzing the rot characteristics of the recorded polypores, it was found that white rot polypores have notable dominance over brown rot polypores. Out of the 57 species analysed, 52 polypores were white rotters and only five species were brown rotters. During the present study, three species (*Phylloporia pectinata*, *Trametes menziesii*, and *Trametes ochracea*) were found to be new records from the southern Western Ghats. An identification key was developed for the polypores documented from Silent Valley National Park based on micro and macro morphological features.

Keywords: Brown rot, evergreen forest, new record, Polyporaceae, shola forest, white rot.

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Author Contribution: CKA carried out research and performed analyses as part of his MSc programme under the guidance of KV and PNIG. All the authors wrote the paper together.

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INTRODUCTION

The polypores are fascinating and specialized wood-rotting macrofungi that play a major role in decomposition and biomass turnover in forest ecosystems. Wood rotting polypores are important elements of forest ecosystems since they decompose wood and coarse wood debris, and play a primary and central role in nutrient cycling. Most polypores depend on woody substrates while the rest are terrestrial. Most of them inhabit living wood as parasites subsequently killing them slowly and continue as saprophytes while the remaining are true saprophytes. Taxonomically, polypores are macro fungi under the division Basidiomycota and order Polyporales. They produce holobasidia and ballistosporic basidiospores typically on the inside of the tubes lining the underside of fructifications (Leelavathy & Ganesh 2000). The importance of polypores and the diversity of polypores in tropical forests were not known or not properly assessed. The tropics are a very rich source of potentially useful polypores, many of which probably have not even been recognized, described, or named (Yamashita et al. 2015).

The first Indian record of a member of polyporales was by Klotzsch (1832) when he described a total of four polypores from India. In 1833, Klotzsch described 25 polypores from the Himalayan valleys. Sundararaman & Marudarajan (1925) reported 11 species of polypores from Chennai. Butler & Bisby (1931) brought together all the records of Indian fungi in their valuable compilation The Fungi of India, which included 293 polyporoid species under 16 genera. Bakshi (1971) gave an account of 355 species of polypores belonging to 15 genera in his most outstanding work Indian Polyporaceae (on trees and timber). Roy & De (1996) listed 114 poroid species in Polyporaceae of India based on exhaustive studies on fungi belonging to the family Polyporaceae collected from different parts of India. Further, Florence (2004) reported 555 species of basidiomycetes under 179 genera from Kerala State. Bhosale et al. (2005) gave a tabulated account of 251 species of order *Aphyllophorales* from the Western Ghats. Swapna et al. (2008) reported 778 species of macrofungi belonging to 101 genera under 43 families from the semi-evergreen and moist deciduous forests of Shimoga District, Karnataka.

The study of the polypores of Kerala was initiated by Rangaswami et al. (1970). In his outstanding work Fungi of South India, 44 polyporoid species representing 13 genera were described, of which five species were from Kerala. Roy & De (1996) in their work Polyporaceae of India reported six polypore species from Kerala. Leelavathy & Ganesh (2000) reported 78 species belonging to 26 genera under families Ganodermataceae, Hymenochaetaceae, and Polyporaceae in their classical work Polypores of Kerala. The majority of the specimens described in that treatise was collected by the authors during the period 1983–1987 from the forests as well as inhabited areas of central and northern Kerala. Florence & Yesodharan (2000) reported 35 polypores from the Peechi-Vazhani Wildlife Sanctuary. Florence (2004) recorded 93 species of polypores from the state. Lately, Mohanan (2011) identified and described a total of 89 species of polypores belonging to 32 genera from different forest ecosystems in Kerala. Recently, Iqbal et al. (2016) reported 36 polypores under 21 genera belonging to six families from Peechi-Vazhani Wildlife Sanctuary.

In Kerala, studies on polypores are done not much exhaustively as compared to mushrooms (Agaricales). The literature shows only sporadic reports and the assessments are still preliminary. Even though the polypores of Kerala were studied in detail by Bakshi (1971), Leelavathy & Ganesh (2000), and Mohanan (2011), much of the forests remain unexplored. Here we summarise the findings of the exploration of polypore diversity in specialized ecosystems like wet evergreen and shola forests of the Silent Valley NP from March 2014 to February 2015.

MATERIALS AND METHODS

Study area

The Silent Valley National Park (SVNP) lies within the geographical extremes of latitudes 11°,2' N–11°, 13' N & longitudes 76°, 24' E–76°, 32' E (Fig. 1) in the southwest corner of the Nilgiri Hills of the southern Western Ghats. Silent Valley National Park constitutes part of the core area of India's first biosphere reserve, the Nilgiri Biosphere Reserve. The terrain of the SVNP is generally undulating with steep escarpments and many hillocks. The elevation ranges from 900–2300 m with the highest peak at 2383m (Anginda Peak). Both the southwestern and northeastern monsoon cause rains in this area. The major share, however, comes from the southwestern monsoon, which sets in during the first week of June. The heaviest rainfall is during the months of June, July, and August. Variation in the intensity of rainfall is observed across the area. The elevated hills on the western side of Silent Valley receive an average of 5045mm rainfall, and near Walakkad the rainfall received goes up to 6500mm.

The forests exhibit considerable variation in floristic

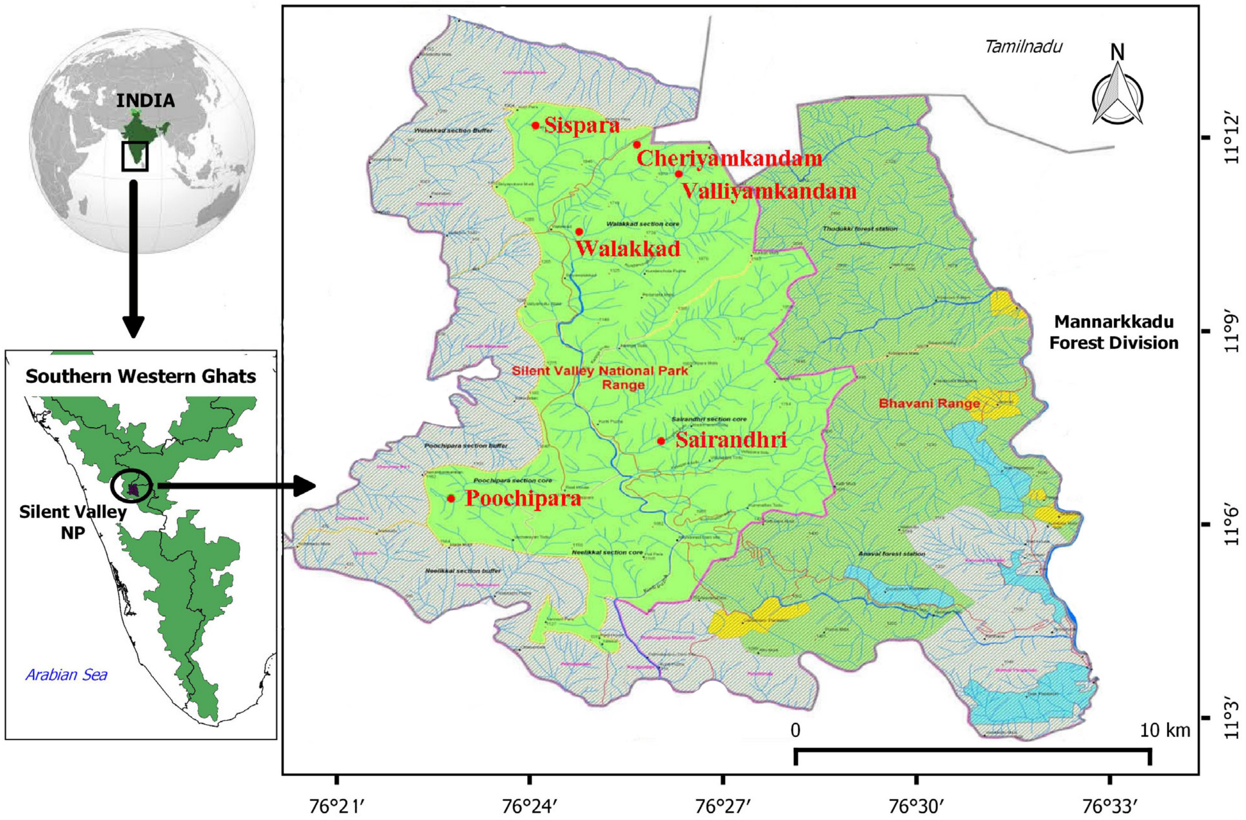

Figure 1. Silent Valley National Park, southern Western Ghats, India.

composition, physiognomy, and life forms due to climatic, edaphic, and altitudinal variations. About 75–80 % of the land in the protected area is covered with thick woody vegetation and about 20% of the area has grassland and a small area is under rocky patches with a little vegetation cover. The Silent Valley, in general, embodies vast stretches of wet evergreen forest in the undulating hills and valleys between an elevation of 900–1500 m. The evergreen forest of Silent Valley is the home par excellence of the broad-leaved evergreen trees in multi-storeyed canopies often reaching up to 40m or more. The dominant tree species in this type of forests are usually about 45m in height, and consists generally of *Cullenia exarillata*, *Machilus macrantha*, *Elaeocarpus munronii*, *Palaquim ellipticum*, *Mesua ferrea*, *Calophyllum inophyllum*, *Cinnamomum malabatrum*, *Canarium strictum*, *Syzygium cumini*, *Syzygium laetum*, *Dysoxylum malabaricum*, *Poeciloneuron indicum*, *Mangifera indica*, *Artocarpus integrifolia*, *Holigarna grahamii*, *Hopea glabra*, and *Garcinia gummi-gutta.*

The shola forests are seen in cliffs and sheltered folds above 1800m where water is available in surplus. The Sispara area is enriched with typical shola forests. Because of winds and high altitudes, these forests are stunted, the trees seldom attaining a height above 10m. Lauraceae and Myrtaceae members constitute the bulk of the flora. The dominant species found are *Rhododendron arboreum*, *Schefflera rostrata*, *Ternstroemia gymnanthera*, *Michelia nilgirica*, *Gordonia obtusa*, *Ilex wightiana*, *Meliosma pinnata*, *Cinnamomum sulphuratum*, *Cinnamomum wightii*, *Litsea floribunda*, *Litsea stocksii*, *Euonymaus crenulatus*, *Glochidion ellipticum*, and *Symplocos racemosa*.

Survey methodology, collection, identification, and preservation of polypores

The polypores were surveyed in Silent Valley National Park (SVNP) from March 2014 to February 2015. Six permanent sample plots of size 100m × 100m were established in evergreen and shola forests (three in each ecosystem) as per the methodology followed in earlier studies (Yamashita et al. 2010; Mohanan 2011). In evergreen forests, the sample plots were taken in three different locations: Sairandhri, Poochipara, and Walakkad sections (Images 1–3). Three sample plots of shola forest were taken in different locations: Sispara, Cheriyamkandam, and Valliyamkandam (Images 4–6). The sample plots were visited during the premonsoon, monsoon, and post-monsoon periods for the documentation of polypores, including collection of sporocarps, labelling, identification of rot character, taking photographs, and recording macromorphological description and details of substratum in the illustrated data sheet. The rot characters were documented by examining the substrate characters and basal attached portion of polypores. A total area of 60000m^2 was surveyed in each of the three climatic seasons. Additional collection of polypores was also made from "off-plots" in the study area. Thus, a combination of opportunistic and plot-based survey was carried out to maximize the documentation of polypore diversity and distribution.

The polypore specimens collected from the study area were kept in paper bags and brought to the lab. The specimens were properly air-dried or oven-dried at 70^{o}C and stored in polythene zip-cover under less humid conditions. The specimens were identified based on their macro and micro morphological features. The colour names and colour codes of the specimens were given as per Kornerup & Wanscher (1967). The identification keys provided by Bakshi (1971) and Leelavathy & Ganesh (2000) were used for the confirmation of polypore species. The micromorphological characteristics of the polypores were studied using a Lieca DM 750 microscope. Some of the specimens were compared with those in the herbaria at Kerala Forest Research Institute, Peechi. The taxonomy and nomenclature are as per indexfungorum. All the specimens collected during the study period were catalogued and kept under less humid conditions in the Department of Forest Management and Utilization, College of Forestry, Kerala Agricultural University.

The diversity of polypores was calculated using PAST 3.14. The following formulae have been used to determine the diversity of polypores:

1. Simpson Index of Diversity, $D = 1- \sum (ni / N)^2$ (Simpson 1949)

Where,

ni - Number of individuals of the species

N - Total number of individuals in the plot

D - Diversity

2. Shannon-Weiner's Index, $H = 3.3219 (\text{Log } N-1/N \sum ni \log ni)$ (Shannon & Weiner 1963)

Where,

ni - Number of individuals of the species

N - Total number of individuals

3. Pielou's Evenness Index, $E = (\text{Ln}N-1/N \sum ni \ln ni)/\text{Ln } N$ (Pielou 1966)

Where,

ni - Number of individuals of the species

N - Total number of individuals

4. Berger-Parker Dominance Index, $D = nmax/N$

Where,

nmax - Highest value of number of individuals of species

N - Total number of individuals

5. Margalef Richness Index, $R = (S-1)/N$ (Margalef 1968)

Where,

S - Total number of species

N - Total number of individuals

6. Sorenson Similarity Index

Similarity of each polypore community was calculated by the following equation:

$QS = 2c/a+b$

Where, a & b represent the species numbers occurring in two different plots, and c the species occurring in both plots (Sorenson 1948).

RESULTS

Fifty-seven polypore species in 29 genera belonging to seven families were documented (Table 1). The wet evergreen forest was enriched with 52 species whereas the shola forest harboured 20 polypore species. Fifteen species were found in both ecosystems while five species were exclusively found in shola forest (Fig. 2).

The Polyporaceae was the dominant family with 30 species followed by Hymenochaetaceae (16 sp.), Fomitopsidaceae, and Meripilaceae with three species each. Ganodermataceae and Schizoporaceae made their presence with two species each while only one species was reported under the family Meruliaceae (Fig. 3). Among the polypores documented, 42 species were annuals and 15 were perennials. While analyzing the rot characteristics of the recorded polypores, it was found that the white rot polypores had a notable dominance over brown rot polypores. Out of the 57 species analysed, 52 polypores were white rotters and only five species were brown rotters.

During the present study, five species (*Inonotus pachyphloeus*, *Phylloporia pectinata*, *Trametes menziesii*, *Trametes ochracea*, and *Trametes pubescens*) were found to be new records from the southern Western Ghats. An identification key was developed for the

Table 1. Species composition of polypores in the wet evergreen and shola forests of Silent Valley National Park.

	Species	Image no.	Family	Habit	Rot	Study areas					
						Evergreen			Shola		
						Sairandhri	Poochippara	Walakkad	Sispara	Cheriyamkandam	Valliyamkandam
1	*Abortiporus biennis* (Bull.) Singer	12	Meruliaceae	A	W	+	-	+	-	-	-
2	*Cellulariella acuta* (Berk.) Zmitr. & V. Malysheva	13	Polyporaceae	A	W	+	+	+	-	-	+
3	*Coriolopsis telfairii* (Klotzsch) Ryvarden, 1972	14	Polyporaceae	A	W	+	+	+	-	-	-
4	*Cyclomyces setiporus* (Berk.) Pat.	15	Hymenochaetaceae	A	W	A	+	-	-	-	-
5	*Daedalea dochmia* (Berk. & Broome) T. Hatt.	16	Fomitopsidaceae	P	B	+	+	+	-	-	-
6	*Earliella scabrosa* (Pers.) Gilb. & Ryvarden	17	Polyporaceae	A	W	+	+	+	+	-	+
7	*Favolus tenuiculus* P. Beauv.	18	Polyporaceae	A	W	+	+	+	-	-	-
8	*Fomes extensus* (Lev.) Cooke	19	Polyporaceae	P	W	+	-	-	-	-	-
9	*Fomes pseudosenex* (Murrill) Sacc. & Trotter	20	Polyporaceae	P	W	+	+	-	-	-	-
10	*Fomitopsis feei* (Fr.) Kreisel	21	Fomitopsidaceae		B	+	+	+	-	-	-
11	*Fomitopsis palustris* (Berk. & M.A. Curtis) Gilb. & Ryvarden	22	Fomitopsidaceae	A	B	+	-	+	-	-	-
12	*Fulvifomes cesatii* (Bres.) Y.C. Dai	23	Hymenochaetaceae	A	W	A	-	v	+	-	-
13	*Funalia caperata* (Berk.) Zmitr. & V. Malysheva	24	Polyporaceae	A	W	+	+	+	-	-	-
14	*Fuscoporia contigua* (Pers.) G. Cunn.	25	Hymenochaetaceae	P	W	+	+	+	-	-	-
15	*Fuscoporia ferrea* (Pers.) G. Cunn.	26	Hymenochaetaceae	A	W	+	+	+	-	-	-
16	*Fuscoporia senex* (Nees& Mont.) Ghob.-Nejh.	27	Hymenochaetaceae	A	W	+	+	+	-	-	-
17	*Fuscoporia wahlbergii* (Fr.) T. Wagner & M. Fisch.	28	Hymenochaetaceae	P	W	+	+	-	+	+	-
18	*Ganoderma australe* (Fr.) Pat.	29	Ganodermataceae	P	W	+	+	+	-	+	-
19	*Ganoderma lucidum* (Curtis) P. Karst.	30	Ganodermataceae	A	W	+	+	+	+	-	+
20	*Hexagonia tenuis* (Hook.) Fr.	31	Polyporaceae	A	W	+	+	+	-	-	-
21	*Inonotus luteoumbrinus* (Romell) Ryvarden	32	Hymenochaetaceae	P	W	+	+	-	-	-	-
22	*Inonotus pachyphloeus* * (Pat.) T. Wagner & M. Fisch.	33	Hymenochaetaceae	P	W	+	+	-	-	-	-
23	*Inonotus* sp.	34	Hymenochaetaceae	P	W	+	+	-	-	-	-
24	*Inonotus tabacinus* (Mont.) G. Cunn.	35	Hymenochaetaceae	A	W		+				
25	*Leucophellinus hobsonii* (Berk. ex Cooke) Ryvarden	36	Schizoporaceae	A	W	-	-	-	+	-	-
26	*Microporellus obovatus* (Jungh.) Ryvarden	37	Polyporaceae	A	W	+	+	+	-	+	-
27	*Microporus affinis* (Blume & T. Nees) Kuntze	38	Polyporaceae	A	W	+	+	+	-	-	+
28	*Microporus* sp.	39	Polyporaceae	A	W	A	+	-	-	-	-
29	*Microporus xanthopus* (Fr.) Kuntze	40	Polyporaceae	A	W	+	+	+	+	+	-
30	*Neofomitella rhodophaea* (Lev.) Y.C. Dai	41	Polyporaceae	A	B	+	+	+	-	-	-
31	*Nigroporus vinosus* (Berk.) Murrill	42	Polyporaceae	A	W	+	+	+	-	-	-
32	*Phellinus dependens* (Murrill) Ryvarden	43	Hymenochaetaceae	P	W	+	+	+	-	-	-
33	*Phellinus fastuosus* (Lev.) S. Ahmad	44	Hymenochaetaceae	P	W	+	+	+	+	-	-

	Species	Image no.	Family	Habit	Rot	Study areas					
						Evergreen			Shola		
						Sairandhri	Poochippara	Walakkad	Sispara	Cheriyamkandam	Valliyamkandam
34	*Phellinus gilvus* (Schwein.) Pat.	45	Hymenochaetaceae	A	W	+	+	+	-	-	-
35	*Phellinus nilgheriensis* (Mont.) G. Cunn.	46	Hymenochaetaceae	P	W	+	+	+	+	-	+
36	*Phellinus zealandicus* (Cooke) Teng	47	Hymenochaetaceae	A	W	+	+	+	-	-	-
37	*Phylloporia pectinata* * (Klotzsch) Ryvarden	48	Hymenochaetaceae	P	W	-	-	-	-	+	+
38	*Polyporus dictyopus* Mont.	49	Polyporaceae	A	W	+	-	+	-	-	-
39	*Polyporus grammocephalus* Berk.	50	Polyporaceae	A	W	+	+	+	-	-	-
40	*Polyporus leprieurii* Mont.	51	Polyporaceae	A	W	+	+	+	-	-	-
41	*Polyporus* sp.	52	Polyporaceae	A	W	+	-	-	-	-	-
42	*Rigidoporus lineatus* (Pers.) Ryvarden	53	Meripilaceae	A	W	+	+	-	-	-	+
43	*Rigidoporus microporus* (Sw.) Overeem	54	Meripilaceae	A	W	A	+	-	-	-	-
44	*Rigidoporus ulmarius* (Sowerby) Imazeki	55	Meripilaceae	P	B	+	-	+	-	-	-
45	*Schizopora paradoxa* (Schrad.) Donk	56	Schizoporaceae	A	W	+	+	+	-	+	+
46	*Spongipellis unicolor* (Schwein.) Murrill	57	Polyporaceae	A	W	+	-	-	-	-	-
47	*Trametes cingulata* Berk.	58	Polyporaceae	A	W	+	+	-	-	-	-
48	*Trametes cotonea* (Pat.) Ryvarden	59	Polyporaceae	A	W	+	-	+	-	-	-
49	*Trametes hirsuta* (Wulfen) Pilat	60	Polyporaceae	A	W	+	+	-	-	-	+
50	*Trametes marianna* (Pers.) Ryvarden	61	Polyporaceae	A	W	+	+	+	-	-	-
51	*Trametes maxima* (Mont.) A. David & Rajchenb	62	Polyporaceae	A	W	+	+	+	-	-	-
52	*Trametes menziesii* * (Berk.) Ryvarden	63	Polyporaceae	A	W	+	+	+	+	+	+
53	*Trametes ochracea* * (Pers.) Gilb. & Ryvarden	64	Polyporaceae	A	W	-	-	-	+	+	+
54	*Trametes pubescens* * (Schumach.) Pilat	65	Polyporaceae	A	W	-	-	-	+	+	+
55	*Trametes versicolor* (L.) Lloyd	66	Polyporaceae	A	W	-	-	-	+	+	+
56	*Trichaptum biforme* (Fr.) Ryvarden	67	Polyporaceae	A	W	+	+	+	-	-	-
57	*Trichaptum byssogenum* (Jungh.) Ryvarden	68	Polyporaceae	A	W	+	-	+	-	-	-

A - Annual, P - Perennial, W - White rot, B - Brown rot, * New report from southern Western Ghats, + Present, - Absent

polypores documented from Silent Valley National Park based on their micro and macro morphological features (Appendix 1).

Phylloporia pectinata **(Klotzsch) Ryvarden**

Fruit body annual, solitary, imbricate, effused reflexed to pileate, attached with a broad base, 1–1.5 x 1.5–2.5 x 0.2–0.4 cm; pileus surface concentrically grooved, highly velutinate, smooth glabrous, uneven, dark brown (6F8), margin smooth, entire, velutinate. Pore surface dark brown (6F8); pores not visible to naked eye, 9–10 per mm, pore mouth 70–100 µm wide, margin distinct; pore tubes of varying length, 1–2 mm long, shining; dissepiments thin (40) 50–70 (120) µm thick; context uniform, shining, brownish orange (6E7), 0.8–1 mm thick.

Hyphal system dimitic. Skeletal hyphae yellowish-brown, thick walled, usually unbranched, but extremities sparsely branched, bent sometimes, lumen narrow, 2.5–3.5 µm in diameter. Basidiospore yellowish, round to globose to slightly sub globose, slightly thick walled. Basidia long, clavate, sleritmata incipient, four-spored,

Image 1. Wet evergreen forest at Sairandhri.

Image 2. Wet evergreen forest at Poochippara.

Image 3. Wet evergreen forest at Walakkad.

Image 4. Shola forests at Sispara.

Image 5. Shola forests at Cheriyamkandam.

Image 6. Shola forests at Valliyamkandam.

7–8 x 2.5–3 µm (Image 7).

Decay: White rot.

Specimen examined: On decaying log of *Cinnamomum sulphuratum*, Cheriamkandam, Silent Valley National Park, ACK 45/23-5-2014; ACK 39/30-1-2015; ACK 20, 32/28-2-2015; ACK 22/30-3-2015.

This species was reported on the bark of *Glycosmis pentaphylla*, from Kolkata, WB (Berkeley 1839).

Trametes menziesii **(Berk.) Ryvarden**

Fruitbody annual, solitary, imbicate, confluent, laterally stipitate, flabelliform to spathulate, lobed towards margin, stipe prominent when young, 1.5–4-5 x 1–4 x 0.15 cm. Pileus surface uneven, orange white (5A2), radially folded, concentrically zonate, warty towards base, finely velutinate towards margin, shining, margin very thin, stipe rudimentary to 5mm, spreading at base, greyish-orange (5B4), tough, soft hyphae, angulate, to give a warty appearance; pore surface brown (6E7) to greyish-brown (5B3); pores almost visible to naked eye, 5–6 per mm, pore mouth (50) 70–90 (110) µm wide, uneven stripe, margin distinct, shining, young and smaller towards margin, older region yellowish brown, margin lighter; dissepiments thin (30) 50–70 (100) µm thick; pore tubes pale orange (5B3), uniform, 1.5mm long; context less than 1mm, homogenous towards margin, pores angular, round when young.

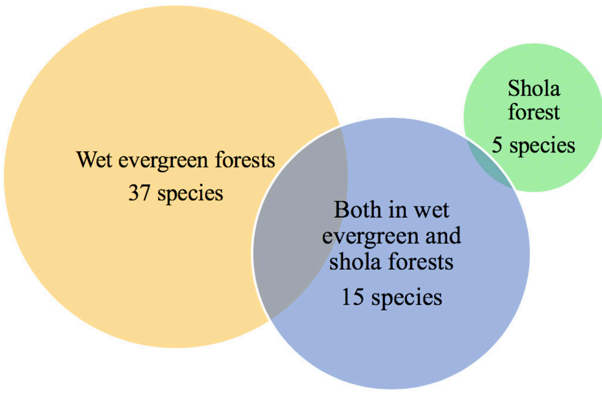

Figure 2. Habitat-wise analysis of polypores.

Hyphal system trimitic. Generative hyphae hyaline, thin slightly thick walled, septate with clamp connections, branched, (3) 3.5–4.5 (5) µm in diam. Skeletal hyphae hyaline, thin to slightly thick walled, 4–5 in diameter (Image 8).

Decay: White rot.

Specimen observed: On decaying log of *Cullenia exarillata*, Sairandhri, Silent Valley National Park, ACK 13/29-7-2014; ACK 43/28-8-2014; ACK 58/19-10-2014, ACK 9/9-12-2014; ACK 21/30-1-2015; 35, 38, 41/28-2-

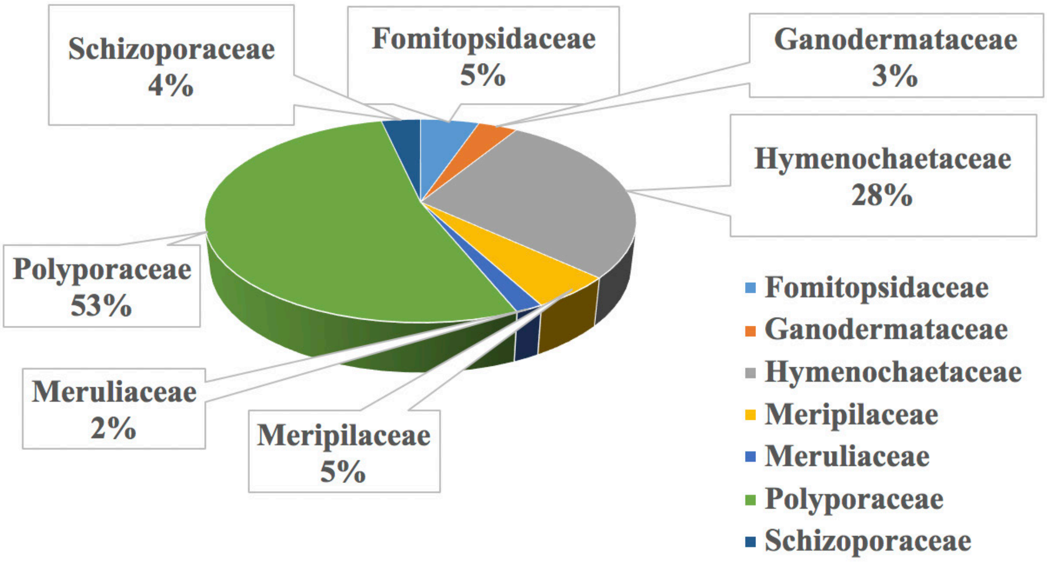

Figure 3. Family-wise distribution of polypores.

2015; ACK 41/30-2-2015.

The species was earlier reported on trunks, from Sikkim (Berkeley MJ 1854), on logs of *Shorea robusta* and stumps of *Euphorbia nerrifolia* (Bose 1921) in Lokra Hills, Assam (Bose 1934), and on a stump of *Querscus* sp. in Arunachal Pradesh (De 1985).

Trametes ochracea **(Pers.) Gilb. & Ryvarden**

Fruitbody annual, solitary, imbricate, confluent, attached with broad base, often centrally stipitate but growth not uniform, coriaceous while flesh, hard and pliable when dry, almost round to applanate, flabelliform while young, 0.8–2 x 1–3 x 0.1–0.2 cm. Pileus surface concentrically zonate, light brown (7D1) to dark brown (8F7) to reddish brown (8D8, 9E6) to grey (9D1), finely velutinate to glabrous, shining, margin uneven, smooth, incurved, thin when dry, stipe rudimentary, dark brown (8F8), warty, velutinate; pore surface even shining, brownish orange (5C4); pores not visible to naked eye, margin very thin but distinct, 6–7 per mm, pore mouth (100) 120–140 (155) µm wide; pore tube uniform, 0.1–0.15 cm long, pale yellow (4A3); dissepiments thin (40) 50–60 µm thick; context yellowish-white (4E2), concolorous, with poretubes, very thin, less than 1mm, homogenous.

Hyphal system trimitic. Generative hyphae hyaline, thin walled, closely branched, zigzag, septate with clamps, 2–3 µm in diameter. Binding hyphae hyaline, sparsely branched, thick-walled with narrow lumen, nonseptate, 2–3.5 µm in diameter. Skeletal hyphae hyaline to slightly brownish, long and branched, thick-walled, nonseptate, lumen narrow, sometimes obliterated, 4–5 (7) µm in diameter. Basidia broadly clavate, four spored, 3.5–4.5 x 6–7 µm. Cystidia none. Basidiospore not observed (Image 9).

Decay: White rot.

Specimen observed: On a decaying log of *Cinnamomum sulphuratum*, Sisppara, Silent Valley National Park, Herb. ACK 1, 13/28-2-2015; ACK 20, 40/30-3-2015.

This species was reported earlier on dead branches from Mumbai, MS (Theissen 1911) and on stumps and logs of a deciduous tree from Shillong, Meghalaya (Bose 1946).

In order to understand the diversity attributes of the polypores in wet evergreen and shola forests, the diversity, richness, dominance, and evenness were analyzed using Simpson diversity index, Shanon-Wiener index, Pielou's evenness index, Berger-Parker dominance Index, and Margalef richness Index (Table 2).

In wet evergreen forest, Simpson's Index of diversity was observed to be 0.92 while in shola it was only 0.78. The wet evergreen forest showed higher Shanon-Wiener Index value (2.83) than that in shola forest (2.02). The Margalef richness index was also found to be relatively high in wet evergreen forest (3.15) while it was 1.74 in shola forest. The evenness in the distribution of polypores was observed to be comparatively higher in wet evergreen forest with Pielou's evenness index 0.84 than in shola forest (0.77). The shola forest showed more Berger-Parker dominance index value (0.42) in the polypore distributon while it was only 0.12 in evergreen forest (Table 2).

Sorenson's similarity index was worked out to find the

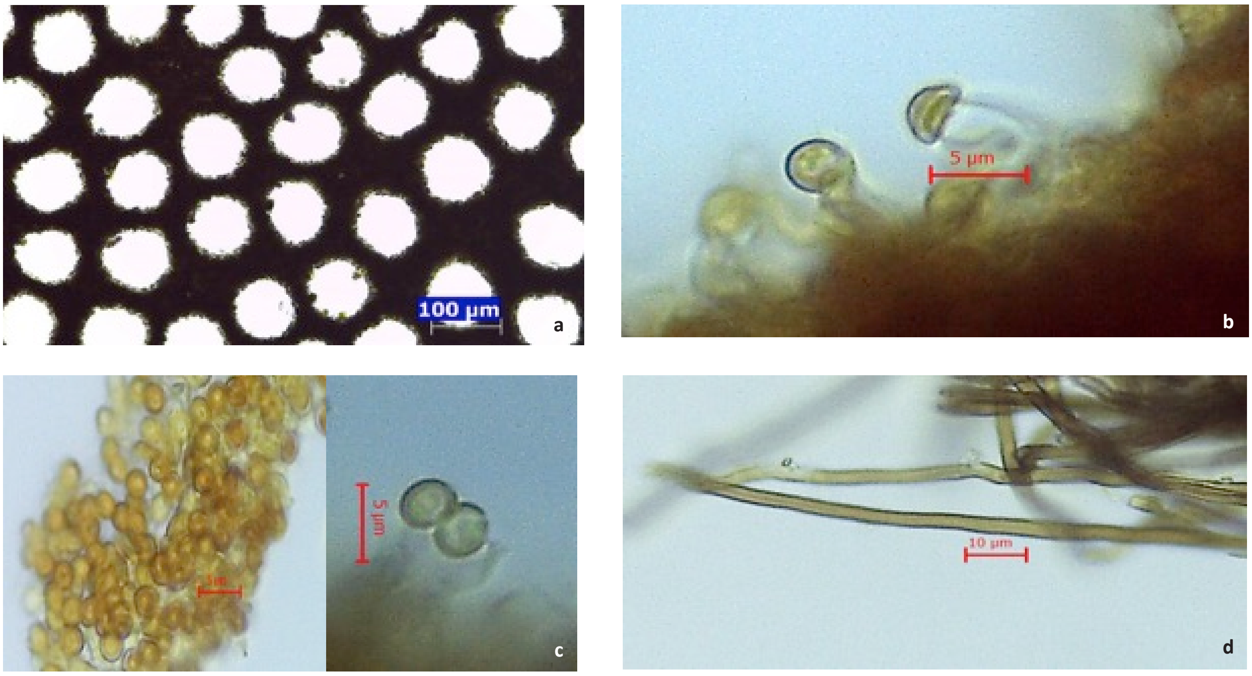

Image 7. ***Phylloporia pectinata*** **(Klotzsch) Ryvarden: a - Pore surface, b - Basidia, c - Spore, d - Skeletal hyphae.**

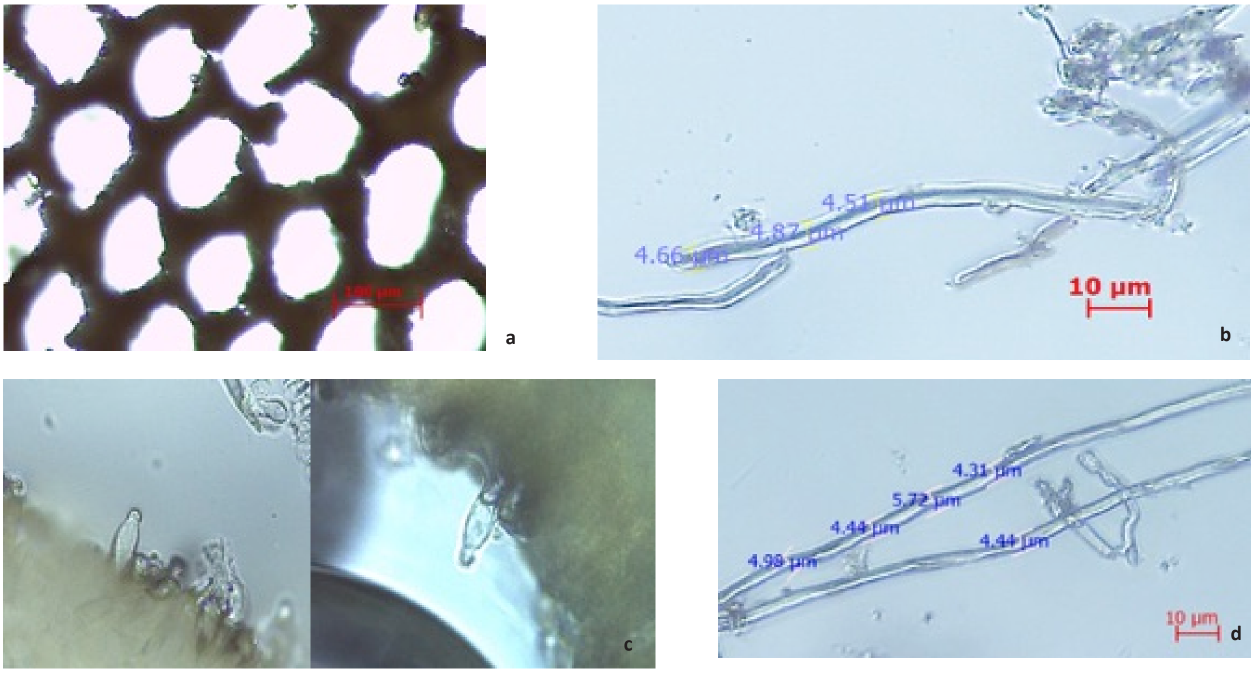

Image 8. ***Trametes menziesii*** **(Berk.) Ryvarden: a - Pore surface, b - Generative hyphae, c - Basidium, d - Skeletal hyphae.**

similarity of polypore community in the wet evergreen forest and shola forest during different seasons. In all the seasons similarity between polypore community in the two ecosystems was found to be low (0.44).

DISCUSSION

The present study on the diversity and distribution of polypores in wet evergreen and shola forest of Silent Valley National Park reported 57 species altogether. The species composition analysis of polypores in the wet

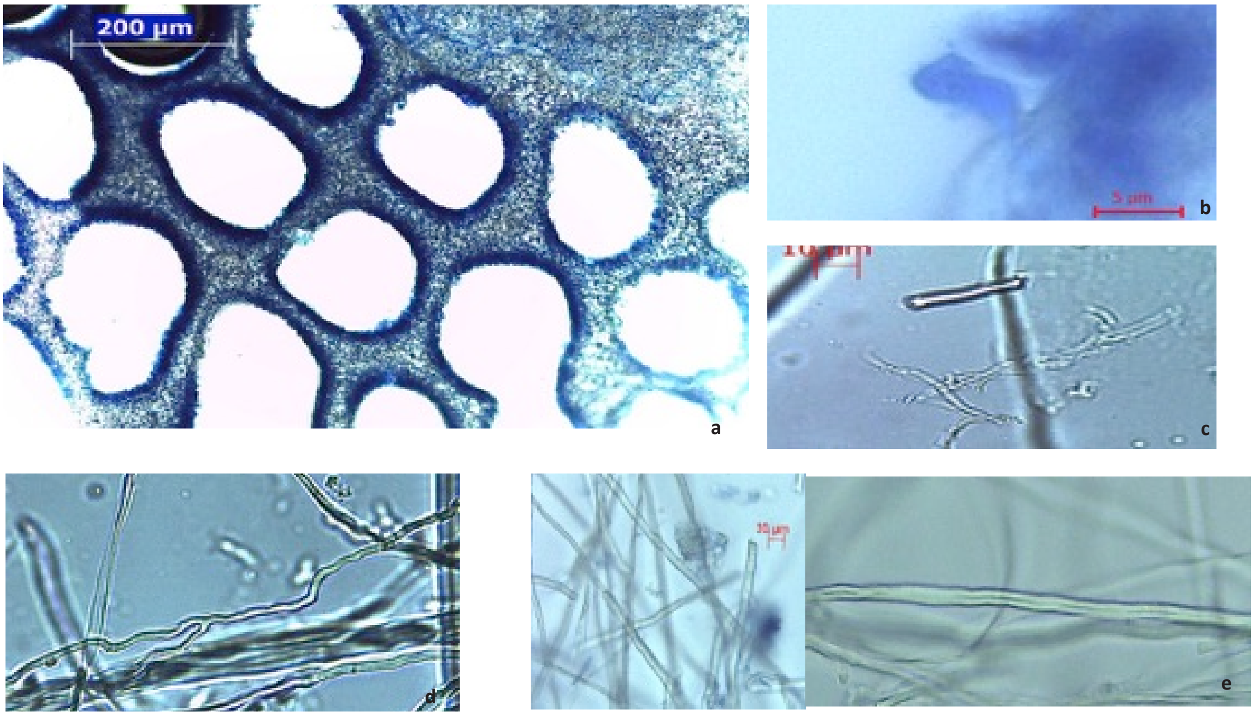

Image 9. *Trametes ochracea* (Pers.) Gilb. & Ryvarden: a - Pore surface, b - Basidia, c - Generative hyphae, d - Binding hyphae, e - Skeletal hyphae.

evergreen and shola forests highlighted the dominance of family Polyporaceae over others in all seasons. Of the 57 species identified, 52.63% belonged to Polyporaceae and 28.07% belonged to Hymenochaetaceae followed by Fomitopsidaceae and Meripilaceae with 5.26% each. The families Ganodermataceae and Schizoporaceae constituted 3.50% each. Meruliaceae (1.75%) was with the least number of species. The rot character analysis proved the dominancy of white rot polypores over brown rotter with 91.22% of the total species. This observation is in agreement with Lyngdoh & Dkhar (2014), Leelavathy & Ganesh (2000), Florence & Yesodharan (2000), Mohanan (2008, 2011), and Iqbal et al. (2016).

It was suggested that brown-rot has been repeatedly derived from white-rot (Gilbertson 1980). In contrast, it was also suggested that brown-rot fungi forms the plesiomorphic form in the homobasidiomycetes, and that white-rot has been repeatedly derived by elaborated wood decay mechanisms (i.e., gaining the ability to degrade lignin) (Nobles 1965, 1971). Studies by Ryvarden (1991) and Worrall et al. (1997), however, have supported Gilbertson’s view that brown-rot fungi were derived from white-rot fungi.

White-rot fungi occur frequently on hardwoods while brown-rot fungi have an obvious preference for coniferous substrates (Tuor et al. 1995; Schmidt 2006; Karami et al. 2014). Hardwood lignin is composed mainly of gluaiacyl and syringyl units. Lignin distribution, content, and composition have a significant influence on decay resistance (Frankenstein & Schmitt 2006). White-rot fungi achieve wood degradation with several different combinations of peroxidases and oxidases like ligninase, Manganese peroxidase (Mnp), Lignin peroxidase (Lip), and lactase and are able to utilize a wide variety of substrates (Tuor et al. 1995). On the other hand, white rot fungi have a geographic distribution not corresponding to their most suitable hosts (Gilbertson 1980). These views support the high proportion of white rot polypores in the study area.

Leelavathy & Ganesh (2000) have reported 19 species of polypore from the national park area. Of these, 15 species were observed during the present study. Species like *Hexagonia sulcata, Pycnoporus sanguineus*, *Trametes modesta,* and *Coriolopsis sanguinaria* were not observed during the present study. Polypore diversity exploration in the present study added five new reports to polypores of southern Western Ghats. The identities of the species were confirmed by comparing the characters described for the specimens collected by Bakshi (1971), Ryvarden & Jonansen (1980), and Leelavathy & Ganesh (2000).

The wet evergreen forest showed relatively high polypore diversity and evenness than that of the shola forest (Table 2). Also, wet evergreen forest showed relatively high species richness (29 species) than that

Table 2. Diversity Indices of polypores of wet evergreen and shola forests.

Forest type	Simpson diversity Index	Shanon-wiener Index	Margalef richness Index	Pielou's evenness Index	Berger-Parker dominance Index
Wet evergreen forest	0.92	2.83	3.15	0.84	0.12
Shola forest	0.78	2.02	1.74	0.77	0.42

of shola forest (14 species). In wet evergreen forest, Simpson's Index of diversity was observed to be 0.92, i.e., if 100 pairs of polypores were taken at random, 92 will comprise different species while in shola it was only 0.78. The species richness was also found to be relatively high in wet evergreen forest than in shola forest. The less polypore diversity and richness in the shola forest can be explained on the basis of the theory of ecological niches and strategies of saprophytic fungi by Cooke & Rayner (1984). The availability of suitable substrate is an important determinant of polypore diversity. Two characteristics of substrates influencing patterns of fungal development are the ease with which they can be assimilated and their spatial and temporal distribution (Cooke & Rayner 1984).

The arborescent floras of the two forest types also contained many disjunctively distributed species. Only a few species were found to be common to both ecosystems. Tree species of shola forest is characterized by much stunted habit (seldom attaining a height above 15m) with spreading, umbrella-shaped canopy, and crooked and twiggy branches and branchlets (Nair & Menon 2000). The trees are very often covered with several epiphytic lichens, mosses, ferns, and orchids. Even though they are mostly associated with living trees, they will remain on the logs of early stages of decay. The number of logs was also noticed to be comparatively less in shola forest. It has been pointed out that a broad diversity of host tree species of various volumes, diameters, and degrees of decomposition seem to be major factors contributing to the diversity of the wood-rotting fungi (Kuffer & Senn-Irlet 2005). Thus, the less availability of suitable substrate is a major factor for the low diversity and richness of polypores in shola forest.

The ecological strategy of polypores is strongly influenced by three factors: competition, stress, and disturbance (Cooke & Rayner 1984). Competition involves the struggle for capture and defence of resources between neighbours. In shola forest, the tree branches are often covered with several epiphytic lichens, mosses, ferns, and orchids which could be a barrier for the germination and establishment of polypores. Similarly, the undergrowth of shrubs like *Strobilanthus* sp. was found to prevent light on the fallen logs. The shady environment around the logs is not favourable for polypore establishment. Light has a wide range of effects on basidiomycete fruiting such as production, development, and abundance (Moore et al. 2008). Additionally, the undergrowth of *Strobilanthus* sp. may also prevent spore dispersal of the polypores in shola forests.

Further, the stress may be any form of continuously imposed environmental extremes that tend to restrict fruitbody production of polypores (Cooke & Rayner 1984). The low temperature of the shola forest could also be a limiting factor for polypore diversity. Extension rate of mycelial cord-forming basidiomycetes generally increases as the temperature does, up to optima of about 20–25 °C (A'Bear et al. 2014). The low temperature of the shola forest also cause physiological dryness to the plants growing there, restricting their moisture absorption capability from the topsoil, which is often frozen (Nair & Menon 2000). The lower temperature is, therefore, an important determinant of polypore diversity in shola forests. Finally, the disturbance describes a state in which the whole or part of the total fungal biomass is destroyed or subjected to new selection pressures by a drastic change in environmental conditions (Cooke & Rayner 1984). The severe low temperature in the shola forest could be acting as a disturbance for most of the polypores.

The evenness in the distribution of polypores was found to be comparatively high in wet evergreen forest with Pielou's Evenness Index 0.84 than in shola forest (0.77). On the other hand, shola forest showed more Berger-Parker Dominance Index value (0.42) in polypore distribution, which was low (0.12) in evergreen forest. This could be due to polypores that can tolerate the prevailing environmental severity and dominate over the rest. Species like *Phylloporia pectinata*, *Fulvifomes cesatii*, *Leucophellinus hobsonii*, *Trametes ochracea*, and *Trametes pubescens* were recorded only from high altitude shola forest, indicating their environmental tolerance and adaptation to disturbances.

The present study recorded 57 polypore species with a few new records from the southern Western Ghats. Much of the forests in the Western Ghats remain unexplored in case of diversity and ecology of polypores. More detailed explorations have to be done for understanding the actual diversity and ecological functions of polypores in forest ecosystems.

Image 12. *Abortiporus biennis*.

Image 13. *Cellulariella acuta*.

Image 14. *Coriolopsis telfairii*.

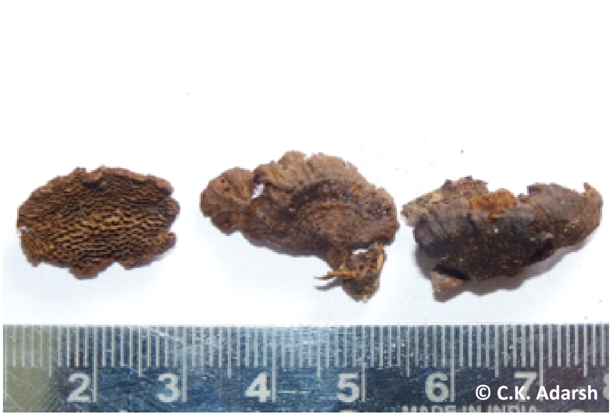

Image 15. *Cyclomyces setiporus*.

Image 16. *Daedalea dochmia*.

Image 17. *Earliella scabrosa*.

Image 18. *Favolus tenuiculus*.

Image 19. *Fomes extensus*.

Image 20. *Fomes pseudosenex*.

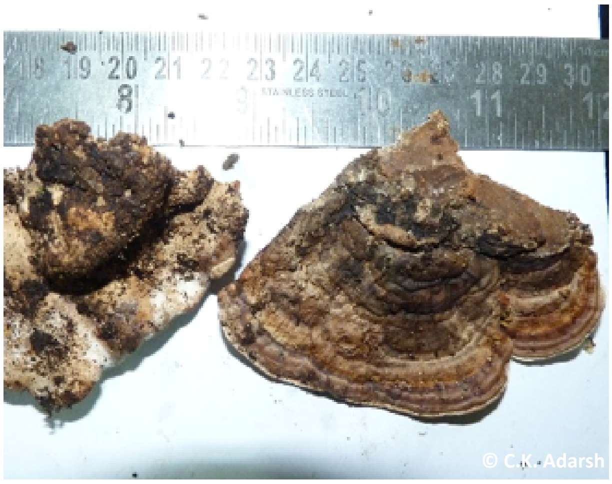

Image 21. *Fomitopsis feei*.

Image 22. *Fomitopsis palustris*.

Image 23. *Fulvifomes cesatii*.

Image 24. ***Funalia caperata*****.**

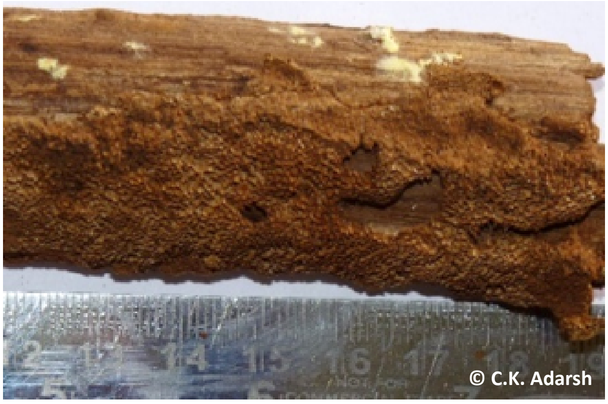

Image 25. ***Fuscoporia contigua*****.**

Image 26. ***Fuscoporia ferrea*****.**

Image 27. ***Fuscoporia senex*****.**

Image 28. ***Fuscoporia wahlbergii*****.**

Image 29. ***Ganoderma australe*****.**

Image 30. *Ganoderma lucidum*.

Image 31. *Hexagonia tenuis*.

Image 32. *Inonotus luteoumbrinus*.

Image 33. *Inonotus pachyphloeus*.

Image 34. *Inonotus* sp.

Image 35. *Inonotus tabacinus*.

Image 36. *Leucophellinus hobsonii*.

Image 37. *Microporellus obovatus*.

Image 38. *Microporus affinis*.

Image 39. *Microporus* sp.

Image 40. *Microporus xanthopus*.

Image 41. *Neofomitella rhodophaea*.

Image 42. *Nigroporus vinosus*.

Image 43. *Phellinus dependens*.

Image 44. *Phellinus fastuosus*.

Image 45. *Phellinus gilvus*.

Image 46. *Phellinus nilgheriensis*.

Image 47. *Phellinus zealandicus*.

Image 48. *Phylloporia pectinata*.

Image 49. *Polyporus dictyopus*.

Image 50. *Polyporus grammocephalus*.

Image 51. *Polyporus leprieurii*.

Image 52. *Polyporus* sp.

Image 53. *Rigidoporus lineatus*.

Image 54. *Rigidoporus microporus*.

Image 55. *Rigidoporus ulmarius*.

Image 56. *Schizopora paradoxa*.

Image 57. *Spongipellis unicolor*.

Image 58. *Trametes cingulata*.

Image 59. *Trametes cotonea*.

Image 60. *Trametes hirsuta*.

Image 61. *Trametes marianna*.

Image 62. *Trametes maxima*.

Image 63. *Trametes menziesii*.

Image 64. *Trametes ochracea*.

Image 65. *Trametes pubescens*.

Image 66. ***Trametes versicolor*.**

Image 67. ***Trichaptum biforme*.**

Image 68. ***Trichaptum byssogenum*.**

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Appendix 1. Key to genus and species of Polypores

Ganodermataceae Donk,
Bull. bot. GdnsBuitenz. 17(4): 474 (1948)

1. Fruitbody leathery, (sub) stiptate; pileus surface laccate, reddish brown or greyish .... *Ganoderma lucidum*
1'. Fruitbody sessile, surface never laccate, brownish or darker .... *Ganoderma australe*

Hymenochaetaceae Donk,
Bull. bot. GdnsBuitenz. 17(4): 474 (1948)

1. Sporophore annual or perennial; hyphal system dimitic, generative hyphae hyaline, thin-walled 2
1'. Sporophore usually annual; hyphal system monomitic ... 3

2. Context homogeneous; tubes stratified in perennials .... ***Phellinus***
2'. Context duplex with spongy upper layer............................ .. ..***Phylloporia*** (*P. pectinata*)

3. Sporophore annual, resupinate, setae absent...................... .... ***Fulvifomes*** (*F. cesatii*)
3'. Sporophore annual or perennial, never resupinate, setae present or absent 4

4. Hyphal system monomitic .... ***Inonotus***
4'. Hyphal system dimitic 5

5. Sporophore annual, coriaceous, concentrically lamellate to minutely poroid, spores hyaline .... ***Cyclomyces*** (*C. setiporus*)
5'. Sporophore annual to perennial, hard woody, strictly poroid, spores hyaline or greyish .... ***Fuscoporia***

Phellinus **Quel.,**
Enchir. fung. (Paris): 172 (1886)

1. Setae present in trama or hymenium 2
1'. Setae absent 4

2. Sporophore annual, pileus surface hirsute to glabrous....... .. .. *Phellinus gilvus*
2'. Sporophore perennial, glabrous 3

3. Setae up to 12–15 x 5–7 µm .... *Phellinus dependens*
3'. Setae up to 25–40 x 7–10 µm .... *Phellinus zealandicus*

4. Fruitbody flabelliform to spathulate, velutinate when young; spores subglobose .... *Phellinus fastuosus*
4'. Fruitbody applanate to ungulate, glabrous, spores globose .... *Phellinus nilgheriensis*

Inonotus **P. Karst.,**
Meddn Soc. Fauna Flora fenn. 5: 39 (1879)

1. Hymenial and setal hyphae absent 2
1'. Hymenial and setal hyphae present 3

2. Pores 6–7 per mm; hyphal system monomitic; spores globose .... *Inonotus* sp. nov.
2'. Pores 4–5 per mm; hyphalsystem dimitic; spores 5–6 x 4.5–5 µm .... *Inonotus luteoumbrinus*

3. Setal hyphae abundant, 12–20 µm broad; hyphalsystemdimitic .... *Inonotus pachyphloeus*
3'. Setal hyphae 7.5–10 µm broad; hyphal system monomitic .... *Inonotus tabacinus*

Fuscoporia **Murrill,**
N. Amer. Fl. (New York) 9(1): 3 (1907)

1. Fruitbody pileate; pores 4–5 per mm 2
1'. Fruitbody resupinate; pores 6–7 per mm 3

2. Setae 15–25 µm long; decay: white stringy .... *Fuscoporia senex*
2'. Setae 30–40 µm long; decay: white rot .... *Fuscoporia wahlbergii*

3. Pores irregular, angular to daedaloid ... *Fuscoporia contigua*
3'. Pores smooth round .... *Fuscoporia ferrea*

POLYPORACEAE Fr. ex Corda [as 'Polyporei'],
Icon. fung. (Prague) 3: 49 (1839)

1. Hymenophore angular, hexagonal or daedaloid 2
1'. Hymenophore poroid 3

2. Hymenophore hexagonal .... ***Hexagonia*** (*H. tenuis*)
2'. Hymenophore daedaloid or lamellate .... ***Cellulariella*** (*C. acuta*)

3. Context not xanthochroic, hyphal system dimitic or trimitic, clamps present or not 4
3'. Context not xanthochroic, hyphal system dimitic or trimitic, clamps present or not 6

4. Sporophore annual, leathery, pileus surface yellowish-brown, hairs present 5
4'. Sporophore perennial, heavy woody, glabrous .... ***Fomes***

5. Pileal surface yellowish, hispid to scrupose, pores angular, up to 2 per mm; dissepiments often sharp or tricolor .... ***Coriolopsis*** (*C. telfairii*)
5'. Sporophore brown, soft, tomentose, pores round, 3–5 per mm; dissepiments smooth .... ***Funalia*** (*F. caperata*)

6. Sporophore stipitate, stipe central or lateral 7
6'. Sporophore resupinate to pileate, never stipitate 9

7. Stipe central, hyphal system dimitic .... ***Polyporus***
7'. Stipe lateral, hyphal system trimitic 8

8. Spore elliptical, coralloid elements present ...... ***Microporus***
8'. spores globose to subglobose; coralloid elements absent .... ***Microporellus*** (*M. obovatus*)

9. Pileus surface vinaceus brown, context reddish-brown .... ***Nigroporus*** (*N. vinosus*)
9'. Pileus surface yellowish, context lighter 10

10. Pileus surface with prominent hairs, pore round to daedaloid to irpicoid .... ***Trichaptum***
10'.Pileus surface almost glabrous, pore mouth minute 11

11. Pore tubes sunk into even depth in forming a uniform stratum 12
11'Pore tubes sunk into uneven stratum .... ***Trametes***

12. Pore small, more than 6 per mm .... ***Neofomitella*** (*N. rhodophaea*)
12'. Pores large, 1 per mm .... ***Spongipellis*** (*S. unicolor*)

Fomes **(Fr.) Fr.,**
Summa veg. Scand., Section Post. (Stockholm): 319 (adnot.), 321 (1849)

1. Fruitbody triquetrous, context with a black crusty line .... *Fomes extensus*

1'. Fruitybodyconchate, irregular, context without black crusty line .... *Fomes pseudosenex*

Polyporus **P. Micheli ex Adans.,**
Fam. Pl. 2: 10 (1763)

1. Stipe central to eccentric .... *Polyporus leprieurii*
1'. Stipe lateral 2

2. Pores more than 10 per mm; dissepiments 20–30 µm thick .... *Polyporus* sp. nov.
2'. Pore less than 8 per mm; dissepiments more than 35 µm thick 3

3. Pileus surface orange yellow to greyish, radially straite; pore surface brownish-yellow to light orange .... *Polyporus grammocephalus*
3'. Pileus surface corn to hair brown; pore surface yellowish-white .... *Polyporus dictyopus*

Microporus **P. Beauv.,**
Fl. Oware 1: 12 (1805)

1. Stipe central, funnel-shaped .... *Microporus xanthopus*
1'. Stipe lateral, flabelliform 2

2. Pore mouth 50–70 µm wide; dissepiments 35–75 µm thick .... *Microporus affinis*
2'. Pore mouth 90–100 µm wide; dissepiments 50–60 µm thick .... *Microporus* sp. nov.

Trichaptum **Murrill, Bull.**
Torrey Bot. Club 31(11): 608 (1904)

1. Pileus surface hispid, yellowish-grey to violet, pores 1–2 per mm .... *Trichaptum byssogenum*
1'. Pore surface tomentose, yellowish-white with greyish patch; Pores 3–5 per mm .... *Trichaptum biforme*

Trametes **Fr., Fl. Scan.: 339 (1836)**

1. Pileus surface hirsute, velutinate 2
1'. Pileus surface glabrous 6

2. Pileus surface azonate, white to cream coloured 3
2'. Pileus surface yellowish to brownish coloured 4

3. Pores 2–3 per mm, basidiospores cylindric to elliptic, 4–5 x 2.5–3 µm .... *Trametes cotonea*
3'. Pores 4–5 per mm, basidiospores oval, 6–7 x 2.5 µm .... *Trametes pubescens*

4. Pore surface white to cream .... *Trametes versicolor*
4'. Pore surface yellowish to yellowish-grey 5

5. Pileus surface velvety tomentose with glabrous bands .... *Trametes ochracea*
5'. Pileus surface with coarse hairs in bundles .... *Trametes hirsuta*

6. Pore surface irpicoid to dentate .... *Trametes maxima*
6'. Pore surface smooth 7

7. Pileus surface yellowish; pores 6–8 per mm .... *Trametes marianna*
7'. Pileus surface with dark zonations in bands, Pores less than 5 per mm 8

8. Laterally substipitate to very narrow attachment; Pileus surface with narrow grey zonations .... *Trametes menziesii*
8'. Attachment with broad lateral base; Pileus surface sooty brown broad strations .... *Trametes cingulate*

Meripilaceae Julich
Biblthca Mycol. 85: 378, 1981

1. Encrusted cystidia present .... *Rigidoporus lineatus*
1'. Cystidia usually absent, if present mucronate, not encrusted 2

2. Spores size: 4–5 µm or 4–5 x 3.5–4.5 µm; decay causing white rot .... *Rigidoporus microporus*
2'. Spores size: 5–6 µm; decay causing brown cuboidal rot .... *Rigidoporus ulmarius*

Schizoporaceae Julich,
Biblthca Mycol. 85: 389 (1982)

1. Sporophore resupinate; pores 4–6 per mm .... ***Schizopora*** (*S. paradoxa*)
1'. Sporophore effused reflexed, pileus surface hispid to strigose; Pores 1 per mm .... ***Leucophellinus*** (*L. hobsonii*)

Fomitopsidaceae Julich,
Biblthca Mycol. 85: 367 (1982)

1. Sporophore annual, coriaceous .... ***Fomitopsis***
1'. Sporophore perennial, hard, woody .... ***Daedalea*** (*D. dochmia*)

Fomitopsis **P. Karst.,**
Meddn Soc. Fauna Flora fenn. 6: 9 (1881)

1. Pileus surface rust brown to reddish blonde; Spore cylindic to ellipsoid, 4–6 x 1.5–2.5 µm .... *Fomitopsis feei*
1'. Pileus surface white cream to pure yellow; Spore cylindric to oblong ellipsoid .... *Fomitopsis palustris*

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