Unique Southeast Asian peat swamp forest habitats have relatively few distinctive plant species

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SUMMARY

The peat swamp forests of Southeast Asia are often described as having a unique biodiversity. While these waterlogged and nutrient-poor habitats are indeed unique and include a distinct fauna (especially fish), the peat swamp forest flora is much less distinct and shares a surprisingly large number of species with other habitats. Out of 1,441 species of higher plants found in Southeast Asian swamps (from Thailand to Papua), 1,337 are found in the lowlands (< 300 m a.s.l.). Of these 1,337 species, 216 (16.2 %) occur mainly in lowland swamps, 75 (5.7 %) are shared with freshwater swamps and riparian habitats, 49 (3.7 %) are shared with heath forests, 7 (0.5 %) are shared with montane ecosystems, and 86 (6.5 %) are shared with a range of other lowland habitats. Of the 216 species (16.2 %) that occur in lowland swamps, 120 (9.2 %) are restricted to this habitat (which includes freshwater swamps), and 45 (3.4 %) are restricted to lowland peat swamp forests. Thus, more than 80 % (1,152 species) of the known peat swamp forest flora is common to a wide range of habitats, while 12.4 % (166 species) is composed of opportunistic pioneer or secondary forest species.

KEY WORDS: endangered species, flora, Indonesia, lowland swamp, Malaysia, opportunistic species

INTRODUCTION

The peat swamp forests of Southeast Asia are often described as having unique biodiversity, including endemic tree species and rare and endangered animals (van der Meer *et al.* 2008, Yule 2010). These waterlogged and nutrient-poor habitats host a distinctly adapted, highly endemic fish fauna (Ng *et al.* 1994, Kottelat & Widjanarti 2005, Kottelat *et al.* 2006) and the largest remaining populations of threatened animals such as the false gharial (*Tomistoma schlegelii*), Storm's stork (*Ciconia stormi*) and white-winged wood duck (*Asarcornis scutulata*), plus a large proportion of the Bornean and Sumatran orangutans (*Pongo* spp.; Meijaard 1997, Husson *et al.* 2009, Yule 2010, Wetlands International 2010) and southern Bornean gibbon (*Hylobates albibarbis*; Cheyne *et al.* 2008). While the peat swamp forest (PSF) flora has received less attention than the fauna, botanists have observed that it is less distinct, sharing a relatively large number of species with other habitats (Anderson 1963, Whitmore 1984). In this article we attempt to assess the degree of floristic similarity amongst Southeast Asian peat swamp forests, and their floristic relationships with other habitat types.

METHODS

Over the past eight years, the first author has compiled a comprehensive spreadsheet database of Southeast Asian swamp plant species, based on species habitat records from key taxonomic references (van Steenis 1950–1984, Backer & Bakhuizen van den Brink 1963–1968, Whitmore 1972, Whitmore 1973, Ng 1978, Ng 1989, van Steenis & de Wilde 1984–1989, de Wilde 1992–1996, Kalkman 1997, Stevens 2000–2001, Nooteboom 2002, Nooteboom & Kirkup 2005, Nooteboom 2007–2010, van Welzen 2011–2016), scientific papers and 'grey literature' reports on peat swamp forests (more than 140 references, available from the first author upon request). Attention was paid to accuracy, particularly with regard to excluding potentially doubtful species records because of uncertain taxonomy or locality information. The plant taxonomy follows *The Plant List* (2010) Version 1.0 (www.theplantlist.org/), accessed between 2012 and 2016. The assessment of whether a species occurred in lowland PSF was made by referring to the habitats listed in the key taxonomic references mentioned above, and consulting herbarium records made accessible *via* the Global

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Biodiversity Information Facility Version 1.2.6 (http://data.gbif.org/), in which all major herbaria with Southeast Asia collections collaborate. The tendency for taxonomists and scientists to report limited habitat information required some level of leniency when dealing with the specific habitat record 'swamp', which could also mean freshwater swamp. While a 'swamp' habitat listing was not used to justify adding a species to the PSF restricted list, a species already on the list due to information from a different reference was not removed if a 'swamp' listing was found later. Information on geographical distribution and the occurrence of each species in habitats other than peat swamps was obtained from the key taxonomic references listed above, and from herbarium collections. The chance occurrence of a species outside of PSF was regarded as too rigorous a criterion for excluding it from the restricted PSF list, so species were not moved from the restricted to the non-restricted PSF list on the basis of one record or a few occurrences outside PSFs. Information about whether species were pioneer species or common to primary and secondary forest was obtained from Kostermans (1958), Kessler *et al.* (1995), Kessler (2000), van Eijk *et al.* (2009), Giesen *et al.* (2009), Palangkaraya University (2012) and Giesen (2013). Many species are only infrequently recorded in PSF and site-specific abundances are often not recorded. Therefore, a cut-off of four or more records in PSF was used to identify 'common' or 'widespread' species.

RESULTS

The swamp plants database includes 1,441 plant species found in Southeast Asian swamps, from Thailand and Vietnam to Papua. Of these, 1,337 are lowland swamp species (< 300 m a.s.l.) and 1,313 are lowland swamp angiosperms. Considering the 1,313 lowland swamp angiosperms, 216 (16.5 %) occur predominantly in lowland swamps (Table 1). Amongst these 216 species, 120 (9.1 %) are found in lowland swamps only, with 75 (5.7 %) in freshwater swamps, 45 (3.4 %) restricted to lowland peat swamp forests (Table 2) and the remaining 96 (7.3 %) mainly in lowland swamps. The majority (> 80 %) of the 1,313 lowland swamp angiosperms are found in both peat swamps and a variety of other habitats, including many non-waterlogged lowland evergreen rainforest

Table 1. Swamp plant species in Southeast Asia: overlap with other habitats.

Habitat	Number of plant species				% of total
1. All Southeast Asian swamps	1,451				
2. Variety of habitats including lowland swamps	1,337				
of which angiosperms	1,313				100
3. Swamps, plus lowlands (>300 m a.s.l.) to hills/ridges (300–800 m a.s.l.)		405			30.8
4. Swamps, plus a variety of lowland habitats		331			25.2
5. Swamps, plus a variety of lowland to montane habitats		305			23.2
6. Lowland swamps and montane habitat		7			0.5
7. Lowland swamps and heath forest (kerangas)		49			3.7
8. Predominantly in lowland swamps		216			16.5
8a. Only in lowland swamps			120		9.1
8a.i Lowland peat swamp forests and riparian/mineral soil swamps				75	(5.7)
8a.ii Restricted to lowland peat swamp forests				45	(3.4)
8b. Mainly in lowland swamps			96		7.3
TOTALS		1,313	216	120	

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(LERF) habitats. In total, 405 species are shared with LERF lowlands and hill/ridge habitats (300–800 m a.s.l.) and 331 species are shared with a variety of lowland habitats, while 305 species are shared with a range of habitats from LERF lowlands to montane habitats (> 800m asl). Forty-nine species (3.7 %) are shared with heath forests (*kerangas*) only and seven species (0.5 %) are shared with montane/highland ecosystems (i.e. > 800 masl) only (Figure 1). Note that many more species are shared by PSF and *kerangas* (63 species), and by PSF and montane habitats (305 species), but are not exclusive to these

Table 2. Plant species restricted to peat swamp forests in Southeast Asia.

#	Family	*Scientific name*	Status	Singapore	Thailand	Brunei	Indonesia	Malaysia	Sumatra	Borneo	P. Malaysia
1	Annonaceae	*Goniothalamus andersonii* J.Sinclair	U				+	+		+	
2	Annonaceae	*Xylopia coriifolia* Ridl.	C				+	+		+	
3	Apocynaceae	*Dyera polyphylla* (Miq.) Steenis *(D. lowii)*	C			+	+	+	+	+	
4	Apocynaceae	*Willughbeia grandiflora* Dyer ex Hook.f.	R			+	+	+		+	
5	Arecaceae	*Korthalsia paucijuga* Beccari	U			+	+	+	+	+	
6	Caesalpiniaceae	*Crudia venenosa* de Wit	R					+		+	
7	Celastraceae	*Lophopetalum sessilifolium* Ridl.	R				+	+		+	
8	Chrysobalanaceae	*Parastemon urophyllus (Wall. ex A.DC.) A.DC.*	C	+		+	+	+	+	+	+
9	Clusiaceae	*Calophyllum ardens* P.F.Stevens	U				+	+		+	
10	Clusiaceae	*Calophyllum hosei* Ridl. *(C. fragrans)*	C				+			+	
11	Clusiaceae	*Calophyllum lowei* Planch. & Triana	R				+		+	+	
12	Clusiaceae	*Calophyllum sundaicum* P.F. Stevens	R	+			+		+	+	+
13	Clusiaceae	*Garcinia apetala* Pierre	R				+			+	
14	Clusiaceae	*Mesua congestiflora* P.F. Stevens	R				+			+	
15	Cucurbitaceae	*Baijiania borneensis* var. *paludicola* Duyfjes	U					+		+	
16	Dipterocarpaceae	*Shorea hemsleyana* (King) King ex Foxw. ssp. *hemsleyana*	C		+	+	+	+	+	+	+
17	Dipterocarpaceae	*Shorea inaequilateralis* Symington	C			+		+		+	
18	Dipterocarpaceae	*Shorea pachyphylla* Ridl.	C			+	+	+		+	
19	Dipterocarpaceae	*Shorea platycarpa* Heim.	C			+	+	+	+	+	+
20	Dipterocarpaceae	*Shorea teysmanniana* Dyer ex Brandis	C			+	+	+	+	+	+
21	Dipterocarpaceae	*Shorea uliginosa* Foxw.	C			+	+	+	+	+	+
22	Ebenaceae	*Diospyros pseudomalabarica* Bakh.	R				+		+	+	
23	Ebenaceae	*Diospyros siamang* Bakh.	C	+		+	+	+	+	+	+
24	Euphorbiaceae	*Croton macrocarpus* Ridl.	R					+			+
25	Fagaceae	*Lithocarpus andersonii* Soepadmo	U			+	+	+		+	
26	Hanguanaceae	*Hanguana exultans* Siti Nurfazilah, Mohd Fahmi, Sofiman Othma	U					+			+
27	Hanguanaceae	*Hanguana thailandica* Wijedasa & Niissalo	R		+						
28	Lauraceae	*Cryptocarya enervis* Hook.f.	R			+	+	+		+	+
29	Lauraceae	*Litsea crassifolia* (Blume) Boerl.	R				+	+		+	
30	Lauraceae	*Litsea grandis* var. *paludosa* (Kosterm.) Ng	R				+		+	+	
31	Loranthaceae	*Lepidaria oviceps* Danser	R			+	+	+		+	
32	Meliaceae	*Sandoricum beccarianum* Baill.	C		+		+	+	+	+	+
33	Myristicaceae	*Knema mamillata* W.J. De Wilde	R				+			+	
34	Myrtaceae	*Tristaniopsis beccarii* (Ridl.) Peter G.Wilson & J.T.Waterh.	R					+		+	
35	Pandanaceae	*Pandanus vinaceus* B.C. Stone	R					+		+	
36	Penaeaceae	*Dactylocladus stenostachys* Oliv.	C			+	+	+		+	
37	Pentaphyllaceae	*Ternstroemia hosei* Ridl.	R					+		+	
38	Polygalaceae	*Xanthophyllum ramiflorum* Meijden	U					+		+	
39	Rosaceae	*Prunus turfosa* Kalkman	C				+	+		+	
40	Rubiaceae	*Dichilanthe borneensis* Baill.	R				+			+	
41	Rubiaceae	*Ixora pyrantha* Bremek.	R					+		+	
42	Rubiaceae	*Tarenna adpressa* (King) Merr.	U	+				+			+
43	Sapotaceae	*Palaquium burckii* H.J. Lam	C				+	+	+	+	+
44	Sapotaceae	*Palaquium cochleariifolium* P. Royen	C				+			+	
45	Stemonuraceae	*Stemonurus scorpioides* Beccari	C	+		+	+	+	+	+	+
Status: c=common or widespread (17); u=uncommon (8); r=rare (20); Note that Papua and Vietnam are not included as both are zero; for Papua this is likely due to lack of data.				**5**	**3**	**16**	**33**	**34**	**15**	**41**	**14**

habitats and are shared among a range of habitats. In total, 166 lowland swamp species (12.4 %) are pioneer species or are characteristic of secondary habitats. Of the 200+ most common lowland peat swamp species in Southeast Asia, the largest percentage (97 %) occurs on Borneo, followed by Peninsular Malaysia (87 %), Sumatra (82 %) and Thailand (56 %) (Appendix).

The 45 species restricted to PSF (Table 2) are found in Borneo (41 species or 91 %), Sumatra (15 species), Peninsular Malaysia (14 species), Singapore (5 species) and Thailand (3 species). None have been recorded in Vietnam or Papua.

DISCUSSION

Floristically, PSF is less diverse than everwet lowland forest on mineral soils in Southeast Asia. The count of 30–122 tree species *per* hectare in PSF is lower than the 70–220 or even 100–280 tree species *per* hectare commonly recorded in Malesian everwet lowland forest on mineral soils (Whitmore 1984, Posa *et al.* 2011). This is also reflected in the overall numbers of tree species in specific regions, with only 234 tree species being recorded for Sarawak and Brunei PSF compared to 1800–2300 in lowland forests (Whitmore 1984).

Only a relatively small number (45 or 3.4 %) of species found in PSF are truly restricted to this habitat. This contrasts with the findings of Posa *et al.* (2011), who report 172 plant species (11 % of their total) restricted to peat swamp forests. Given that the total numbers of PSF species are similar (1,337 in our report *versus* 1,524 in Posa *et al.* 2011), this difference can probably be explained by a different definition of 'restricted'. In a more general study on tree species distribution across five habitats including PSF and *kerangas*, Cannon & Leighton (2004) found that while 67 % of common species were significantly associated with one habitat, few species were restricted to a single habitat, although the peatland habitat had the most profound effect on species distribution. They also found that 16 % of their species appeared to be habitat generalists.

In the present study, if habitat records were unclear, herbarium records were consulted as these often include habitat descriptions. Often, species that have been described as 'typical for peat swamps' (*e.g.*, *Campnosperma coriaceum*, *Combretocarpus rotundatus*, *Cratoxylum arborescens*, *Eleiodoxa conferta*, *Gonystylus bancanus*, *Ilex cymosa*, *Lophopetalum multinervium*, *Madhuca malayana*, *Syzygium zeylanicum*, *Tetramerista glabra*; Whitmore 1984) were also found to occur regularly in other habitats and are, therefore, not exclusive to PSF. However, a total of about 200+ species (similar to the number of restricted species according to Posa *et al.*) are commonly found in PSF and are less common in other habitats; therefore, these can be

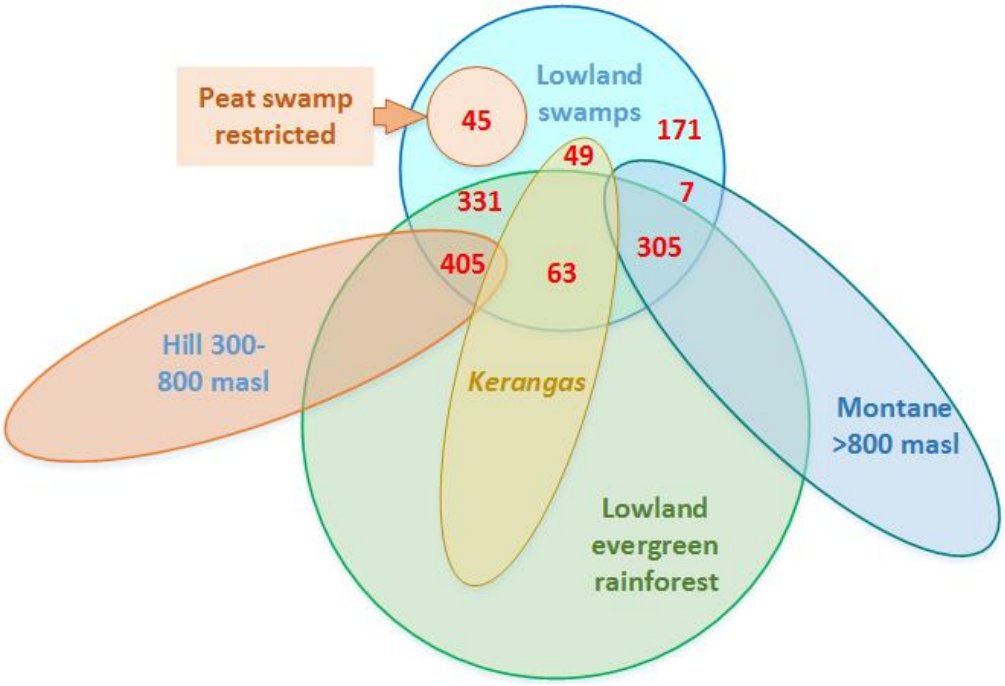

Figure 1: Plant species shared between lowland swamps and other habitats in Southeast Asia.

regarded as (non-exclusive) PSF species (listed in the Appendix). The fact that 41 of the 45 PSF restricted species occur on Borneo, and 25 of these are endemic to the island, further confirms the importance of Borneo for biodiversity (Raes *et al.* 2009, de Bruyne *et al.* 2014). The 17 PSF restricted species that are common or widespread are either found on Borneo only (eight species) or on Borneo, Sumatra and Peninsular Malaysia (nine species). No known plant genera are restricted to PSF, nor does any ecological characteristic (*e.g.* physiognomy, growth rate) stand out as being a common denominator for the restricted species.

The (exclusive) sharing of species between PSF and habitats such as *kerangas* and montane forests is puzzling, given the physical demands that these habitats place on the plants. *Kerangas* forests are characterised by very dry and nutrient deficient sandy soils, and while nutrient deficiency is a trait shared with PSF, the waterlogging typical of PSF and the everwet conditions of montane habitats are the opposite of what a plant faces in *kerangas.* Low pH is a feature that these three habitats do share, with pH averaging 2.9–4.0 in *kerangas* (Proctor 1999), 2.9–4.0 in PSF (Yule 2010) and 3.0–4.0 in montane habitats on Borneo (Ushio *et al.* 2008). Suzuki (2010) proposes that both *kerangas* and PSF promote the growth of species preferring cooler habitats, because of the periodic occurrence of water on the ground surface. That would also explain the overlap with montane habitats. Studies by Nishimura & Suzuki (2001) on growth patterns in *kerangas* and PSF trees shows that plants allocate resources where they are required (*e.g.*, increased root depth and smaller leaves in *kerangas*, more lateral root growth in PSF), and that there is plasticity within species. Nishimura & Suzuki's (2001) study on intraspecific differentiation in two species (*Canarium* sp. and *Shorea teysmanniana*) that occurred in both PSF and *kerangas* shows that phenotypic plasticity enables them to grow in these environmentally contrasting forests. As a result of their phenotypical adaptations, drought affects PSF trees more than *kerangas* trees, with higher mortalities occurring in PSF during prolonged El Niño associated dry spells (Nishimura *et al.* 2007).

Interestingly, while it seems that only a few species are exclusively specialised for PSF environments, some reach levels of dominance not seen in other forest types. For example, *Shorea albida* dominates PSF in Sarawak (Whitmore 1984, Bruenig 1990), while *Combretocarpus rotundatus* and *Dactylocladus stenostachys* dominate the central parts of peat domes in Kalimantan (Anderson 1983). This indicates a possibility of relative advantage and specialisation; although these species occasionally occur outwith PSF, they are apparently considerably better adapted than other species to peatland.

PSF is declining rapidly and by 2010 only 2.1 % and 4.6 % was left in a pristine condition in Kalimantan and on Sumatra, respectively (Miettinen & Liew 2010); while a dramatic 70 % decline in key PSFs in the Rajang Delta (Sarawak) occurred during 2000–2014 alone (Hooijer *et al*. 2015). Wetlands International (2010) conclude that "No example of a hydrologically intact peat dome remains anywhere in Malaysia". Given the rate and extent of change, it is to be expected that the eight uncommon and 20 rare PSF restricted plant species may be under threat. Five of the rare species are known from 1–2 locations/collections and three of these are either endangered (*Crudia venenosa*, known from type collection in Sabah only) or possibly extinct (*Croton macrocarpus* from the now fully converted Telok PSF in Selangor, Peninsular Malaysia; *Knema mamillata*, known only from PSF in South Kalimantan, where this habitat is fully converted). A number of rare species known only from Sarawak and Peninsular Malaysia can be considered endangered given the current state of the hosting habitat; these include *Garcinia apetala, Ixora pyrantha, Litsea crassifolia, Pandanus vinaceus, Tarenna adpressa, Ternstroemia hosei* and *Tristaniopsis beccarii. Lophopetalum sessilifolium*, which is known from Sarawak and the now disappeared PSF of Sungai Landak in West Kalimantan, further extends the list of endangered species. Even common/widespread species (see Appendix) are locally under threat. *Combretocarpus rotundatus* has disappeared from Peninsular Malaysia (where it was never really common), and five species that are common/widespread overall have disappeared from Singapore in recent decades (*Austrobuxus nitidus, Calophyllum calaba, Litsea gracilipes, Neesia altissima* and *Syzygium leucoxylon*). Extinctions may also have occurred elsewhere in the region, but gone unnoticed because local recording is less assiduous than in Singapore.

The coastal/sub-coastal PSFs of Southeast Asia are generally only 5–15,000 years old (Page *et al.* 2010, Dommain *et al.* 2011), but peat formations 75 m below present sea level (dated at 13,000 years BP) off the east coast of Peninsular Malaysia (Voris 2000) indicate that the habitat itself is older. The PSFs of Borneo, Sumatra and Peninsular Malaysia may have been (relatively) interconnected until 8,000–10,000 BP, when the Sunda Shelf was still exposed (Voris 2000), but due to sea level rise since

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the last glacial maximum (10,000–13,000 BP) PSFs probably now occur at their highest altitude for millennia. According to Hanebuth *et al.* (2011), the development of PSFs would be especially affected by rates of coastal migration, and the rate of sea level rise would have influenced their degree of development and duration at any specific location. It is hypothesised that this relatively rapid 'landward retreat' of the PSF habitat may have contributed to the relative paucity of unique plant species and an abundance of opportunistic species able to adapt. Based on our dataset, 166 lowland peat swamp species (12.4 %) are pioneer species or are characteristic of secondary habitats, compared with 4 % for lowland rain forest in Peninsular Malaysia (Putz & Appanah 1987) and 8.7 % for similar habitat in eastern Borneo (Slik & Eichhorn 2003). Alternatively, the last glacial maximum was also associated with lower rainfall, and according to proponents of the 'savannah corridor hypothesis' (*e.g.* Bird *et al.* 2005, Raes *et al.* 2014) the middle part of Sundaland may have been a savannah corridor and hence too dry for PSF habitats to survive.

Models described by Cannon *et al.* (2009) and de Bruyn *et al.* (2014) provide an alternative explanation for the relative paucity of PSF restricted species (C.H. Cannon, personal communication 2017). At the last glacial maximum, sea levels were at their lowest and the entire continental shelf of Sundaland was exposed. Areas with favourable topography and drainage for coastal peat formation would have been limited, although scattered peatlands would have occurred on more elevated ground inland. This setting would present a severe bottleneck to PSF specialists. When the Sunda Shelf subsequently flooded during deglaciation, vast areas of peat could have formed (6,000–15,000 BP) because of the flat topography of the shelf and the large amount of water running onto it from rivers draining Indochina, Borneo and Sumatra. This might have forced lowland specialist species to become at least tolerant of PSF conditions. In general, the historical instability in extent and distribution of this unique habitat has probably played a central role in determining how many tree species became exclusively specialised.

Interestingly, a recent study of the floristic composition of lowland tropical peatlands in northern Peru shows that these comparable ecosystems, although in a very different geographical setting, probably have no endemic tree species (Draper 2016). Instead, the peatlands provide habitat for many generalist tree species, as well as for some specialists from adjacent white sand and floodplain forests. Draper (2016) attributes the paucity of endemics to the dynamic geomorphological setting of these peatlands, although environmental filtering and dispersal limitations may also play a role. As more information becomes available about the vegetation of peatlands across the tropical zone, it will be interesting to make further comparisons and to establish whether any commonalities can be identified in terms of the processes that determine the assembly of peatland plant communities.

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Appendix. Plant species that are common or widespread in Southeast Asian peat swamp forests.

				Habitat			Geographic range					
No.	Family	Species	abundance	Peat restricted	Mainly in peatland	Wide-ranging	Singapore	Thailand	Viet Nam	Borneo	Sumatra	Pen. Malaysia
		number of species:		17	59	132	115	116	56	202	170	181
1	Anacardiaceae	*Campnosperma coriaceum* (Jack) Hallier	***		1			1		1	1	1
2	Anacardiaceae	*Campnosperma auriculatum* (Blume)	***		1		1	1		1	1	1
3	Anacardiaceae	*Gluta aptera* (King) Ding Hou	**			1				1	1	1
4	Anacardiaceae	*Gluta beccarii* (Engler) Ding Hou	*			1				1		1
5	Anacardiaceae	*Gluta renghas* Linné	*			1				1	1	1
6	Anacardiaceae	*Gluta wallichii* (Hook.f.) Ding Hou	***			1	1			1	1	1
7	Anacardiaceae	*Mangifera foetida* Lour.	*			1	1	1	1	1	1	1
8	Anacardiaceae	*Mangifera havilandii* Ridl.	*			1				1		
9	Anacardiaceae	*Parishia insignis* Hook.f.	**			1	1	1		1	1	1
10	Anisophylleaceae	*Combretocarpus rotundatus* (Miq.) Danser	***		1					1	1	1#
11	Annonaceae	*Drepananthus biovulatus* (Boerl.)	**		1					1		
12	Annonaceae	*Goniothalamus malayanus* Hook.f. et	*			1		1			1	1
13	Annonaceae	*Mezzettia parviflora* Beccari	***			1		1		1	1	1
14	Annonaceae	*Polyalthia glauca* (Hassk.) Boerl.	***		1			1		1	1	1
15	Annonaceae	*Polyalthia hypoleuca* Hook.f. et Thoms.	***		1		1			1	1	1
16	Annonaceae	*Polyalthia lateriflora* (Blume) King	**			1		1		1	1	1
17	Annonaceae	*Xylopia coriifolia* Ridl.	**	1						1		
18	Annonaceae	*Xylopia fusca* Maing. ex Hk.f. & Thoms.	***		1		1	1		1	1	
19	Apocynaceae	*Alstonia angustiloba* Miq.	**			1	1	1		1	1	1
20	Apocynaceae	*Alstonia pneumatophora* Backer ex Den	***		1		1			1	1	1
21	Apocynaceae	*Alstonia spatulata* Blume	*		1		1	1	1	1	1	1
22	Apocynaceae	*Alyxia reinwardtii* Blume	*			1	1	1	1	1	1	1
23	Apocynaceae	*Dyera polyphylla* (Miq.) Steenis *(D. lowii)*	***	1						1	1	1
24	Aquifoliaceae	*Ilex cymosa* Blume	***		1		1	1		1	1	1
25	Aquifoliaceae	*Ilex hypoglauca* Loes.	*		1					1		
26	Araceae	*Lasia spinosa* (L.) Thwaites	*		1		1	1	1	1	1	1
27	Araliaceae	*Arthrophyllum diversifolium* Blume	*			1	1			1	1	1
28	Araucariaceae	*Agathis borneensis* Warb.	**			1				1	1	1
29	Arecaceae	*Caryota mitis* Lour.	*			1	1	1	1	1	1	1
30	Arecaceae	*Cyrtostachys renda* Blume	***		1			1		1	1	1
31	Arecaceae	*Eleiodoxa conferta* (Griff.) Burret	***		1		1	1		1	1	1
32	Arecaceae	*Korthalsia flagellaris* Miq.	*			1				1	1	1
33	Arecaceae	*Nenga pumila* (Blume) H.Wendl.	*			1	1	1		1	1	1
34	Aspleniaceae	*Asplenium nidus* L.	**			1	1	1	1	1	1	1
35	Blechnaceae	*Blechnum indicum* Burm. f.	*			1	1	1	1	1	1	1
36	Blechnaceae	*Stenochlaena palustris* (Burm. f.) Bedd.	***		1		1	1	1	1	1	1
37	Bombaceae	*Durio carinatus* Mast.	***		1					1	1	1
38	Bombaceae	*Neesia altissima* (Blume) Blume	*			1	1#	1		1	1	1
39	Bonnetiaceae	*Ploiarium alternifolium* (Vahl.) Melchior	***		1		1	1		1	1	1
40	Burseraceae	*Canarium pilosum* Benn.	*			1	1			1	1	1
41	Burseraceae	*Dacryodes macrocarpa* (King) H.J. Lam	**		1					1	1	1
42	Burseraceae	*Dacryodes rostrata* (Blume) H.J. Lam	*			1	1	1	1	1	1	1
43	Burseraceae	*Santiria apiculata* Benn.	**			1				1	1	1
44	Burseraceae	*Santiria griffithii* (Hook.f.) Engl.	*			1	1			1	1	1
45	Burseraceae	*Santiria laevigata* Blume	***			1		1		1	1	1
46	Burseraceae	*Santiria oblongifolia* Blume	*			1		1		1	1	1
47	Burseraceae	*Santiria rubiginosa* Blume	***			1	1			1	1	1
48	Burseraceae	*Santiria tomentosa* Blume	*			1	1	1		1	1	1
49	Caesalpiniaceae	*Dialium indum* L. *var. indum*	***			1	1	1		1	1	1
50	Caesalpiniaceae	*Koompassia malaccensis* Benth.	***			1	1	1		1	1	1
51	Caesalpiniaceae	*Pseudosindora palustris* (Sym.) de Wit	*		1					1		
52	Caesalpiniaceae	*Sindora leiocarpa* de Wit	**			1				1	1	

				Habitat			Geographic range					
No.	Family	Species	abundance	Peat restricted	Mainly in peatland	Wide-ranging	Singapore	Thailand	Viet Nam	Borneo	Sumatra	Pen. Malaysia
53	Calophyllaceae	*Calophyllum calaba* L.	*			1	1#		1			1
54	Calophyllaceae	*Calophyllum ferrugineum* Ridley var.	**			1	1			1		1
55	Calophyllaceae	*Calophyllum hosei* Ridl.	*	1						1		
56	Calophyllaceae	*Calophyllum sclerophyllum* Vesque	***			1		1		1	1	1
57	Calophyllaceae	*Calophyllum soualattri* Burm.f.	***			1		1	1	1	1	1
58	Casuarinaceae	*Gymnostoma sumatranum* (Jungh. ex de	*			1				1	1	1
59	Celastraceae	*Bhesa paniculata* Arn.	*			1	1	1		1	1	1
60	Celastraceae	*Lophopetalum multinervium* Ridl.	***			1	1			1	1	1
61	Chrysobalanaceae	*Parastemon urophyllus (Wall. ex A.DC.)*	***	1			1			1	1	1
62	Clusiaceae	*Garcinia bancana* Miq.	***			1	1			1	1	1
63	Clusiaceae	*Garcinia cuneifolia* Pierre	*		1					1		
64	Clusiaceae	*Garcinia rostrata* Hassk. ex Hook.f.	**			1	1					1
65	Crypteroniaceae	*Dactylocladus stenostachys* Oliv.	***	1						1		
66	Ctenolophonaceae	*Ctenolophon parvifolius* Oliver	***			1	1	1		1	1	1
67	Cyperaceae	*Eleocharis dulcis* (Burm.f.) Henschel.	*		1		1	1	1	1	1	1
68	Cyperaceae	*Hypolytrum nemorum* (Vahl.) Spreng	*			1	1	1		1	1	1
69	Cyperaceae	*Mapania bancanum* (Miq.) Kurz.	***		1		1	1	1	1	1	1
70	Cyperaceae	*Mapania sumatranum* (Miq.) Kurz	*		1		1			1	1	1
71	Cyperaceae	*Rhynchospora corymbosa* (L.) Britt.	*		1		1	1	1	1	1	1
72	Cyperaceae	*Scleria purpurescens* Steud.	*			1	1	1	1	1	1	1
73	Cyperaceae	*Scleria sumatrensis* Retz.	**			1	1	1	1	1	1	1
74	Davalliaceae	*Nephrolepis biserrata* (Sw.) Schott	**			1		1	1	1	1	1
75	Dilleniaceae	*Dillenia excelsa* (Jack) Gilg.	**			1		1		1	1	1
76	Dilleniaceae	*Dillenia pulchella* (Jack) Gilg	***		1			1		1	1	1
77	Dipterocarpaceae	*Anisoptera marginata* Korth.	***		1					1	1	1
78	Dipterocarpaceae	*Dryobalanops rappa* Beccari	***		1					1		
79	Dipterocarpaceae	*Shorea albida* Symington ex Thomas	**		1					1		
80	Dipterocarpaceae	*Shorea balangeran* (Korth.) Burck.	***		1					1	1	
81	Dipterocarpaceae	*Shorea hemsleyana* (King) King ex Foxw.	*	1				1		1	1	1
82	Dipterocarpaceae	*Shorea inaequilateralis* Symington	*	1						1		
83	Dipterocarpaceae	*Shorea leprosula* Miq.	**			1		1		1	1	1
84	Dipterocarpaceae	*Shorea pachyphylla* Ridl.	*	1						1		
85	Dipterocarpaceae	*Shorea pauciflora* King	**			1				1	1	1
86	Dipterocarpaceae	*Shorea platycarpa* Heim.	***	1			1			1	1	1
87	Dipterocarpaceae	*Shorea rugosa* Heim.	**			1				1		
88	Dipterocarpaceae	*Shorea teysmanniana* Dyer ex Brandis	***	1						1	1	1
89	Dipterocarpaceae	*Shorea uliginosa* Foxw.	***	1						1	1	1
90	Dipterocarpaceae	*Vatica mangachapoi* Blanco *ssp.*	*		1			1	1	1		1
91	Ebenaceae	*Diospyros evena* Bakh.	***		1					1	1	
92	Ebenaceae	*Diospyros maingayi* (Hiern) Bakh.	***			1				1	1	1
93	Ebenaceae	*Diospyros siamang* Bakh.	***	1			1			1	1	1
94	Elaeocarpaceae	*Elaeocarpus floribundus* Blume	**			1		1	1	1	1	1
95	Elaeocarpaceae	*Elaeocarpus griffithii* (Wight) A.Gray	**		1		1	1		1	1	1
96	Elaeocarpaceae	*Elaeocarpus mastersii* King	*			1	1			1	1	1
97	Elaeocarpaceae	*Elaeocarpus petiolatus* (Jacq.) Wall.	***			1	1	1	1	1	1	1
98	Euphorbiaceae	*Blumeodendron kurzii* (Hook.f.) J.J.Sm. ex	*			1		1		1	1	1
99	Euphorbiaceae	*Blumeodendron tokbrai* (Blume) Kurz	***			1				1	1	1
100	Euphorbiaceae	*Macaranga caladiifolia* Beccari	**		1					1		1
101	Euphorbiaceae	*Macaranga gigantea* (Rchb.f. & Zoll.)	*			1		1		1	1	1
102	Euphorbiaceae	*Macaranga pruinosa* (Miq.) Müll.Arg.	***			1		1		1	1	1
103	Euphorbiaceae	*Macaranga puncticulata* Gage	***			1	1			1	1	1
104	Euphorbiaceae	*Macaranga triloba* (Thunb.) Müll.Arg.*(var.*	*			1		1			1	1

				Habitat			Geographic range					
No.	Family	Species	abundance	Peat restricted	Mainly in peatland	Wide-ranging	Singapore	Thailand	Viet Nam	Borneo	Sumatra	Pen. Malaysia
105	Euphorbiaceae	*Neoscortechinia kingii* (Hook.f.) Pax &	***			1				1	1	1
106	Euphorbiaceae	*Pimelodendron griffithianum* (Müll.Arg.)	**			1				1	1	1
107	Fagaceae	*Lithocarpus dasystachyus* (Miq.) Rehd.	**			1				1		
108	Flagellariaceae	*Flagellaria indica* Linné	**			1	1	1	1	1	1	1
109	Flagellariaceae	*Hanguana malayana* (Jack) Merr.	**			1	1	1	1	1	1	1
110	Gentianaceae	*Fagraea auriculata* Jack	*			1	1	1	1	1	1	1
111	Gentianaceae	*Fagraea fragrans* Roxb.	*			1	1	1	1	1	1	1
112	Gentianaceae	*Fagraea racemosa* Jack ex Wall.	**			1	1	1	1	1	1	1
113	Hypericaceae	*Cratoxylum arborescens* (Vahl) Blume	***			1	1	1		1	1	1
114	Hypericaceae	*Cratoxylum glaucum* Korth.	***		1					1	1	1
115	Icacinaceae	*Platea excelsa* Blume var. *Riedeliana*	**		1					1	1	
116	Juglandaceae	*Engelhardtia serrata* Blume	*			1	1	1	1	1	1	1
117	Lamiaceae	*Vitex pinnata* L.	*			1	1	1	1	1	1	1
118	Lauraceae	*Litsea gracilipes* Hook.f.	***		1		1#			1		1
119	Lauraceae	*Litsea grandis* (Nees) Hook. f.	**			1	1	1	1	1	1	1
120	Lauraceae	*Nothaphoebe coriacea* (Kosterm.)	**		1		1			1	1	1
121	Lauraceae	*Nothaphoebe umbelliflora* (Blume) Blume	*			1	1	1	1	1	1	1
122	Lauraceae	*Tetranthera resinosa* (Blume) Nees	***		1			1		1		1
123	Lecythidaceae	*Barringtonia reticulata* (Blume) Miq.	**			1	1	1	1	1	1	1
124	Magnoliaceae	*Magnolia bintuluensis* (Agostini) Noot.	*		1					1	1	1
125	Malvaceae	*Scaphium macropodum* (Miq.) Beumée ex	**			1		1		1	1	1
126	Malvaceae	*Sterculia bicolor* Mast.	**		1							1
127	Melastomataceae	*Melastoma malabathricum* L.	**			1		1	1	1	1	1
128	Melastomataceae	*Pternandra galeata* Jack	**		1					1	1	1
129	Meliaceae	*Aglaia rubiginosa* (Hiern) Pannell	***			1	1			1	1	1
130	Meliaceae	*Sandoricum beccarianum* Baill.	***	1			1	1		1	1	1
131	Mimosaceae	*Adenanthera pavonina* L.	*			1	1	1	1	1	1	1
132	Mimosaceae	*Archidendron borneense* (Benth.) Nielsen	*		1					1	1	
133	Mimosaceae	*Archidendron clypearia* (Jack) Nielsen	***			1	1	1	1	1	1	1
134	Moraceae	*Artocarpus elasticus* Reinw. Ex Blume	*			1	1	1		1	1	1
135	Moraceae	*Artocarpus kemando* Miq.	**			1	1	1		1	1	1
136	Moraceae	*Ficus deltoidea* Jack	**			1	1	1		1	1	1
137	Moraceae	*Ficus microcarpa* l.f.	**			1	1	1		1	1	1
138	Moraceae	*Ficus punctata* Thunb.	*			1		1	1	1	1	1
139	Moraceae	*Ficus sumatrana* (Miq.) Miq.	**			1		1	1	1	1	1
140	Moraceae	*Ficus sundaica* Blume	**			1	1	1	1	1	1	1
141	Moraceae	*Parartocarpus venenosus* (Zoll. & Moritzi)	***			1		1		1	1	1
142	Myristicaceae	*Gymnacranthera farquhariana* (Hook.f. &	**			1	1	1		1	1	1
143	Myristicaceae	*Horsfieldia crassifolia* (Hook.f. & Thomson)	***		1		1	1		1	1	1
144	Myristicaceae	*Knema intermedia* (Blume) Warb.	**			1				1	1	1
145	Myristicaceae	*Knema laurina* (Blume) Warb.	*			1	1	1	1	1	1	1
146	Myristicaceae	*Myristica elliptica* Wall. ex Hook.f. &	**		1		1	1		1	1	1
147	Myristicaceae	*Myristica iners* Blume	*			1	1	1	1	1	1	1
148	Myristicaceae	*Myristica lowiana* King	***		1		1			1	1	1
149	Myrtaceae	*Melaleuca cajuputi* Powell	*		1		1	1	1	1	1	1
150	Myrtaceae	*Syzygium chloranthum* (Duthie) Merr. &	**			1	1	1		1	1	1
151	Myrtaceae	*Syzygium grande* (Wight) Walp.	**			1	1	1	1	1		1
152	Myrtaceae	*Syzygium havilandii* (Merr.) Merr. &	*			1				1		
153	Myrtaceae	*Syzygium incarnatum* (Elmer) Merr. &	***			1	1			1	1	1
154	Myrtaceae	*Syzygium leucoxylon* Korth.	*			1	1#			1		
155	Myrtaceae	*Syzygium lineatum* Merr. & L.M.Perry	***			1	1	1	1	1	1	1
156	Myrtaceae	*Syzygium napiforme* (Koord. & Valeton)	*			1				1	1	1

				Habitat			Geographic range					
No.	Family	Species	abundance	Peat restricted	Mainly in peatland	Wide-ranging	Singapore	Thailand	Viet Nam	Borneo	Sumatra	Pen. Malaysia
157	Myrtaceae	*Syzygium nemestrinum* (M.R.Hend.)	*			1	1					1
158	Myrtaceae	*Syzygium oblatum* (Roxb.) Wall. ex	*		1		1	1	1	1		1
159	Myrtaceae	*Syzygium palembanicum* Miq.	***			1	1			1	1	1
160	Myrtaceae	*Syzygium zeylanicum* (L.) DC.	***			1	1	1	1	1	1	1
161	Myrtaceae	*Tristaniopsis merguensis* (Griff.) Peter	**			1	1	1		1		1
162	Myrtaceae	*Tristaniopsis obovata* (Benn.) Peter	***			1	1			1	1	1
163	Nepenthaceae	*Nepenthes ampullaria* Jack	**		1		1	1		1	1	1
164	Nepenthaceae	*Nepenthes gracilis* Korth.	***		1		1	1		1		
165	Nepenthaceae	*Nepenthes mirabilis* (Lour.) Druce	**			1	1	1	1	1	1	1
166	Ochnaceae	*Brachenridgea hookeri* (Planch.) A. Gray	*			1	1	1		1		1
167	Ochnaceae	*Brackenridgea palustris* Bartell.	**			1	1			1	1	1
168	Opiliaceae	*Champereia manillana* (Blume) Merr.	*			1	1	1	1	1	1	1
169	Pandanaceae	*Pandanus helicopus* Kurz ex Miq.	*		1			1		1	1	1
170	Phyllanthaceae	*Antidesma coriaceum* Tul.	***			1				1	1	1
171	Phyllanthaceae	*Antidesma montanum* Blume	*			1		1	1	1	1	1
172	Phyllanthaceae	*Austrobuxus nitidus* Miq.	*			1	1#	1		1	1	1
173	Phyllanthaceae	*Baccaurea bracteata* Müll. Arg.	***		1			1		1	1	1
174	Phyllanthaceae	*Glochidion rubrum* Blume	*			1	1	1	1	1	1	1
175	Podocarpaceae	*Dacrydium pectinatum* de Laub.	*		1					1		
176	Polygalaceae	*Xanthophyllum amoenum* Chodat	**			1				1	1	1
177	Polygalaceae	*Xanthophyllum ellipticum* Korth. ex Miq.	*			1	1	1		1	1	1
178	Primulaceae	*Labisia pumila* (Blume) Mez	**			1	1	1		1		1
179	Rhizophoraceae	*Carallia brachiata* (Lour.) Merr.	***			1	1	1		1	1	1
180	Rhizophoraceae	*Gynotroches axillaris* Blume	**			1	1	1		1	1	1
181	Rosaceae	*Prunus arborea* (Blume) Kalkman	*			1	1	1	1	1	1	1
182	Rosaceae	*Prunus turfosa* Kalkman	*	1						1		
183	Rubiaceae	*Gardenia pterocalyx* Valeton	**			1				1		1
184	Rubiaceae	*Gardenia tubifera* Wall. ex Roxb.	**			1	1	1		1	1	1
185	Rubiaceae	*Jackiopsis ornata* (Wall.) Ridsdale	***			1				1	1	1
186	Rubiaceae	*Mussaendopsis beccariana* Baill.	*		1		1			1	1	1
187	Rubiaceae	*Timonius flavescens* (Jacq.) Baker	***		1		1			1	1	1
188	Rubiaceae	*Urophyllum arboreum* (Reinw. ex Blume)	*			1	1	1		1	1	1
189	Sapindaceae	*Pometia pinnata* Forst. & Forst.	***			1	1	1	1	1	1	1
190	Sapindaceae	*Nephelium maingayi* Hiern	***			1				1	1	1
191	Sapindaceae	*Xerospermum noronhianum* (Blume)	*			1	1	1		1	1	1
192	Sapotaceae	*Madhuca motleyana* (de Vriese)	***		1			1		1	1	1
193	Sapotaceae	*Palaquium burckii* H.J. Lam	**	1						1	1	1
194	Sapotaceae	*Palaquium cochleariifolium* P. Royen	***	1						1		
195	Sapotaceae	*Palaquium leiocarpum* Boerlage	*			1				1	1	1
196	Sapotaceae	*Palaquium ridleyi* King & Gamble	***		1		1	1	1	1	1	1
197	Sapotaceae	*Planchonella maingayi* (C.B.Clarke)	**			1				1	1	1
198	Schizaceae	*Lygodium microphyllum* (Cav.) R. Br.	**			1	1	1	1	1	1	1
199	Simaroubaceae	*Quassia indica* (Gaertn.) Nooteboom	**		1		1	1	1	1	1	1
200	Stemonuraceae	*Stemonurus scorpiodes* Beccari	**	1						1	1	1
201	Stemonuraceae	*Stemonurus secundiflorus* Blume var.	***		1					1		
202	Stemonuraceae	*Stemonurus umbellatus* Beccari	*			1				1		1
203	Tetrameristaceae	*Tetramerista glabra* Miq	***			1	1			1	1	1
204	Thymelaeaceae	*Gonystylus bancanus* (Miq.) Kurz.	***		1					1	1	1
205	Ulmaceae	*Gironniera subaequalis* Planch.	*			1	1	1	1	1	1	1
206	Ulmaceae	*Trema cannabina* Lour.	*			1	1	1	1	1	1	1
207	Ulmaceae	*Trema orientalis* (L.) Blume	**			1		1	1	1	1	1
208	Urticaceae	*Poikilospermum suaveolens* (Blume) Merr.	**			1	1	1	1	1	1	1

Notes: abundance: *** = very common or widespread; ** = common or widespread; * = fairy common or widespread; # = presumed extinct