FLORISTIC COMPOSITION OF PASOH FOREST RESERVE, A LOWLAND RAIN FOREST IN PENINSULAR MALAYSIA

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KOCHUMMEN, K.M., LaFRANKIE, J.V., & MANOKARAN, N. 1990. Floristic composition of Pasoh Forest Reserve, a lowland rain forest in Peninsular Malaysia. We tabulate and analyze the tree flora of Pasoh Forest Reserve, Malaysia, based on an enumeration of all trees ≥ 1 *cm* diameter at breast height (dbh) in a 50-*ha* plot. The diversity was very high: 820 species, 294 genera and 78 families. Mean density for trees ≥ 10 *cm* dbh was 530 trees per *ha* representing about 210 species. The most diverse families were Euphorbiaceae, Myrtaceae and Lauraceae. The most abundant families across all size classes were Euphorbiaceae, Dipterocarpaceae, and Annonaceae. Among trees larger than 30 *cm* dbh, the Dipterocarpaceae was the most abundant family, followed by Leguminosae and Burseraceae. The forest was without dominant species. The most abundant species, *Xerospermum noronhianum* (Sapindaceae), accounted for only 2.5% of the total number of trees, and 2.3% of trees over 10 *cm* dbh. Likewise, for trees over 30 *cm* dbh, the most abundant species, *Shorea leprosula* (Dipterocarpaceae), accounted for only 3.9% of the total. The common species of canopy and emergent trees at Pasoh are also widespread throughout Malaya and are characteristic of the primary rain forest, whereas species that indicate early succession or large gaps were rare in the plot. On floristic evidence, the forest bounded by the 50-*ha* plot is a homogeneous example of the Malayan south-central lowland rain forest; long term studies at the site should be of general applicability within Malaysia.

Key words: Flora - rain forest - Malaysia - diversity - tree

Introduction

Between 1985 and 1988, the Forest Research Institute Malaysia (FRIM) established a large scale forest plot at Pasoh Forest Reserve, Negeri Sembilan, to monitor long term changes in a primary forest. In this paper

we summarise the floristic composition of the trees and shrubs in the plot to answer two questions: Can the chosen forest site be generally regarded as representative of Malayan lowland type? Is there evidence that the plot has seen significant past disturbance? In the course of answering these questions we also provide a general reference for more specialised long term studies that will follow. A second companion paper will examine the stand structure with the same intent.

Site description and methods

Pasoh Forest Reserve was chosen as the site for the large scale forest plot because it was far from centres of population and yet still easily accessible by car, and also because its ecology and flora had been studied during the International Biological Program (Ashton 1976, Soepadmo & Kira 1977). The reserve is located at 2° 59' N latitude and 102° 18' W longitude, or about 140 *km* southeast of Kuala Lumpur, in the interior portion of Negeri Sembilan amidst a broad expanse of flat lands and gently rolling ridges that abut the westward side of the Main Range. Prior to 1900, this south-central portion of the Malay Peninsula comprised nearly 100,000 *ha* of relatively unbroken forest. The plot is situated in the last remnant of that forest.

Pasoh Forest Reserve was much larger before the early 1970s when many of the southern compartments were converted to plantations of oil palm, so that today, the reserve is only about 6000 *ha* in size. The southernmost 2000 *ha* are administered by FRIM as a Research Centre, and are divided into three portions: a core of 650 *ha* of primary lowland forest that lies between 80 and 120 *m* above sea level; a buffer zone of 30-*y*-old selectively logged forest on three sides of the core; and primary hill forest on the western side of the core rising to an elevation of about 500 *m*.

As the boundaries of the reserve receded during the past decades, many of the species of larger mammals have declined in number or disappeared altogether. The Sumatran rhinoceros has likely been absent for 70 years. Guar, tigers, tapirs and bear have been very rare at Pasoh since the mid 1960s. At least one elephant remains somewhere in the reserve, and intermittently enters the 50-*ha* plot. The remaining species of mammals number about 90, and many are quite numerous, including native pigs and primates (Kemper 1988). The avifauna is mostly intact and characteristic for the habitat; 200 species are resident in the primary forest, and another 42 are migrant (D. Wells, personal communication).

The mean annual rainfall is roughly 2000 *mm* with a known range of 1700 to 3200 *mm*. Although monthly means all exceed 10 *cm*, the forest is not everwet, in that a rain free period of 20 to 25 days is expected each year either between January and March or between July and August (Dale 1959, Soepadmo & Kira 1977, and unpublished weather data from Pasoh Forest Research Station).

The permanent plot lies in a mostly level plain of relatively uniform terrain between two meandering streams. Small scale variation in

topography and soil moisture provide a level of heterogeneity that is reflected to some extent in the vegetation. About half of the plot lies within a range of 2 *m* of topographic change; a hill rises in the centre of the plot to about 24 *m* above the lowest point (a topographic map is found in Manokaran & LaFrankie 1990). The soils within the plot are, in general, derived from shale and are of a compact and clayey texture (Allbrook 1973). Two intermittent streams form during periods of heavy rain.

The plot is a 50-*ha* rectangle 1 *km* long and 500 *m* wide. The enumeration included all free standing trees and shrubs ≥ 1 *cm* dbh. Climbers were excluded. The methods by which the plot was surveyed, the trees measured and species identified are recounted in Manokaran *et al.* (1990). Here we can note that all trees over 10 *cm* dbh were identified in the field by the senior author, who also identified leaf specimens from saplings of the more difficult taxa. The more common taxa were identified by the staff of FRIM under the training and supervision of the senior author.

Taxonomy and nomenclature followed the Tree Flora of Malaya (Whitmore 1972, 1973, Ng 1978b, 1989) and Ashton (1982), except where a more recent monograph was available. A complete list of all species found in the plot is presented together with citations of voucher specimens in Appendix 1 of Manokaran *et al.* (1990).

The data set used in the present analysis was based on the completed initial census of the plot corrected and updated to October 1988.

To differentiate the floristic contributions made by trees of different habits, we assigned each species to one of five classes according to its stature. The label "shrub" was applied to those species that do not exceed 2 *cm* dbh and 2 *m* height. Shrub is, perhaps, not the best name for this group which includes several distinctive habits or architectures, but no other English term seems appropriate. The second class was "treelet"; these species do not exceed 10 *cm* dbh and 10 *m* height. The third category of stature is "understorey"; these species do not generally exceed 30 *cm* dbh, and are always less than 20 *m* tall. The fourth class is "canopy,"; these species do not usually exceed 60 *cm* dbh and 30 *m* height. The final class is "emergent" and includes those species that regularly exceed 60 *cm* dbh and regularly reach above the canopy to a height of 30 to 50 *m*.

Results and discussion

Diversity

The 50-*ha* sample of 329,000 trees included 820 species in 294 genera and 78 families, which is exceedingly diverse compared to forests elsewhere in the world. Only one other large sample has included trees as small as 1 *cm* dbh, and that was the earlier plot of identical design on Barro Colorado Island (BCI), Panama. The tally for that plot was 238,000 trees, 306 species in 61 families (Hubbell & Foster 1986). The species diversity over 50-*ha* was 2.7 times as high at Pasoh as at BCI, whereas the diversity per tree was about twice as high.

Comparisons with many other forests can be made if we restrict our calculation of diversity to trees above 10 *cm* dbh. For 50-*ha* at Pasoh, we found trees above 10 *cm* representing 660 species in 244 genera and 67 families. Mean density was 530 trees per *ha* representing about 210 species. This is about as high or higher than the diversities reported for other rich primary lowland forests in Malaysia and Indonesia. At Sungei Menyala Forest Reserve, also in Negeri Sembilan but west of the Main Range, Wyatt-Smith (1949) found about 150 species per *ha*, which is about 25% lower diversity than at Pasoh. Ashton (1964) described a lowland forest in Andulau, Brunei, that had about 140 species per *ha*; a lowland forest in East Kalimantan had about 540 trees and 180 species per ha according to Kartawinata *et al.* (1981); while at Gunung Mulu National Park in Sarawak Proctor *et al.* (1983) described two rather dense 1-*ha* samples: 615 trees and 225 species in alluvial forest and 778 trees and 210 species in dipterocarp forest on a hill side. They indicated that their sample sites may not have been representative of median conditions.

Reports from Central American sites have generally shown a relatively low diversity of trees. At La Selva in Costa Rica, most individual hectares of a 12-*ha* sample had about 400 to 500 stems above 10 *cm* dbh and 100 species (trees and lianas), or roughly one half the diversity of Pasoh (Lieberman *et al.* 1985).

However, some Amazonian forests may be as diverse, or even more diverse, than Pasoh. Gentry (1988) described a pair of 1-*ha* samples in aseasonal Amazonian forest, each of which had more than 250 species with stems > 10 *cm* dbh. It would seem that the species diversity of trees at Pasoh is comparable with the highest diversities recorded on a per hectare or per tree basis anywhere in the world, and roughly similar to many other aseasonal forests of Malaysia.

Relative abundance of species

The most abundant species in the plot was *Xerospermum noronhianum* Bl. (Sapindaceae), but it accounted for only 2.5% of all trees, which is a very low level of dominance. This species was also the most common tree over 10 *cm* dbh, but again accounted for only 2.3% of the total. For trees over 30 *cm* dbh, the most abundant species was *Shorea leprosula* King (Dipterocarpaceae), but it accounted for only 3.9% of all trees in that class.

The relative densities with which species are represented are uniformly low, thus corresponding to Richard's (1952) notion of the mixed forest type, which he contrasted with those forests characterized by one or two species of very high densities.

Uniformly low densities and the absence of clear dominants are two attributes of composition that can be seen in most other forests in Malaysia. For example, the most common tree at Sungei Menyala was *Santiria laevigata* Bl. (Burseraceae), accounting for only 3.7% of all trees above 10 *cm* dbh (Wyatt-Smith 1966).

The mixed forest type contrasts sharply with some of the better studied forest of the Neotropics, especially the forests of central America. At La Selva, the most common species, *Pentaclethra macroloba* (Willd.) Benth. (Leguminosae) accounted for about 14% of trees over 10 *cm* dbh and for over one-half of the canopy (Lieberman & Lieberman 1987). In the 50-*ha* plot on BCI, the population of the treelet *Hybanthus prunifolius* (Humb. & Bompl.) G. K. Schulze (Violaceae) exceeded 40,000 trees, which is almost five times the most numerous species at Pasoh; and the canopy species *Trichilia tuberculata* C. DC. (Meliaceae) was represented by 13,000 trees (Hubbell & Foster 1986).

Familial composition of the tree flora

In the same way that individual species did not constitute conspicuous dominants, we found that taxonomic families were represented in regularly diminishing proportions. The relative importance of different families with regard to number of species, number of stems and basal area is illustrated in Table 1. This table was based on all stems ≥ 1 *cm* dbh for 50 *ha*, except for the values of basal area, which are based on 20 *ha*.

The Euphorbiaceae was ranked first in species diversity, first in abundance of trees, and third in basal area. The significance of this family in the Malayan lowland forest was noted by early students of the forest, but its importance may often be overlooked because many of the species are smaller trees of the understorey and lower canopy.

The Myrtaceae and Lauraceae may be considered together for they ranked second and third in species diversity, but twelfth and sixteenth in tree density, and eighth and twenty-first in basal area. The attributes of high diversity and low density were not unexpected for these families in the lowland forest; it was, to the contrary, entirely in keeping with what little is known of these two poorly understood families. They included species of all five stature classes, but in neither family did we find a particular species to be very common (Tables 2, 3, 4). In diversity of genera, the two families were very different from one another. Nearly all of the species of Myrtaceae at Pasoh belong to the genus *Eugenia*, whereas the Lauraceae was represented by many more or less equally diverse genera.

The Rubiaceae is the most diverse of all families of trees when the flora of the entire Malay Peninsula is tallied, but at Pasoh it ranked only fourth in species diversity and fourth in tree density. Its relatively lower ranking at Pasoh may be explained by the isolated and restricted geographic distribution of many of its species. Most of the species of Rubiaceae at Pasoh were shrubs and treelets, but nonetheless, the family was represented by two of the most frequent species for trees over 10 *cm* dbh, *Aidia wallichiana* Tirving, and *Porterandia anisophylla* (Roxb.) Ridl. Among the many species of smaller trees, several were very numerous.

Table 1. Pasoh Forest Reserve, Malaysia: family rankings for all trees 1 *cm* dbh or greater (species diversity and density tabulated for 50 *ha*, basal area tabulated for 20 *ha* subsample)

Family	Species			Abundance			Basal area		
	Rank	Spp.	%	Rank	Trees	%	Rank	Sum	%
Euphorbiaceae	1	87	10.60	1	45480	13.81	3	20930	7.41
Myrtaceae	2	50	6.09	12	9825	2.98	8	8192	2.90
Lauraceae	3	48	5.85	16	7008	2.13	21	3941	1.39
Rubiaceae	4	46	5.60	4	19501	5.92	13	5723	2.03
Annonaceae	5	44	5.36	3	23222	7.05	6	10330	3.66
Meliaceae	6	43	5.24	13	8634	2.62	23	3689	1.31
Anacardiaceae	7	32	3.90	15	7408	2.25	11	7222	2.56
Guttiferae	8	31	3.78	11	10693	3.25	12	5752	2.04
Myristicaceae	9	31	3.78	7	14096	4.28	7	8683	3.07
Dipterocarpaceae	10	30	3.65	2	30727	9.33	1	68902	24.38
Leguminosae	11	28	3.41	10	10872	3.30	2	25111	8.89
Moraceae	12	24	2.92	28	2170	0.66	15	5198	1.84
Burseraceae	13	22	2.68	5	17911	5.44	4	15997	5.66
Ebenaceae	14	21	2.56	8	13777	4.18	20	4052	1.43
Sapindaceae	15	20	2.44	6	16397	4.98	9	7594	2.69
Fagaceae	16	15	1.83	20	5245	1.59	5	12911	4.57
Flacourtiaceae	17	15	1.83	18	6396	1.94	19	4054	1.43
Melastomataceae	18	15	1.83	17	6828	2.07	27	2482	0.88
Sapotaceae	19	14	1.71	22	4109	1.25	22	3745	1.33
Sterculiaceae	20	14	1.71	27	2593	0.79	10	7575	2.68
Rosaceae	21	13	1.58	29	1953	0.59	31	2017	0.71
Polygalaceae	22	10	1.22	21	4634	1.41	17	4905	1.74
Arecaceae	23	8	0.97	40	785	0.24	48	220	0.08
Elaeocarpaceae	24	8	0.97	41	663	0.20	39	680	0.24
Icacinaceae	25	8	0.97	31	1661	0.50	42	398	0.14
Myrsinaceae	26	8	0.97	9	11760	3.57	38	706	0.25
Tiliaceae	27	8	0.97	24	3776	1.15	29	2371	0.84
Verbenaceae	28	8	0.97	44	564	0.17	46	283	0.10
Apocynaceae	29	6	0.73	35	1071	0.33	14	5422	1.92
Celastraceae	30	6	0.73	38	850	0.26	41	426	0.15
Rutaceae	31	6	0.73	36	1060	0.32	43	359	0.13
Bombacaceae	32	5	0.61	33	1263	0.38	32	1090	0.39
Combretaceae	33	5	0.61	68	30	0.01	57	72	0.03
Symplocaceae	34	5	0.61	42	663	0.20	49	212	0.08
Ulmaceae	35	5	0.61	19	5381	1.63	25	3633	1.29
Alangiaceae	36	4	0.49	25	3290	1.00	30	2270	0.80
Hypericaceae	37	4	0.49	59	104	0.03	37	709	0.25
Lecythidaceae	38	4	0.49	23	3963	1.20	28	2392	0.85
Olacaceae	39	4	0.49	30	1839	0.56	24	3654	1.29
Oleaceae	40	4	0.49	52	237	0.07	52	159	0.06
Dilleniaceae	41	3	0.37	46	467	0.14	34	963	0.34
Liliaceae	42	3	0.37	39	814	0.25	62	28	0.01
Pandanaceae	43	3	0.37	63	70	0.02	67	8	0.00
Rhizophoraceae	44	3	0.37	32	1281	0.39	26	2942	1.04
Theaceae	45	3	0.37	58	119	0.04	51	195	0.07
Violaceae	46	3	0.37	14	8509	2.58	33	988	0.35
Aquifoliaceae	47	2	0.24	55	177	0.05	54	108	0.04
Araliaceae	48	2	0.24	64	69	0.02	69	2	0.00
Bignoniaceae	49	2	0.24	75	6	0.00	68	6	0.00
Boraginaceae	50	2	0.24	69	27	0.01	65	10	0.00
Cornaceae	51	2	0.24	72	16	0.00	73	.	.
Ixonanthaceae	52	2	0.24	26	3202	0.97	16	5050	1.79
Magnoliaceae	53	2	0.24	62	72	0.02	40	652	0.23
Ochnaceae	54	2	0.24	53	237	0.07	45	330	0.12
Opiliaceae	55	2	0.24	34	1099	0.33	55	108	0.04
Oxalidaceae	56	2	0.24	48	378	0.11	18	4283	1.52
Proteaceae	57	2	0.24	45	490	0.15	60	41	0.01
Thymeliaceae	58	2	0.24	47	433	0.13	44	342	0.12
Aristolochiaceae	59	1	0.12	70	26	0.01	74	.	.
Asteraceae	60	1	0.12	57	124	0.04	61	38	0.01
Capparidaceae	61	1	0.12	77	4	0.00	75	.	.
Convolvulaceae	62	1	0.12	51	305	0.09	66	10	0.00
Crypteroniaceae	63	1	0.12	67	34	0.01	50	197	0.07
Dichaepetalaceae	64	1	0.12	60	99	0.03	76	.	.
Erythroxylaceae	65	1	0.12	66	54	0.02	59	44	0.02
Gnetaceae	66	1	0.12	43	580	0.18	64	11	0.00
Irvingiaceae	67	1	0.12	54	224	0.07	35	881	0.31
Juglandaceae	68	1	0.12	74	14	0.00	70	1	0.00
Linaceae	69	1	0.12	56	172	0.05	56	74	0.03
Loganaceae	70	1	0.12	61	92	0.03	63	16	0.01
Monimiaceae	71	1	0.12	73	15	0.00	71	1	0.00
Podocarpaceae	72	1	0.12	71	24	0.01	72	1	0.00
Santalaceae	73	1	0.12	50	308	0.09	58	61	0.02
Simaroubaceae	74	1	0.12	37	859	0.26	47	276	0.10
Staphyleaceae	75	1	0.12	78	1	0.00	77	.	.
Styracaceae	76	1	0.12	65	67	0.02	53	127	0.04
Trigoniaceae	77	1	0.12	49	359	0.11	36	729	0.26
Vitaceae	78	1	0.12	76	5	0.00	78		-

Table 2. Number of trees ≥ 1 *cm* dbh in 50 *ha* lowland rain forest, Pasoh Forest Reserve, Malaysia, arranged by species (only the ten most frequent species in each class are shown, classes are described in text)

Species	Family	50 *ha* Frequency
Shrubs:		
Lepisanthes tetraphylla (Vahl.) Radlk.	Sapindaceae	2408
Ardisia species 2	Myrsinaceae	1647
Rothmannia macrophylla (Hk. f.) Bremek.	Rubiaceae	1382
Urophyllum hirsutum (Wight) Hk.f.	Rubiaceae	1255
Ixora congesta Roxb.	Rubiaceae	869
Gnetum gnemon L.	Gnetaceae	580
Pavetta species 1	Rubiaceae	576
Antidesma pendulum Hk.f.	Euphorbiaceae	496
Memecylon dichotomum (Cl.) King	Melastomataceae	487
Iguanura wallichiana Hk.f.	Arecaceae	460
Treelets:		
Rinorea anguifera (Lour.) O.K.	Violaceae	8233
Ardisia crassa C.B. Clarke	Myrsinaceae	7653
Anaxagorea javanica Bl.	Annonaceae	7081
Aporusa microstachya (Tul.) M.A.	Euphorbiaceae	6486
Knema laurina (Bl.) Warb.	Myristicaceae	4446
Baccaurea parviflora (M.A.) M.A.	Euphorbiaceae	3474
Diospyros scortechinii King & Gamb.	Ebenaceae	3238
Phaeanthus ophthalamicus (Don.) Sincl.	Annonaceae	2754
Diospyros nutans King & Gamb.	Ebenaceae	2279
Urophyllum glabrum Wall.	Rubiaceae	1927
Understorey:		
Gironniera parvifolia Planch.	Ulmaceae	3955
Barringtonia macrostachya (Jack) Kurz	Lecythidaceae	3718
Scaphocalyx spathacea Ridl.	Flacourtiaceae	3643
Alangium ebenaceum (Cl.) Harms	Alangiaceae	2918
Aidia wallichiana Tirving	Rubiaceae	2452
Aporusa bracteosa P. & H.	Euphorbiaceae	2451
Memecylon minutiflorum Miq.	Melastomataceae	2213
Knema furfuracea (Hk.f. & Thoms.) Warb.	Myristicaceae	2117
Macaranga lowii Hk.f.	Euphorbiaceae	2107
Oncodostigma monosperma (Hk.f. & Thoms.) Sincl.	Annonaceae	2095
Canopy:		
Xerospermum noronhianum Bl.	Sapindaceae	8968
Dacryodes rugosa (Bl.) Lam	Burseraceae	5569
Canarium littorale Bl.	Burseraceae	3404
Ixonanthes icosandra Jack	Ixonanthaceae	3202
Dacryodes rostrata (Bl.) Lam	Burseraceae	2583
Pimelodendron griffithianum (M.A.) Benth.	Euphorbiaceae	2336
Xanthophyllum eurhynchum Miq.	Polygalaceae	2017
Mesua ferrea L.	Guttiferae	193
Lithocarpus curtisii (Hk.f.) Camus	Fagaceae	1770
Vatica bella V. Sl.	Dipterocarpaceae	1658
Emergent:		
Shorea maxwelliana King	Dipterocarpaceae	5652
Neobalanocarpus heimii (King) Ashton	Dipterocarpaceae	3308
Shorea leprosula Miq.	Dipterocarpaceae	3006
Shorea pauciflora King	Dipterocarpaceae	2357
Shorea acuminata Dyer	Dipterocarpaceae	2205
Shorea parvifolia Dyer	Dipterocarpaceae	1669
Shorea macroptera Dyer	Dipterocarpaceae	1601
Dipterocarpus cornutus Dyer	Dipterocarpaceae	1431
Shorea ovalis (Korth.) Bl.	Dipterocarpaceae	1309
Sindora coriacea Prain	Leguminosae	1229

The Dipterocarpaceae ranked only tenth in species diversity, with 30 species, but it constituted more than 9% of the trees and 25% of the basal area, which ranked the family second and first in those respective categories. This is the family that best characterizes the upper canopy and emergent layers of the Malaysian forest, and the family by which most lowland rain forests are classified to type.

Table 3. Number of trees ≥ 10 *cm* dbh in 50 *ha* lowland rain forest, Pasoh Forest Reserve, Malaysia (species are arranged in order of abundance, only the 25 most frequent species are shown)

Species	Family	50 *ha* Frequency
Xerospermum noronhianum Bl.	Sapindaceae	563
Shorea maxwelliana King	Dipterocarpaceae	544
Dacryodes rugosa (Bl.) Lam	Burseraceae	520
Ixonanthes icosandra Jack	Ixonanthaceae	517
Canarium littorale Bl.	Burseraceae	343
Shorea leprosula Miq.	Dipterocarpaceae	342
Ochanostachys amentacea (Hk.f. & Th.) Sincl.	Olacaceae	338
Barringtonia macrostachya (Jack) Kurz	Lecythidaceae	324
Xanthophyllum eurhynchum Miq.	Polygalaceae	322
Pimelodendron griffithianum (M.A.) Benth.	Euphorbiaceae	316
Millettia atropurpurea (Wall.) Benth.	Leguminosae	279
Neoscortechinia kingii (Hk.f.) P. & H.	Euphorbiaceae	275
Aidia wallichiana Tirving	Rubiaceae	274
Dipterocarpus cornutus Dyer	Dipterocarpaceae	262
Shorea parvifolia Dyer	Dipterocarpaceae	258
Cynometra malaccensis Meeuwen.	Leguminosae	257
Quercus argentata Korth.	Fagaceae	253
Mesua ferrea L.	Guttiferae	244
Payena lucida (G. Don) D.C.	Sapotaceae	232
Scaphium macropodum (Miq.) Heyne	Sterculiaceae	221
Alangium ebenaceum (Cl.) Harms	Alangiaceae	218
Lithocarpus curtisii (Hk.f.) Camus	Fagaceae	212
Koompassia malaccensis Benth.	Leguminosae	209
Monocarpia marginalis (Scheff.) Sincl.	Annonaceae	206
Porterandia anisophylla (Roxb.) Ridl.	Rubiaceae	206

Table 4. Number of trees ≥ 30 *cm* dbh in 50 *ha* lowland rain forest, Pasoh Forest Reserve, Malaysia, arranged by species in order of abundance (only the 25 most abundant species are shown)

Species	Family	50 *ha* Abundance
Shorea leprosula Miq.	Dipterocarpaceae	140
Shorea maxwelliana King	Dipterocarpaceae	139
Ixonanthes icosandra Jack	Ixonanthaceae	111
Koompassia malaccensis Benth.	Leguminosae	106
Shorea lepidota (Korth.) Bl.	Dipterocarpaceae	100
Dipterocarpus cornutus Dyer	Dipterocarpaceae	94
Shorea acuminata Dyer	Dipterocarpaceae	93
Quercus argentata Korth.	Fagaceae	92
Shorea parvifolia Dyer	Dipterocarpaceae	82
Cynometra malaccensis Meeuwen.	Leguminosae	76
Shorea paucíflora King	Dipterocarpaceae	72
Neobalanocarpus heimii (King) Ashton	Dipterocarpaceae	71
Scaphium macropodum (Miq.) Heyne	Sterculiaceae	67
Intsia palembanica Miq.	Leguminosae	64
Pentaspadon motleyi Hk.f.	Anacardiaceae	60
Millettia atropurpurea (Wall.) Benth.	Leguminosae	57
Shorea macroptera Dyer	Dipterocarpaceae	48
Canarium littorale Bl.	Burseraceae	44
Sarcotheca griffithii (Hk.f.) Hall.f.	Oxalidaceae	41
Castanopsis schefferiana Hance	Fagaceae	40
Mesua ferrea L.	Guttiferae	37
Pometia pinnata Forst.f.	Sapindaceae	35
Shorea bracteolata Dyer	Dipterocarpaceae	34
Shorea ovalis (Korth.) Bl.	Dipterocarpaceae	34
Atuna excelsa (Jack) Kosterm.	Rosaceae	33

** 345 other species **

The Annonaceae ranked third in density, and fifth and sixth in number of species and basal area respectively. The uniformly high rankings indicate the importance of this family, especially among the smaller trees and lower canopy. We might note that if woody climbers were included in the study, then Annonaceae would likely become the most diverse and most abundant family.

The penultimate family to consider is the Burseraceae, which ranked only thirteenth in diversity, with 22 species, but ranked fifth in density and fourth in basal area. We can here note that three of the most frequent canopy tree species are members of the Burseraceae (Table 2). The family is important in all lowland and lower hill forests of Peninsular Malaysia, and very often it includes the most frequent species at a site, as it does in Sungei Menyala.

Finally, we note the family Fagaceae because of the sharp discordance of its rankings. With only 15 species it ranked sixteenth in diversity, and seventeen in density, but it ranked fifth in basal area, contributing 4.57% of the total. The Fagaceae is well known for its importance in the upper hill and montane forest of Peninsular Malaysia, but it is also conspicuous in the lowlands.

The Dipterocarpaceae was the most abundant family for trees larger than 10 *cm* dbh, and accounted for four of the 25 most abundant species (Table 3). The Euphorbiaceae was the second most abundant family, and the most diverse family, but only two of the 25 most abundant species are euphorbs, indicating the extent to which the family dominated the minor components of the forest. The 19 other most abundant species represent 11 different families.

For trees over 30 *cm* dbh, family representation was much less mixed (Table 4). Seventeen of the most abundant species in this class were in three families, Dipterocarpaceae, Leguminosae, and Fagaceae.

The composition of minor families at Pasoh, such as the diversity and frequency of Ebenaceae, and the scarcity of palm trees, was also entirely consistent with other lowland Dipterocarp forests of Peninsular Malaysia.

Individual species considered by stature

Most species of trees included in the enumeration were classified as either canopy or understorey species (Table 5). Emergents and shrubs together contributed only 12% of the flora. The treelets were not especially diverse but they were evidently very common in that they accounted for only 13% of the flora but 23% of the trees.

Table 5. Species diversity and tree frequency tabulated by stature class (classes are defined in text, the sample size is 50 *ha*, all trees ≥ 1 *cm* dbh)

Stature	Species	Flora (%)	Trees ha^{-1}	Forest (%)
Shrub	54	6.6%	303	4.6
Treelet	111	13.5%	1513	22.9
Understorey	283	34.5%	2114	32.1
Canopy	317	38.7%	1901	28.9
Emergent	55	6.7%	753	11.4

In general, the individual species encountered in the enumeration presented few surprises. Only 20 species (1.5%) of the total Pasoh tree flora could not be identified to one of the species listed in the Tree Flora of Malaya, being either new to science, or new to the Malay Peninsula. In general, the most abundant species of larger trees were typical elements of the Malayan lowland rain forest. The following discussion considers some of these species on a case by case basis, arranged by stature, and refers throughout to Table 2.

In considering the shrubs, we might first note that our sample almost certainly excluded many potentially reproductive plants on account of our size limit. Through supplementary sampling we know that species such as *Thottea grandiflora* Rott. (Aristilochiaceae) and *Goniothalamus macrophyllus* (Bl.) Hk.f. & Thoms. (Annonaceae) were among the most abundant small plants in the plot, but because they did not often reach 1 *cm* diameter, their densities appear misleadingly low. A few of the ten most frequent shrubs are found throughout much of Peninsular Malaysia, and are usually frequent in all forest sites. But other species, such as *Ardisia* species 2 (Myrsinaceae) and *Pavetta* species 1 (Rubiaceae), while very common at Pasoh, have been found in only a few other places.

Treelets were quite numerous, four of the five most frequent species of the whole plot were treelets: *Rinorea anguifera* (Lour.) O.K. (Violaceae); *Ardisia crassa* C.B. Clarke (Myrsinaceae); *Anaxagorea javanica* Bl. (Annonaceae) and *Aporusa microstachya* (Tul.) M.A. (Euphorbiaceae). These four species are common and widely distributed throughout Malaya. This was also true of the other abundant species of treelets, except for *Diospyros scortechinii* King & Gamb. (Ebenaceae) which Ng (1978a) considered an uncommon species of hill forests. Conspicuous in its absence was *Agrostachys longifolia* (Wight) Benth. (Euphorbiaceae), a treelet that very commonly dominates the lower strata of hill forests beneath *Shorea laevis* and *Shorea multiflora* (Symington 1943), but can also be the most abundant plant in lowland forests, as it was in Sungei Menyala.

Among the ten most abundant understorey species, the most notable feature was the mix of families, only the Euphorbiaceae was represented twice. The species are well known members of the Peninsular Malaysian lowland flora, found more or less throughout the Peninsula, with the exception of *Oncodostigma monosperma* (Hk.f. & Thoms.) Sincl. (Annonaceae) which is rather rare and of scattered occurrence. *Macaranga lowii* Hk.f. (Euphorbiaceae) should not be mistakenly considered an indicator of early succession, because unlike its congeners, it is a characteristic species of the primary forest.

Among the ten most abundant species of canopy trees, the Burseraceae was represented by three species, while the remaining seven species represent seven different families. The most common species was *Xerospermum noronhianum*, in the Sapindaceae, and it was also the most abundant species in the entire plot, and also the most abundant species over 10 *cm* dbh. This species, like the other canopy species, is widely distributed in Peninsular Malaysia, and usually ranks as one of the five or ten most common species in a sample.

The ten most abundant species of emergent trees were dominated by the Dipterocarpaceae. Four of the species were red meranti, *Shorea* sect. Muticae: *Shorea leprosula* Miq., *S. acuminata* Dyer, *S. parvifolia* Dyer, and *S. macroptera* Dyer. The heavy hardwoods were represented among the most abundant emergents by balau, *Shorea maxwelliana* King and chengal, *Neobalanocarpus heimii* (King) Ashton. The seventh most abundant emergent was a keruing, *Dipterocarpus cornutus* Dyer. This particular mix of species conforms to the mixed-red meranti forest of the south-central subtype of Wyatt-Smith (1987).

Species indicative of disturbance

We found no floristic evidence of recent fire, major windthrows, or other types of significant disturbance. This is seen principally through the low diversity and abundance of species that are known to indicate disturbance. For example, *Endospermum malaccensis* M.A. (Euphorbiaceae) is a light demanding species that can dominate roadsides and disturbed land; its population in the plot consists of only only 35 widely scattered trees, of which only 14 are saplings less than 5 *cm* dbh. Some species of simpoh (*Dillenia*) are also indicative of disturbance, but the plot sample of sample of *Dillenia grandifolia* Hk.f. & Thoms. totals six adult trees that fruit in abundance, but only 11 smaller trees were found, while the sample of *Dillenia reticulata* King included only 47 trees, most of them were isolated saplings in the middle of large tree falls. The early successional species of *Mallotus* were not found in the plot, while those of *Macaranga* were rare: *M. gigantea* (Richb. f. & Zoll) M.A., four trees in 50 *ha*; *M. hosei* Hk, f,, ten trees; *M. hypoleuca* (Richb. f. & Zoll.) M.A., 123 trees. The species *Campnosperma auriculatum* (Bl.) Hk.f. (Anacardiaceae) is an important species along steep stream banks and in secondary forests, especially wet forests, and can even become the dominant species in regenerated forests. Only three adult trees were found in the 50-*ha* plot.

Conclusion

Pasoh Forest exhibited most of the important characteristics of the Peninsular Malaysian lowland rain forest. The species diversity was high, and the mix of species was very even. The more important families were Euphorbiaceae and Annonaceae among the smaller trees, and Dipterocarpaceae, Leguminosae and Burseraceae among larger trees. The constituent species are, by and large, widely distributed and characteristic elements of the Peninsular Malaysian rain forest. The low diversity and low abundance of species that indicate disturbance supports the conclusion that the 50-*ha* plot circumscribes a relatively homogeneous example of lowland rain forest. Long term studies based at the Pasoh forest site should be of general applicability.

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References

ALLBROOK, R.F. 1973. The soils of Pasoh Forest Reserve, Negeri Sembilan. *Malaysian Forester* 36:22-33.

ASHTON, P.S. 1964. Ecological studies in the mixed dipterocarp forests of the Brunei state. *Oxford Forestry Memoirs 25.*

ASHTON, P. S. 1976. Mixed dipterocarp forest and its variation with habitat in the Malayan lowland: a re-evaluation at Pasoh. *Malaysian Forester* 39:56-72.

ASHTON, P. S. 1982. Dipterocarpaceae. *Flora Malesiana* 9:237-340.

DALE, W.L. 1959. The rainfall of Malaya. *Journal of Tropical Geography* 13:23-37.

GENTRY, A. 1988. Tree species richness in upper Amazonian forests. *Proceedings of the National Academy of Science (U.S.A.)* 85:156-159.

HUBBELL, S.P., & FOSTER, R.B. 1986. Commonness and rarity in a neotropical forest: Implications for tropical tree conservation. Pp. 205-231 in Soule, M.E. (Ed.) *Conservation biology.* Sinauer Associates, Sunderland Massachusetts, United States of America.

KARTAWINATA, K., ROCHADI ABDULHADI & TUKIRIN PARTOMIHARDJO. 1981. Composition and structure of a lowland Dipterocarp forest at Wanariset, East Kalimantan. *Malaysian Forester* 44:397-406.

KEMPER, C. 1988. The mammals of Pasoh Forest Reserve, Peninsular Malaysia. *Malayan Nature Journal* 42:1-19.

LIEBERMAN, D., LIEBERMAN, M., PERALTA, R. & HARTSHORN, G.S. 1985. Mortality patterns and stand turnover rates in a wet tropical forest in Costa Rica. *Journal of Ecology* 73:915-924.

LIEBERMAN, D. & LIEBERMAN, M. 1987. Forest tree growth and dynamics at La Selva, Costa Rica (1969-1982). *Journal of Tropical Ecology* 3:347-358.

MANOKARAN, N. & LAFRANKIE, J.V. 1990. Stand structure of Pasoh Forest Reserve, a lowland rain forest in Peninsular Malaysia. *Journal of Tropical Forest Science* 3(1): 14 - 24.

MANOKARAN, N., LAFRANKIE, J.V., KOCHUMMEN, K.M., QUAH, E.S., KLAHN, J., ASHTON, P.S. & HUBBELL, S.P. 1990. Methodology for the 50-*ha* research plot at Pasoh Forest Reserve. *Research Pamphlet Number 104.* Forest Research Institute Malaysia, Kepong, Malaysia.

NG, F.S.P. 1978a. Ebenaceae. Pp. 56 - 94 in Ng, F.P.S. (Ed.) *Tree Flora of Malaya Volume 3.* Longman, Kuala Lumpur.

NG, F.S.P. (Ed.) 1978b. *Tree Flora of Malaya Volume 3.* Longman, Kuala Lumpur.

NG, F.S.P. (Ed.) 1989. *Tree Flora of Malaya Volume 4.* Longman, Kuala Lumpur.

PROCTOR, J., ANDERSON, J., CHAI, P. & VALLACK, H. 1983. Ecological studies in four contrasting lowland rain forests in Gunung Mulu National Park, Sarawak. I. Forest environment, structure and floristics. *Journal of Ecology* 71:237-260.

RICHARDS, P.W. 1952. *The tropical rain forest.* Cambridge University Press, London.

SOEPADMO, E. & KIRA, T. 1977. Contribution of the IBP-PT Research Project to the understanding of Malaysian forest ecology. Pp. 63-94 in Sastry, C.B., Srivastra, P.B. & Abdul Manap, A. (Eds.) *A new era in Malaysian forestry.* Universiti Pertanian Malaysia Press, Serdang, Malaysia.

SYMINGTON, C.F. 1943. Foresters' manual of dipterocarps. *Malayan Forest Records 16.* Forest Research Institute, Kepong, Federated Malay States (Malaysia).

WHITMORE, T. (Ed.) 1972. *Tree Flora of Malaya Volume 1.* Longman, Kuala Lumpur.

WHITMORE, T. (Ed.) 1973. *Tree Flora of Malaya Volume 2.* Longman, Kuala Lumpur.

WYATT-SMITH, J. 1949. A note on tropical lowland evergreen rain-forest in Malaya. *Malayan Forester* 12(2):58-64.

WYATT-SMITH, J. 1966. Composition and dynamic studies in lowland rainforest in two 5-acre plots. *Research Pamphlet Number 52.* Forest Research Institute, Kepong, Malaysia.

WYATT-SMITH, J. 1987. Manual of Malayan silviculture for inland forest: red meranti-keruing forest. *Research Pamphlet Number 101.* Forest Research Institute Malaysia, Kepong, Malaysia.