Distribution and Abundance of Malayan Trees: Significance of Family Characteristics for Conservation

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Abstract

Taxonomic families of plants that characterize the lowland Malayan rain forest differ from one another nearly ten-fold in quantitative measures of distribution and abundance. A 50-ha sample of 300,000 trees includes 814 species or fully one-fourth of the Malayan tree-flora. The median adult population size for trees and shrubs is a linear function of area. From the Pasoh equations, we can calculate the area needed to capture an adult population of a specific size for a particular fraction of the flora, i.e., for 90% of the Pasoh tree flora to be represented by more than 200 adults per species will require about 3000 ha of forest. These equations indicate how many species will have a specific population size within a forest, but not which species. I test the alternative hypotheses that the large characteristic families of the Malayan forest either do or do not differ more than 10-fold in median species abundance and species representation. The Pasoh data reject the latter hypothesis. The characteristic taxonomic families of the lowland forest, e.g., Dipterocarpaceae, Sapotaceae and Burseraceae vary in representation from 10% of regional species to 60%, the power functions of species- area curves vary nearly 10-fold, and median abundances vary from less than 1 to more than 10 individuals per ha. These findings are confirmed in part from an analysis of the flora of Singapore which, with regard to representation, illustrates patterns identical to those at Pasoh. The consequences for conservation are two-fold: (1) general conservation strategies should not be based on studies of focal families; (2) different taxonomic families of trees and shrubs will require very different strategies of reserve design for their conservation.

Introduction

Do taxonomic families of plants differ from one another in quantitative measures of abundance and distribution? Of course, taxonomic families differ markedly in distribution at the broadest scales of geography: Dipterocarpaceae are found in Asia, bromeliads in the Neotropics, Proteaceae are predominantly in Australia and Africa. But within a geographic province, and within a single habitat such as the Malayan lowland rain forest, do the plant families that characterize that habitat, such as the Dipterocarpaceae, Myristicaceae, Sapotaceae and Lauraceae, differ in quantitative features of distribution and abundance?

Plant collectors and field botanists know in a qualitative fashion that some tropical families tend to show up in characteristic ways. For example, Symington (1943, pp xii) wrote of the Dipterocarpaceae of the Malay Peninsula: "In these lowland Dipterocarp forests about 130 species of dipterocarps, representing all the main groups, occur, but in any one district it is doubtful whether there are more than 60 species, and the representation of groups may be incomplete. In any one reserve there may, exceptionally, be as many as 40 species, but between 10 and 30 is the more usual number." We could add that those few species of the

Dipterocarpaceae that do occur tend be among the most abundant trees in that forest. Nutmegs are quite different, and most of the 53 Malayan species can be collected without traveling far.

A quantitative comparison of families along these lines could influence our ideas about conservation biology in two ways. First, large differences in local representation and abundance among taxonomic families would indicate that the numerical loss of species with reducing land area would not be a random loss from the flora, but would rather be concentrated in certain families. Second, if large inter-familial differences are found, then efforts either to study biodiversity or to develop conservation policies, should avoid the use of one taxonomic group as a proxy representative of overall biodiversity.

This paper compiles the results of a large-scale inventory of the lowland forest of Malaya (50 ha, 320,000 trees, 814 species) and quantitatively compares those results with the entire known tree flora of Malaya (13 million ha, 3500 species), thereby testing the alternative hypotheses that the large characteristic families of trees either do or do not differ more than 10-fold in median species abundance and species representation. The findings are then qualitatively compared with the findings of floristic inventory from Singapore.

Methods and study site

The study was made at Pasoh Forest Reserve, Malaysia, which is located at 2° 59' N latitude and 102° 18' W longitude, or about 140 km south-east of Kuala Lumpur, in the interior portion of the state of Negeri Sembilan amidst a broad expanse of flat lands and gently rolling ridges that abut the westward side of the Main Range (Fig. 1). 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.

The 50-ha plot is situated in the center of the primary forest reserve, and comprises 1250 contiguous quadrates each 20 m on a side. Over the course of three years, a team of roughly 20 people enumerated all the free-standing woody plants that exceeded 1 cm diameter at a height of 1.3 meters. The identifications were documented through collection of about 3000 herbarium specimens that include either flower or fruit, and through another 4000 specimens of sterile material. Specimens are stored at KEP and cited in Manokaran et al. (1990), together with a complete list of species. Further details of the plot survey methods, including the methods of measuring and identifying trees, are also described in Manokaran et al. (1990). The base data set has been published in Manokaran et al. (1993).

The present tabulation of the Malayan tree and shrub flora is based upon a 1990 analysis of the published Tree Flora of Malaya (Whitmore 1973, 1974; Ng

1978, 1989), and further details can be found in Kochummen et al. (1990). In tabulating the flora, we used the same definition of a tree that was used in the 50-ha plot, creating a slight discordance with the flora as originally published: we excluded climbers, epiphytes and stranglers, and scrambling shrubs, and also a few of the smaller plants in the Rubiaceae. On the other hand, we added a few shrubs that were not included in the treatment of the Melastomataceae. For the Dipterocarpaceae, we followed Ashton (1983), and in a few other minor ways our tabulation departed from the Tree Flora of Malaya series (e.g., we include the tiny families Dichapetalaceae and Goodeniaceae which were overlooked in the Flora), and for these reasons, our tabulation differs from those in Whitmore (1973) and Ng (1988).

Those species in the plot that were new records for the Malay Peninsula (about 2% of the plot flora) were also added to the total Malayan flora. Monocotyledons, which represent 1-2% of the plot flora, and less than 1% of the trees, were excluded from the analysis because the regional floristic tally has yet to be completed. A brief discussion of the distribution of individual trees species based on an earlier version of this tabulation was presented in Kochummen et al. (1992).

For the purposes of the present analysis, the 50-ha plot is treated as one very large and robust sample of over 320,000 trees that is representative of the South-Central lowland forest type, and the results are used as ecological descriptions of the constituent families. Tests of statistical significance for differences among families cannot be derived from the plot itself because it is being considered as a single sample. It would be improper to use the fifty contiguous one-ha plots as independent samples because they are spatially contiguous, and because the plot was specifically chosen for its homogeneity.

Percent representation for each family is the number of species represented by at least one tree in the 50-ha plot divided by the number of species in the Tree Flora of Malaya. To find the median abundance for each family, we first tally the number of individuals for each species, then sort the species by family. For each family the median abundance is the abundance of the species closest to the 50th percentile. For a family represented in the 50-ha plot by 11 spp, this would be the 6th most abundant species, with 5 species more abundant and 5 species less abundant. The median is preferable to the mean in that the latter is greatly influenced by the magnitude of the most abundant species.

Species area curves were prepared for selected families using nested cumulative plots of 0.1, 1, 10, 30 and 50 ha and the entire Malayan flora. An estimate was made for the each family at the scale of 100,000 ha in the South-Central Peninsula based on the institutional records of the herbarium in Kepong. This estimate is distinguished from the actual plot data.

To determine the number of adults of each species per unit area, I estimated the diameter at first reproduction based on published reports, advice of local residents, and personal field experience. These were liberal estimates erring toward smaller diameters. Then I tallied the number of adults for each species within areas of 1, 2, 4, 8, 16, 32 and 50 ha, and then determined for each area sample the 50th, 75th, and 90th percentile ranking, that is, the adult population that 50%, 75% and 90% of the species exceeded. The samples of 1, 2, 4, 8, and 16 ha were independent of one another, while the 32 and 50 ha samples necessarily included the smaller samples. Thus, the samples are, in part, autocorrelated, which precludes a strict determination of significance for the r^2 values.

Results and Discussion

1. The sample, covering only 0.0004% of land area of Malaya, includes at least one individual of 814 species or 25% of the Malayan tree flora. This is much higher than anticipated and suggests that the usefulness of small reserves for conservation of trees may have been previously underestimated. Several important caveats are rather obvious: one individual does not constitute a conserved population, and no population is secure if a obligate pollinator has been lost from the system. On the other hand, a single self-fertile canopy tree could live for a hundred years or more in relative isolation, and produce thousands of offspring in a single season.

2. The median adult population size for trees and shrubs is a linear function of area. The relationship is the outcome of three constituent functions: the number of trees per area, which is linear; the number of species per area, which is a power function; and the number of individuals per species, which is close to a negative binomial. That the resulting function is very nearly linear is empirically interesting, and can be useful for calculating the numbers of adult trees in this lowland rain forest. The relationship between median adult number (N) and area (A) in ha follows the equation $N = 2.02 + 0.56 * A$. The relationship is non-linear over the first hectare, as species rapidly accumulate, but thereafter conforms closely to the equation, with an r^2 value of 0.99 (Fig. 2). The relationship between the 75th percentile population and area is much less steep, and is fitted to the equation $N = 0.96 + 0.16 * A$, and again has an r^2 value of 0.99. The 90th percentile was only three adults per species at the 50 ha sample, i.e., 10% of the species were represented by fewer than three adults in 50 ha. The relationship follows the equation $N = -.19 + 0.07 * A$, and the r^2 value is 0.98.

If we choose 200 adults as a safe population level, then this level would be achieved for half of the species in the Pasoh tree flora in 357 ha; for 75% of the tree flora in 1250 ha; and for 90% of the tree flora in 2856 ha.

3. These equations indicate how many species might be considered 'safe' within a forest, but not which species. Individual taxonomic families differ markedly in representation of species (Table 1). First, restricting ourselves to

families with more than 5 species in Malaya, representation in the 50- ha plot ranged from 66% for the Hypericaceae (consisting solely of the genus *Cratoxylum*) to 0% for six families. Among the larger families, representation ranged from 32 out of 53 spp., about 60 % for the Myrsisticaceae to 5 out of 88 spp. or 5% for the Myrsinaceae. The large and characteristic families of the lowland forest differed in the best-fit power functions from 0.06, for the Anacardiaceae and Burseraceae, to 0.15 for the Dipterocarpaceae and Rubiaceae. These different species-area curves are graphically illustrated in Figure 3.

4. Furthermore, median abundance of species varies ten-fold with taxonomic family. The overall median abundance of individual trees greater than 1 cm dbh is about 2 per hectare. Thus, about 400 species are represented by more than 2 individuals per hectare and 400 by less. Median species abundances varied among the larger characteristic rain forest families by nearly 100-fold (Table 2). Considering first those families with 5 or more species within the plot, the abundances range from a high of 14 individuals per ha for the Ulmaceae, and 11 individuals per ha for the Dipterocarpaceae, to lows of 0.4 and 0.1 per ha for the Symplocaceae and Combretaceae respectively.

5. Characteristic taxonomic families of the lowland forest, Dipterocarpaceae, Rubiaceae, Sapotaceae and Burseraceae will have varying levels of species representation and numbers of individuals at different spatial scales. Tables 1 and 2 can be usefully combined by taking all Malayan families represented by more than five species in the 50-ha plot, and ranking them in thirds by percent representation and by abundance, then cross-tabulating the families into a nine-cell (Table 3). The families in the upper left are those that are relatively well-represented in a single forest and also have a relatively high median abundance in that forest. These families comprise what are widespread and abundant species, e.g., Burseraceae. Those in the lower left, e.g., Rubiaceae, are represented by relatively few of the regionally available species, but the species that do occur in a particular forest are very abundant.

The most obvious question to ask at this point is whether or not these patterns are truly recurrent and characteristic features of the taxonomic families, or are they peculiar to Pasoh Forest Reserve. Are there not lowland forests in Malaya where the patterns are reversed for different families, where the Rubiaceae are represented by 50% of their species and the Myristicads by 15%?

A natural, but misleading, approach to that question would be to statistically compare each of the 50 individual one-hectare samples of roughly 6,000 trees each. Doing this, one finds nearly complete concordance among the fifty samples. However, this does not answer the question, but rather only tells us that the one-ha plots, being spatially proximate, are autocorrelated in compositional features, and represent a relatively homogenous forest, something that we already knew having specifically chosen this particular forest for its homogeneity. What we want to know is whether or not these patterns are found recurrently in further samples around Malaya and Borneo.

There are no other plots comparable to the Pasoh plot where these hypothesis can be tested. The many line, quadrat, and growth and yield samples made in the Forest Reserves of Malaya over the past hundred years do not reject the hypothesis or contradict the findings, but they too heterogenous in method to be used for quantitative comparisons.

An alternative test is to use verified lists of species compiled for local floras, and while these offer no insight on abundances, they do represent hard evidence of a species occurrence. Singapore is one of the better collected tropical locales, and it's well-documented list of species describes the original forest cover at a time long before the great changes brought to the island by economic growth (Turner et al. 1990). A compilation of percent representation of the characteristic lowland families represented in on the island (corrected to include only shrubs and trees) would reject the hypothesis that families display haphazard quantitative patterns of occurrence. Ulmaceae is represented by 7/8 of the Malayan flora, Myristicaceae by 34/53 or 64%; at the other end, the Dipterocarps are represented in Singapore by 25/156 species or 16%; the Lauraceae by 45/213 or 18%. No family is represented by more species than might be predicted from Figure 3 for an area of 60,000 ha. For those families of small shrubs that bloom frequently and which, therefore, should be expected to be thoroughly collected, such as the Rubiaceae, the representation is roughly as predicted : 89/296 or 30%, and the Myrsinaceae: 14/88 or 15.9%. This analysis shows that the data from an ecological sample from Pasoh can successfully predict the percent representation of taxonomic families in Singapore, something that was not at all intuitively obvious.

The description of these patterns and the magnitude of the differences among the families leads to two question: First, what is the ecological basis for these patterns, and second, what significance do these patterns hold for conservation policy?

Why should taxonomic families differ from one another in their patterns of distribution and abundance? Why should species of laurels be patchy in geographic distribution and sparse in local density, while species of dipterocarps are patchy in geographic distribution but high in local density, and the kedendongs (Burseraceae) are both widely distributed and relatively high in local density?

One of the more obvious factors regulating geographic distribution is the capacity for wide dispersal. The big trees with low representation, the Dipterocarps and very big Apocynads, seem to be invariably wind-dispersed. By contrast, the highest representations are found in trees such as the Anacards, nutmegs, and kedendongs, which bear large, often arilate seeds in fleshy fruits, many of which are routinely dispersed by mammals and strong flying birds such as the hornbills. But we can see that dispersal is not a completely adequate explanation, for among the species with low representation, along side the Dipterocarps and Apocynads, are the berry-fruited species of the Rubiaceae and Myrsinaceae. Those latter two families are comprised chiefly of shrubs and smaller trees, in complete contrast with the stature of the towering Dipterocarps. Stature is an interesting factor, in that the highest levels of very local endemism among Malayan plants seem to invariably occur among small herbaceous genera. According to Kiew (1990), 50 percent of the species of Malayan Begonia (Begoniaceae) and 75 percent of 80 species of Malayan Didymocarpus (Gesneriaceae) are known from single localities. There are no genera of large trees that have distribution patterns anything like that. The only genera that might come close are the smaller shrubs in the Rubiaceae and Myrsinaceae. More complete data on reproductive ecology of these trees and a more thorough statistical approach may reveal further patterns and correlations.

The consequences of these patterns for conservation are two-fold. First of all, with regard to the methods of policy formulation, it is clear that the focal-family approach should be avoided. Choosing one taxon as a proxy representative for biodiversity is sometimes done explicitly, but more often it is only tacitly done through the limitations inherent in personal knowledge. Consultants who are engaged to aid the development of conservation plans often have, as a necessity of modern research, an intimate taxonomic and ecological knowledge of one or two families, and they perhaps inevitably draw upon their knowledge in forming opinions. The results from Pasoh show that this practice is very dangerous. In deciding upon the size and number of nature reserves, we would reach very different recommen-dations if we base our study on the Dipterocarpaceae rather than on, e.g., Myristicaceae.

Second, with regard to a national strategy for conservation, reserves of different size and number will have a varying success in securing safe populations of species representative of different families. One large preserve, such as Taman Negara in the center of the Peninsula will include the overwhelming majority of species in the Anacardiaceae, Burseraceae, and Myristicaceae. But it will certainly not include the major portion of Dipterocarps, Rubiaceae or Myrsinaceae. Where the representative species of these latter families occur, they are extremely abundant and a small park would include a large population. For these, a greater number of small parks in more scattered locations about the Peninsula would better serve their preservation. For the Lauraceae and Sapotaceae, trees with very low abundance and low representation, it may not be possible preserve their diversity in the wild through any means short of very large-scale conservation of the landscape. If only 10% of the Malayan Peninsula is retained under mixed forest cover, then for these families, ex situ conservation may be a priority.

Table 1 Representation of families of Malayan trees in 50-ha plot at Pasoh Forest Reserve, arranged in descending order of representation; families with more than five species appear before families with less than five species.

Family	Total Malayan spp.	Pasoh Plot spp.	Percent
Hypericaceae	6	4	66.7
Ulmaceae	8	5	62.5
Burseraceae	36	22	61.1
Myristicaceac	53	32	60.4
Alangiaceae	7	4	57.1
Olacaceae	9	5	55.6
Combretaceae	10	5	50.0
Polygalaceae	21	10	
47.6Meliaceae	98	42	42.9
Anacardiaceae	78	32	41.0
Sapindaceae	52	20	38.5
Rosaceae	27	10	37.0
Icacinaceae	19	7	36.8
Ebenaceae	65	23	35.4
Moraceae	72	25	34.7
Violaceae	9	3	33.3
Annonaceae	133	43	32.3
Flacourtiaceae	48	15	31.6
Dilleniaceae	10	3	30.0
Melastomataceae	56	16	28.6
Elaeocarpaceae	28	8	28.6
Leguminosae	102	28	27.5
Sterculiaceae	48	13	27.1
Euphorbiaceae	324	87	26.9
Guttiferae	122	32	26.2
Boraginaceae	8	2	25.0
Fagaceae	64	16	25.0
Symplocaceae	21	5	23.8
Lecythidaceae	17	4	23.5
Myrtaceae	209	49	23.4
Bombacaceae	22	5	22.7
Lauraceae	213	48	22.5
Oleaceae	18	4	22.2
Celastraceae	33	7	21.2
Bignoniaceae	10	2	20.0
Dipterocarpaceae	156	30	19.2
Sapotaceae	73	14	19.2
Tiliaceae	45	8	17.8
Verbenaceae	45	8	17.8
Apocynaceae	36	6	16.7
Proteaceae	12	2	16.7
Sabiaceae	6	1	16.7
Thymelaeaceae	18	3	16.6
Rubiaceae	296	46	15.5
Rutaceae	46	6	13.0
Loganiaceae	8	1	12.5
Vitaceaeae	8	1	12.5
Rhizophoraceae	26	3	11.5
Simaroubaceae	9	1	11.1
Theaceae	36	4	11.1
Magnoliaceae	18	2	11.1
Aquifoliaceae	19	2	10.5
Podocarpaceae	10	1	10.0
Araliaceae	21	2	9.5
Saxifragaceae	17	1	5.9
Myrsinaceae	88	5	5.7
Ericaceae	34	0	0.0
Actinidiaceae	10	0	0.0
Lythraceae	7	0	0.0
Hamamelidaceae	6	0	0.0
Urticaceae	6	0	0.0
—Families with less than Five Species—			
Ixonanthaceae	2	2	100.0
Asteraceae	1	1	100.0
Convolvulaceae	1	1	100.0
Dichaepetalaceae	1	1	100.0
Gnetaceae	1	1	100.0
Irvingiaceae	1	1	100.0
Linaceae	1	1	100.0
Santalaceae	1	1	100.0
Trigoniaceae	1	1	100.0
Cornaceae	3	2	66.7
Ochnaceae	4	2	50.0
Erythroxylaceae	2	1	50.0
Monimiaceae	2	1	50.0
Oxalidaceae	5	2	40.0
Capparidaceae	3	1	33.3
Crypteroniaceae	3	1	33.3
Juglandaceae	4	1	25.0
Opiliaceae	4	1	25.0
Staphyleaceae	4	1	25.0
Styracaceae	4	1	25.0
Aristolochiaceae	5	1	20.0
Sonneratiaceae	5	0	0
Caprifoliaceae	4	0	0
Malvaceae	4	0	0
Rhamnaceae	4	0	0
Illiciaceae	3	0	0
Nyctaginaceae	3	0	0
Araucariaceae	2	0	0
Clethraceae	2	0	0
Daphniphyllaceae	2	0	0
Hernandiaceae	2	0	0
Pittosporaceae	2	0	0
Sarcospermataceae	2	0	0
Aceraceae	1	0	0
Casuarinaceae	1	0	0
Connaraceae	1	0	0
Cunoniaceae	10		0
Datiscaceae	1	0	0

Family	Pasoh spp.	Median population	
Epacridaceae	1	0	0
Goodeniaceae	1	0	0
Myricaceae	1	0	0
Nyssaceae	1	0	0
Pentaphylaceae	1	0	0
Tetrameristaceae	10		0

Table 2 Median population size of species in the Pasoh 50-ha plot. arranged by family. Median population is in individuals larger than 1 cm dbh per ha.

Family	Pasoh spp.	Median population
Ulmaceae	5	13.70
Dipterocarpaceae	30	10.96
Ebenaceae	23	7.58
Myrsinaceae	5	7.30
Burseraceae	22	6.70
Melastomataceae	16	6.66
Tiliaceae	8	6.30
Polygalaceae	10	3.63
Annonaceae	43	3.58
Rubiaceae	46	3.53
Apocynaceae	6	3.46
Euphorbiaceae	87	3.16
Celastraceae	7	3.06
Myrtaceae	49	2.92
Anacardiaceae	32	2.76
Rutaceae	6	2.74
Sterculiaceae	13	2.68
Rosaceae	10	2.67
Guttiferae	32	2.53
Leguminosae	28	2.44
Fagaceae	16	2.40
Icacinaceae	7	2.20
Meliaceae	42	1.97
Bombacaceae	5	1.82
Myristicaceae	32	1.82
Elaeocarpaceae	8	1.70
Flacourtiaceae	15	1.62
Sapotaceae	14	1.21
Sapindaceae	20	1.14
Lauraceae	48	0.96
Olacaceae	5	0.90
Verbenaceae	8	0.84
Moraceae2	5	0.72
Symplocaceae	5	0.40
Combretaceae	5	0.10
—Families with less than five species—		
Ixonanthaceae	2	32.01
Simaroubaceae	1	17.14
Gnetaceae	1	11.60
Opiliaceae	1	11.21
Trigoniastraceae	1	7.34
Rhizophoraceae	3	7.08
Santalaceae	1	6.26
Convolvulaceae	1	6.22
Proteacaceae	2	5.11
Violaceae	3	4.90
Irvingiaceae	1	4.62
Alangiaceae	4	3.90
Oxalidaceae	2	3.86
Linaceae	1	3.62
Lecythidaceae	4	2.67
Asteraceae	1	2.52
Thymeliaceae	3	2.50
Ochnaceae	2	2.40
Dichaepetalaceae	1	2.06
Aquifoliaceae	2	1.99
Loganiaceae	1	1.92
Oleaceae	4	1.39
Erythroxalaceae	1	1.10
Dilleniaceae	3	0.80
Magnoliaceae	2	0.80
Theaceae	4	0.78
Crypteroniaceae	1	0.64
Hypericaceae	4	0.56
Podocarpaceae	1	0.54
Aristilocaceae	1	0.50
Juglandaceae	1	0.40
Monimiaceae	1	0.36
Boraginaceae	2	0.36
Cornaceae	2	0.28
Araliaceae	2	0.16
Capparidaceae	1	0.04
Vitaceae	1	0.04
Bignoniaceae	2	0.02
Loganiaceae	1	0.02
Sabiaceae	1	0.02
Staphyleaceae	1	0.02
Styracaceae	1	0.02
Saxifragaceae	1	0.02

ABUNDANCE

Table 3. The major taxonomic families characteristic of the lowland Malaysian rain forest divided by thirds with regard to their abundance with representationin the 50-ha plot in Pasoh Forest Reserve.

REPRESENTATION	HIGH	MEDIUM	LOW
HIGH	Burseraceae (22 spp.) (61.1 %) (6.70 ind.) Polygalaceae (10 spp.) (47.6 %) (3.63 ind.) Ulmaceae (5 spp.) (62.5 %) (13.70 ind.)	Meliaceae (42 spp.) (42.9 %) (1.97 ind.) Anacardiaceae (32 spp.) (41.0 %) (2.76 ind.) Myristicaceae (32 spp.) (60.4 %) (1.82 ind.) Rosaceae (10 spp.) (37.0 %) (2.67 ind.) Icacinaceae (7 spp.) (36.8 %) (2.20 ind.)	Sapindaceae (20 spp.) (38.5 %) (1.14 ind.) Combretaceae (5 spp.) (50.0 %) (0.10 ind.) Olacaceae (5 spp.) (55.6 %) (0.90 ind.)
MEDIUM	Ebenaceae (23 spp.) (35.4 %) (7.58 ind.) Annonaceae (43 spp.) (32.3 %) (3.58 ind.) Melastomataceae (16 spp.) (28.6 %) (6.66 ind.)	Euphorbiaceae (87 spp.) (26.9 %) (3.16 ind.) Myrtaceae (49 spp.) (23.4 %) (2.92 ind.) Leguminosae (28 spp.) (27.5 %) (2.44 ind.) Fagaceae (16 spp.) (25.0 %) (2.40 ind.) Sterculiaceae (13 spp.) (27.1 %) (2.68 ind.) Guttiferae (32 spp.) (26.2 %) (2.53 ind.)	Symplocaceae (5 spp.) (23.8 %) (0.40 ind.) Flacourtiaceae (15 spp.) (31.6 %) (1.62 ind.) Elaeocarpaceae (8 spp.) (28.6 %) (1.70 ind.) Moraceae (25 spp.) (34.7 %) (0.72 ind.)
LOW	Rubiaceae (46 spp.) (15.5 %) (3.53 ind.) Dipterocarpaceae (30 spp.) (19.2 %) (10.96 ind.) Myrsinaceae (5 spp.) (5.7 %) (7.30 ind.) Tiliaceae (8 spp.) (17.8 %) (6.30 ind.) Apocynaceae (6 spp.) (16.7 %) (3.46 ind.)	Celastraceae (7 spp.) (21.2 %) (3.06 ind.) Rutaceae (6 spp.) (13.0 %) (2.74 ind.)	Sapotaceae (14 spp.) (19.2 %) (1.21 ind.) Verbenaceae (8 spp.) (17.8 %) (0.84 ind.) Bombaceae (5 spp.) (22.7 %) (1.82 ind.) Lauraceae (48 spp.) (22.5 %) (0.96 ind.)

Figure 1 Map of Pasoh and Malaya depicting the number of trees and shrubs with documented occurrence. (These figures exclude monocotyledons, and differ from the tallies in the Tree Flora of Malaya and the Pasoh data set in a few other minor respects which are described in the methods.)

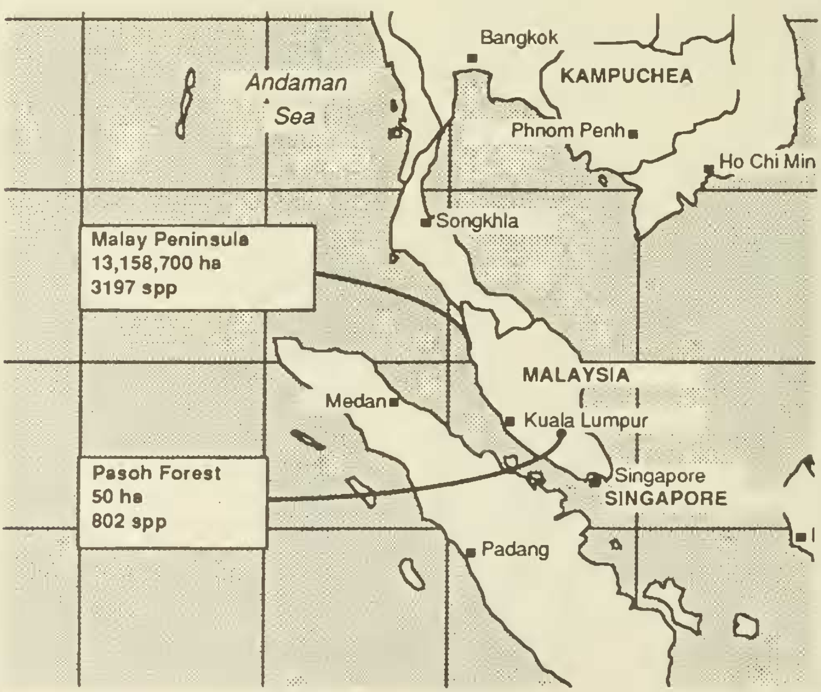


Figure 2 The 50th (median), 75th and 90th percentile of adult trees per species related to area at Pasoh Forest Reserve, Malaysia.

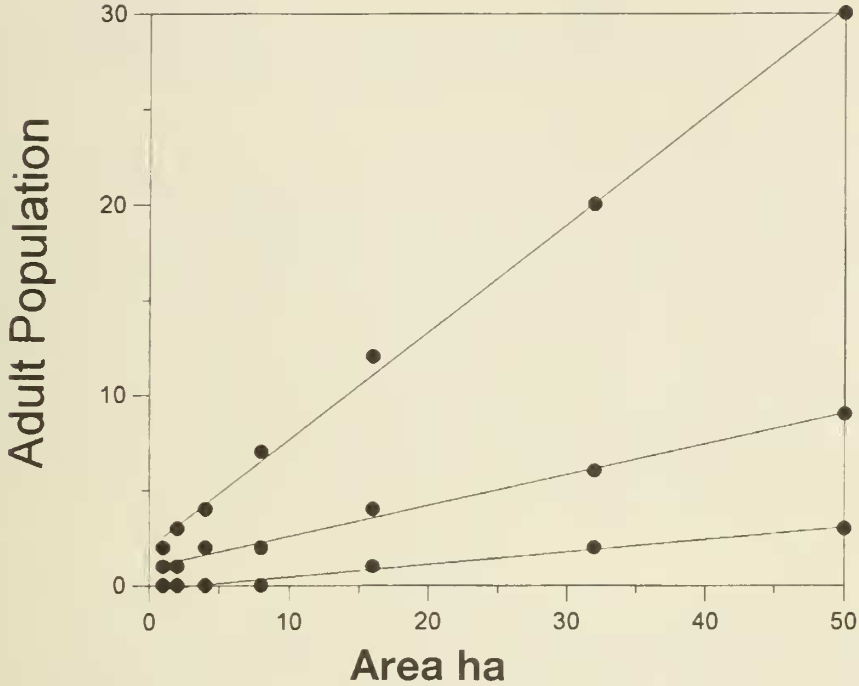
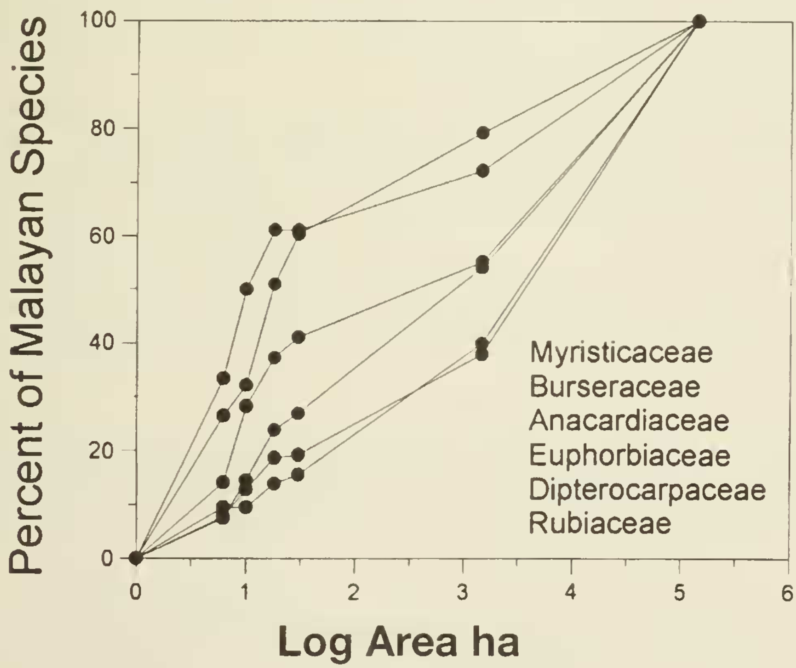


Figure 3 For six characteristic families of the lowland tropical rain forest, the number of species per area, all trees over 1 cm dbh, starting at Pasoh Forest Reserve Malaysia. Data points for 100,000 ha is estimated from records of plant collectors.



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