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Tree diversity and forest structure in northern Siberut, Mentawai islands, Indonesia

SUSILO HADI[1,2,3], THOMAS ZIEGLER[2*], MATTHIAS WALTERT[3] & J. KEITH HODGES[2]

[1]*Faculty of Biology, Gadjah Mada University, Jogjakarta 55281, Indonesia*
[2]*Department of Reproductive Biology, German Primate Centre, Kellnerweg 4, D 37077 Goettingen, Germany*
[3]*Department of Conservation Biology, Centre for Nature Conservation, Georg -August-Universität Göttingen, Von-Siebold Strasse 2, 37075 Göttingen, Germany*

Abstract: We assessed tree diversity, species composition and forest structure of 3.4 km² of primary rainforest in an important conservation area in North Siberut, Indonesia. We used floristic data from 34 20 m x 20 m plots for trees ≥20 cm diameter at breast height (dbh), 34 10 m x 10 m plots for poles (10-19 cm dbh) and 34 5 x 5 m plots for saplings (≤ 9cm dbh). In total, 139 species were recorded from 93 trees, 57 poles and 86 saplings, with an estimated total species richness of 180 (Michaelis Menten species richness estimator). Overall, 70 genera and 35 families were represented, with Euphorbiaceae, Myrtaceae, Lauraceae and Moraceae being most important in terms of species diversity and Myristicaceae in terms of total individuals recorded. At species level, species of the genera *Mallotus* and *Knema*, as well as *Baccaurea sumatrana* were most dominant in all dbh classes based on the Importance Value Index (IVI), but only six species (none of which a dipterocarp) reached IV indices of ≥ 15, reflecting the high eveness and low dominance of dipterocarps in the tree community. Among trees ≥20 cm dbh, >50% were within the 20-39 cm dbh class and 73% of trees formed a canopy between 6 and 20 m in height, whereas emergent dipterocarps reached heights above 55 m (*Dipterocarpus* sp.) and diameters above 230 cm (*Shorea pauciflora*). The mixed composition of this forest emphasizes its significance for the biodiversity of the region.

Resumen: Evaluamos la diversidad de árboles, la composición de especies y la estructura de bosque en 3.4 km² de bosque lluvioso primario en una área de conservación importante en el norte de Siberut, Indonesia. Usamos datos florísticos de 34 parcelas de 20 m × 20 m para árboles ≥ 20 cm de diámetro a la altura del pecho (dap), 34 parcelas de 10 m × 10 m para árboles jóvenes (10-19 cm dap) y 34 parcelas de 5 × 5 m para brinzales (≤ 9 cm dap). En total, se registraron 139 especies en 93 árboles, 57 árboles jóvenes y 86 brinzales, con una riqueza total estimada de 180 especies (estimador Michaelis Menten de la riqueza de especies). En total, estuvieron representados 70 géneros y 35 familias, siendo Euphorbiaceae, Myrtaceae, Lauraceae y Moraceae las más importantes en términos de diversidad de especies, y Myristicaceae en términos del número total de individuos registrados. A nivel de especie, especies de los géneros *Mallotus* y *Knema*, así como *Baccaurea sumatrana*, fueron los más dominantes en todas las clases de dap de acuerdo con el índice de Valor de Importancia (VI), pero sólo seis especies (ninguna de ellas dipterocarpácea) alcanzaron índices de VI ≥ 15, reflejando la alta equitatividad y la baja dominancia de las dipterocarpáceas en la comunidad de árboles. Entre los árboles con dap ≥ 20 cm, >50 % estuvieron en la categoría diamétrica de 20-39 cm y 73% de los árboles formaron un dosel entre 6 y 20 m de altura, mientras que las dipterocarpáceas emergentes alcanzaron alturas superiores a 55 m (*Dipterocarpus* sp.) y diámetros arriba de 230 cm (*Shorea pauciflora*). La composición mixta de este bosque enfatiza su importancia para la biodiversidad de la región.

* *Corresponding Author*; e-mail: tziegl@dpz.gwdg.de

Resumo: Avaliou-se a diversidade arbórea, a composição das espécies e a estrutura de uma floresta primária de chuvas de 3,4 km² numa área de conservação importante no norte de Siberut, Indonésia. Usaram-se os dados florísticos obtidos em 34 parcelas de 20 m x 20 m para árvores com diâmetros à altura do peito (DAP) ≥ 20 cm, 34 parcelas de 10 m x 10 m para árvores no estádio de varas (10-19 cm DAP) e 34 parcelas de 5 x 5 m para árvores no estádio de estacas (DAP≤ 9 cm). No total foram registadas 139 espécies sendo 93 de árvores, 57 no estádio de postes e 86 no estádio de estacas com uma riqueza específica estimada de 180 (estimador de riqueza específica de Michaelis Menten). No seu conjunto estavam representados 70 géneros e 35 famílias, sendo as *Euphorbiaceae*, *Myrtaceae*, *Lauraceae* e *Moraceae* as mais importantes em termos da diversidade específica e as *Myristicaceae* em termos do total de indivíduos registados. Ao nível das espécies, as espécies do género *Mallotus* e *Knema*, bem como as *Baccaurea sumatrana* eram as mais dominantes em todas as classe de DAP com base no índice do Valor de Importância (IV), mas somente seis espécies (nenhuma delas dipterocarpus) atingiu o índice IV ≥ 15, reflectindo a alta uniformidade e a baixa dominância dos dipterocarpus na comunidade arbórea. Entre as árvores com DAP ≥ 20 cm, > 50% encontravam-se dentro da classe de DAP 20-39 cm e 73% das árvores formam um copado entre os 6 e os 20 m de altura, enquanto os dipterocarpus (*Dipterocarpus* sp) emergentes atingiram alturas acima dos 55 m e diâmetros acima dos 230 cm (Shorea pauciflora). A composição mista nesta floresta enfatiza a sua significância para a diversidade da região.

Key words: Evergreen lowland rainforest, forest structure, Mentawai, Siberut island, species richness, tree diversity.

Introduction

The Malesian region is considered to be one of the most diverse of the world's 152 floristic provinces, with about 40.000 vascular plants recorded (Baas *et al.* 1990; Roos 1993). About one third of these species are trees more than 10 cm in diameter (Jacobs 1974; Whitmore 1989). Due to their different biogeographical and palaeoecological histories, the islands of this region show extraordinary floristic differences.

A chain of four main islands represents the Mentawai archipelago, situated about 130 km off Sumatra's west coast. Siberut, the largest and northernmost island of the Mentawais, lost its last land-bridge connection to mainland Sumatra more than 500 000 years ago (Verstappen 1975). Due to this prolonged period of biogeographic separation, its fauna and flora have evolved in isolation since the mid-Pleistocene and this process has resulted in a relatively high number of endemic species. Some species are considered to be relicts of early Sundaland communities, whereas others have evolved into forms clearly distinct from the representatives found on the Asian mainland. Accordingly, twelve bird taxa and seventeen out of thirty-four mammal species, including all four primate species found on Siberut, are known to be endemic (WWF 1982; Whitten *et al.* 2000; Roos *et al.* 2003), whereas the number of endemic animal species on lower taxonomic levels can only be estimated. Consequently, the protection of Siberut´s wildlife habitats ranks as a priority for conservation even within the "Sundaland Hotspot of Biodiversity" (Conservation International 2002).

Although the primary forests on the Mentawai islands represent the ecological refuge for the survival of most of these unique species, they have been under relentless pressure from logging and land conversion for several decades. Previously, the richness of plant species that make up these forests was reported to be relatively low compared to mainland forests on Sumatra (WWF 1980; Whitten 1982; Whitten *et al.* 2000) with several species of trees (e.g. Leguminosae) being completely absent. In general the tropical evergreen rainforests of Siberut can be categorized into five different forest types: primary dipterocarp and primary mixed forest, the less widespread peat swamp forest, mangrove forest and *Barringtonia* forest types. According to Whitten *et al.* (2000), up to 90% of Siberut`s forests are made up from primary dipterocarp and primary mixed forest. Many of the common plants found on the island are very similar to those found on mainland Sumatra, having evolved during the Tertiary when the Mentawais were still connected to the mainland (Paciulli 2004). Nevertheless, many of the woody plants and herbs remain to be described, despite the fact it is now over 80 years since the original floristic explorations of the Mentawai islands by Ridley (1926). Today Siberut's flora is reported to consist of 846 species out of 390 genera belonging to 131 families, but it is generally assumed that the list of plant species known to be endemic is incomplete, and that over time new species will be identified (UNESCO MAB 2004).

Due to the dramatic loss of rainforest habitat on the islands during the last three decades, all endemic forest wildlife of the Mentawais is under threat (e.g. primates: Eudey *et al.* 2000). According to Whittaker (2006) who compiled forest cover data for Siberut, the primary forests that covered almost all of the 4,030 km^2 island has been reduced to 3,500 km^2 by the 1980´s and in 1995 only 2,400 km^2 remained. Today most of the remaining intact forest is found within Siberut National Park on the western part of the island and in the North, while forest disturbance and fragmentation caused by legal and illegal logging as well as land conversion for local agriculture (Martin in prep.) is visibly increasing in the remaining parts of the island.

Although logging companies have operated systematically on Siberut since the early 70´s and the forest plays an important role in the traditions and daily life of the indigenous people, there is still very little published information on the tree communities and vegetation structure of the primary forests on this island. The only previous detailed study on primary forests of Siberut, using floristic and structural data, was conducted at Paitan and Sirimuri in central Siberut (Whitten 1982) as part of a study on the ranging behaviour of Kloss Gibbons (*Hylobates klossii*). Other research on forest structure and tree species composition was carried out mainly in secondary and disturbed forests of the southern Mentawai islands (Fuentes 1994; Paciulli 2004; Sangchantr 2004). No information exsists about the remaining evergreen rain forest in northern Siberut.

Here, we report on the tree community and forest structure of a largely undisturbed primary forest in northern Siberut. The study aims to determine the taxonomic and structural composition of the Peleonan forest. This forest represents the core study area of an important field site for primate research and conservation (Waltert *et al.* 2008). The data presented here form an important basis for comparative ecological studies on this ecosystem. This includes not only the comparison of tree diversity and composition with mainland forests, but also the ecology and habitat use of Siberut´s endemic primates and the establishment of a biological database urgently needed for effective conservation strategies on Siberut island.

Materials and methods

Study area

The study was conducted in a primary forest representing a tropical lowland evergreen rainforest, situated between the Peleonan and Sigep rivers at 0°58' and 1°03'S (latitude); and 98°48' and 98°51'E (longitude) in northern Siberut (Fig. 1). Most of the study area is hilly with elevation measurements ranging from 2-182 m above sea level. The forest area is drained by numerous small to medium sized creeks and rivers.

Due to their geographic location, the Mentawai islands are characterized by weak seasonal changes of an equatorial tropical climate. The mean annual rainfall on Siberut was measured at 4217 mm (Whitten 1982). In general, the drier season occurs from February to June and the wetter season from July to January (Mitchell 1982). Daily minimum and maximum temperatures range from 22°C to 31°C, while humidity levels range from 80 to 95 percent (Whitten 1982; WWF 1980).

Field sampling

The study site is accessible through 13 transects, ranging from 1 to 3 km in length and crossing riversides and hills (see also Waltert *et al.* 2008). For this study eight of these transects were selected randomly. On six of these transects four plots and on two of these transects five plots were marked measuring 20 m x 20 m with a distance of 200 m to each other, such that a total area of 3.41 km^2 was investigated. Within these plots all trees of ≥ 20 cm diameter at breast height (dbh; tree stage), were measured. Smaller trees (pole stage) were measured in smaller plots of 10 m x 10 m for dbh class 10 -19 cm and 5 m x 5 m

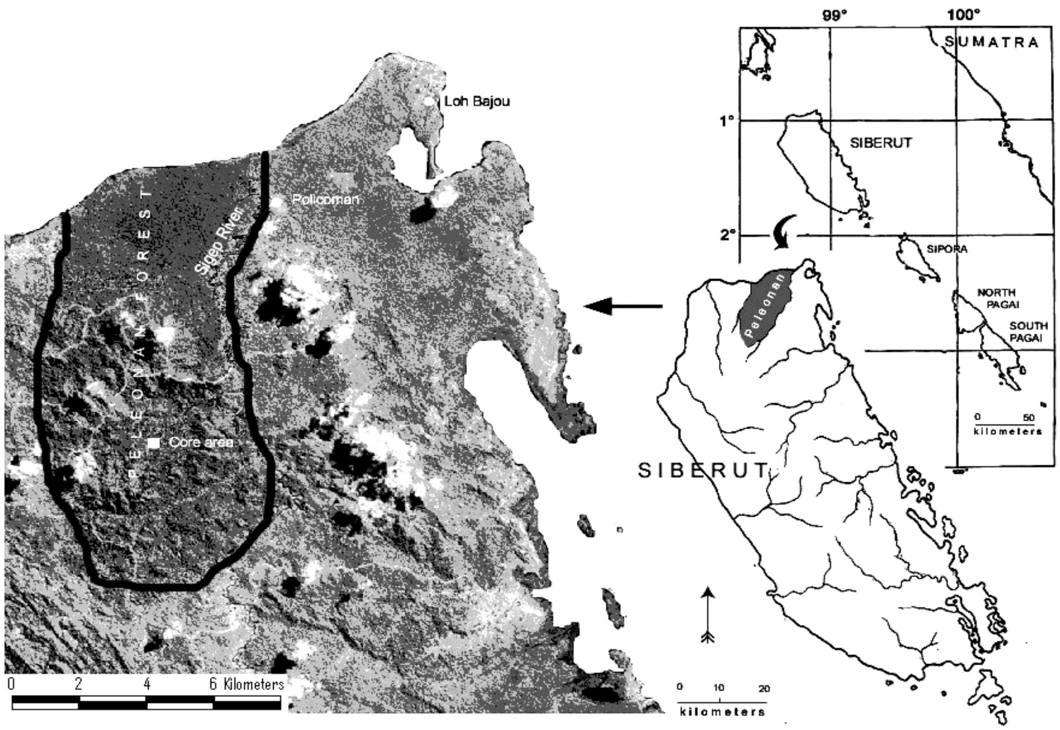

Fig. 1. Map of study area in Peleonan forest, North Siberut.

plots for saplings with dbh ≤ 9 cm and a minimum height of 1.5 m. The smaller plots were nested within the 20 m x 20 m plots. Full spatial coverage of these smaller trees would have been impractical as the total sampling area encompassed 1.36 ha.

For each tree of any size within the plots, botanical name or local name was recorded. Local names were provided by three experienced natives of northern Siberut all of which were informed to rather leave a specimen unnamed instead of giving an unreliable information. Diameter at breast height (dbh) was measured using a "meter tape" and total heights of trees were taken as the distance from their base to the top of their crowns using a Leica LRF 800 digital rangefinder. From each tree recorded, three samples of terminal twigs were collected and preliminarily assigned to morphospecies. Occasionally fruits or flowers were collected to confirm identification in the field and to be used as additional references in the form of pictures or dried samples. From each specimen, one of the three dried twig samples were stored at research station facilities in the forest and in a dry storage room in Padang (West Sumatra), respectively, whereas the third sample was sent to the Herbarium of Andalas University in Padang for further scientific identification and storage.

Even without an existing Flora for the Mentawai archipelago, more than 90% of the specimen recorded could be identified up to species or genus level using keys and descriptions of standard Malesian Floras (Whitmore 1972, 1973), the pilot study on the Mentawai Flora by Ridley (1926) and specimen references from the Herbarium of Andalas University.

Data analysis

Based on the individuals recorded in the discrete plot samples, species richness was calculated using both, species accumulation curves and species richness estimators. Species accumulation curves were generated for three different sample sets: "Riverine-", "Hillside-" and "All plots", in which the number of species found is shown in relation to the accumulating number of tree individuals or plots sampled.

Estimation of total richness was performed using the software *Estimate S* 6.0b1 (Colwell 2000).

The MMMeans richness estimator was selected here, as it was shown to be the least biased estimator provided in the software package (Kessler *et al.* 2005), but the range of results from the other estimators in Colwell (2000) are also given.

Furthermore, floristic structure was assessed quantitatively by calculating the Importance Value Index (IVI) for each species. The IVI represents the sum of the values for relative density (RD), relative frequency (RF) and relative dominance (RDo), which are determined by the following equations:

$$\text{Relative density} = \frac{\text{Number of individuals of a taxon}}{\text{Total number of individuals}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Number of plots containing a taxon}}{\text{Total frequencies of all taxa}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Basal area of a taxon}}{\text{Total basal area of taxa}} \times 100$$

Structural analysis of the forest was made by comparing the distribution of canopy heights and trunk diameter classes. For the analysis of height distribution, all trees were allocated to one of ten height classes, arranged in 5 meter categories, covering all trees from 6 to 60 m height. To analyse diameter distribution, dbh measurements of trees with dbh ≥ 20 cm were allocated to nine different categories arranged in 10 cm intervals.

Results

Floristic composition and species richness

Within the total area sampled, we recorded 93 trees, 57 poles and 86 saplings in our plots. They could be assigned to 139 tree species, representing 70 different genera out of 35 tree families. With regard to the number of species found within families, Euphorbiaceae was the most diverse tree family in the samples, being represented by 20 species, followed by Myrtaceae (12 species), Lauraceae (9 species) and Moraceae (8 species). Within the family Euphorbiaceae, *Baccaurea* was the most common genus, being represented by 7 species. Whilst the Myrtaceae was dominated by the genus *Eugenia* (9 species), the families Lauraceae and Moraceae were dominated by *Litsea* and *Artocarpus* respectively (6 species each).

Calculations performed with the MMMeans richness estimator revealed a tree species richness for the 3.41 km^2 study area of an estimated total of 180 species. Results from other species richness estimators range from 169 to 187 (e.g. Jack1=182 ± 5; Chao1=187 ± 21; Chao2 = 178 ± 16; ICE=176 ± 0; ACE=169 ±p 0).

On average, 10.2 ± 3.3 trees ≥ 20 cm dbh (mean ± s.d.) were recorded within one 20 m x 20 m plot, belonging to 8.3 ± 2.4 species. Hill plots generally had about similar numbers of individuals (hill 10.5 ± 3.6 and river 9.7 ± 2.5) (Mann-Whitney U test, U=116, p=0.7) and species (hill 8.4 ± 2.6 and river 8.2 ± 2.0) (Mann-Whitney U test, U=125, p=1.0). There were also only slight differences between species accumulation curves from plots situated near rivers and those from plots in hilly areas, showing that species richness was only slightly lower near rivers (Fig. 2a & b).

Species such as *Mallotus* sp. 1 and *Xanthophyllum* sp. 2 were mainly found in riverine plots , while *Shorea pauciflora* and *Dipterocarpus* species were more common in hill plots. A similar topological preference was not found for *Baccaurea javanica* and *Knema* sp. 1, which were common in both, riverine and hill plots (Table 1).

Data based on the Importance Value Index (IVI) ranked within the three different dbh classes (Appendix Table 1) showed that species such as *Mallotus* sp. 1 (15.5%; 19.9% and 7.1%), *Knema* sp. 1 (15.7%; 16.7% and 4.7%) and *Baccaurea sumatrana* (15.0%; 8.4% and 5.9%) were quite abundant in all dbh classes. These species were followed by *Santiria* sp. 1 (22.1% and 5.7%), *Excoecaria* sp. (20.7% and 49.0%) and *Baccaurea javanica* (42.0% and 11.3%), dominating two dbh classes. Species like *Artocarpus heterophyllus* (14.3%), *Canarium magalanthum* Merr. (15.0%), *Urophyllum griffithianum* (11.6%) and *Eugenia* sp. 5 (9.5%), dominated only one dbh class.

According to their IVI, *Santiria* sp.1 (Burseraceae), *Excoecaria* sp. (Euphorbiaceae) and *Urophyllum griffithianum* (Rubiaceae) are the dominant species within the dbh classes ≥ 20 cm, 10 -19 cm and < 10 cm, respectively. Species of the family Dipterocarpaceae were not found to be dominant in any of the (sub)samples. The highest IVI for any species of this family was obtained for *Shorea ovalis* (8.68%) with regard to the dbh class ≥ 20 cm only. Calculations by all dbh-classes pooled - i.e. all trees recorded - revealed that only seven species reached an IVI > 5 (*Santiria* sp.1, *Mallotus* sp. 1, *Excoecaria* sp., *Knema* sp. 1, *Baccaurea sumatrana*, *Baccaurea javanica* and *Urophyllum griffithianum).* On the other hand, for

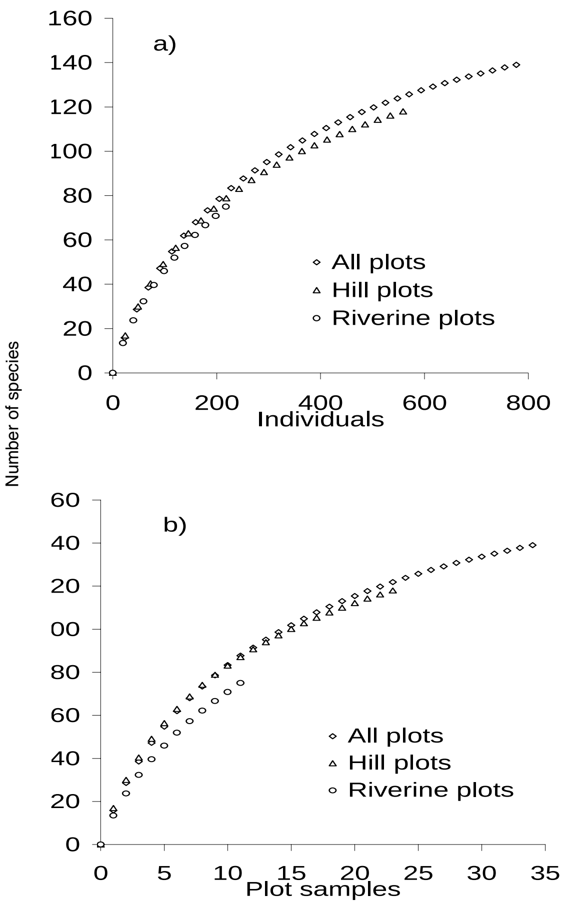

Fig. 2. Species-accumulation curves based on numbers of individual trees (a) and on cumulative plot samples (b) in hill plots, riverine plots and all plots combined.

84.21% of all species listed in the data set an IVI of < 2 was determined. These values indicate that there is no single species or genus clearly dominating the plotted areas, but a group of seven species, representing six different genera, show relatively high importance values.

Structural composition, diameter and height class distribution

A relatively high proportion of trees in the samples was represented by small individuals, i.e. belonging to the dbh classes 20-29 cm (36.4%) and 30-39 cm (17.5%) (Fig. 3a). Hence, more than 50% of the trees in the samples were represented by individuals with dbh values of less than 40 cm. If the dbh class 10-19 cm (pole stage) would be included (not shown in Fig. 3a) here, the trees recorded for this category only would represent 61% of all individuals sampled.

If all trees with dbh-values between 50 and 100 cm are pooled together, this (mature) age class represents a fourth (24%) of all individuals plotted in Fig. 3a. About 15% of all trees in this figure belonged to the class of the largest trees with dbh values > 100 cm. A majority of these large trees is represented by species of the genera *Shorea* and *Dipterocarpus*. The maximum dbh-value in the present sample is 235 cm recorded for *Shorea pauciflora*. Individuals of similar size were recorded for *Diospyros ellipticifolia, Mallotus* sp. and *Campnosperma auriculatum*.

Height distribution

As depicted in Fig. 3b, trees belonging to the first three height classes (measuring 6-20 m) accounted for 73% of all trees in the samples. The remaining 27% were distributed over seven height categories ranging from 21 to 60 m. The tallest tree (*Dipterocarpus* sp.) was measured at 56 m. This figure also shows, that the canopy of the Peleonan forest is predominantly built by trees, which are almost equally distributed over the first three height classes, i.e. trees less then 21 m in height. Notably, there is a major drop in the number of individuals reaching heights of more than 20 meter and a gradual decrease in numbers with increasing height class (Fig. 3b).

Discussion

Floristic composition and species richness

This study characterizes a lowland evergreen rainforest of high conservation value in northern Siberut. It provides a systematically collected data set that can be compared to a large number of similar plot inventories of other tropical rainforests. To date the only other quantitative floristic description of a primary forest area on Siberut was published by Whitten (1982). He reported comparable data collected from two study areas located in the centre of the island, which became increasingly disturbed by legal logging activities. In total, he sampled 11.25 ha on which 162 "types" or "morpho"- species of trees ≥ 15 cm dbh were found. Similar to our study Myristicaceae and Euphorbiaceae were the most common tree families but in contrast to the present study, Dipterocarpaceae were also

Table 1. Importance Value Index (IVI) of the ten most dominant species recorded for three different dbh classes in riverine and hill plots.

Riverine area		Hilly area	
Species (DBH < 10cm)	IVI	Species (DBH < 10cm)	IVI
Mallotus sp. 1	29.57	*Urophyllum griffithianum* Hook.f.	13.21
Baccaurea javanica	11.36	*Eugenia* sp. 5	11.47
Xanthophyllum sp. 2	10.18	*Baccaurea javanica*	11.34
Cannarium megalathum Merril	9.99	*Phaenathus* sp. 2	8.16
Artocarpus sp. 4	9.99	*Anisophyllea disticha* Baill	8.16
Bridelia stipularis Bl.	8.03	*Baccaurea sumatrana*	7.71
Eugenia sp. 4	8.03	*Alangium ridleyi*	5.63
Antidesma sp. 1	7.44	*Horsfieldia* sp. 2	5.18
Alangium ridleyi	6.66	*Knema sp. 1*	5.18
Disoxylum sp. 1	6.66	*Psychotria* sp.	5.18
Species (DBH 10-19 cm)	IVI	Species (DBH 10-19 cm)	IVI
Mallotus sp. 1	88.63	*Excoecaria* sp.	67.47
Baccaurea javanica	54.85	*Baccaurea javanica*	26.89
Knema sp. 1	21.43	*Horsfieldia* sp. 2	17.78
Xanthophyllum sp. 2	17.51	*Cannarium megalathum* Merril	12.79
Durio sp. 1	16.29	*Knema* sp. 1	12.20
Cannarium megalathum Merril	15.57	*Baccaurea sumatrana*	12.12
Aporosa benthamiana Hook.f.	14.67	*Drypetes* sp. 1	9.15
Excoecaria sp.	7.45	*Durio* sp. 1	7.98
Diospyros ellipticifolia	7.41	*Ixora* sp.	7.53
Cinnamomum iners Bl.	7.41	*Dipterocarpus* sp.	6.12
Species (DBH ≥20 cm)	IVI	Species (DBH ≥20 cm)	IVI
Mallotus sp. 1	60.41	*Excoecaria* sp.	30.80
Knema sp. 1	24.48	*Santiria* sp. 1	19.79
Santiria sp. 1	17.25	*Baccaurea sumatrana*	19.66
Bhesa paniculata Am.	16.85	*Horsfieldia* sp. 2	15.04
Eugenia grandis Wight.	14.96	*Artocarpus heterophyllus*	13.49
Baccaurea sp. 3	13.71	*Diospyros ellipticifolia*	13.34
Dillenia excelsa	11.26	*Cannarium megalathum* Merril	11.48
Artocarpus heterophyllus	10.72	*Bhesa paniculata* Am.	10.90
Horsfieldia irya	10.54	*Knema* sp. 1	9.41
Durio sp. 1	8.66	*Shorea pauciflora* King.	8.92

abundantly present. The latter is obviously the result of a relatively large proportion of samples from minor and major hill ridges, as these are also the preferred ranging areas of the author's main study subject, the Kloss Gibbon, and in general, Dipterocarpaceae are more common in elevated areas.

The results of this study are also comparable to similar studies, based on small plot inventories, conducted in other tropical rainforests. Our record of 139 species with dbh ≥ 10 cm found on 1.36 ha is within the range of 100-150 species recorded in studies using comparative methods to describe primary forest in SE Asia (Whitmore 1995). Considering the estimated total species richness of 180 species for such a relatively small study area, the tree flora of Siberut does not appear to be depauperate relative to other primary forests on small to medium sized SE-asian islands. For example, Whitmore (1974) found 184 species ≥ 10

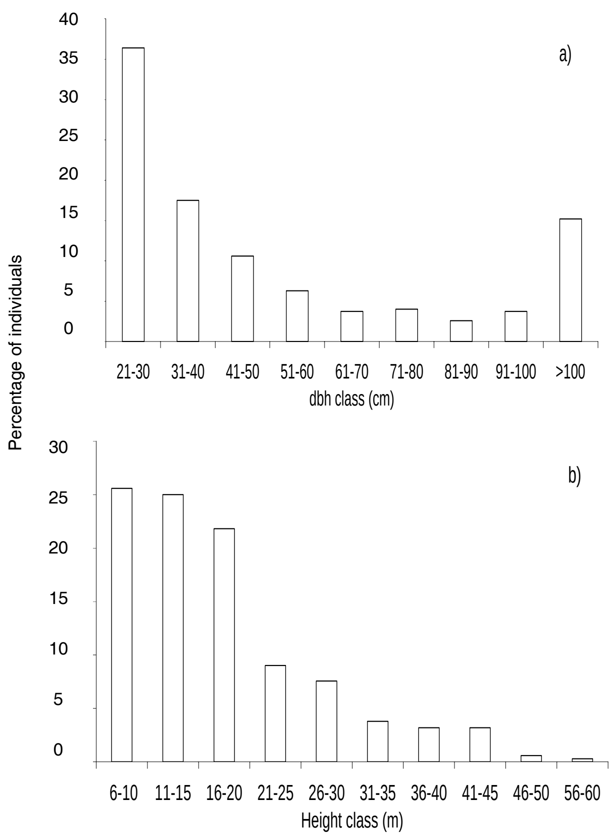

Fig. 3. Distribution of trees in dbh-classes (a) and height classes (b).

cm in 13.7 ha (22 non-contiguous plots) on the small Solomon island Kolombangara, whereas on a 1 ha plot on Negros Island (Philippines) Hamann *et al.* (1999) found 92 species representing 54 genera from 39 families. The fact that the latter study was conducted at about 1000 m above sea level explains the lower number of species found, since species richness generally declines with altitude. Surprisingly, however, a study by Kessler *et al.* (2005), from a submontane area in Central Sulawesi, reported almost 150 tree species belonging to 82 genera from 42 families in one plot of 100 m x 100 m. In two smaller plots of 0.25 ha, about half the number of species was found.

At the family level, the primary forest investigated in that study was also dominated by Meliaceae and Lauraceae, whilst - in contrast to our study - members of the family Euphorbiaceae only dominated the understory.

On the other hand, compared to the geographically nearest and palaeoecologically most closely related forests on Malaya and the greater Sunda Islands Sumatra and Kalimantan, tree diversity on Siberut is definitely lower. A study in a lowland "mixed dipterocarp rainforest" in Riau, Sumatra, revealed an extraordinary diversity of trees, with 504 species being identified from 1885 trees sampled on a 3 ha area (Renolls & Laumonier 2000). An almost equal diversity was found in a longer-termed study by Newbery *et al.* (1992), conducted in a lowland forest of Danum Valley, Sabah, Malaysia. Here, 511 species ≥ 10 cm were identified on two plots of 4 ha each. The total sample of 17985 individuals comprised 164 genera from 59 families. Earlier studies on the Malayan peninsula found 164 and 176 species per ha, respectively (Wyatt-Smith 1966). For Wanariset on Kalimantan, Kartawinata *et al.* (1981) reported 239 species on a 1.6 ha plot. Similarly, Sidiyasa (2001) found 385 tree species within a 3,6 ha plot containing a tree density of 535 trees ha^{-1} at a protected forest site at Wain River, East Kalimantan. These species were allocated to 143 genera out of 49 families. Similar to our study, most of the species recorded belonged to the family Euphorbiaceae, but in contrast to the present results for North Siberut, this family was followed by Lauraceae, Myristicaceae and Myrtaceae. Like on Siberut, *Baccaurea* was recorded to be the most abundant genus within the family Euphorbiaceae. In general the studies on Sumatra and Kalimantan showed a greater diversity on all taxonomic levels and - similar to Siberut - a numerical prevalence of species from the families Euphorbiaceae and Lauraceae.

The difference in species richness between Sumatra and the island of Siberut fits into the species-area pattern from several studies in SE-Asia (MacArthur & Wilson 1967; Welzen *et al.* 2005) showing that the number of species found is positively correlated with the size of the island. However, it has to be noted that instead of complete species inventories only available plot sample analysis of various studies can be compared here, and lists of species only represent relatively small defined areas within these different ecosystems.

In our study, numerically, no species or group of species could be identified to dominate the forest investigated. If our study is representative of Siberut, it might show, that Siberut's forests clearly differ from forests studied on Kalimantan, Sumatra and the Malayan Peninsula, where trees of the family Dipterocarpaceae would account for up to 21.9% of all trees recorded and are considered to be the numerically dominant family (Ashton 1982; Kessler *et al*. 2005; see also: Manokaran 1995 for SE Asia and Vasanthraj & Chandrashekar 2006 for Western Ghats, India). Therefore, and in contrast to some early assessments which report dipterocarps being relatively common on Siberut (e.g. WWF 1980), the study area in the Peleonan forest can be described as a typical mixed primary forest.

Structural composition, diameter and height class distribution

The forest investigated in this study is characterized by a high abundance of relatively small trees with diameters in breast height below 40 cm (with 60.91% of all individuals sampled ranging between 10-19 cm). This pattern is not unusual for primary lowland forests, which are un- or only weakly affected by human exploitation and indicates a high potential for regeneration processes (Whitmore 1984, 1989). The relatively small number of high trees with dbh values ≥ 40 cm can be explained by two main, but not mutually exclusive, reasons. Firstly, there might be a limited number of species that naturally grow up to these heights/ diameters (Hartshorn 1980) and their seedlings need to meet optimal conditions/locations for growth, to out-compete other (especially fast growing) species. Secondly, the numbers of certain big tree species (i.e. members of the family Dipterocarpaceae) could have been already reduced by selective logging for local use, especially traditional construction of dugout-canoes and houses.

As commercial logging in northern Siberut was in the past restricted to only a few strips along the hill ridges accessible for heavy equipment, and the use of the Peleonan forest by locals has been rather negligible in the past, we consider natural causes to play a significant role in restricting the number of big trees in our study area. This assumption is based on the prevailing weather conditions and supported by the fact that Siberut`s geology is dominated by Miocene beds of unresistant shales, silts and marls (van Bemmelen 1949). Annual precipitation records for Siberut reach 4,420 mm (Tenaza & Fuentes 1995) and during heavy rain, the alluvial soil becomes soaked with water causing instability of the ground and even landslides (pers. observ.). Under these conditions, tall and heavy trees are more likely to fall during thunderstorms, causing a higher overall tree turnover and hence a higher proportion of small, regenerating trees.

The combination of these geological conditions with relatively frequent tropical thunderstorms, have probably influenced the structure of the Peleonan forest more than any anthropogenic factors so far. However, due to the ongoing loss of primary forest in the vicinity of the study area, the demand for big timber trees of high quality is rising and the remaining natural resources are becoming increasingly threatened.

The truly mixed composition of the forest studied, made up by an estimated 180 species, provides numerous important ecological niches, not only for plant-, but also (endemic) animal species and emphasizes the outstanding contribution of this forest to the biodiversity of the region. Hence, our data confirm that sustainable management of the remaining primary rainforests on Siberut is of major importance for the conservation of the "Sundaland biodiversity" (Conservation International 2002). The data presented here provide a basis for future studies on this ecosystem in general, and for the assessment of its present and potential threats for the implementation of effective conservation measures.

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Appendix Table 1. Floristic composition and Importance Value Indices (IVI) in three different dbh classes: ≥ 20cm, 10-20 cm and ≤10 cm.

dbh ≥ 20cm		dbh = 10 - 20 cm		dbh < 10 cm	
Species	IVI	Species	IVI	Species	IVI
Santiria sp. 1	22.05	*Excoecaria* sp.	48.93	*Urophyllum griffithianum*	11.63
Excoecaria sp.	20.66	*Baccaurea javanica*	42.03	*Baccaurea javanica*	11.31
Knema sp. 1	15.69	*Mallotus* sp.1	19.87	*Eugenia* sp.5	9.50
Mallotus sp. 1	15.46	*Knema* sp.1	16.74	*Mallotus* sp.1	7.13
Baccaurea sumatrana	15.01	*Canarium megalanthum*	14.95	*Phaenathus* sp.2	7.00
Artocarpus heterophillus	14.31	*Horsfieldia* sp.2	12.00	*Anisophyllea disticha*	6.21
Eugenia grandis	11.87	*Durio* sp.1	11.23	*Alangium ridleyi*	5.87
Diospyros ellipticifolia	11.10	*Baccaurea sumatrana*	8.42	*Baccaurea sumatrana*	5.87
Bhesa paniculata	9.15	*Drypetes* sp.1	6.35	*Horsfieldia* sp.2	5.53
Shorea ovalis	8.68	*Santiria* sp.1	5.66	*Knema* sp.1	4.74
Canarium megalanthum	8.32	*Ixora* sp.	5.44	*Eugenia grandis*	4.63
Shorea pauciflora King	8.18	*Dipterocarpus* sp.	4.19	*Canarium megalanthum*	3.95
(Kangduk)	7.30	*Xanthophyllum* sp.2	4.19	*Psychoria* sp.	3.95
Dillenia excelsa	5.56	*Baccaurea* sp.1	4.04	*Diospyros ellipticifolia*	3.84
(Sipululuituet)	5.12	*Garcinia* sp.1	3.84	*Xanthophyllum* sp.2	3.63
Durio sp.1	5.07	*Diospyros ellipticifolia*	3.84	*Santiria* sp.2	3.50
Horsfieldia sp.2	5.04	*Aglaia (korthalsii Miq. ?)*	3.79	*Bridelia* sp.1	3.39
Pometia pinnata	4.37	*Vatica* sp.2	3.79	*Antidesma* sp.1	3.39
Gymnocranthera paniculata	4.35	*Litsea* sp.1	3.73	*Disoxylum* sp.1	3.16
Baccaurea sp.3	4.27	*Bhesa paniculata Arn.*	3.70	*Swintonia* sp.1	3.16
Actinodaphne sp.3	4.16	*Callophyllum saulatri*	3.70	*Artocarpus* sp.3	3.16
Madhuca sp.	3.43	*Goniothalamus* sp.	3.68	*Artocarpus* sp.4	3.16
Pentace floribunda King	3.13	*Aporosa benthamiana*	3.59	*Excoecaria* sp.	3.16
Caralia ceriifolia	3.08	*Eugenia grandis*	3.58	*Mangifera* sp	3.16
(Toingetngetet)	3.04	*Eugenia* sp.7	3.56	*Phaenathus* sp.1	3.05
Eugenia sp.7	3.03	(Sipuluituet)	1.82	*Bridelia stipularis*	3.05
Dipterocarpus sp.	3.01	*Gironiera subequalis*	1.82	(Sipululuituet)	2.71

Contd...

Appendix Table 1. Continued

dbh ≥ 20cm Species	IVI	dbh = 10 - 20 cm Species	IVI	dbh < 10 cm Species	IVI
Horsfieldia irya	3.00	*Cinnamomum iners Bl.*	1.81	*Callophyllum saulatri*	2.37
Litsea sp.6	2.96	*Eugenia* sp.2	1.80	*Aegiceros corniculatum*	2.37
Artocarpus elasticus	2.79	*Drypetes* sp.2	1.79	*Semecarpus* sp.	2.37
Vatica sp.1	2.52	*Pometia pinnata*	1.79	*Santiria* sp.1	2.15
Baccaurea sp.1	2.32	*Durio lowianus*	1.78	*Garcinia* sp.2	1.92
Baccaurea javanica	2.31	*Maduca* sp.	1.76	*Baccaurea* sp.1	1.92
Artocarpus sp.1	2.13	(Magritsijokjok)	1.75	*Ficus* sp.2	1.92
Fagraea sp.	2.00	*Ficus variegata Bl.*	1.75	*Eugenia* sp.4	1.92
Baccaurea deflexa	2.00	*Nauclea* sp.2	1.75	*Diospyros bornensis*	1.92
Litsea sp.7	1.96	*Dillenia excelsa*	1.74	*Aglaia* sp.1	1.58
Camnosperma auriculatum	1.85	*Phaenathus* sp.3	1.74	*Drypetes* sp.2	1.58
Canarium sp.1	1.83	*Quercus* sp.	1.73	*Garcinia* sp.1	1.58
Endospermum malaccense	1.71	*Santiria* sp.2	1.73	*Shorea ovalis*	1.58
Palaquium (obovatum ?)	1.63	*Evodia macrocarpa*	1.72	*Randia macrophylla*	1.58
Strombosia javanica Bl.	1.56	*Litsea* sp.7	1.71	*Rhodamnia* sp.	1.58
Artocarpus sp.4	1.52	*Nephelium* sp.	1.71	*Durio* sp.1	1.58
(Mangritsijokjok)	1.45	*Artocarpus* sp.1	1.70	*Xanthophyllum* sp.1	1.58
Aglaia sp.2	1.40	*Pentace floribunda*	1.70	(Tepek)	1.58
Evodia macrocarpa King	1.39	Artocarpus sp.3	1.70	*Artocarpus heterophyllus*	1.47
Ficus variegata	1.36	*Alangium ridleyi*	1.69	*Pentace floribunda*	1.13
Actinodaphne sp.2	1.36	Aporosa sp.1	1.69	*Dipterocarpus* sp.	1.13
Rhodamnia cinerea	1.36	*Gymnocranthera paniculata*	1.68	*Elaeocarpus petiolatus*	1.13
Vatica sp.2	1.33	*Rhodamnia cinerea*	1.68	*Gymnocranthera paniculata*	0.79
Nephelium sp.	1.32	*(Enau)*	1.67	*Polyalthia* sp.1	0.79
Saurauia sp.1	1.31	*Caralia ceriifolia Ridl.*	1.67	*Nephelium* sp.	0.79
Litsea sp.1	1.31	*Aglaia* sp.1	1.66	*Litsea* sp.1	0.79
Litsea sp.5	1.02	*Horsfieldia irya*	1.66	*Calophyllum depresinervosum*	0.79
Gonystylus sp.	0.95	*Pternadra* sp.	1.65	*Endospermum malaccense*	0.79
Pterospermum javanicum	0.95	*Diospyros polyalthoides*	1.65	*Myristica maxima* Warb.	0.79
Myristica maxima	0.90	*Urophyllum griffithianum*	1.65	(Kangduk)	0.79
Octomeles sumatrana	0.84			*Bhesa paniculata*	0.79
Scaphium sp.	0.82			*Eugenia* sp.1	0.79
Aglaia sp.1	0.74			*Goniothalamus* sp.	0.79
Artocarpus sp.2	0.70			*Ixora* sp.	0.79
Alangium ridleyi	0.68			(Magritsijokjok)	0.79
Eugenia sp.8	0.68			*Eugenia filiformis*	0.79
Garcinia nervosa	0.68			*Baccaurea* sp.3	0.79
Astronia sp.1	0.67			*Eugenia* sp.2	0.79
Disoxylum sp.3	0.67			*Garcinia nervosa*	0.79
Diospyros buxifolia	0.66			*Dillenia indica* L.	0.79
Xanthophyllum sp.1	0.66			*Eugenia* sp.3	0.79
Aporosa sp.1	0.66			*Horsfieldia irya*	0.79

Contd...

Appendix Table 1. Continued

dbh ≥ 20cm		dbh = 10 - 20 cm		dbh < 10 cm	
Species	IVI	Species	IVI	Species	IVI
Eugenia filiformis	0.65			*Bridelia* sp.2	0.79
(Puilut)	0.65			*Litsea* sp.6	0.79
Callophyllum saulatri	0.65			*Litsea* sp.7	0.79
Mangifera sp.3	0.65			*Baccaurea deflexa*	0.79
Phaenathus sp.2	0.65			*Polyalthia* sp.2	0.79
(Eneu)	0.65			*Aglaia (korthalsii Miq. ?)*	0.79
Quercus sp.	0.65			*Drypetes* sp.1	0.79
Vitex pubescens	0.65			*Phaenathus* sp.3	0.79
Litsea sp.4	0.65			*Ervatamia* sp.	0.79
Astronia specabilis	0.65			*Actinodaphne* sp.3	0.79
(Umankaleak)	0.65			*Vatica* sp.1	0.79
Mangifera sp.1	0.65			*Aglaia* sp.2	0.79
Drypetes sp.1	0.65			*Baccaurea* sp.4	0.79
Antidesma velutinosum	0.65			*Mallotus subpeltatus*	0.79
Xanthophyllum sp.2	0.65			*Eugenia* sp.7	0.79
Nauclea sp.1	0.65			*Radermachera gigantea*	0.79
Calophyllum javanicum	0.65			*Gironiera subequalis*	0.79
Santiria sp.2	0.65				
Ervatamia sp.	0.65				
Gironiera subequalis	0.65				
Baccaurea sp.2	0.65				
Garcinia forbesii	0.65				
Garcinia sp.1	0.65				
Aporosa benthamiana	0.65				