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Tree Diversity and Structure of Andaman Giant Evergreen Forests, India

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ABSTRACT: We investigated tree diversity in 'giant evergreen forest' of Andaman and Nicobar Islands, which falls within the Indo-Burma hot spot of biodiversity in the world. A one hectare square plot was established in sites Kalapahad (KP) and Macarthy Valley (MV) of Middle Andamans, in which all trees ≥ 30 cm girth at breast height (gbh) were enumerated. Tree diversity totaled 105 species that belonged to 63 genera and 49 families. Site MV harboured ~10% greater species richness than KP. Species diversity indices did not vary much between the two sites. In the two sites, there were 1311 individuals of trees (579 ha^{-1} in KP and 732 in MV). The stand basal area was nearly equal in both the sites (KP- 45.59 $m^2 ha^{-1}$; MV- 47.93 $m^2 ha^{-1}$). Thirteen tree species (12.38%) were strict endemics to Andamans. Ten species recorded are rare to the flora of these islands. The two sites are distinctly dominated by two different plant families; Dipterocarpaceae in KP and Myristicaceae in MV. Most of the species were common to central and lower region of Myanmar and Indian mainland. The forest stand structure exhibited a typical reverse-J shape, but site MV had double the density of stems in the lower tree size class than that of KP. The voluminous dipterocarps contributed more to the total above-ground live biomass. The need to preserve these species- and endemics- rich, fragile island forests, prioritized for biodiversity conservation, is emphasized.

KEY WORDS: Tropical rainforests, Andamans, Tree diversity, Forest structure, Dipterocarpaceae, Myristicaceae.

INTRODUCTION

Tremendous diversity in tropical tree species has long been a source of fascination and research. In tropics, India is among the few countries endowed with rainforests, in the Western Ghats and the North-east. More interestingly, in the north-eastern Indian Ocean 7170.69 km^2 of forest area (State Forest Report, 2003) are represented in the Andaman and Nicobar Islands (6˚45' to 13˚41' N and 92˚12' E to 93˚57' E), which are peaks of a submerged mountain hill range, arching from Myanmar in the north to Sumatra and Indonesia in the south (Saldanha, 1989). Dense forests, which constitute 86.93% of the total geographic area of the Andaman and Nicobar Islands are unique in plant species richness, many of them are local endemics; their existence and intactness are undoubtedly critical in preserving the world's biodiversity, as it also falls under one of the eight hottest hot spots of biodiversity in the world viz., the Indo-Burma (Myers et al., 2000). These forests contribute considerably to the stability of regional climate and harbor rich biodiversity, which has not been fully documented yet.

Quantitative inventories provide information on the diversity and structure of forest ecosystem. Tree species diversity in the tropics varies from place to place (Whitmore, 1998; Pitman et al., 2002). Ecological inventories have been carried out across tropics at the comparable scale of one hectare from several sites (Black et al., 1950; Uhl and Murphy, 1981; Valencia et al., 1994; Wattenberg and Breckle, 1995; Parthasarathy and Karthikeyan, 1997; Wright et al., 1997; Proctor et al., 1998; Small et al., 2004) for decades, but few studies are available on selected forest types from Andamans (Lal, 1990; Tilak, 1993; Padalia, 2004). The present research is aimed to investigate tree diversity and forest structure in hitherto unstudied and a unique forest type named Andaman giant evergreen forest (Type 1A/C1 of Champion and Seth, 1968) in Middle Andaman Island. Giant evergreen forest is one of the most important and luxuriant of all vegetation types in Andaman and Nicobar Islands. The canopy is characteristically formed by the giant evergreen trees which attain heights of 40-70 m tallness, occupied by species of *Dipterocarpus*, *Calophyllum*, *Artocarpus* and *Amoora*, mostly occurring in deep alluvial soil near the banks of large streams and creeks

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(Parkinson, 1923). The present study deals with the forest structure and floristic composition of this unique and unstudied forest type. We also plotted species-area curve to determine the rate at which additional species are found in these islands. Further, we calculated above-ground live biomass (AGB), as AGB comprises roughly 80% of total live biomass (Steininger, 2000) and estimation of biomass density, directly from forest inventory data provides more reliable information on quantity of forest resources (Brown, 1997). Biomass estimates for Andaman forests sites are needed because they are increasingly subjected to forest fragmentation and affected by natural calamities such as, cyclone and tsunami and reliable biomass estimates for these tropical forests are hardly available.

MATERIALS AND METHODS

Study area

Based on vegetation structure and varying soil types and floristic composition, the forests of Andamans are classified into twelve types - Giant evergreen forests (1A/C1), Andaman tropical evergreen forest (1A/C2), Southern hilltop evergreen forests (1A/C3), Andaman semi-evergreen forests (2A/C1), Andaman moist deciduous forests (3A/C1), Andaman secondary moist deciduous forests (3A/C1/2S1), Littoral forests (4A/L1), Mangrove (Tidal swamp) forests (4B/TS2), Brackish water mixed forests (4B/TS4), Sub-mountain hill valley swamp forests(4C/FS2), Cane brakes (1/E1) and Wet bamboo brakes (1/E2) (Champion and Seth, 1968).

Our study sites, the giant evergreen forests, are composed of dense canopy of trees in middle and upper layers, lower storey with palms of *Licuala* and *Areca* species and a typical understorey of herbs and shrubs (mostly gingers), apart from tall, lofty trees of mainly dipterocarps occupying the emergent layer.

The soil cover is rather thin, varying from 2 m to 5 m, mostly alluvial, mild to moderately acidic with high humus on top. The climate is wet tropical and oceanic with rainfall from both the south-west and north-east monsoon winds. The annual average rainfall is 3200 mm, with mean relative humidity of 79%. The mean maximum temperature is 30.2˚C and mean minimum temperature is 23.8˚C. Present work was carried out in giant evergreen forest of Kalapahad (KP) and Macarthy Valley (MV) in Middle Andamans (12˚5' and 12˚50' N; 92˚40' E and 93˚50' E; Fig. 1). Kalapahad (178 ha) is an isolated, small, human un-inhabited island, whereas Macarthy Valley (95 ha) is a part of larger island mass in Middle Andaman island with human settlements located 3 km away from the study site.

Field sampling

Two one-ha square plots were established, one each in site KP and MV. Field work on quantitative inventory was carried out in April-June 2006. Each 1-ha plot was divided into one hundred 10 m ×10 m quadrats and was surveyed for all tress ≥ 30 cm girth at breast height (gbh) to determine tree species composition and forest structure. Borders of the study plots were marked to facilitate future re-census. Girth for all trees was measured at 1.3 m from the ground level and above the buttresses for those with tall buttresses. In the case of trees with multiple stems, each stem at gbh was measured separately and added to obtain basal area of the single individual. Voucher specimens were collected for all trees which were accessible, and for few inaccessible specimens, leaf litter and bark samples were collected meticulously for species recognition and lodged in the herbarium of Department of Ecology and Environmental Sciences, Pondicherry University. The unidentified species were treated as distinct morpho-species, but their families could not be ascertained.

Data analysis

The Shannon (H') and Simpson (1/D) indices (as in Magurran, 2004) were calculated for species diversity. Species richness was determined directly by totaling the number of species in each plot. The importance value index (IVI) was used to understand a species' share in the tree community (as per Cottam and Curtis, 1956). IVI of a species is defined as the sum of its relative dominance (RD_m), its relative density (RD) and its relative frequency (RF), which is calculated as follows:

RD_m = Total basal area for a species/total basal area for all species × 100

RD = Number of individuals of a species/total number of all individuals × 100

RF = Frequency of a species/sum frequencies of all species × 100

Thus, Importance value index = RD_m + RD + RF

Species accumulation curve was plotted against area for both the plots. After randomizing the samples for 50 times using EstimateS (Version 6.0b1, 2000), the Chao1 species number generated for the 0.1 ha subplots (100 m × 10 m) were used to raise the species accumulation curve.

Above-ground live biomass was estimated using the equation $Y = 21.297 - 6.953\ (D) + 0.740\ (D^2)$, where Y is biomass per tree in kg and D is diameter at breast height (dbh) in cm, from Brown (1997) for tropical wet climate zone.

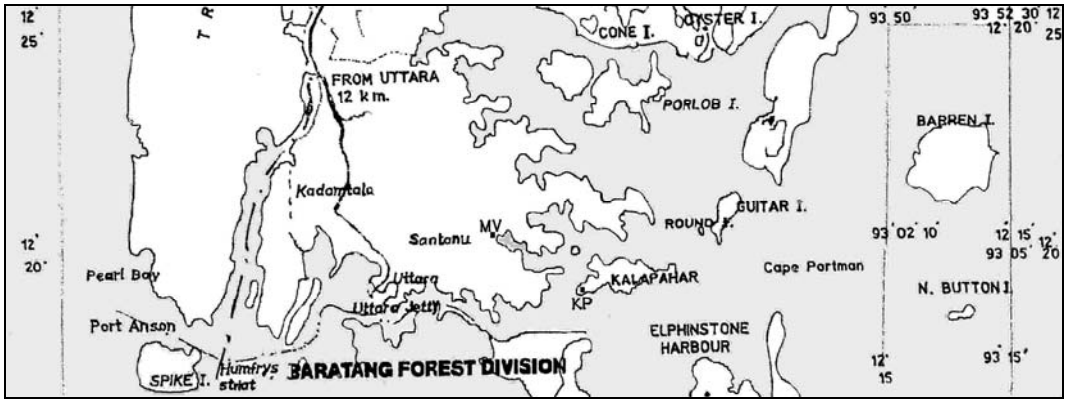

Fig. 1. Map of Andaman Islands, indicating the study sites KP and MV in Middle Andamans (Source: ANI Forest Department).

RESULTS

Species diversity

Tree diversity inventory (stems ≥ 30 cm gbh) of the two sites KP and MV in Andaman giant evergreen forests yielded a total of 105 species that belonged to 63 genera and 49 families. Tree species richness of the sites KP and MV were 68 and 75, respectively. Site KP had a total of 51 genera and 31 families, whereas in site MV, there were 52 genera and 32 families. Tree species richness was ~10% greater in site MV than KP. Forty-two species (40%) were shared by both the sites. Of the total 105 species, 29 species were exclusive to site KP and 36 species were exclusive to site MV. The Shannon andSimpson diversity indices were 3.14 & 0.07 and 3.05 & 0.12, respectively for site KP and MV (Table 1). The Evenness indices value of Simpson was 0.18 in site KP and 0.11 in site MV.

Table 1. Summary of tree diversity inventories (stems ≥30 cm gbh) in two 1- ha plots of Andaman giant evergreen forest at sites Kalapahad (KP) and Macarthy Valley (MV) in Middle Andamans, India.

Variable	KP	MV
Species richness	68	75
No. of genera	51	52
No. of families	31	32
Diversity indices		
Shannon	3.14	3.05
Simpson (D)	0.07	0.12
Evenness Index (Simpson)	0.18	0.11
Tree density (no. ha^{-1})	579	732
Stand basal area (m^2 ha^{-1})	45.25	47.51

Density and Basal area

There were 1311 individuals of trees in the two plots, 579 trees ha^{-1} in site KP and 732 trees ha^{-1} in site MV. The stand basal area was 45.59 m^2 ha^{-1} and 47.93 m^2 ha^{-1} in KP and MV, respectively. Abundance of the 105 species varied considerably between the two sites (Appendix 1). A few species contributed greater proportion of the abundance in two sites. *Dipterocarpus incanus* (15.71%, of all stems) was the most abundant species in site KP, whereas the endemic species of Myristicaceae, *Knema andamanica* (31.83%, of all stems) was abundant in site MV. Species with more than 10 individuals ha^{-1}, *Dipterocarpus incanus, D. andamanicus*, *Knema andamanica*, *Terminalia procera*, *T. catappa*, *D. kerrii*, *Garcinia cadelliana*, *Ficus racemosa*, *F. magnoliifolia*, *Planchonia valida*, *Artocarpus chaplasha* and *Baccaurea ramiflora* accounted for 74.26% of tree numbers in site KP; and *Knema andamanica*, *Dipterocarpus kerrii*, *D. costatus*, *Pometia pinnata*, *Ficus magnoliifolia*, *D. incanus*, *Baccaurea ramiflora*, *Pajanelia longifolia*, *D. andamanicus*, *Canarium euphyllum*, *Artocarpus chaplasha*, *Diospyros undulata*, *Planchonia valida* and *Rothmannia schoemannii* contributed 76.63% of total abundance in MV. A total of 36 species were just represented by single individuals.

Species accumulation curve

The species accumulation curve (Fig. 2) showed an increasing trend and the number of species has not saturated at the 1-ha scale in both the sites. The slope of species-area curve in site KP is steeper than site MV. There is a gradual addition of species until the last block in both the sites indicating the site heterogeneity within the giant evergreen forest. This reveals that 1-ha sampling size in this forest type is inadequate to document all the tree species of the two study sites.

Importance Value Index

The top ten species of each site contributed 69.39% and 64.43% of importance value index at site KP and MV, respectively (Table 2). In terms of basal area, these species accounted for 76.83% and 69.54%

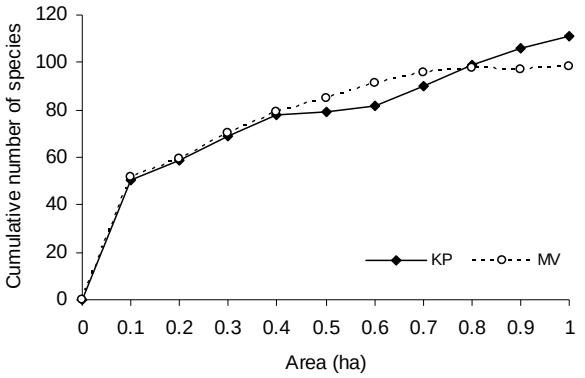

Fig. 2. Species-area curves for the two Andaman giant evergreen forest sites Kalapahad (KP) and Macarthy Valley (MV) of Middle Andamans.

Table 2. Species importance value (IVI) for top ten species in sites KP and MV.

Species	Family	IVI
KP		
Dipterocarpus incanu	Dipterocarpaceae	43.21
Dipterocarpus andamanicus	Dipterocarpaceae	38.48
Knema andamanica	Myristicaceae	30.13
Terminalia procera	Combretaceae	26.55
Terminalia catappa	Combretaceae	20.87
Dipterocarpus kerrii	Dipterocarpaceae	13.01
Ficus racemosa	Moraceae	11.62
Artocarpus chaplasha	Moraceae	8.68
Garcinia cadelliana	Clusiaceae	8.61
Planchonia valida	Barringtoniaceae	7.01
Total (& % for top 10 species)		208.17 (69.39%)
MV		
Knema andamanica	Myristicaceae	59.46
Dipterocarpus kerrii	Dipterocarpaceae	31.10
Dipterocapus costatus	Dipterocarpaceae	22.36
Pometia pinnata	Sapindaceae	15.31
Pajanelia longifolia	Bignoniaceae	11.86
Ficus magnoliifolia	Moaraceae	11.61
Canarium euphyllum	Burseraceae	11.17
Artocarpus chaplasha	Moaraceae	11.07
Dipterocarpus incanus	Dipterocarpaceae	10.59
Baccaurea ramiflora	Euphorbiaceae	8.78
Total (& % for top 10 species)		193.30 (64.43%)

of the total basal area in site KP and MV, respectively. The most important species based on IVI scores out of 300 were, *D. incanus* (43.21) and *D. andamanicus* (38.48) in KP and *K. andamanica* (59.46) and *D. kerrii* (31.10) in site MV.

Plant families

A total of 49 families were represented in the two 1-ha plots, of which 24 families were common to both the sites; nine families were exclusive to site KP and 14 were exclusive to site MV (Table 3). The family richness was 31 in site KP and 32 in site MV. The most speciose family was Euphorbiaceae with a total of 7 species in MV and 4 species in KP. Moraceae with 3 genera and 6 species ranked second in the stand. Anacardiaceae, Rubiaceae and Meliaceae with 5 species each were equally represented in both the sites (Table 3). Based on the family importance value (FIV), Dipterocarpaceae was the most important family inboth sites, with an FIV of 75.70 and 57.38 in site KP and MV, respectively, followed by Combretaceae (39.78) in site KP and Myristicaceae (50.11) in site MV.

The dominance of Dipterocarps and Myristicas

The two study sites were distinctly dominated by two different families- site KP by Dipterocarpaceae and MV by Myristicaceae. The Dipterocarpaceae contributed 35.4% and 19.4% of forest stand density and 34.39% and 36.62% of stand basal area in site KP and MV, respectively. Whereas the Myristicaceae accounted for 14.33 and 33.46% of stand density and 4.35 and 12.98% of basal area in sites KP and MV, respectively.

Five species of dipterocarps were enumerated in the study sites- *Dipterocarpus andamanicus, D. griffithii, D. incanus, D. costatus* and *D. kerrii*. Of these five species, *D. griffithii* was exclusive to site KP, but absent in MV, while *D. costatus* occurred only in site MV and notably absent in KP. The girth class distribution of dipterocarps exhibited a reverse J-shaped curve, but flat for *D. griffithii* and *D. kerrii* (Fig. 3).

The population structure of three dominant species of Myristicaceae was studied. In terms of total forest stand, Myristicaceae dominated the site MV forming 33.5% of it. The occurrence of *Myristica andamanica* in site MV and its absence in site KP is notable. The tree size class distribution of Myristicas revealed that, the species had a healthy population (Fig. 4). *Horsfieldia glabra* and *Knema andamanica* were represented mainly in the medium-size class, occupying the middle storey of the giant evergreen forest with their maximum recorded girth threshold of 60-90 cm. Whereas, the girth class distribution of *Myristica andamanica* was more or less reverse J-shaped, but for 120-150 cm size class.

Forest structure

The forest stand structure based on tree girth classes and basal area distribution was studied. The chart revealed that the number of individuals across girth classes in both sites decreased from the smaller to larger size classes (Fig. 5). It exhibited a reverse J-pattern, which indicates a healthy recruitment of the individuals in the sites. Based on

Table 3. Family diversity, density (stems ha^{-1}) and family importance value (FIV) in two sites (KP and MV) of giant evergreen forest of Middle Andaman Island.

Family	Species richness		Genera		Density			FIV	
	KP	MV	KP	MV	KP	MV	Total	KP	MV
Dipterocarpaceae	4	4	1	1	205	142	347	76.51	58.75
Myristicaceae	2	3	2	3	83	243	326	21.94	51.27
Moraceae	6	3	3	2	45	52	97	28.8	21.13
Combretaceae	3	1	1	1	66	2	68	40.25	1.90
Euphorbiaceae	4	7	4	6	14	40	54	10.04	19.82
Clusiaceae	2	3	2	2	26	13	39	10.7	7.33
Sapindaceae	2	1	2	1	5	34	39	4.33	11.18
Burseraceae	3	3	2	1	10	23	33	8.32	15.52
Ebenaceae	3	4	1	1	7	22	29	6.37	9.45
Barringtoniaceae	1	1	1	1	15	14	29	5.40	4.72
Bignoniaceae	1	1	1	1	3	22	25	2.86	9.69
Anacardiaceae	5	3	5	2	17	7	24	12.59	5.85
Sterculiaceae	3	3	3	3	9	15	24	7.63	9.21
Rubiaceae	2	5	2	4	2	18	20	3.56	11.35
Meliaceae	4	5	2	4	4	13	17	7.08	10.95
Bombacaceae	1	1	1	1	9	6	15	4.91	2.69
Annonaceae	1	3	1	3	1	12	13	1.75	6.63
Lythraceae	1	1	1	1	9	3	12	5.33	2.42
Papilionaceae	1	1	1	1	8	2	10	5.95	5.16
Arecaceae	2	0	2	0	9	0	9	4.87	0
Myrtaceae	1	1	1	1	2	7	9	1.93	3.25
Verbenaceae	1	1	1	1	5	4	9	4.32	3.69
Xanthophyllaceae	1	1	1	1	1	6	7	1.85	2.45
Sapotaceae	2	1	2	1	5	1	6	5.28	1.65
Mimosaceae	0	1	0	1	0	6	6	0	6.49
Ternstroemiaceae	0	1	0	1	0	5	5	0	2.66
Rutaceae	2	0	2	0	4	0	4	4.64	0
Loganiaceae	1	1	1	1	3	1	4	2.28	1.70
Flacourtiaceae	0	2	0	1	0	2	2	0	3.92
Apocynaceae	0	1	0	1	0	2	2	0	1.79
Datiscaceae	1	1	1	1	1	1	2	1.98	2.06
Elaeocarpaceae	1	1	1	1	1	1	2	1.85	1.84
Lauraceae	1	0	1	0	2	0	2	2.27	0
Ulmaceae	1	0	1	0	2	0	2	2.64	0
Diachapetalaceae	0	1	0	1	0	1	1	0	1.65
Rosaceae	0	1	0	1	0	1	1	0	1.84
Tiliaceae	1	0	1	0	1	0	1	1.75	0

the forest structural analysis (Brunig, 1974; Proctor et al., 1983 and Newbery, 1991), the size class distribution of this forest were classified under four distinct categories, namely, smaller (30-60 cm gbh); medium (60-150 cm gbh); large (150-300 cm gbh) and largest (300-390 cm gbh). The forest stand density in the smaller tree girth class was almost half the number in site KP than that of MV. The trend in medium and larger size classes did not vary much for both the sites. However, largest size class was not represented at all in site KP, but contributed 0.81% in site MV.

Above-ground Biomass

The total above-ground live biomass estimates of trees was 332.40 t ha^{-1} and 353.00 t ha^{-1} in sites KP and MV respectively. The voluminous trees of dipterocarps in the giant evergreen forest contributed bulk of the biomass (112.40 t ha^{-1}, KP and 118.44 t ha^{-1}, MV). Whereas, the dominant family Myristicaceae contributed much less (10.70 t ha^{-1}, KP and 39.19 t ha^{-1}, MV) to total biomass, although their abundance was much greater (Table 4).

DISCUSSION

The difference in tree species richness between the two study sites, was not much high (KP-68; MV-75), probably because of the proximity of the study sites. Dipterocarpaceae, which consisted mainly of upper canopy or emergent tree species, was the most dominant tree family in the studied sites with 26.4% of trees. The Myristicaceae, which mainly consists of lower to middle layer tree species, ranked second with 24.8% of trees and a pattern typical for most tropical rainforests of south-east Asia (Ashton, 1964; Proctor et al., 1983; Whitmore, 1984; Kochummen et al., 1990; Condit et al., 2000). The floristic composition of these forests has closer affinity with other tropical regions of south-east Asia.

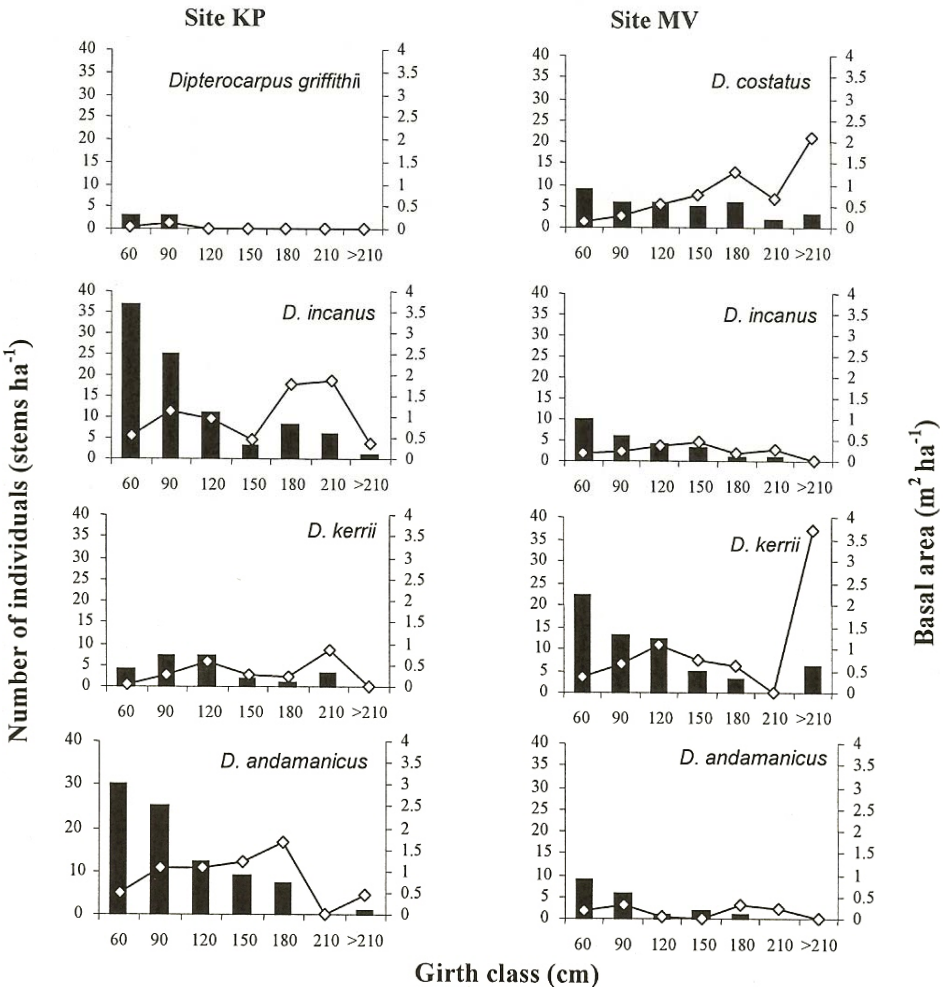

Fig. 3. Population structure of four *Dipterocarpus* species based on abundance (bars) and basal area (line), encountered in two sites of Andaman giant evergreen forests.

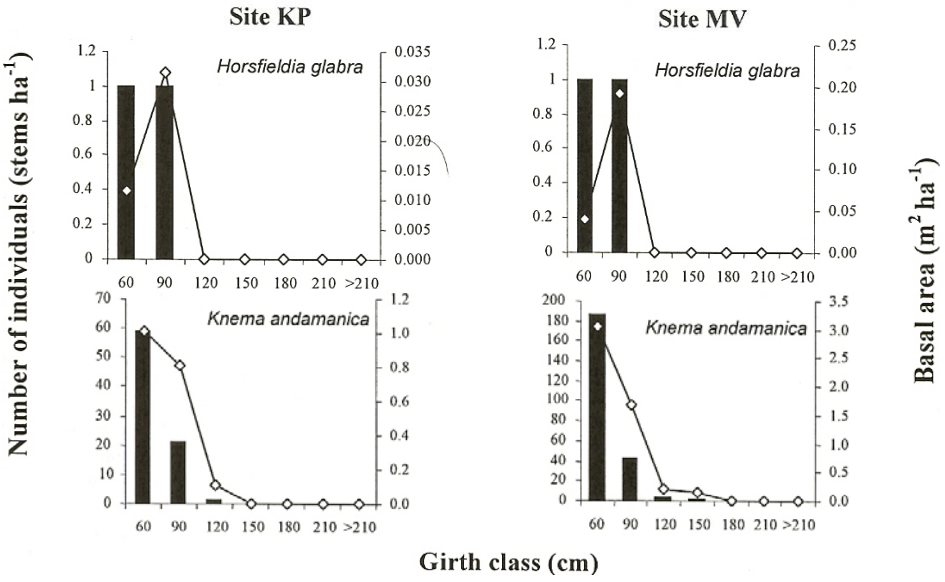

Fig. 4. Population structure of three Myristicaceae species based on abundance (bars) and basal area (line), encountered in two sites of Andaman giant evergreen forests.

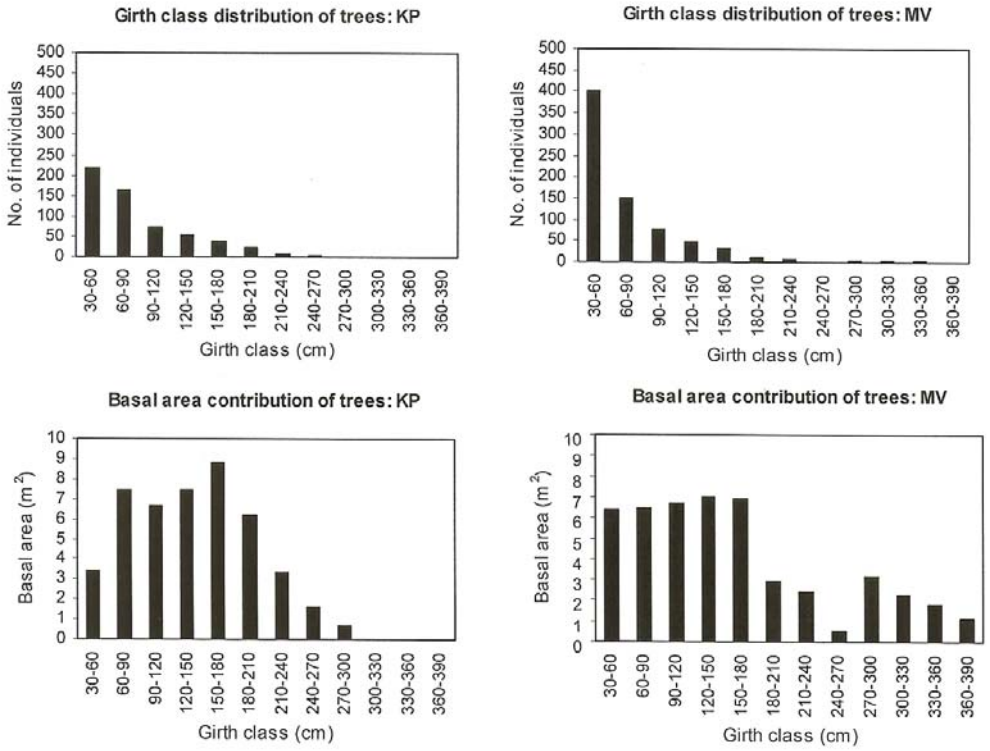

Fig. 5. Stand structure of trees (stems ≥ 30 cm gbh) based on girth class frequency and basal area contribution in sites KP and MV.

Table 4. Total AGB (t ha^{-1}) of trees (≥10 cm dbh) in studied sites and the share of two dominant families Dipterocarpaceae and Myristicaceae.

	Y = 21.297-6.953 (D) + 0.740 (D^2)
Sites	AGB
KP	332.40
Dipterocarpaceae	112.40
Myristicaceae	10.70
MV	353.00
Dipterocarpaceae	118.44
Myristicaceae	39.19

Y = Biomass per tree in kg, D = dbh in cm

This affinity is probably related to the fact that these islands are the sub-aerial expressions of a continuous ridge which connects the Arakan-Yoma range of western Myanmar to the festoon of islands south and west of Sumatra (Srinivasan, 1986). However, the diversity of dipterocarps in the studied sites is markedly poorer when compared to south-east Asian dipterocarp forests (Kartawinata et al., 1981; Manokaran, 1988; Manokaran et al., 1991; Newbery, 1992; Sist, 1996).

Both Shannon and Simpson (D) indices indicate that the diversity is higher in site KP than MV. The contributions of common and rare species to the diversities in two sites reveal that, there were more rare species (singleton + doubleton) in site MV (40) than KP (35); but evenness was more in KP than MV. Therefore Shannon index value which is influenced by evenness was more in site KP than MV.

Simpson index which is heavily weighted by dominance shows a higher value in site MV, because the most common species in site MV (*Knema andamanica*) accounts 32% of stem density, while the common species in site KP (*Dipterocarpus incanus*) accounted only for 16%.

Both the family and species richness were comparatively lower in site KP than MV, part of the explanation for lower diversity recorded in site KP can be related to the small size of this island (178 ha), as compared to site MV which is a part of larger island mass, and as such diversity is negatively related with the island size (Mc Arthur and Wilson, 1967). In addition, the slightly higher species richness in site MV can be assigned to the fact that, moderately or slightly disturbed tropical forests tend to support more number of species in comparison with a forest which is dense and undisturbed (Mishra et al., 2004).

In fact, the tree species richness of the studied sites is greater when compared to North Andaman (87 species; Tilak, 1993) and Little Andaman (84 and 73 species; Rasingam, 2007), whereas it is slightly less than South Andaman (110 species; Lal, 1990). The

degree of endemism in Andaman and Nicobar Islands is estimated as 18% of the total flora (Mathew, 1998). In our enumeration, a total of 22 tree species (21%) are endemic to Andaman and Nicobar Islands. Another unique feature of this floristic region is the striking geographical distribution of species between the Andaman group of islands and the Nicobar group (Mathew, 1998). Strikingly, the species of *Dipterocarpus* and *Pterocarpus* are confined to Andaman group of islands and do not occur in the Nicobar islands. Thirteen tree species (12.38%) are strict endemics of Andamans. Among the enumerated species, 25 species (~24%) occur in forests of Pegu and Tenasserim in central and lower Myanmar region. Seventeen per cent of species occur in Malaysia, followed by 11% each in Bangladesh and Sri Lanka. At least 21% species are common to Indian mainland. Ten species recorded, are taxonomically rare to the flora of these islands.

The most speciose family was Euphorbiaceae (7 species) and Moraceae (6 species) in site MV and KP respectively. Three families Rubiaceae, Meliaceae and Anacardiaceae in the studied sites were represented by 5 species each, and the remaining families were represented by fewer species. Pires (1978) reported that Leguminosae and Lecythidaceae were the abundant families in Terra firme forest, Brazil. In Chamela Jalisco, Lott et al. (1987) reported Leguminosae, Euphorbiaceae and Bignoniaceae as predominant families. In Malaysia, Ho et al. (1987) recorded Euphorbiaceae, Dipterocarpaceae, Leguminosae, Meliaceae and Olacaceae as dominant families. Swan (1988) in Singapore found Euphorbiaceae with greatest density and number of species and Dipterocarpaceae contributing to greatest basal area. Whereas Newbery et al. (1992) in Danum Valley reported Euphorbiaceae and Dipterocarpaceae as predominant in terms of density and Lauraceae, Euphorbiaceae, Meliaceae were the most species-rich families. Thus, the family representation of these study sites are in consistent with other closer tropical forests.

Of the five species of dipterocarps encountered, those with more individuals in small size classes reveal that the population structure is expanding, ensuring their stability. Whereas *D. griffithii* with just 6 individuals in one hectare plot that represented only in medium size classes, increases the concern of local extinction, subject to various human and natural disturbances. Although these forests are less diverse in dipterocarps as compared to other south-east Asian forests, trees of Dipterocarpaceae form an important layer in the giant evergreen forest as emergents.

In comparison with other tropical forests, the range of total above- ground live biomass of giant evergreen forests (332.40 t ha^{-1} in KP and 353.00 t ha^{-1} in MV) is notably lower than those of high and medium yield evergreen forests of Sri Lanka (435-530 t ha^{-1}; 365-470 t ha^{-1}; FAO/UNDP, 1969) and old-growth and logged dipterocarp forests in Philippines (370-520 t ha^{-1}; 300-370 t ha^{-1}; Philippine-German FRIP,1986-1988), but our values lie well within the range of mixed dipterocarp forests of Malaysia-Sarawak (325-385 t ha^{-1}; FAO,1973). However, these variations can be attributed to factors such as forest type, sampling intensity within the plot, inter-site variation, edaphic factors and annual rainfall, besides geographical location of forests (Mani and Parthasarathy, 2007).

CONCLUSION

Although these unique forests contain good stands of commercially valuable trees, stocking is variable. With ever increasing human population in these islands, pressure on forests for domestic needs, damage to forests in the form of selective felling and encroachment of forest land has increased substantially in recent times. In the light of high tree diversity and in particular the unique dipterocarp diversity and *Myristica* association of Andaman giant evergreen forests, effective conservation of Andaman group of islands, which is one of the centers of plant diversity and endemism in India, as well as being one of the eight hot spots of global biodiversity, is imminent. There is an urgent need to protect and preserve these important and fragile island forests in order to manage the sites, already prioritized for biodiversity conservation (Myers et al., 2000) before it's "too late".

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Appendix 1. List of tree species enumerated in two tropical rainforest sites at KP and MV, arranged in decreasing order of their total abundance.

Sl. no.	Species name	Family	KP	MV	Total
1	*Knema andamanica* (Warb.) de Wilde * [A]	Myristicaceae	81	233	314
2	*Dipterocarpus incanus* Roxb.	Dipterocarpaceae	91	25	116
3	*Dipterocarpus andamanicus* (King) Tewary & Sarkar *	Dipterocarpaceae	84	19	103
4	*Dipterocarpus kerrii* King	Dipterocarpaceae	24	61	85
5	*Ficus magnoliifolia* Bl.	Moraceae	15	29	44
6	*Pometia pinnata* J. R. & G. Forst.	Sapindaceae	4	34	38
7	*Terminalia procera* Roxb. *	Combretaceae	36	2	38
8	*Dipterocapus costatus* Gaertn.f.	Dipterocarpaceae	-	37	37
9	*Baccaurea ramiflora* Lour.	Euphorbiaceae	10	24	34
10	*Planchonia valida* (Bl.) Bl.	Barringtoniaceae	15	14	29
11	*Terminalia catappa* L.	Combretaceae	29	-	29
12	*Artocarpus chaplasha* Roxb.	Moraceae	10	17	27
13	*Garcinia cadelliana* King * [A]	Clusiaceae	18	9	27
14	*Pajanelia longifolia* (Willd.) K.Sch.	Bignoniaceae	3	22	25
15	*Ficus racemosa* Roxb.	Moraceae	17	6	23
16	*Canarium euphyllum* Kurz	Burseraceae	4	17	21
17	*Diospyros undulata* Wall.ex G. Don	Ebenaceae	1	17	18
18	*Bombax insigne* Wall. * [A]	Bombacaceae	9	6	15
19	*Lagerstroemia hypoleuca* Kurz * [A]	Lythraceae	9	3	12
20	*Pterospermum acerifolium* (L.) Willd.	Sterculiaceae	3	9	12
21	*Rothmannia schoemannii* (T. & B.) Tirveng.	Rubiaceae	-	12	12
22	*Calophyllum spectabile* Willd.	Clusiaceae	8	3	11
23	*Semecarpus kurzii* Engler *	Anacardiaceae	8	3	11
24	*Canarium* sp.	Burseraceae	5	5	10
25	*Goniothalamus macranthus* (Kurz) Boerl. *	Annonaceae	1	9	10
26	*Pterocarpus dalbargioides* Roxb. * [A]	Papilionaceae	8	2	10
27	*Dysoxylum andamanicum* King * [A]	Meliaceae	1	8	9
28	*Pterocymbium tinctorium* (Blanco) Merr.	Sterculiaceae	5	4	9
29	*Vitex diversifolia* Kurz * [A]	Verbenaceae	5	4	9
30	*Myristica andamanica* Hk.f. *	Myristicaceae	-	8	8
31	*Endospermum malaccense* Benth. ex Muell.- Arg.	Euphorbiaceae	-	7	7
32	*Xanthophyllum andamanicum* King * [A]	Xanthophyllaceae	1	6	7
33	*Archindendron monadelphum* Roxb. *	Mimosaceae	-	6	6
34	*Areca triandra* Roxb.	Arecaceae	6	-	6
35	*Dipterocarpus griffithii* Miq.	Dipterocarpaceae	6	-	6
36	*Syzygium cymosum* (Lamk.) DC.	Myrtaceae	-	6	6
37	*Ternstroemia wallichiana* (Griff.) Engler	Ternstroemiaceae	-	5	5
38	*Diospyros multibracteata* Wall.ex G. Don	Ebenaceae	4	-	4
39	*Drypetes longifolia* (Bl.) Pax. & Hoffm.	Euphorbiaceae	2	2	4
40	*Fagraea racemosa* Jack. ex. Wall.	Loganiaceae	3	1	4
41	*Horsfieldia glabra* (Bl.) Warb.	Myristicaceae	2	2	4
42	*Planchonella longipetiolatum* (King & Prain) H.J. Lam.	Sapotaceae	4	-	4
43	*Cleistanthus myrianthus* (Hassk.) Kurz	Euphorbiaceae	-	3	3
44	*Diospyros andamanica* (Kurz) Bakh.	Ebenaceae	2	1	3
45	*Drimycarpus racemosus* (Roxb.) Hk.f. ex March.	Anacardiaceae	3	-	3
46	*Evodia glabra* (Bl.) Bl.	Rutaceae	3	-	3
47	*Glochidion hirsutum* (Roxb.) Voigt	Euphorbiaceae	1	2	3
48	*Lannea coramandelica* (Houtt.) Merr.	Anacardiaceae	3	-	3
49	*Licuala spinosa* Wurmb.	Arecaceae	3	-	3
50	*Mangifera comptosperma* Pierre	Anacardiaceae	2	1	3
51	*Semecarpus prainii* King	Anacardiaceae	-	3	3
52	*Sterculia villosa* Roxb.	Sterculiaceae	1	2	3
53	*Syzygium* sp.1	Myrtaceae	2	1	3
54	Unidentified 7		-	3	3
55	*Neolamarckia cadamba* (Roxb.)	Rubiaceae	-	2	2
56	*Aphananthe cuspidata* (Bl.) Planch.	Ulmaceae	2	-	2
57	*Canthium glabrum* Bl.	Rubiaceae	1	1	2
58	*Dehaasia kurzii* King	Lauraceae	2	-	2
59	*Diospyros oocarpa* Thw. H.	Ebenaceae	-	2	2
60	*Diospyros pyrrhocarpa* Miq. var. *andamanica* Kurz	Ebenaceae	-	2	2
61	*Dysoxylum arborescens* (Bl.) Miq.	Meliaceae	1	1	2
62	*Elaeocarpus* sp.	Elaeocarpaceae	1	1	2
63	*Miliusa tectona* Hutchinson * [R]	Annonaceae	-	2	2
64	*Rothmannia pulcherima* (Kurz) Tirveng. * [A R]	Rubiaceae	-	2	2
65	*Tabernaemontana crispa* Roxb. * [A R]	Apocynaceae	-	2	2

Appendix 1. Continued.

Sl. no.	*Species name*	Family	KP	MV	Total
66	*Tetrameles nudiflora* R. Br.	Datiscaceae	1	1	2
67	Unidentified 9		-	2	2
68	Unidentified 3		2	-	2
69	*Walsura candollei* King * [A R]	Meliaceae	-	2	2
70	*Acronychia pedunculata* (L.) Miq.	Rutaceae	1	-	1
71	*Aglaia* sp.	Meliaceae	1	-	1
72	*Aglaia spectabilis* (Miq.) Jain & Bennet	Meliaceae	1	-	1
73	*Aglaia sylvestris* (M. Roem.) Spreng.	Meliaceae	-	1	1
74	*Aphanamixis polystachya* (Wall.) Parker	Meliaceae	-	1	1
75	*Aporusa dioica* (Roxb.) Muell. Arg.	Euphorbiaceae	-	1	1
76	*Artocarpus gomeziana* Wall.	Moraceae	1	-	1
77	*Berrya cordifolia* (Willd.) Burret	Tiliaceae	1	-	1
78	*Bouea oppositifolia* (Roxb.) Meissn.	Anacardiaceae	1	-	1
79	*Canarium denticulatum* Bl.	Burseraceae	-	1	1
80	*Casearia andamanica* King * [A R]	Flacourtiaceae	-	1	1
81	*Casearia* sp.	Flacourtiaceae	-	1	1
82	*Cleidion nitidum* Thw.	Euphorbiaceae	1	-	1
83	*Dichapetalum gelonioides* Roxb. * [A R]	Dichapetalaceae	-	1	1
84	*Diploknema butyracea* (Roxb.) H.J. Lam.	Sapotaceae	1	-	1
85	*Ficus curipes* Corner	Moraceae	1	-	1
86	*Garcinia cowa* Roxb.	Clusiaceae	-	1	1
87	*Garuga pinnata* Roxb.	Burseraceae	1	-	1
88	*Glochidion* sp.	Euphorbiaceae	-	1	1
89	*Harpullia cupanioides* Roxb.	Sapindaceae	1	-	1
90	*Palaquium semarum* H. J. Lam.	Sapotaceae	-	1	1
91	*Prunus javanica* (T. & B.) Miq.	Rosaceae	-	1	1
92	*Psueduvaria prainii* (King) Merr. * [R]	Annonaceae	-	1	1
93	*Psychotria adenophylla* Wall.	Rubiaceae	1	-	1
94	*Streblus asper* Lour.	Moraceae	1	-	1
95	*Tarenna weberaefolia* (Kurz) Balakr. * [R]	Rubiaceae	-	1	1
96	*Terminalia manii* King * [R]	Combretaceae	1	-	1
97	Unidentified 1		1	-	1
98	Unidentified 10		-	1	1
99	Unidentified 11		-	1	1
100	Unidentified 12		-	1	1
101	Unidentified 2		1	-	1
102	Unidentified 4		1	-	1
103	Unidentified 5		-	1	1
104	Unidentified 6		-	1	1
104	Unidentified 8		-	1	1
	Total		579	732	1311

(Unidentified 1-12 are distinct morpho-species)

* Endemic to Andaman and Nicobar Islands; [A] Strict endemic to Andamans; [R] Rare species

安達曼常綠巨木林之樹種多樣性與森林構造

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摘　　要

Andaman 及 Nicobar 島位於世界上重要的生物多樣性熱點上-印緬熱點之上。我們調查了位於 Andaman 及 Nicobar 島上之常綠巨木林的樹種多樣性。在中安達曼的 Kalapahad (KP) 及 Macarthy Valley (MV) 地區，我們分別建立了一公頃的樣區，並調查區內所有胸高圓周徑 (gbh)大於 (含) 30 公分的植株。兩區取樣共得 105 種，分屬 63 屬及 49 科。MV 樣區種樹高出 KP 區約 10%，然而兩區之間的樹種多樣性相差並不大。兩區共有 1311 棵植株 (KP：579 ha^{-1}；MV：732 ha^{-1})；樹木總斷面積值相近 (KP：45.59 $m^2 ha^{-1}$； MV：47.93 $m^2 ha^{-1}$)。調查所得之植株中有 13 種為安達曼之固有種 (佔 12.38%)；此外，有 10 個樹種為稀有植物。兩調查區的優勢科各有不同：KP 以龍腦香科為優勢而 MV 區則為肉荳蔻科。樣區內大部分物種為印緬大陸中南部之常見物種。樹木徑級結構呈現典型的反 J 型，但 MV 地區的小徑級樹木量為 KP 地區的兩倍。巨大的龍腦香科樹木對地面總生物量貢獻頗巨。本研究認為這些多樣性高、固有種繁多的脆弱島嶼森林的保育優先度應被重視。

關鍵詞：熱帶雨林、安達曼、樹種多樣性、森林構造、龍腦香科、肉荳蔻科。

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