Tropical Ecology **47**(2): 279-290, 2006 ISSN 0564-3295

www.tropecol.com

Analysis of the structure of Charmady reserve forest

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Abstract: The structural analysis of Charmady reserve forest, near Belthangady of Dakshina Kannada district, India was carried out in five belt transect plots covering 5000 m^2 area. Ninety nine species belonging to 84 genera and 47 families were recorded, of which 67 were tree species belonging to 37 families with ≥ 10 cm girth at breast height. The forest is of evergreen type with the dominance of members of Dipterocarpaceae (*Dipterocarpus indicus, Hopea ponga* and *Vateria indica*), Fabaceae (*Humboldtia brunonis*) and Rubiaceae (*Ixora brachiata*) etc. The forest floor was fully covered by the canopy without any openings. Regeneration was moderate as indicated by fewer seedlings in the forest. This may lead to the reduction of mature trees and hence change in the structure of the forest. The endemism was fairly high, with 37 species being endemic to the western ghats. Due to the overexploitation or opening up of the forest as a result of death of the individuals there may be threat to the endemic and endangered species in near future. The members of dipterocarps constitute more than half of the total basal area. The species diversity was more, however, only a few species had more number of individuals as compared to the other species.

Resumen: Se realizó un análisis estructural del bosque de la reserva Charmady, cerca de Belthangady en el distrito Dakshina Kannada, India, en cinco transectos de banda que cubrían un área de 5000 m^2. Se registraron 99 especies pertenecientes a 84 géneros y 47 familias; de ellas, 67 fueron especies arbóreas pertenecientes a 37 familias con ≥ 10 cm de perímetro a la altura del pecho. El bosque es de tipo perennifolio con dominancia de miembros de Dipterocarpaceae (*Dipterocarpus indicus*, *Hopea ponga* y *Vateria indica*), Fabaceae (*Humboldtia brunonis*) y Rubiaceae (*Ixora brachiata*), etc. El piso del bosque estuvo completamente cubierto por el dosel sin ninguna abertura. La regeneración fue moderada, de acuerdo con el bajo número de plántulas en el bosque. Esto podría conducir a una disminución en el número de árboles maduros y por lo tanto a un cambio en la estructura del bosque. El endemismo fue bastante alto, con 37 especies exclusivas de los Ghates Occidentales. Debido a la sobreexplotación o a la apertura del bosque como resultado de la muerte de los individuos, podría existir una amenaza en el futuro cercano a las especies endémicas y en riesgo. Las dipterocarpáceas constituyen más de la mitad del área basal total. La diversidad de especies fue mayor, sin embargo, sólo unas pocas especies tuvieron un mayor número de individuos en comparación con las otras especies.

Resumo: A análise estrutural da reserva florestal de Charmady, próximo de Belthangady do distrito de Dakshina Kannada, Índia for efectuada em cinco transeptos cobrindo uma área de 5000 m^2. Registaram-se noventa e nove espécies pertencendo a 84 géneros e 47 famílias, das quais 67 eram espécies arbóreas com um perímetro à altura do peito ≥ 10 cm pertencendo a 37 famílias: A floresta é do tipo sempreverde com dominância para os membros das Dipterocarpaceae (*Dipterocarpus indicus, Hopea ponga* e *Vateria indica*), Fabaceae

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(*Humboldtia brunonis*) e Rubiaceae (*Ixora brachiata*) etc. O solo da floresta encontrava-se totalmente coberto pelo copado sem quaisquer clareiras. A regeneração era moderada como indicado pela presença de poucas plântulas na floresta. Isto pode conduzir à redução de árvores maduras e assim mudar a estrutura da floresta. Os endemismos eram razoavelmente altos com uma presença de 37 espécies endémicas aos Ghats ocidentais. Devido à sobreexploração, ou clareamento da floresta em resultado da morte das árvores, pode haver, num futuro próximo, uma ameaça para as espécies endémicas, ou em risco. Os dipterocarpus contribuíam com mais de metade da área basal total da floresta. A diversidade específica era alta mas, contudo, só poucas espécies mostram um largo número de indivíduos.

Key words: Canopy, Charmady reserve forest, density, dipterocarps, endemism, regeneration and structure.

Introduction

The rain forests are most important areas of biodiversity with respect to the floristic richness. In India, the tropical rain forests are distributed in the western ghats, Andaman and Nicobar Islands and north-eastern Himalaya. The western ghats is one of the 25 hot spots of the world (Myers *et al*. 2000), with about 4500 species (1720 species and 135 infraspecific categories as endemic) of flowering plants (Ahmedullah & Nayar 1987; Shetty & Kaveriappa 1991). Nearly, one third of identified endemic species of the region are rare and threatened and several believed to be extinct (Shetty *et al*. 2002).

In Karnataka, Elouard *et al*. (1997) has investigated the structure and dynamics of moist evergreen forests of Kadamakal reserve in Kodagu district. Other studies on the structure of forests include those from the deciduous forests of Madhumalai in Nilgiris (Sukumar *et al*. 1992), the semi-evergreen forests of eastern ghats (Kadavul & Parthasarathy 1999), the wet evergreen forests of western ghats (Bonadie & Bacon 1999; Pascal & Pelissier 1996; Rai & Proctor 1986; Shivaprasad *et al*. 2002) and lowland dipterocarp forests of south-east Asia (Newbery *et al*. 1992; Newbery *et al*. 1999). Pascal (1988) conducted a detailed study on the ecology, structure, floristic composition and succession of wet evergreen forests of the western ghats of India. As there were no reports on the structure of Charmady reserve forest, the study was undertaken. The present study attempts to reveal the structure of dipterocarp forests, their density, basal area and canopy characters. An attempt has also been made to assess the endemism and status of regeneration of species.

Materials and methods

The study area in the Charmady forest range (13°25′N and 75°45′E) is situated 85 km away from Mangalore in Belthangady Taluk of Dakshina Kannada District of Karnataka. The forest is located at an elevation of 240 to 430 m above msl with steep slope in some areas (Fig. 1) and represents rainforests of western ghats. These forests correspond well with wet evergreen dipterocarp forests of Champion & Seth (1968). The vegetation is evergreen with the dominance of members of Dipterocarpaceae viz., *Dipterocarpus indicus, Hopea ponga* and *Vateria indica*. The soil is lateritic to sandy loam type and the forest receives an annual rainfall of 3800 mm, mainly during the southwest monsoon season i.e., June-November with a prolonged dry season of about 6 months. The mean annual temperature is 25°C.

Five belt transects (Fig. 1), each 250 m x 4 m (covering an area of 1000 m^2) were randomly laid in such a way so as to include locations with varying tree density. Each transect was divided into 25 plots of 10 m x 4 m. In each plot, all the individuals with girth ≥ 10 cm at breast height (gbh at 1.3 m) were identified by referring to Gamble (1921-1935) and Pascal & Ramesh (1987) and their gbh was recorded. The endemic plants

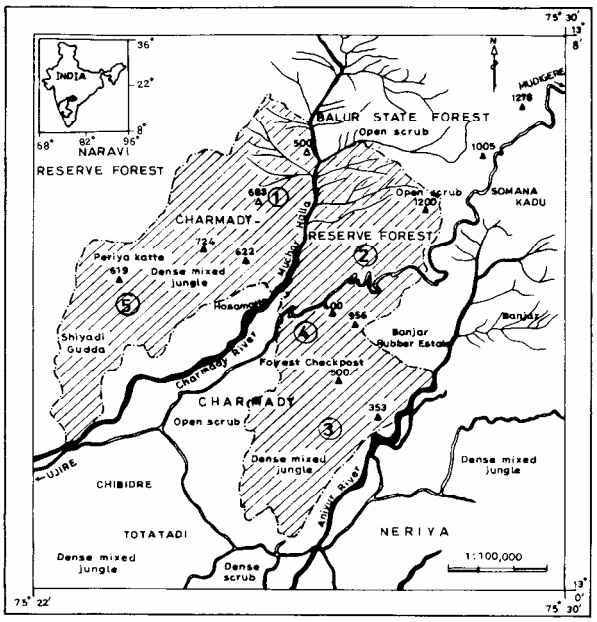

Fig. 1. Location map of Charmady reserve forest (Numbers 1-5 transects). Δ indicates the altitude above msl.

were listed by referring to Ahmedullah & Nayar (1987) and Pascal (1988). Height of the trees with gbh ≥ 10 cm in these transects was measured with the help of a clinometer. The associations of trees with other species including climbers, epiphytes and mosses were noted. Seedlings of all tree species in each plot were identified and counted to get an idea of status of regeneration. The voucher specimens of the plants bearing flowers/fruits have been deposited in the Herbarium of the Department of Applied Botany, Mangalore University, Karnataka, India.

In order to prepare a plan of slopes, rock, dead and fallen wood, strangling lianas etc. a plot of 20 x 50 m was chosen near one of the transects. Profile and canopy projection diagrams were prepared for the same plot. Profile diagram was prepared for 5 m x 50 m area within this plot.

The trees were divided into three sets based on their architecture, viz., set of the past (trees which were senescent and badly damaged), set of the present (trees which have attained their maximum size and reached maturity) and set of the future (trees which are still in rapid vegetative growth phase) following Halle *et al.* (1978). The set of the present was further divided into three structural ensembles (SE) based on height vs. gbh graph. The SE I represents the individuals of upper canopy, SE II of sub canopy and SE III of under canopy.

The number of individuals of different gbh classes and height classes were calculated. The density, basal area, frequency, Importance Value Index (IVI) and stand density for each species were calculated as follows (Pascal 1988). The density (D) of each species was recorded by counting the total number of individuals per plot. The frequency (F) was determined by using the following formula: F = (C_i/C) x 100, where, C_i = no. of plots in which the species is present and C = no. of plots studied. The basal area (BA) of different species was determined by the basal areas (at 1.3 m height) of their individuals. The relative frequency (rf) was determined by using the formula: rf = (F/f) x 100, where, F = frequency of the species and f = ΣF (sum of the frequency of all the species). Relative density (rD) was calculated by using the formula: rD = (D/N) x 100, where, D = number of individuals of species and N = total number of individuals in the plot. Relative dominance (rd) was calculated using the formula: rd = (BA/d) x 100, where, BA = sum of basal areas of the individuals of species and d = total basal area of the plot. Sum of the values of relative frequency, relative density and relative dominance gave the values of Importance Value Index (IVI) of a species. The Family Importance Value (FIV) index was calculated by adding the IVI for different species of the same family.

The floristic diversity was measured by using:

$$\text{Simpson's index, } D = 1 - \sum_{i=1}^{S} (n_i / N)^2$$

where, n_i = number of individuals of the species I;
N = total number of individuals in the plot;
S = number of species in the plot.

Shannon-Wiener's Index

$$(1)\quad H' = 3.3219\left(\log_1 N - 1/N \sum_{i=1}^{S} n_i \log_{10} n_i \right)$$

where, n_i , N and S are as for Simpson's index and 3.3219 is conversion factor from $\log_2$ to $\log_{10}$.

$$(2)\quad H_{max} = 3.3219 \log_{10} S$$

$$(3)\quad \text{Equitability } (E) = H'/H_{max}$$

Results

Floristic studies

A total of 99 species (84 genera and 47 families) were identified from sampling plots covering an area of 5000 m², of which 67 species had a GBH ≥ 10 cm. Dipterocarps were the dominant members of the forest (Appendix 1). The family Clusiaceae was represented by maximum number of six species belonging to four genera. Among genus, *Artocarpus, Garcinia* and *Syzygium* were represented by three species each. Deciduous species like *Aglaia lawii, Terminalia paniculata, T. chebula* etc. were less represented in the forest. Climbers observed in the study plots were *Acacia sinuata, Ancistrocladus heynianus, Combretum latifolium, Entada pusaetha, Jasminum malabaricum, Uvaria narum* etc. Most of the tree species in the sampling plots had lichens associated with them. Two species of *Calamus* viz., *C. prasinus* and *C. thwaitesii* were also abundant in this forest.

Of the total, 37 species (37.4%) were endemic to the western ghats. Among endemics *V. indica* exhibited a very high IVI (61.0), followed by *Hopea ponga* (IVI of 29.1) (Appendix 1). All the ten species having maximum IVI, nine were endemic to the western ghats. Three species each belonging to Arecaceae, Dipterocarpaceae, Moraceae, Myristicaceae and Rubiaceae were endemic.

Structural ensembles

The set of three structural ensembles (SE) are shown in Fig. 2. The trees of *Artocarpus hirsutus, Holigarna arnottiana, Hopea ponga, Kingiodendron pinnatum, Terminalia paniculata* and *V. indica* ranging between 11 and 24 m height, constituted the SE I, and together comprised about 8% of the total individuals. In the SE II, the dominants were *Aglaia lawii, Cinnamomum malabatrum, Elaeocarpus tuberculosis, Garcinia indica, G. morella, Gymnacranthera farquhariana, Knema attenuata, Myristica dactyloides, Polyalthia fragrans* and *Syzygium caryophyllatum* whose height ranged between 11 to 6 m, representing 23% of the total individuals. Moderate sized trees and shrubs like *Aporusa lindleyana, Atlantia* sp. *Humboldtia brunonis*, *Ixora brachiata, Memecylon terminale* and *Syzygium laetum* represented the SE III, with < 6 m tree height comprising 32% of the total individuals. The numbers of individuals of the set of the future were scarce in the forest indicating the poor regeneration of various species in the recent past. Very few individuals of the set of the past were seen in the plot, which indicates least human disturbance in the forest. However, the ground vegetation was dense by the presence of numerous seedlings of *Vateria indica, Humboldtia brunonis, Hopea ponga* and *Nothopegia racemosa*, herbs/shrubs and climbers like *Pteris* sp., *Piper* sp., *Psychotria dalzelli*.

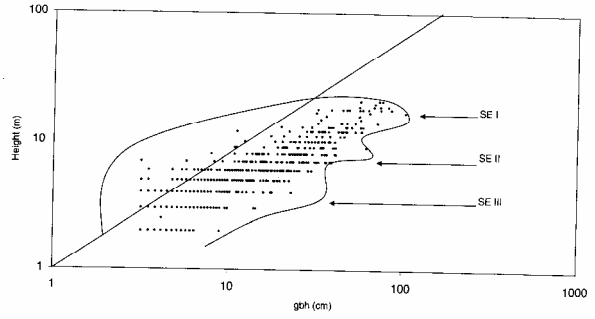

Fig. 2. Tree height vs. gbh graph of Charmady reserve forest; SE I = structural ensemble I; SE II = structural ensemble II; SE III = structural ensemble III.

Canopy characteristics

Reaching a height of 24 m, the canopy was thick and almost continuous with very few gaps. The vegetation was differentiated into three layers of which, top most and lower most layers were prominent and the middle layer with scattered tree species gives a rough idea of the layer.The emergents (the trees which grow beyond the canopy layer) were absent (Fig. 3). This was reflected by the height vs. gbh (Fig. 2). The association of lichens, *Piper* sp. and *Pothos scandens* with most of the trees was characteristic of the forest. Epiphytes were not found associated with the trees in the sampling area.

The canopy projection diagram indicates the coverage of nearly 75% of sample plots by species like *V. indica* (occupies about 60%) *Humboldtia brunonis* (about 15%) (Fig. 4). There were a few openings in the canopy, which might be the result of heavy wind and landslides. But, the smaller tree species like *Humboldtia brunonis* occupied these areas. Very few heliophytes, particularly *Macaranga peltata* were found.

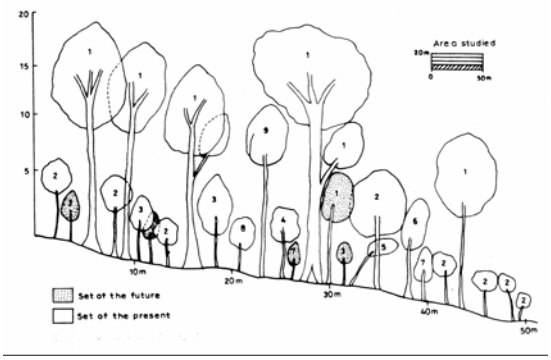

Fig. 3. Profile diagram of Charmady reserve forest. The tree species shown are: (1) *Vateria indica* (2) *Humboldtia brunonis* (3) *Nothopegia racemosa* (4) *Syzygium laetum* (5) *Leea indica* (6) *Polyalthia fragrans* (7) *Gymnacranthera farquhariana* (8) *Ixora brachiata* (9) *Terminalia paniculata.*

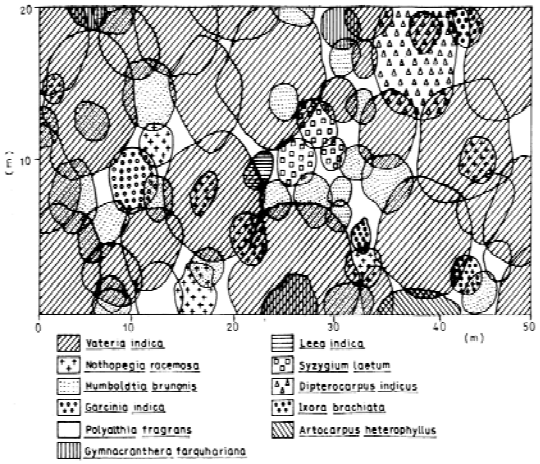

Fig. 4. Canopy projection diagram of Charmady reserve forest.

Density

A total of 961 individuals were recorded in the 5000 m^2 study area (Appendix 1). The members of Dipterocarpaceae accounted for 31% of the total individuals. Among the dipterocarps, *V. indica* (59.9%), *H. ponga* (32.1%) and *D. indicus* (8.1%) were most represented. Other than dipterocarps, *H. brunonis* (14.6%), *Ixora brachiata* (6.2%), *Vepris bilocularis* (5.3%), *Syzygium laetum* (4.8%), *Gymnacranthera farquhariana* (4.2%) and *Memecylon terminale* (3.9%) were common.

About 63% of the individuals belonged to the set of the present, 36.9% belonged to the set of the future, and only 0.1% of the individuals (one individual) belonged to the set of the past in the sampling plot.

Basal area

The total basal area was 58.0 m^2 ha^{-1}. Of this, members of dipterocarps constituted nearly 53% of total basal area. *V. indica* alone represented a basal area of 17.4 m^2 ha^{-1}, followed by *H. ponga* 5.3 m^2ha^{-1} and *D. indicus* 4.8 m^2 ha^{-1}. In spite of high density the basal areas of *H. brunonis* and *I. brachiata* were low (1.3 and 0.4 m^2ha^{-1}). The basal area of other species was relatively low.

Height and GBH classes

Nearly 83% of the individuals were within 1-8 m height range, most of them belonging to the set of the present (Table 1). Only 2.2% individuals exceeded 16 m height most of them belonged to Dipterocarpaceae.

More than two third individuals (70%) belonged to the 10-40 cm gbh class and about 18% came under the gbh class 40-80 cm (Table 2). Most individuals of *Humboldtia brunonis* formed 10-40 cm gbh class and majority of them belonged to the set of present. Only about 1.1% individuals showed above 200 cm gbh, (mostly *V. indica* and *H. ponga*).

Table 1. Height class distribution of Charmady reserve forest.

Height class (m)	No. of individuals	%
0-4	501	52.1
4-8	295	30.7
8-12	77	8.0
12-16	22	2.3
16-20	19	2.0
20-24	3	0.3

Table 2. Girth class distribution of Charmady reserve forest.

Range (cm)	No. of individuals	%
10-40	671	69.8
40-80	170	17.7
80-120	65	6.8
120-160	30	3.1
160-200	14	1.5
200-240	8	0.8
240-280	2	0.2
280-320	0	0.0
320-360	1	0.1

Importance value index

The IVI of dipterocarps, *V. indica* (61.0) and *H. ponga* (29.1), was considerably greater than other species. Only four species showed an IVI over 10. The maximum family importance value (FIV) was observed for Dipterocarpaceae (105.1), followed by Fabaceae (31.1), Myristicaceae (14.8), Moraceae (14.1), Myrtaceae (13.4), Euphorbiaceae (12.7), Anacardiaceae (12.3) (Table 3).

Species diversity

The indices of species diversity are given in Table 4. The high values for Simpson's index (0.9) indicated high floristic richness of the forest. The lower N/S ratio of the plot (14.4) suggested that the number of individuals of different species in the plot was less. The Shannon-Wiener's Index (H′=4.9) and the equitability ratio (E = 0.8) were high which indicate moderate representation of most of the species in the forest.

Table 3. Family Importance Value (FIV) index of Charmady reserve forest.

Family	FIV
Dipterocarpaceae	105.1
Fabaceae	31.1
Myristicaceae	14.8
Moraceae	14.1
Myrtaceae	13.4
Euphorbiaceae	12.7
Anacardiaceae	12.3
Combretaceae	9.7
Clusiaceae	9.5
Rubiaceae	9.3
Rutaceae	8.9
Oleaceae	7.6
Lauraceae	6.9
Celastraceae	5.2
Annonaceae	4.9
Sapotaceae	4.6
Melastomataceae	4.6
Ebenaceae	3.8
Rhizophoraceae	3.6
Elaeocarpaceae	2.4
Flacourtiaceae	2.3
Meliaceae	2.2
Verbenaceae	2.2
Burseraceae	1.6
Leeaceae	1.4
Ancistrocladaceae	1.4
Sapindaceae	0.9
Lythraceae	0.7
Sterculiaceae	0.6
Gramineae	0.4
Tiliaceae	0.3

Table 4. Indices of species diversity of Charmady reserve forest.

Area (m^2)	5000
Number of Individuals (N)	961
Number of Species (S)	67
N/S	14.4
Simpson's Index (D)	0.9
Shannon-Wiener's index H'	4.9
H_{max}	6.1
$E = H'/H_{max}$	0.8

Regeneration

Of the 67 tree species, about 50 species showed their seedlings. Among 17 tree species which had no seedlings in the plot, *Myristica dactyloides, Mimusops elingi, Actinodaphne malabarica* and *Ficus glomerata* were the important ones. The seedlings of dipterocarps viz., *D. indicus, H. ponga* and *V. indica* accounted for about 22% of total (Appendix 1) indicating a good regeneration of these species. The seedlings of *H. brunonis* were also well represented in the forest, accounting for about 8% of total. Other abundant seedlings belonged to *Psychotria dalzelli, Nothopegia racemosa, Memecylon terminale, Pothos scandens, Smilax zeylanica, Thottea siliquosa, Leea indica* and *Entada pusaetha*.

Discussion

The species richness (99) recorded presently is lower compared to plant species recorded in other tropical forests (Table 5). This may be due to distribution of Charmady reserve forest on the sloppy terrain at 240 to 430 above msl altitude unlike those of lowland dipterocarps forest at Malaysia. The maximum 24 m height of canopy without emergents in the present study was distinctly lesser than the canopy height of rainforests in different regions of the western ghats ranging from 28 to 48 m (Kadambi 1936, 1939, 1942; Pascal 1988; Proctor *et al.* 1983; Rai & Proctor 1986). Richards (1981) observed three layers and a shrub layer in a primary mixed dipterocarp forest of Mt. Dulit, Borneo where the

Table 5. A comparative account of floristic richness of some tropical forest locations.

Forest location	Area (ha)	No. of species	No. of genera	No. of families	References
Kadamakal reserve forest	3.12	91	–	31	Elouard *et al.* (1991)
Jadkal forest	0.5	103	85	46	Vasanthraj *et al.* (2005)
Low elevation forest, Kodagu	–	111	–	–	Pelissier *et al.* (1998)
Pilarkan reserve forest	–	160	135	75	Bhat (1993)
Lowland rain forest, Sabah, Malaysia	8	329	128	52	Campbell & Newbery (1993)
Lowland dipterocarp forest, Danum Vallery, Malaysia	8	511	164	59	Newbery *et al.* (1999)
Keranga forest, Sarawak and Brunei	–	637	–	60	Newbery (1991)

upper most storey extended up to 45 - 60 m. In some of the dipterocarp forests, *D. indicus, V. indica* and *Poeciloneuron indicum* were found to exist as emergents (Kadambi 1939, 1942). In the present study, however, *D. indicus* and *V. indica* were not the emergents. Nearly 50% occupation of the canopy by *V. indica* indicates its dominance in the forest and the possibility of grouping as emergent in the future provided it is not cut. Another potential emergent species, *P. indicum* normally exists in the pockets of higher altitude forests near Kudremukh, Agumbe and Coorg regions (Krishna Kumar 1998; Pascal 1988).

Dipterocarps are the dominant members in the rainforests of south-east Asia (Manokaran 1995; Richards 1981). According to Rai & Proctor (1986) in three of the four forest sites studied, viz., Agumbe, Bannadapare and Kagneri, the Dipterocarps were dominant and in the fourth South Bhadra forest site, *Poeciloneuron indicum* was dominant. In a low elevation dense moist evergreen forest in the western ghats, *V. indica* is most common species (Pelissier *et al.* 1998). Vasanthraj *et al.* (2005) also reported the dominance of dipterocarps in Jadkal forest of Karnataka. A dipterocarp, *Shorea robusta,* was dominant in the sal forests of Bankura north forest division, West Bengal (Lal *et al.* 1994). The dominance of species in various forests may be the result of edaphic factors of the area or also due to the recent low level disturbance in the forest. The regeneration of *D. indicus* distributed throughout the western ghats of Karnataka, is dependent on the dry seasons because it has been reported that in the areas with prolonged dry season and with openings in the canopy, this species will not regenerate profusely (Meher-Homji 1997). The species like *Hopea parviflora* and *H. ponga* are found growing through out the lower altitudinal areas of secondary semi evergreen forests of the western ghats. In these species, gregarious flowering and fruiting is observed. Also, aseasonal flowering is seen in the case of *H. ponga*. These factors may influence the dominance of these species in the forest.

Shivaprasad *et al.* (2000) reported the gregarious formation and wide distribution of *H. ponga* in the western ghats of Karnataka, also observed in the lower elevations of the Charmady reserve forest. The common occurrence of *V. indica* in the Charmady reserve forest goes well with similar observations of Pelissier *et al.* (1998) in low elevation dense moist evergreen forest in the western ghats. The climbers like *Ancistrocladus heynianus, Combretum latifolium, Entada pusaetha* and *Uvaria narum* were moderately abundant in the forest, indicating that the forest belongs to the category of evergreen forests of the '*Dipterocarpus indicus – Kingiodendron pinnatum – Humboldtia brunonis*' type of Pascal (1988).

The density of trees in evergreen forests of the western ghats ranges from 578 to 2943 individuals ha^{-1} (Pascal 1988; Pelissier *et al.* 1998; Shivaprasad *et al.* 2002; Vasanthraj *et al.* 2005) and in the lowland dipterocarp forests of Malaysia 2248 to 3385 individuals ha^{-1} (Newbery 1991; Newbery *et al.* 1992). Tree density recorded in the present study (1922 individuals ha^{-1}) is medium compared to the above reports. The basal area of Charmady reserve forest (52.1 m^2 ha^{-1}) is also moderate compared to these reports. The basal area of lowland dipterocarp forests of Malaysia, ranged from 28 to 57 m^2 ha^{-1} (Manokaran & Kochummen 1987; Newbery 1991; Newbery *et al.* 1992; Proctor *et al.* 1983), in moist deciduous forests of Karnataka it ranged from 21.59 to 32.62 m^2 ha^{-1} (Bhat *et al.* 2000) and in the evergreen forests of western ghats it ranged from 58.79 m^2 to 64.89 m^2 ha^{-1} (Pascal, 1988; Vasanthraj *et al.* 2005).

The Simpson's index in the present study (0.93) was towards the upper end of values reported in various evergreen forests of western ghats (0.78 to 0.95, Elouard *et al*. 1997; Pascal 1988; Vasanthraj *et al*. 2005). It was 0.66 in the swamp forest, this index was much lower (0.66) (Bonadie & Bacon 1999). The Shannon-Wiener's Index (H') for evergreen forests of western ghats ranged from 2.1 to 5.2 (Elouard *et al*. 1997; Pascal 1988; Shivaprasad *et al*. 2002; Vasanthraj *et al*. 2005), for semi-evergreen forests from 2.3 to 4.3 (Kadavul & Parthasarathy 1999; Pascal 1988) and for deciduous forests from 2.6 to 3.5 (Pascal 1988). In comparison the index in the present study (4.9) indicates moderately high diversity.

It is interesting that more species (81) were represented as seedlings of trees against 67 tree species in the canopy. Some of the tree species, viz., *Caryota urens, Elaeocarpus tuberculatus, Arenga wightii, Myristica malabarica, Mammea suriga* and *Nothopodytes nimmoniana* are represented only in seedlings but not as mature trees. Some tree species (e.g. *M. dactyloides, Mimusops elingi, Ficus glomerata* and *Actinodaphne malabarica*) are not represented in the ground vegetation. The fruits of *Myristica dactyloides* are collected for the extraction of aril and that of *Mimusops elingi* are edible. As such these trees are smaller in size, resulting in limited fruiting. Many other species are represented by a few individuals hence, the chances of seedling development are scarce. The seeds of these trees might have dispersed from adjacent areas.

Richness of endemic species (37%) in the present study is fairly high compared to many other tropical forests. Regeneration of *D. indicus* was moderate in this study, and this species has been classified as a threatened species (Ravikumar & Ved 2000). A reduction in the mature trees in the forest can be expected. At present, the canopy is continuous without openings, but, this continuity may be broken due to the death of some individuals of the set of the present especially the plants belonging to SE I. While selective logging may be found to be productive in this forest, the opening of canopy due to selective logging and lesser regeneration in the forest may lead to changed composition of the forest. The opening up of the canopy may result into the development of heliophytes, thereby affecting species diversity, and posing threat to the endemic and endangered species present in the forest. Therefore, the protection of the whole forest, thereby the threatened and endemic flora, is called for.

Acknowledgements

The authors are grateful to K.M. Kaveriappa, Chairman, Department of Applied Botany, Mangalore University, for providing necessary facilities. The financial assistance given by the U.G.C., New Delhi, in the form of a major research project is gratefully acknowledged. The help given by M. Ramakrishna during the fieldwork is also gratefully acknowledged.

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Appendix 1. The frequency (F, %), density (D, no. plot^{-1}), basal area (BA, m^2 ha^{-1}) and Importance Value Index (IVI) of Charmady reserve forest; also shown are stratification (C - canopy species; SC - sub canopy species; UC - under canopy species; S - seedling), seedlings (number plot^{-1}) and endemic species (*).

	Species	Stratification	Seedlings	≥ 10 cm gbh trees			
				F	D	BA	IVI
	Acacia pennata (L.) Willd. (Fabaceae)	UC, S	03	-	-	-	-
	Acacia sinuata (Lour.) Merr. (Fabaceae)	UC	06	24.0	20	0.17	5.92
*	*Actinodaphne malabarica* Balakr. (Lauraceae)	SC, UC	a	13.3	14	0.12	3.67
	Adenia hondala (Gaertner) De Wilde (Passifloraceae)	S	05	-	-	-	-
*	*Aglaia lawii* (Wight) Saldahna (Meliaceae)	SC, UC, S	98	8.0	10	0.03	2.22
	Ammomum sp. (Gingiberaceae)	S	23	-	-	-	-
	Ancistrocladus heynianus Wallich ex. Graham (Ancistrocladaceae)	UC, S	17	5.3	6	0.01	1.36
	Aporusa lindleyana (Wight) Baillon (Euphorbiaceae)	UC, S	81	10.6	27	0.41	5.81
*	*Arenga wightii* Griffith (Arecaceae)	UC	14	-	-	-	-
*	*Artocarpus gomezianus* Wallich ex Trecul subsp. *zeylanicus* Jarrett (Moraceae)	SC, UC	a	5.3	5	0.25	2.19
*	*Artocarpus heterophyllus* Lam. (Moraceae)	SC, UC	a	5.3	4	0.16	1.75
*	*Artocarpus hirsutus* Lam. (Moraceae)	C, SC	11	13.3	11	0.82	6.06
	Asparagus racemosa Willd. (Liliaceae)	S	10	-	-	-	-
	Atlantia sp. (Rutaceae)	UC	20	-	-	-	-
*	*Calamus prasinus* Lakshmana & Renuka (Arecaceae)	UC, S	58	-	-	-	-
	Calamus thwaitesii Becc. & Hook. f. (Arecaceae)	UC, S	68	-	-	-	-
	Callicarpa tomentosa (L.) Murray (Verbenaceae)	UC	10	2.6	2	0.01	0.61
*	*Calophyllum apetalum* Willd. (Clusiaceae)	SC	12	5.3	5	0.03	1.35
*	*Canarium strictum* Roxb. (Burseraceae)	SC	a	5.3	4	0.11	1.55
	Carallia brachiata (Lour.) Merr. (Rhizophoraceae)	SC	13	5.3	5	0.60	3.55
	Caryota urens L. (Arecaceae)	SC, UC, S	63	-	-	-	-
	Catunaregam spinosa(Thunb.) Triven (Rubiaceae)	UC	20	-	-	-	-
	Chionanthus malabarica (G. Don) Beddome (Oleaceae)	UC	a	5.3	5	0.05	1.42
	Chromolaena odorata (L.) King & Robinson (Asteraceae)	S	14	-	-	-	-
*	*Cinnamomum malabatrum* (Burm. f.) Blume (Lauraceae)	SC, UC	06	6.6	6	0.18	2.22
	Clerodendrum viscosum Vent. (Verbenaceae)	UC, S	82	1.3	1	x	0.28
	Combretum latifolium Blume (Combretaceae)	UC, S	08	12.0	11	0.02	2.83
	Croton sp. (Euphorbiaceae)	UC	19	1.3	2	0.01	0.40
	Cyclia peltata (Lam.) Hook.f. & Thomson (Menispermaceae)	S	17	-	-	-	-
	Cyperus rotundus L.	S	41	-	-	-	-
*	*Diospyros saldahnae* Koestrm. (Ebenaceae)	SC, UC, S	76	14.6	15	0.07	3.79
*	*Dipterocarpus indicus* Beddome (Dipterocarpaceae)	C, SC, S	155	24.0	24	2.40	14.88
	Dracaena terniflora Roxb. (Dracaenaceae)	S	30	-	-	-	-
	Elaeocarpus serratus L. (Elaeocarpaceae)	SC	21	9.3	9	0.05	2.39
	Elaeocarpus tuberculatus Roxb. (Elaeocarpaceae)	SC	18	-	-	-	-
	Entada pusaetha DC. (Fabaceae)	UC, S	107	-	-	-	-
	Ficus hispida L.f. (Moraceae)	UC	a	1.3	1	0.02	0.37
	Ficus racemosa L. (Moraceae)	SC	a	5.3	5	0.65	3.73
*	*Flacourtia Montana* Graham (Flacourtiaceae)	UC	04	4.0	7	0.12	1.74
	Garcinia gummigutta (L.) N. Robson (Clusiaceae)	UC, S	75	5.3	4	0.09	1.49

Continued…

Appendix 1. Continued.

	Species	Stratification	Seedlings	≥ 10 cm gbh trees			
				F	D	BA	IVI
*	*Garcinia indica* (Thousars) Choisy (Clusiaceae)	SC, S	55	14.6	14	0.13	3.92
	Garcinia morella (Gaertner) Desr. (Clusiaceae)	UC	07	2.6	4	0.01	0.79
	Glochidion sp. (Euphorbiaceae)	UC	04	2.6	2	0.13	1.08
	Grewia microcos L. (Tiliaceae)	UC	08	1.3	1	x	0.29
*	*Gymnacranthera farquhariana* (Hook. f. & Thomson) Warb. (Myristicaceae)	SC, UC, S	58	26.6	28	0.38	7.89
	Hibiscus furcatus Willd. (Malvaceae)	S	05	-	-	-	-
*	*Holigarna arnottiana* Hook. f. (Anacardiaceae)	SC, UC, S	22	14.6	12	0.67	5.77
*	*Holigarna grahamii* (Wight) Kurz. (Anacardiaceae)	C	a	2.6	2	0.01	0.60
*	*Hopea ponga* (Dennst.) Mabb.(Dipterocarpaceae)	SC, UC, S	417	68.0	95	2.68	29.14
*	*Humboldtia brunonis* Wall. (Fabaceae)	UC, S	477	49.3	97	0.68	19.21
*	*Hydnocarpus pentandra* (Buch.-Ham) Oken (Flacourtiaceae)	UC	a	1.3	1	0.07	0.55
*	*Ixora brachiata* Roxb. (Rubiaceae)	UC, S	84	29.3	41	0.23	9.01
*	*Ixora polyantha* Wight (Rubiaceae)	S	05	-	-	-	-
*	*Jasminum malabaricum* Wight (Oleaceae)	UC, S	12	-	-	-	-
*	*Kingiodendron pinnatum* (Roxb. Ex. DC.) Harms (Fabaceae)	C, SC, S	69	22.6	21	0.19	5.93
*	*Knema attenuata* (Hook. f. & Thomson) Warb. (Myristicaceae)	SC, UC	21	6.6	5	0.03	1.52
*	*Lagerstroemia microcarpa* Wight (Lythraceae)	SC, UC	a	2.6	2	0.03	0.68
	Lauraceae member	UC	a	1.3	1	x	0.28
	Leea indica (Burm.f.) Merr. (Leeaceae)	UC, S	114	6.6	5	0.01	1.41
	Litsea sp. (Lauraceae)	UC	14	-	-	-	-
	Lophopetalum wightianum Arn. (Celastraceae)	C, SC	06	9.3	7	0.84	5.18
	Macaranga peltata(Roxb.) Muell.-Arg. (Euphorbiaceae)	UC	47	10.6	10	0.12	2.93
	Mallotus philippensis (Lam.) Muell. –Arg. (Euphorbiaceae)	UC	23	6.6	6	0.26	2.51
	Mammea suriga (Buch.-Ham. Ex Roxb.) Kosterm (Clusiaceae)	SC, UC	05	-	-	-	-
	Mangifera indica L. (Anacardiaceae)	SC	11	2.6	2	0.10	0.95
*	*Memecylon talbotianum* Brandis (Melastomataceae)	UC, S	02	-	-	-	-
*	*Memecylon terminale* Dalz. (Melastomataceae)	UC, S	146	12.0	26	0.07	4.57
	Mesua ferrea L. (Clusiaceae)	SC, UC	a	5.3	7	0.12	1.92
	Mimusops elingi L.(Sapotaceae)	SC	a	13.3	10	0.28	3.90
	Myristica dactyloides Gaertner (Myristicaceae)	SC, UC	a	14.6	14	0.52	5.40
*	*Myristica malabarica* Lam. (Myristicaceae)	SC, UC	06	-	-	-	-
	Nothapodytes nimmoniana (Graham) Mabb. (Icacinaceae)	UC	03	-	-	-	-
	Nothopegia racemosa (Dalz.) Ramam. (Anacardiaceae)	SC, S	206	18.6	18	0.17	4.99
*	*Ochlandra travancorica* (Beddome) Mabb. (Gramineae)	UC, S	75	1.3	2	x	0.39
	Olea dioica Roxb. (Oleaceae)	UC	17	21.3	18	0.39	6.20
*	*Palaquium ellipticum* (Dalz.) Baillon (Sapotaceae)	SC	08	2.6	2	0.03	0.71
	Pandanus sp. (Pandanaceae)	S	35	-	-	-	-
	Persea macrantha (Nees.) Kosterm. (Lauraceae)	UC	a	1.3	1	0.11	0.72
*	*Pinanga dicksonii* (Roxb.) Blume (Arecaceae)	UC	11	-	-	-	-
	Piper sp. (Piperaceae)	S	324	-	-	-	-
*	*Polyalthia fragrans* ((Dalz.) Ramam. (Annonaceae)	C, SC	05	9.3	11	0.17	3.04

Continued…

Appendix 1. Continued…

	Species	Stratification	Seedlings	≥ 10 cm gbh trees			
				F	D	BA	IVI
	Pothos scandens L. (Arecaceae)	S	138	-	-	-	-
*	*Psychotria dalzelli* Hook. f. (Rubiaceae)	UC, S	312	1.3	1	x	0.28
	Pteris sp. (Pteridacee)	S	409	-	-	-	-
	Rutaceae member	S	02	-	-	-	-
	Schleichera oleosa (Lour.) Oken (Sapindaceae)	SC	04	4.0	3	0.02	0.92
	Smilax zeylanica L. (Liliaceae)	S	138	-	-	-	-
	Sterculia guttata Roxb. (Sterculiaceae)	SC	02	2.6	2	0.01	0.60
	Strobilanthus sp. (Acanthaceae)	S	70	-	-	-	-
	Syzygium caryophyllatum (L.) Alston (Myrtaceae)	UC	05	1.3	1	x	0.28
	Syzygium cumini (L.) Skeels (Myrtaceae)	SC, UC	32	10.6	11	0.54	4.62
*	*Syzygium laetum* (Ham.) Gandhi (Myrtaceae)	UC, S	49	29.3	32	0.33	8.48
	Terminalia chebula Retz. (Combretaceae)	C, SC	a	6.6	5	0.33	2.69
	Terminalia paniculata Roth. (Combretaceae)	SC	16	9.3	8	0.54	4.14
	Thottea siliquosa (Lam.) Ding Hoh (Aristolochiaceae)	S	119	-	-	-	-
	Unidentified	UC	a	6.6	5	0.03	1.55
	Uvaria narum (Dunal) Wight & Arn. (Annonaceae)	S	15	8.0	7	0.01	1.85
*	*Vateria indica* L. (Dipterocarpaceae)	C, SC, S	659	68.0	178	8.74	61.04
*	*Vepris bilocularis* (Wight & Arn.) Engl. (Rutaceae)	C, S	57	28.0	35	0.41	8.92
	Vitex altissima L.f. (Verbenaceae)	SC	a	5.3	4	0.04	1.28
	Total				961	26.04	300.0

x – values less than 0.01; - not represented as tree species; a – seedlings are absent.