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ORIGINAL PAPER

Structure and floristic composition of old-growth wet evergreen forests of Nelliampathy Hills, Southern Western Ghats

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Abstract: We analyze the structure and composition of old-growth wet evergreen forest of Nelliampathy hills, the chain of hills lying immediately south of Palghat Gap, in the southern Western Ghats of India. We sampled 30 plots of 0.1 ha each (50 m × 20 m) at six locations enumerating all plants ≥ 10 cm girth at breast height. We pooled the data and computed various structural parameters. There were 152 species of 120 genera and 51 families of the study area. Of these, 118 (77%) were trees, 24 were climbers (16%) and 10 were shrubs (7%). Species richness varied from 58–99 per 0.5 ha sample and Shannon indices of diversity ranged from 4.4 to 5.2. Fifty-nine per cent (89 species) of the species were Indian Sub-continent elements and 34% (51 species) are endemic to the Western Ghats. Fifteen species are listed in various threat categories. *Aglaia* and *Litsea* were the most species-rich genera. Numbers of families ranged from 27–43 per 0.5 ha sample. Euphorbiaceae and Lauraceae were the most species-rich families. Stand density varied from 1714 to 2244 stems·ha^{-1} and basal area from 53.6 to 102.1 m^2·ha^{-1}. The vegetation was dominated by 3–6 species and six dominance patterns characterized the species composition within the hill complex. The old-growth evergreen forests of Nelliampathy exist as small fragments rich in biodiversity and can be used as benchmarks for comparison with disturbed forests.

Key words: Old-growth, evergreen forest, Nelliampathy, Western Ghats, species richness, tree density, relative abundance, stand structure.

Introduction

Wet evergreen forest is the dominant climax vegetation along the western aspect of the Western Ghats, a region with annual rainfall of over 2000 mm. Renowned for its rich biodiversity, nearly 20% of the southern Western Ghats supports this type of forest (Nair 1986; Ramesh et al. 2003). Many species are characterised by restricted distribution and/or sparse populations (Pascal, 1988; Ramesh et al. 1997). At par with the global scenario, during the past 150 years human activities have impacted forest ecosystems, restricting the old-growth forests to a few fragmented patches in inaccessible pockets of the Western Ghats (Nair 1988). These residual forests, though quite small in area are of great significance because they provide the benchmarks to understand the impact of human interventions on forest ecosystems. The importance of these forest patches is also quite high in investigations of climate change.

There have been limited attempts to understand the natural resources of the wet evergreen forests of the Western Ghats and to examine long-term changes. Pascal's monograph (1988) was a pioneering effort in this direction, and was based on limited samples from deep within the biotope. Evaluating the plant diversity of the Ghats in the Agumbe region north of the Palghat Gap, Srinivas and Parthasarathy (2000) documented a general decrease in species richness with increasing elevation from 100-650 amsl. Based on a general survey, Pascal and Pelissier (1996) proposed that Uppangala is the western extension of the lowland dipterocarp forest (Pascal and Pelissier 1996). Elouard et al. (1997) provided details on species diversity and Pelissier (1998) reported on spatial variation in floristic composition and stand structure in the region. Another area where ecological and silvicultural aspects of the stands have been studied is the Attappady forests (Aiyar 1932a, b). The forest at Silent Valley was characterized by high tree basal area (102.7 m^2·ha^{-1}; Singh et al. 1984).

South of Palghat Gap, Ayyappan and Parthasarathy (1999) studied the forest at Varagalaiar area of the Anamalais, where the vegetation was transitional between the *Cullenia-Mesua-Palaquium* and *Dipterocarpus-Mesua-Palaquium* types. Higher species richness was reported from the Sengaltheri (82 species ha^{-1}; Parthasarathy 1999 2001) and Kakachi (90 species·ha^{-1}; Ganesh et al. 1996) areas of Kalakkad forests. Kodayar showed low species richness (30–39 species·ha^{-1}) but high evenness (Sundarapandian and Swamy 1997; Swamy et al. 2000).

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Nair (1961) studied regeneration patterns of trees in the evergreen forests of Kerala and discussed methods of artificial regeneration. Chandrashekara and Jayaraman (2002) reported the structure and composition of forest stands at Aralam and Nilambur, regions north of Palghat Gap, and Iringole, Thenmala, Ranni and Goodrickal, south of Palghat Gap in Kerala. These studies examined bioresources, describing the gross picture in terms of the structure and composition of the vegetation at one or two locations.

The Nelliampathy hills are a mountain geomorph forming part of Nelliampathy-Anamalai-Palani hill complex. This is a central segment of the southern Western Ghats supporting wet evergreen forests. Information on the vegetation ecology for the Nelliampathy hills is sparse; two studies reported on the structure and composition of the evergreen forests but both were from one location, Pothumala (Chandrashekara 1991; Chandrashekara and Jayaraman 2002). Intensive field explorations, however, enabled us to locate more unlogged evergreen forest patches at Nelliampathy, which contained the relic vegetation of the region. The objective of this paper was to describe the patterns of structure and composition of trees at six locations in the unlogged evergreen forest of the Nelliampathy hills.

Materal and methods

Study area

Rising to an elevation of 1,633 amsl, the Nelliampathy hills edge the Palghat Gap at its south. The hills of Anamalai and Parambikulam flank the Nelliampathy along the east and the south. The western and northern extensions of the Nelliampathy descend down to the Palghat plains. Many tributaries that join to form the Chalakkudy River originate in Nelliampathy. Geologically the rock formations of Nelliampathy are composed of Pre-Cambrian cover (Mani, 1974; Krishnan, 1974) with soil pH ranging from 4.5–7.5. The climate is monsoonal with annual rainfall of 1023–3282 mm, most falling during June-September. The minimal and maximal rainfall reported from 1994–2004, were 626-2028 mm and 1441–4278 mm, respectively. The number of rainy days varies from 127–144·a^{-1}. December to March is comparatively a dry period with mean monthly temperatures from 20.5–23.8ºC in the monsoon and 20.4–25.2ºC in the dry season (Balasubramanyan 1987; Chandrashekara 1991). Evergreen forest of the area is classified as medium elevation type of the *Cullenia exarillata-Mesua ferrea-Palaquium ellipticum* series (Pascal 1988; Ramesh et al. 1997). Most of these forests were selectively logged in 1950–1986 (Mathew 2001) leaving smaller patches as unlogged relic forests sheltered in inaccessible pockets.

Methods

We studied unlogged evergreen forests at six locations (Table 1): Pulikkalchola (hereafter PC), Manguttimala (MM), Manjalkunnu (MK), Pothumala (PM), Karapara-A (KPA) and Karapara-B (KPB) in the Nelliampathy hills (Fig. 1). The unlogged status of the forest patches was confirmed through review of Forest Working Plans (George 1963; Chandrasekharan et al. 1977; Mathew 2001), consultation with people involved in prior felling operations (Forest Department Staff and contractors), and field exploration with support of local people. We made five replicate samples of 0.1 ha sampling plots (50 m × 20 m; Phillips et al. 2003) at each of six locations, providing a combined (*c.f.* Muller-Dombois and Ellenberg, 1974) sample area of 0.5 ha at each location. Within each plot all plants ≥10 cm girth at breast height (gbh), which included tree species, large climbers and shrubs, were enumerated in each of 10 quadrats of 10 m × 10 m. Girth was measured at 1.3 m above ground level (Dallmeier et al. 1992), excluding buttresses or other stem features. All plants were identified in the field and a voucher collection was made if the taxon was encountered for the first time or if its identity was uncertain. Species of uncertain identity were later determined using regional floras, through comparison with herbarium specimens (KFRI), or through consultation with specialists.

Table 1. Details of study locations and sampling in the old-growth evergreen forests at Nelliampathy, southern Western Ghats, India

Sl. No.	Locations	Altitude (m.s.l.)	Latitude	Longitude	Sample size	Replicates
1.	(PC)	780 m	10°26'22" N	76°41' 49" E	0.1 ha	5
2.	(MM)	850 m	10°28'26" N	76°41' 44" E	0.1 ha	5
3.	(MK)	1,050 m	10°26'44" N	76°40' 53" E	0.1 ha	5
4.	(PM)	1,100 m	10°26'34" N	76°38' 35" E	0.1 ha	5
5.	(KPA)	1,150 m	10°27'59" N	76°37' 40" E	0.1 ha	5
6.	(KPB)	1,250 m	10°29'10" N	76°38' 55" E	0.1 ha	5

PC---Pulikkalchola, MM---Manguttimala, MK---Manjalkunnu, PM---Pothumala, KPA---Karapara---A, KPB---Karapara-B

Data from each of the six study locations were pooled and, when necessary, data from all locations were pooled for the entire study area (*c.f.* Campbell et al. 2006). Data were also grouped at species, genus and family levels for various analyses. Phytogeographic analysis of flora was performed after categorization of the species based on known distribution (Sasidharan, 2004). Structural attributes such as density, frequency and cover (basal area) were computed for each species following standard phytosociological practices. Species importance values (IVI) were derived from percentile values of structural attributes (*c.f.* Muller-Dombois and Ellenberg 1974). Conventionally, the stand's IVI, the base figure from which the species IVIs are derived, is 300. The base figure being 300, quick comparison of species IVIs is difficult. Therefore, for easy comparison, the IVI values may be converted to percentile values, the relative importance values (RIVI), which by default is IVI/3 (Narayanan and Swarupanandan 1996; Swarupanandan et al. 1998). We used this convention in analyses of stand parameters. Species richness denotes the number of species in 0.5 ha samples. For species diversity Fisher's α (Magurran, 1988) was computed using PAST (Hammer et al. 2001). Characteristics of population structure

were analyzed by grouping plants into categories of life stage based on girth classes: saplings (10–30 cm), poles (30–60 cm), small trees (60–90 cm), medium trees (90–180 cm) and large trees (>180 cm, Kenfack et al. 2007).

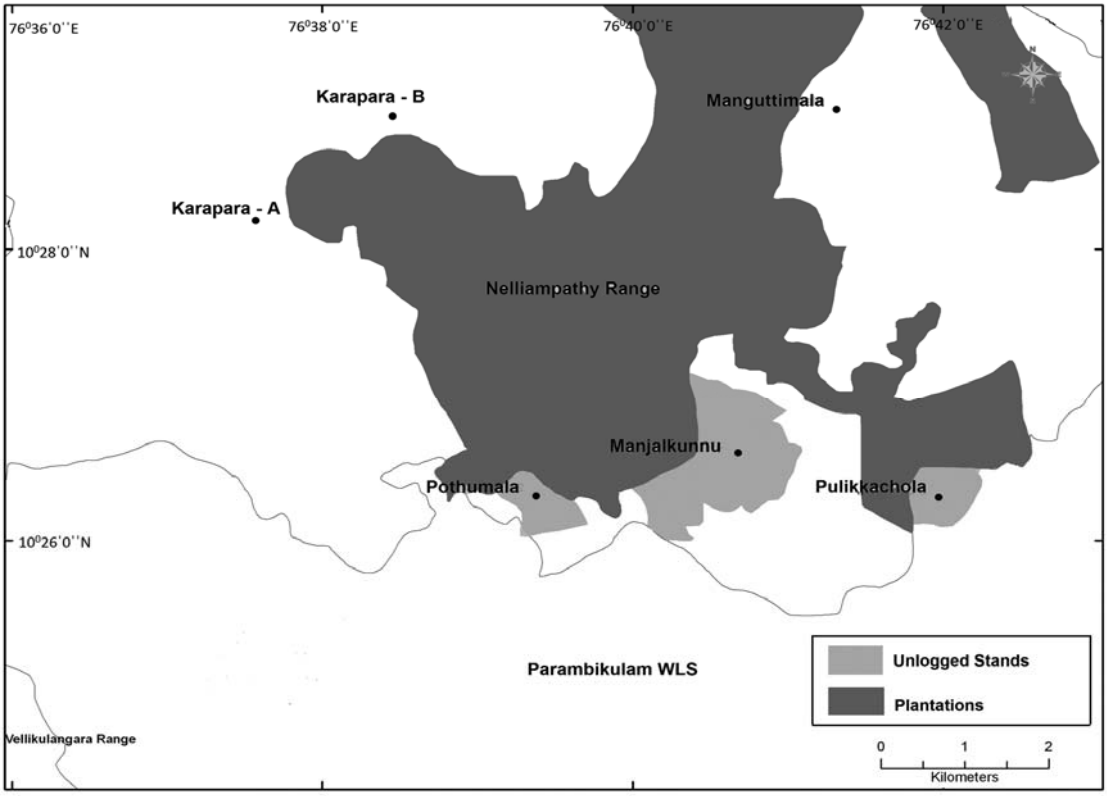

Fig. 1 Map showing the study locations in the old-growth evergreen forests at Nelliampathy, southern Western Ghats, India.

Results

Species richness and diversity

We recorded 152 species of plants ≥ 10 cm gbh of 120 genera and 51 families at the six study locations for the 3-ha sampled area (Appendix 1). Five species were unidentified, of which one was a tree and the remaining four were climbers. Out 152 identified species, 118 (77%) were trees, 24 were climbers (16%) and were 10 shrubs (7%). Species richness varied from 58–99 species per 0.5 ha among the six sampling locations (Table 2). Fisher's alpha varied from 14.05-25.23. Species richness and diversity were highest at PC and lowest at KPB.

Generic richness

Aglaia and *Litsea*, with four species each were the best represented genera, followed by *Artocarpus* and *Syzygium* with three species each. Seventeen genera had two species each: *Croton*, *Cryptocarya*, *Diospyros*, *Drypetes*, *Elaeocarpus*, *Eugenia*, *Ficus*, *Garcinia*, *Mallotus*, *Mesua*, *Neolitsea*, *Orophea*, *Palaquium*, *Polyalthia*, *Psychotria*, *Psydrax*, and *Terminalia* and another 99 genera had one species. The number of genera varied from 49–84 per 0.5 ha sampling location and PC ranked highest with 84 genera (Table 2).

Table 2. Results of phytosociological study in the old-growth evergreen forest at six locations in the Nelliamapathy hills, southern Western Ghats, India

Locations	Species richness	Generic richness	Family richness	Fisher's alpha	Stand density (stems·ha^{-1})	Stand Basal area (m^2·ha^{-1})
PC	99	84	43	25.23	2244	68.5
MM	71	62	31	19.15	1740	102.1
MK	78	60	31	19.84	1982	100.5
PM	59	51	27	14.06	1744	89.1
KPA	65	56	30	16.2	1758	62.3
KPB	58	49	27	14.05	1714	53.6

PC---Pulikkalchola, MM---Manguttimala, MK---Manjalkunnu, PM---Pothumala, KPA---Karapara-A, KPB---Karapara-B.

Family richness

Euphorbiaceae, with 20 species, was the best represented family, followed by Lauraceae (13), Rubiaceae (8), Annonaceae (8), Rutaceae (7), Meliaceae (7), Moraceae (6) and others (Table 3). Ten families had ≥ 5 species, 12 had two species and 25 were represented by one species. In terms of generic richness, Euphorbiaceae ranked highest with 16 genera (Table 3), followed

by Lauraceae (8), Rubiaceae (7), Rutaceae (7), Annonaceae (6) and others. Of the 51 families, 28 had one genus and 10 families had two genera each. Five families had ≥ 5 genera. Number of families recorded at the six sampling sites varied from 27–43 per 0.5 ha, with PC highest at 43 families (Table 2).

Table 3. Plant families and the number of species recorded in each, in the old-growth evergreen forest at Nelliampathy, southern Western Ghats, India.

Fimilies	No. of species	Fimilies	No. of species	Fimilies	No. of species
Euphorbiaceae	20 (16)	Ebenaceae	2 (1)	Icacinaceae	1 (1)
Lauraceae	13 (8)	Elaeocarpaceae	2 (1)	Leeaceae	1 (1)
Annonaceae	8 (6)	Fabaceae	2 (2)	Loganiaceae	1 (1)
Rubiaceae	8 (7)	Myristicaceae	2 (2)	Lythraceae	1 (1)
Meliaceae	7 (4)	Myrsinaceae	2 (2)	Malpigiaceae	1 (1)
Rutaceae	7 (7)	Olacaceae	2 (2)	Melastomataceae	1 (1)
Moraceae	6 (3)	Sterculiaceae	2 (2)	Mimosaceae	1 (1)
Clusiaceae	5 (3)	Urticaceae	2 (2)	Oleaceae	1 (1)
Myrtaceae	5 (2)	Acanthaceae	1 (1)	Rhamnaceae	1 (1)
Sapotaceae	5 (4)	Alangiaceae	1 (1)	Rosaceae	1 (1)
Flacourtiaceae	4 (4)	Ancistrocladaceae	1 (1)	Staphyleaceae	1 (1)
Sapindaceae	4 (4)	Asclepiadaceae	1 (1)	Symplocaceae	1 (1)
Anacardiaceae	3 (3)	Bombacaceae	1 (1)	Verbenaceae	1 (1)
Apocynaceae	3 (3)	Burseraceae	1 (1)	Vitaceae	1 (1)
Celastraceae	2 (2)	Capparadaceae	1 (1)	Xanthophyllaceae	1 (1)
Combretaceae	2 (1)	Cornaceae	1 (1)		
Connaraceae	2 (2)	Gnetaceae	1 (1)		
Dipterocarpaceae	2 (2)	Hippocrateaceae	1 (1)		

Values in the parenthesis is the number of genus recorded in each family

Phytogeography, Endemics and RET species

Of 152 recorded species, 35 (23%) were Indo-Malesian and 89 (59%) Indian; 55 of the latter (36%) were endemic to India. Thirty-one species (20%) were common to Sri Lanka and India. Among the 55 Indian species, 16 were endemic to Western Ghats and 35 restricted to the southern Western Ghats. Out of the total, three species are listed as Endangered (En), five Vulnerable (VU) and four Rare (R); one species was listed as Rare and Threatened (R&TH), one as Low Risk/near threatened (LR/NT) and one as Low Risk/conservation dependent (LR/cd). Of the 12 En, VU, and R, species, four are endemic to Western Ghats and nine restricted to southern Western Ghats.

Structure and composition

Relative Importance Value (RIVI) and Species Dominance

At each location, 11-18 species accounted for 70% of the RIVI of the stand and these species combined totalled 38 in number. Among the dominant RIVI species *Cullenia exarillata* occurred at all six locations, *Palaquium ellipticum*, *Mesua thwaitesii* and *Myristica beddomei* occurred at five locations and *Aglaia tomentosa*, *Agrostistachys borneensis*, *Drypetes oblongifolia* and *Syzygium laetum* at four locations. Based on RIVI, the community structure of trees in the six locations is listed below:

(1) PC: *Palaquium ravii* (9.5) > *Agrostistachys borneensis* (8.5) > *Reinwardtiodendron anamalaiense* (7.2) > *Cullenia exarillata* (7.1)
(2)MM: *Palaquium ellipticum* (16.2) > *Cullenia exarillata* (9.8)> *Calophyllum polyanthum* (9.0) > *Reinwardtiodendron anamalaiense* (8.9)
(3) MK: *Cullenia exarillata* (16.2) > *Palaquium ellipticum* (16.2) > *Mesua thwaitesii* (5.0) > *Agrostistachys borneensis* (4.8)
(4) PM: *Palaquium ellipticum* (17.0) > *Cullenia exarillata* (12.3) > *Mesua thwaitesii* (7.7) > *Drypetes venusta* (5.9)
(5)KPA: *Dimocarpus longan* (12.2) > *Heritiera papilio* (9.5) > *Litsea glabrata* (6.8) > *Palaquium ellipticum* (5.5)
(6)KPB: *Cullenia exarillata* (12.4) > *Litsea glabrata* (9.9) > *Litsea wightiana* (8.8) > *Dimocarpus longan* (7.4)

Relative abundance

Relative abundance of species is listed in Appendix 1. Of 152 species, 20 (13 %) occurred at all six locations, 16 species (11 %) at five locations, 15 (10 %) at four locations, 20 (13 %) at three locations, 29 (19 %) at two locations and 52 (34%) at one location each. *Palaquium ellipticum* was the most abundant species and was recorded at all six locations (Appendix 2). This was followed by *R. anamalaiense*, *C. exarillata*, *Aglaia tomentosa*, *P. ravii* and others.

Stand density

Density of stands ranged from 1,714–2,244 stems·ha^{-1} (Table 2). The highest density was recorded at PC, followed by MK, and the remaining locations had around 1750 stems·ha^{-1}. Nine to 15 species accounted for 70% of density across the six locations and among them only 7–12 had 50 stems·ha^{-1}. *P. ellipticum* ranked first in terms of density of the stands and this was listed at 5 of 6 locations. *C. exarillata*, recorded from all six locations, ranked second but had ≥50 trees at only five locations. Species with high RIVI also had higher density except for minor changes in their ranking at some locations. A few of the species with lower RIVI contributed to higher density of the stands: *e.g.*, *A. borneensis* at MM, *D. oblongifolia* at MK, *Ardisia pauciflora* at PM and KPB, *Syzygium laetum* at KPA and KPB, and *Orophea uniflora* at KPB.

Stand basal area

Basal area of stands ranged from 53.6–102.1 m^2·ha^{-1} (Table 2) and was highest at MM, followed by MK and others. Three to 10 species accounted for 70% of basal area of the stands and among the species *C. exarillata*, *P. ellipticum* and *M. thwaitesii* accounted for most basal area. *C. exarillata* ranked top and occurred at all six locations, *P. ellipticum*, recorded at five locations ranked second. *M. thwaitesii* had low basal area.

Population structure

The stem size class distribution displayed a characteristically inverse J-shaped graphic pattern with more individuals in the lower girth classes (Fig. 2). Density was high in saplings (10–30 cm gbh) at all locations, followed by poles (30–60 cm gbh). At

some areas, lesser numbers of saplings were compensated by poles and at others, vice-versa.

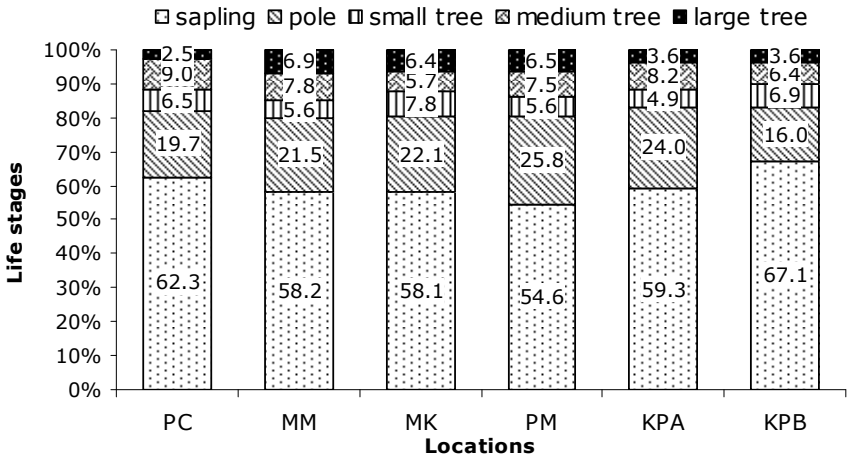

Fig. 2. Population structure of the old-growth evergreen stands at Nelliampathy, southern Western Ghats, India. PC---Pulikkalchola, MM---Manguttimala, MK---Manjalkunnu, PM---Pothumala, KPA---Karapara-A, KPB---Karapara-B

Discussion

Forests of the Western Ghats are classified as Indo-Malayan or belonging to the Asian block (Richard, 1952; Whitmore, 1975, 1990) but only 23% (35) of species were of the Indo-Malayan realm and a greater percentage were of the Indian subcontinent (59%, 89 species). Thirty-four percent (51) of recorded species were endemic to Western Ghats. This high degree of endemism might be due to greater precipitation in the southern Western Ghats, especially in the hills south of the Palghat Gap (Pascal, 1988). In addition, we recorded an endemic vicariant species, *Palaquium ravii*, from PC. Vicariance, occurrence of several related species (derived from a common ancestor) in different niches of the same ecological realm, is known for a number of tree genera along the Ghats (Pascal 1988; Ramesh et al. 1997) and *Palaquium* is a typical example. *P. ellipticum* is widely distributed throughout the Western Ghats and its local vicariant, *P. ravii* is restricted to the Anamalai-Palni-Cardamom hill complex, including the Nelliampathy hills (Ramachandran and Swarupanandan, 2006).

Euphorbiaceae was the largest family at Nelliampathy in terms of species and generic richness (20 species, 16 genera). This confirms other results from the Western Ghats (Varagalaiar - Ayyappan and Parthasarathy 1999; Attapady - Pascal 1988; Kodayar- Sundarapandian and Swamy 1997; Sengaltheri - Parthasarathy 1999). At Nelliampathy, species representation of Euphorbiaceae was followed by Lauraceae, Rubiaceae, Annonaceae, and Rutaceae. However, Rubiaceae was the dominant family at Kakachi (Ganesh et al. 1996) and Kalamalai (Swamy et al. 2000), followed by Lauraceae in the former study and Euphorbiaceae in the latter.

We recorded 152 plant species ≥ 10 cm gbh at the total 3 ha study area at Nelliampathy, representing 120 genera and 51 families. Excluding the 52 species represented only in the 10–30 cm girth class, the list consisted of 100 species ≥ 30 cm of 83 genera and 41 families. These figures are higher than those recorded for Uppangala forest (Kadamakal, 500–600 m: 91 species of 31 families on 3.12 ha; Pascal and Pelissier, 1996) and Kakachi (Kalakad, 1250–1450 m: 90 species of 35 families on 3.8 ha; Ganesh et al. 1996), two other segments of the Western Ghats. The total of 59 species recorded at PM was higher than the previous report at the same location (34 species, Chandrashekara and Jayaraman, 2002), and 58 species recorded at KPB was again higher than 34 species recorded at Meenar, Goodrikal (Chandrashekara and Jayaraman, 2002). Fisher's alpha values recorded for Nelliampathy forests were fairly high (14.05–25.23) and fell within the range of values reported for the evergreen forest of the southern Western Ghats (2.72–28.70, Davidar *et al.*, 2005).

Species composition and dominance varied widely among the six locations at Nelliampathy. The evergreen forest at Nelliampathy is grouped with the *C. exarillata – M. ferrea – P. ellipticum* series of medium elevation forest (Pascal 1988; Ramesh et al. 1997), however, in both studies samples were taken from locations north of the Palghat Gap. The present study identified six different species dominance patterns within the unlogged evergreen forests at Nelliampathy (south of Palghat Gap). Variation in topography, site condition, and elevation, and spatially dispersed samples in the present study would have contributed to the observed variations in species composition, richness and diversity of species, genus and family. These results are compatible with the findings from the African rainforest (Campbell et al. 2006).

Of the six locations, MM had lowest values for species richness and diversity. The probable causes are stand conditions and site factors. The sample plots had rich undergrowth of the shrub, *Strobilanthes anceps*. Species of *Strobilanthes* are an important component of the evergreen forest understory, particularly in

canopy openings. Because the MM site is remote, it is unlikely to have experienced wildfire. The combination of low stem density and high basal area indicates the area was dominated by larger trees. Basal area at MM was highest among the six locations. Thus, we cannot ignore the probability of creation of forest gaps by the falling of larger trees. In addition, of the six locations, MM alone is east facing, while all others are south facing. Compared to the other five sites, MM also has gentle terrain. These site factors might also have accounted for low species richness and diversity.

Stand density at Nelliampathy (1714–2244 stems·ha^{-1}) was moderate and sometimes higher than reported for evergreen forest in the Western Ghats (418–2926 stems ha^{-1}; Singh et al. 1984; Pascal 1988; Srinivas and Parthasarathy 2000; Chandrashekara and Jayaraman 2002). Basal area of the stands recorded in the present study (53.6–102.1 m^2·ha^{-1}) was on the higher end of the range reported (38.53–102.7 m^2·ha^{-1}) for evergreen forest in the Western Ghats (Singh et al. 1984; Pascal, 1988; Srinivas and Parthasarathy 2000; Swamy et al. 2000; Chandrashekara and Jayaraman 2002). Tree saplings and larger shrubs were the categories that accounted for most stand density, but they contributed less to basal area due to their small girth. Thus some species dominant in terms of density were not dominant in terms of basal area. Other species were dominant both in terms of density and basal area. As a result, stands with lower density occasionally exhibit higher values for basal area, or *vice versa* (Fig. 3). More stems of saplings and poles contributed to the higher density values at Nelliampathy. Though large trees were fewer in number, their large boles resulted in higher basal area for the stand.

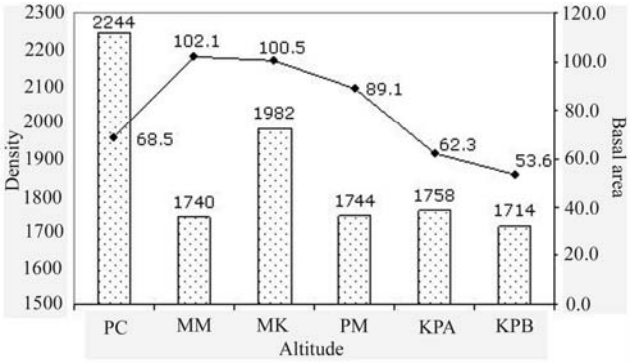

Fig. 3 Relationship between density (stems·ha^{-1}) and basal area (m^2·ha^{-1}) in the old-growth evergreen stands at Nelliampathy, southern Western Ghats, India

Conclusion

Species richness recorded in the unlogged evergreen forest at Nelliampathy is higher than that reported for many regions along the Western Ghats except Varagalaiar in Anamalai, south of Palghat Gap. For trees ≥30 cm, 51–85 species recorded for Varagalaiar (Ayyappan and Parthasarathy 1999) is higher than the 41–60 species recorded at Nelliampathy. Thirty-four per cent (51) of the species recorded at Nelliampathy are endemic to Western Ghats. This underlies its importance as a biodiverse area that requires consideration for conservation. With respect to density as well as basal area, the forest at Nelliampathy was superior compared to other sections of the Western Ghats. Previous studies at Nelliampathy were concentrated at one location, Pothumala (Chandrashekara 1991; Chandrashekara and Jayaraman 2002) and were surveyed in a single sample covering a large area. The present study, using spatially dispersed sampling plots of smaller area at six locations has identified unique structural and compositional characters of the unlogged forest at Nelliampathy. With differing species composition and dominance structure across locations, responses of species to disturbance, natural as well as human induced, could also vary. The unlogged evergreen forest of Nelliampathy exists in small fragments and can be considered as a benchmark for comparison with other disturbed forests.

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Appendix 1. List of plants with family, habit, conservation status, phytogeography and Relative abundance (Relative density + Relative frequency) of plants in six locations in the old-growth evergreen forest at Nelliampathy, southern Western Ghats, India

Sl. No.	Species name	Family	Habit*	Conservation Status#	Distribution	Relative abundance (Relative density + Relative frequency) of plants in six locations					
						PC	MM	MK	PM	KPA	KPB
1	*Acronychia pedunculata*	Rutaceae	T		Indo-Malesia	0.47	-	0.26	-	0.59	-
2	*Actinodaphne malabarica*	Lauraceae	T		S W Ghats	0.79	1.02	2.96	0.9	0.88	1.24
3	*Aglaia barberi*	Meliaceae	T	R	W Ghats	2.61	2.11	1.35	0.3	0.29	-
4	*Aglaia lawii*	Meliaceae	T	R	Indo-Malesia to Pacific islands	-	0.9	1.67	-	-	-
5	*Aglaia perviridis*	Meliaceae	T	VU	Indo-Malesia & China	1.17	1.62	2.34	-	0.59	0.62
6	*Aglaia tomentosa*	Meliaceae	T		Indo-Malesia & Australia	-	-	5.4	10.27	14.75	9.77
7	*Agrostistachys borneensis*	Euphorbiaceae	T		Indo-Malesia	22.13	5.57	12.07	5.87	-	0.74
8	*Agrostistachys indica*	Euphorbiaceae	T		Central & Pen.India	-	-	-	-	-	0.31
9	*Alangium salvifolium* ssp. *sundanum*	Alangiaceae	S		Indo-Malesia	0.47	-	-	-	-	-
10	*Alseodaphne semecarpifolia* var. *semecarpifolia*	Lauraceae	T		Pen.India & Sri Lanka	-	-	-	-	0.29	-
11	*Ancistrocladus heyneanus*	Ancistrocladaceae	L		S.India & Sri Lanka	1.4	-	-	-	0.59	-
12	*Anodendron paniculatum*	Apocynaceae	L		Indo-Malesia	2.05	-	-	-	-	-
13	*Antiaris toxicaria*	Moraceae	T		Paleotropic	0.23	-	-	-	-	-
14	*Antidesma montanum*	Euphorbiaceae	T		Indo-Malesia	0.94	1.21	0.78	0.71	2.76	1.24
15	*Aphanamyxis polystachya*	Meliaceae	T		S.Asia	-	0.3	-	0.3	-	-
16	*Aporusa lindleyana*	Euphorbiaceae	T		Pen.India & Sri Lanka	7.15	-	-	-	-	-
17	*Ardisia pauciflora*	Myrsinaceae	T		S.India & Sri Lanka	1.03	3.43	8.12	14.38	6.26	9.42
18	*Artabotrys zeylanicus*	Annonaceae	L		Pen.India & Sri Lanka	0.23	-	-	-	-	-
19	*Artocarpus gomezianus* ssp. *zeylanicus*	Moraceae	T		W Ghats & Sri Lanka	-	0.3	-	-	-	-
20	*Artocarpus heterophyllus*	Moraceae	T		Pen.India	0.23	-	0.26	2.41	2.64	1.67
21	*Artocarpus hirsutus*	Moraceae	T		S W Ghats	-	-	0.26	-	-	-
22	*Baccaurea courtallensis*	Euphorbiaceae	T		S W Ghats	5.94	5.35	0.26	-	-	-
23	*Beilschmiedia wightii*	Lauraceae	T	R & TH	S W Ghats	-	-	-	-	-	0.62
24	*Bhesa indica*	Celastraceae	T		Indo-Malesia	-	-	-	-	-	0.62
25	*Bischofia javanica*	Euphorbiaceae	T		Indo-Malesia to Pacific islands	-	0.6	-	-	-	-
26	*Calophyllum polyanthum*	Clusiaceae	T		Indo-Malesia & China	2.1	6.45	5.9	0.3	1.76	0.31
27	*Canarium strictum*	Burseraceae	T		India, Myanmar & China	0.94	0.9	0.52	-	-	-
28	*Capparis rheedei*	Capparadaceae	T	R	W Ghats	-	-	-	-	0.29	-
29	*Casearia ovata*	Flacourtiaceae	T		India & Sri Lanka	0.23	1.21	0.78	2.41	3.05	0.31
30	*Cassine paniculata*	Celastraceae	T		Indo-Malesia	-	-	-	-	0.59	-
31	*Cayratia pedata*	Vitaceae	L		Indo-Malesia	0.7	-	0.26	1.21	0.88	0.31
32	*Chionanthus ramiflores* var. *ramiflores*	Oleaceae	T		Indo-Malesia	-	-	-	-	1	0.74
33	*Chrysophyllum roxburghii*	Sapotaceae	T		Indo-Malesia	0.47	-	-	-	0.41	-
34	*Cinnamomum malabatrum*	Lauraceae	T		S W Ghats	0.94	0.6	2.34	1.21	2.94	1.86
35	*Clausena austroindica*	Rutaceae	S		India, Nepal, Sri Lanka & Africa	0.7	-	-	-	0.29	-
36	*Cleidion spiciflorum*	Euphorbiaceae	T		Indo-Malesia	-	-	-	-	-	3.33
37	*Clerodendrum viscosum*	Verbenaceae	T		Indo-Malesia	-	-	-	-	0.3	-
38	*Connarus monocarpus*	Connaraceae	L		Pen.India & Sri Lanka	-	-	-	0.3	2.06	0.86
39	*Croton malabaricus*	Euphorbiaceae	T		S W Ghats	2.79	1.81	1.87	-	-	2.28
40	*Croton zeylanicus*	Euphorbiaceae	T		Pen.India & Sri Lanka	-	0.9	0.26	1.92	-	1.79
41	*Cryptocarya anamalayana*	Lauraceae	T	VU	S W Ghats	0.7	-	-	-	0.29	-
42	*Cryptocarya wightiana*	Lauraceae	T		S.Asia	0.94	1.21	4	4.86	8.4	9.7
43	*Cullenia exarillata*	Bombacaceae	T		S W Ghats	9.22	13.56	13.78	14.66	3.57	7.88
44	*Dendrocnide sinuata*	Urticaceae	T		Pen.India & Sri Lanka	0.7	-	-	2.23	0.29	-
45	*Desmos lawii*	Annonaceae	L		S.India & Sri Lanka	-	-	0.26	-	-	-
46	*Dimocarpus longan*	Sapindaceae	T		Indo-Malesia	0.94	-	3.79	4.67	14.27	9.35
47	*Dimorphocalyx lawianus*	Euphorbiaceae	T		W Ghats	0.7	0.9	0.26	-	-	-
48	*Diospyros candolleana*	Ebenaceae	T		S W Ghats	2.28	7.18	3.95	1.81	1.58	2.17
49	*Diospyros montana*	Ebenaceae	T		Indo-Malesia & Australia	0.23	4.61	0.52	-	-	-
50	*Drypetes oblongifolia*	Euphorbiaceae	T		W Ghats	6.23	7.78	9.58	-	8.46	0.31
51	*Drypetes venusta*	Euphorbiaceae	T		Indo-Malesia	-	3.02	4.15	14.94	1.76	2.48
52	*Dysoxylum malabaricum*	Meliaceae	T		S W Ghats	1.4	3.02	1.3	0.6	0.88	-
53	*Elaeocarpus serratus*	Elaeocarpaceae	T		Indo-Malesia	-	0.6	1.04	-	-	-
54	*Elaeocarpus tuberculatus*	Elaeocarpaceae	T		Indo-Malesia	0.23	-	-	-	-	-
55	*Embelia ribes*	Myrsinaceae	L		Indo-Malesia	-	-	-	-	-	0.31
56	*Entada rheedei*	Mimosaceae	L		Indo-Malesia	0.23	-	-	-	-	-

Continued Appendix 1

Sl. No.	Species name	Family	Habit*	Conser-vation Status#	Distribution	Relative abundance (Relative density + Relative frequency) of plants in six locations					
						PC	MM	MK	PM	KPA	KPB
57	*Eugenia indica*	Myrtaceae	T	EN	S W Ghats	-	-	1.04	-	9.28	4.58
58	*Eugenia thwaitesii*	Myrtaceae	T		Pen.India & Sri Lanka	-	0.9	0.62	7.48	-	-
59	*Excoecaria oppositifolia*	Euphorbiaceae	T		Pen.India & Sri Lanka	-	-	-	0.3	-	-
60	*Ficus amplissima*	Moraceae	T		Pen.India & Sri Lanka	-	-	-	-	0.59	-
61	*Ficus nervosa*	Moraceae	T		Indo-Malesia & Australia	-	-	-	-	-	0.62
62	*Flacourtia montana*	Flacourtiaceae	T		Pen.India	0.47	-	-	-	-	-
63	*Garcinia morella*	Clusiaceae	T		Indo-Malesia	0.7	0.6	3.15	2.71	0.88	0.31
64	*Garcinia spicata*	Clusiaceae	T		India & Sri Lanka	0.23	0.6	0.26	-	-	-
65	*Glochidion zeylanicum* var. *zeylanicum*	Euphorbiaceae	T		Indo-Malesia	0.23	0.6	0.52	-	0.59	-
66	*Glycosmis pentaphylla*	Rutaceae	S		Indo-Malesia	0.23	-	-	-	-	-
67	*Gnetum edule*	Gnetaceae	L		Pen.India	0.7	-	-	-	-	-
68	*Gomphandra tetrandra*	Icacinaceae	T		Indo-Malesia	0.79	2.71	2.08	3.25	2.17	7.72
69	*Gymnema khandalense*	Asclepiadaceae	L		W Ghats	-	-	-	-	0.29	-
70	*Harpullia arborea*	Sapindaceae	T		Indo-Malesia & Australia	0.23	0.3	-	-	-	-
71	*Heritiera papilio*	Sterculiaceae	T		India, Bangladesh	-	-	-	2.61	15	1.98
72	*Hiptage benghalensis*	Malpighiaceae	L		Indo-Malesia & China	0.7	0.3	-	-	-	-
73	*Holigarna nigra*	Anacardiaceae	T		S W Ghats	0.7	0.3	1.41	0.6	1.47	3.95
74	*Hopea parviflora*	Dipterocarpaceae	T		S W Ghats	0.7	-	-	-	-	-
75	*Hydnocarpus alpina*	Flacourtiaceae	T		S.India & Sri Lanka	0.47	1.44	0.78	0.3	-	0.31
76	*Isonandra lanceolata forma. lanceolata*	Sapotaceae	T		S.India & Sri Lanka	-	0.3	-	3.77	0.82	0.62
77	*Ixora nigricans*	Rubiaceae	S		Indo-Malesia	0.23	0.3	1.79	-	-	-
78	*Kammetia caryophyllata*	Apocynaceae	L		S W Ghats	-	-	-	-	0.7	-
79	*Knema attenuata*	Myristicaceae	T		W Ghats	5.39	4.75	-	-	3.93	0.62
80	*Lagerstroemia microcarpa*	Lythraceae	T		W Ghats	0.23	-	-	-	-	-
81	*Lasinthus rostratus*	Rubiaceae	S	VU	S W Ghats	0.23	-	0.26	3.85	-	-
82	*Leea indica*	Leeaceae	S		Indo-Malesia, China & Australia	-	-	0.26	3.48	-	-
83	*Lepisanthes erecta*	Sapindaceae	S		India, Myanmar & China	-	-	-	-	-	0.31
84	*Leptonychia caudata*	Sterculiaceae	T		Paleotropic	-	-	0.52	-	-	-
85	*Litsea floribunda*	Lauraceae	T		W Ghats	0.23	-	0.78	0.3	-	-
86	*Litsea glabrata*	Lauraceae	T		S W Ghats	-	0.3	2.8	2.46	15.91	26.17
87	*Litsea oleoides*	Lauraceae	T		S W Ghats	-	-	0.26	0.6	-	-
88	*Litsea wightiana* var. *wightiana*	Lauraceae	T		S W Ghats	0.23	-	2.96	3.96	8.44	24.89
89	*Loeseneriella arnottiana*	Hippocrateaceae	L		S.India & Sri Lanka	1.03	0.3	-	-	-	-
90	*Macaranga peltata*	Euphorbiaceae	T		India & Sri Lanka	0.47	0.3	2.22	2.38	1.81	1.24
91	*Mallotus atrovirens*	Euphorbiaceae	T	VU	S W Ghats	-	1.21	1.04	2.04	-	-
92	*Mallotus philippensis* var. *philippensis*	Euphorbiaceae	T		Indo-Malesia & Australia	-	-	0.26	-	-	-
93	*Margaritaria indica*	Euphorbiaceae	T		Indo-Malesia & Australia	0.23	-	-	-	-	-
94	*Mastixia arborea* ssp. *meziana*	Cornaceae	T		S W Ghats	3.22	2.11	2.7	-	-	1.24
95	*Meiogyne pannosa*	Annonaceae	T		W Ghats	-	0.3	-	15.89	0.29	-
96	*Melicope lunu-ankenda*	Rutaceae	T		Indo-Malesia	0.23	0.3	-	-	-	-
97	*Memecylon deccanense*	Melastomataceae	T		S W Ghats	0.94	0.3	-	1.55	1.29	-
98	*Mesua ferrea*	Clusiaceae	T		Indo-Malesia	0.7	-	-	0.3	-	-
99	*Mesua thwaitesii*	Clusiaceae	T		S.India & Sri Lanka	2.84	0.9	8.18	8.15	4.75	5.7
100	*Millettia rubiginosa*	Fabaceae	L		S W Ghats	-	0.3	-	-	-	-
101	*Murraya paniculata*	Rutaceae	T		Indo-Malesia & Australia	-	-	-	-	-	0.93
102	*Myristica beddomei* ssp. *beddomei*	Myristicaceae	T		S.India & Sri Lanka	6.57	6.12	7.09	3.25	6.85	3.41
103	*Neolitsea cassia*	Lauraceae	T		Indo-Malesia	3.07	3.85	3.79	3.77	1.7	8.07
104	*Neolitsea scrobiculata*	Lauraceae	T		W Ghats	0.23	2.41	3.63	-	0.88	3.84
105	*Nostolachma crassifolia*	Rubiaceae	T	EN	W Ghats	-	-	-	0.3	3.93	-
106	*Nothopegia colebrookeana*	Anacardiaceae	T		Indo-Malesia & China	-	-	0.52	0.3	0.59	0.31
107	*Olax imbricata*	Olacaceae	L		Indo-Malesia	0.82	-	-	-	-	-
108	*Oreocnide integrifolia*	Urticaceae	T		India, Myanmar & Sri Lanka	0.23	0.6	1.97	0.71	-	0.31
109	*Ormosia travancorica*	Fabaceae	T		S W Ghats	0.94	-	-	-	-	-
110	*Orophea erythrocarpa*	Annonaceae	T		Pen.India & Sri Lanka	6.35	0.6	-	-	-	-
111	*Orophea uniflora*	Annonaceae	T	VU	S W Ghats	3.86	3.36	0.52	-	-	11.21

Continued Appendix 1

Sl. No.	Species name	Family	Habit*	Conser-vation Status#	Distribution	Relative abundance (Relative density + Relative frequency) of plants in six locations					
						PC	MM	MK	PM	KPA	KPB
112	*Otonephelium stipulaceum*	Sapindaceae	T		S W Ghats	5.12	5.17	1.92	-	-	-
113	*Oxyceros rugulosus*	Rubiaceae	L		S.India & Sri Lanka	0.23	-	-	0.71	2.46	-
114	*Palaquium ellipticum*	Sapotaceae	T		W Ghats	10.35	27.52	21.02	18.77	10.14	1.24
115	*Palaquium ravii*	Sapotaceae	T	EN	S W Ghats	9.93	-	-	-	-	-
116	*Paracroton pendulus* ssp. *zeylanicus*	Euphorbiaceae	T		W Ghats & Sri Lanka	2.84	6.79	2.54	-	-	-
117	*Persea macrantha*	Lauraceae	T		Pen.India & Sri Lanka	1.03	0.3	1.82	0.3	0.7	0.31
118	*Polyalthia coffeoides*	Annonaceae	T		S.India & Sri Lanka	1.81	5.7	6.41	1.81	-	-
119	*Polyalthia fragrans*	Annonaceae	T		S.India & Sri Lanka	1.58	-	0.52	-	-	-
120	*Prunus ceylanica*	Rosaceae	T		Indo-Malesia	0.47	-	0.36	-	-	-
121	*Psychotria anamalayana*	Rubiaceae	T		S W Ghats	-	-	0.88	3.63	-	-
122	*Psychotria nudiflora*	Rubiaceae	S		S W Ghats	5.79	4.31	1.3	2.11	-	1.47
123	*Psydrax travancorica*	Rubiaceae	T		S W Ghats	-	0.3	0.26	-	-	-
124	*Psydrax umbellata*	Rubiaceae	T		Indo-Malesia & China	-	-	0.26	-	-	-
125	*Reinwardtiodendron anamalaiense*	Meliaceae	T		S W Ghats	16.88	23.57	4.01	-	2.06	-
126	*Rourea minor*	Connaraceae	L		Indo-Malesia	0.23	0.3	-	-	-	-
127	*Sageraea laurifolia*	Annonaceae	T	LR/NT	W Ghats	-	-	-	-	0.29	-
128	*Scolopia crenata*	Flacourtiaceae	T		Indo-Malesia	-	-	-	-	0.29	-
129	*Spondias pinnata*	Anacardiaceae	T		Indo-Malesia	0.23	-	-	-	-	-
130	*Strobilanthes anceps*	Acanthaceae	S		India & Sri Lanka	-	0.6	-	-	-	-
131	*Strombosia ceylanica*	Olacaceae	T		Indo-Malesia	2.57	5.17	0.52	-	-	-
132	*Strychnos colubrina*	Loganiaceae	L		Indo-Malesia	1.81	0.3	0.26	2.04	-	-
133	*Symplocos macrophylla* ssp *rosea*	Symplocaceae	T		S W Ghats	0.7	-	0.52	-	-	-
134	*Syzygium gardneri*	Myrtaceae	T		W Ghats & Sri Lanka	1.03	2.11	3.89	0.6	0.88	0.62
135	*Syzygium laetum*	Myrtaceae	T		S W Ghats	3.51	3.66	9.36	7.96	13.54	13.54
136	*Syzygium lanceolatum*	Myrtaceae	T		S.India & Sri Lanka	-	-	-	-	0.7	0.62
137	*Tabernaemontana gamblei*	Apocynaceae	S	LR/cd	S W Ghats	-	-	-	-	-	0.31
138	*Terminalia bellirica*	Combretaceae	T		Indo-Malesia	0.47	-	-	-	-	-
139	*Terminalia travancorensis*	Combretaceae	T		W Ghats	0.23	-	-	-	-	-
140	*Toddalia asiatica*	Rutaceae	L		Indo-Malesia & Africa	0.23	1.02	0.88	0.3	0.82	-
141	*Trewia nudiflora*	Euphorbiaceae	T		Indo-Malesia	0.23	-	0.26	-	-	-
142	*Turpinia malabarica*	Staphyleaceae	T		S.India & Sri Lanka	0.23	-	-	-	-	0.31
143	*Vateria indica*	Dipterocarpaceae	T		S W Ghats	4.42	-	2.34	-	-	-
144	*Ventilago bombaiensis*	Rhamnaceae	L		W Ghats	1.17	-	0.26	0.6	1.7	-
145	*Vepris bilocularis*	Rutaceae	T	R	S W Ghats	0.47	0.3	0.52	-	0.59	-
146	*Xanthophyllum arnottianum*	Xanthophyllaceae	T		W Ghats	1.34	0.3	-	-	-	-
147	*Xantolis tomentosa* var.*tomentosa*	Sapotaceae	T		India, Myanmar & Sri Lanka	-	-	-	-	0.29	-
148	*Unidentified Tree1*		T			-	-	-	-	-	1.24
149	*Unidentified Liana1*		L			0.47	-	-	-	-	-
150	*Unidentified Liana2*		L			0.23	-	-	-	-	-
151	*Unidentified Liana3*		L			0.47	-	-	-	0.88	-
152	*Unidentified Liana4*		L			-	-	-	0.3	-	-

* L=Liana, T=Trees, S=Shrub. # EN=Endangered, R=Rare, TH=Threatened, VU=Vulnerable, LR/cd=Low Risk/conservation dependent, LR/NT=Low Risk/Near Threatened.

PC---Pulikkalchola, MM---Manguttimala, MK---Manjalkunnu, PM---Pothumala, KPA---Karapara-A, KPB---Karapara-B