Changes in forest composition and structure in three sites of tropical evergreen forest around Sengaltheri, Western Ghats

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Changes in woody species composition, abundance and forest stand structure were investigated in three sites of tropical wet evergreen forest around Sengaltheri in Kalakad–Mundanthurai Tiger Reserve, Western Ghats, south India. Three 1-ha plots were established one each in undisturbed, selectively-felled, and moderately disturbed sites, located 2 to 4 km apart. In a total of 3.14 ha, 2673 stems (mean 851 ha^{-1}) of ≥ 30 cm girth at breast height covering 125 species (range: 64 to 82 species per site) were enumerated. Species richness and tree density varied moderately among the sites. Changes in species composition and abundance are related to natural site variations as well as human impacts. Need for forest conservation is emphasized.

THE diversity of trees is fundamental to total rain forest biodiversity, because trees provide resources and habitat structure for almost all other rainforest species[1]. Unlike in other forest formations, quantitative enumeration in the species-rich, dense and tall tropical evergreen forests, is a far more complex task. There is also a wide variation in the composition and abundance of species between various tropical forests.

The effect of tree felling on forest diversity is largely unknown. In areas which are selectively-logged, several structural damages may not be noticeable, but eventually species removal would affect local diversity and forest stand structure and in turn the dependent fauna.

The Agasthyamalai range (2000 km^2), located at the southern end of the Western Ghats in south India, is known for high plant diversity, harbouring 2000 flowering plants with 7.5% endemism[2] and the flora of former Kalakad Wildlife sanctuary, which is part of Kalakad–Mundanthurai Tiger Reserve (KMTR) that displays a 3.3% endemism[3]. Two studies are available on the plant diversity in the evergreen forest of Kakachi[4] and of Kalakad[5], both located at higher elevations within KMTR. This area exhibits considerable variation in plant diversity perhaps as a result of small-scale changes in elevation, coupled with the historical differences in land use. Considering these variations and because there were no tree inventories conducted earlier in the low elevation (< 1000 m) and medium elevation (1000–1150 m) forests, this investigation was undertaken. The scope of this paper is thus limited to 920–1150 m stretch of evergreen forest in Sengaltheri.

The prime objective of this paper is to study the patterns of tree diversity and abundance in the undisturbed and human-impacted sites of tropical wet evergreen forest of the low and medium elevation areas of Sengaltheri in KMTR.

Study area

The study sites, located around Sengaltheri (16 km from Kalakad town; elevation, 920–1150 m), are in tropical wet evergreen forest. These forests are classified as Tirunelveli hill top forests[6] and as *Cullenia–Mesua–Palaquium* series[7]. Nearly a century ago three patches of evergreen forest measuring about 5 ha each were converted to cardamom plantations, and cultivation continued until 1993. A few patches initially developed for cardamom plantation were abandoned after about a year, because of poor crop yield. There are no tribals here, but a small population of about 30 families of cardamom estate workers lived near Sengaltheri until 1993, later the plantation was abandoned. Their habitation was located 1–3 km away from the three study plots. Mean annual ambient temperature in the evergreen forest is 22.5°C (range 15–30°C) and soil temperature 21.9°C (range 14–25°C). Mean annual rainfall is about 3000 mm from the southwest (May–August) and northeast monsoons (October–December). Strong winds are common during the southwest monsoon.

The study was conducted from January to May 1989. Three 1-ha plots were established covering one undisturbed and two human-impacted sites of the wet evergreen forest in Sengaltheri and adjoining areas, located about half to 2 km away from Sengaltheri forest rest house (SRH; 920 m). Plot 1 in undisturbed site (named UD) at 1000 m elevation, is located (about 1 km southwest of SRH) in a relatively pristine forest area, with no signs of felling. Plot 2, in an area at 1150 m where selective tree felling was practiced, is located (~ 2 km southeast of

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SRH) in a site that was disturbed 35 years ago. There are no records on the intensity and the extent of disturbance. The site has been regenerating since then. In plot 3, a moderately disturbed area (MD), located at lower elevation in Sengaltheri–Kuliratti route (920 m; half a km south of SRH), gathering fire wood and use as pathway (about 3 m wide) to reach Kuliratti estate were major human impacts. These estates were leased forest lands (leased for 99 years) and after the lease was over (in 1993–1994) they were to be handed over to the state forest department. Presently the site is left for natural regeneration, but during the period of this study cardamom cultivation was still in progress.

Methods

The three 1-ha square plots were tentatively gridded into 10 × 10 m quadrats as workable units. In sites SF and MD, plot size slightly exceeded 1-ha by 0.0125 and 0.125 hectares respectively. All living trees and lianas ≥ 30 cm girth at breast height (gbh) were identified and their girth measured at 1.3 m from ground level. For buttressed trees, measurements were made above the buttress as far as possible and for lianas, 1.3 m from the base of liana stems. For multi-stemmed trees, bole girths were measured separately, basal area calculated and summed. For species diversity, Shannon index (H)[8] was calculated. Species-area curves were constructed by sequential summing of 20 × 20 m (400 m^2) sub-plots.

Results

Species diversity

Woody species ≥ 30 cm gbh totaled 125 species in 91 genera and 42 families in the three study plots. Eleven species remain unidentified, six of them were singletons. Species richness of the three sites varied moderately (Table 1), especially when it is corrected for 1-ha sample units. The (12%) greater stem density could also account for the greater species richness in site UD. The Shannon index also followed the same pattern as that of species richness (Table 1). Genera with a large number of species include *Diospyros* (5 species), *Syzygium* (5, excluding one *Eugenia* sp.), *Artocarpus* (3), *Litsea* (3) and *Pterospermum* (3). Of the 125 species, 11 were lianas, 113 were trees, and one large herb (*Ensete superbum*) was a wild banana. The occurrence of *Nageia wallichiana*, the only conifer native to peninsular India, and the endemic palm, *Bentinckia condapana* is notable. Species-area curves for all the three plots reveal that species increment was more or less the same for all the three plots and the curves approach an asymptote (Figure 1).

Variation in species composition and abundance

The composition and population density of species, particularly of the most abundant trees varied among the three sites (Table 2) (due to page limitation, density of all the 125 species is not provided). Variation in topography and small-scale elevational difference and the extent of human impacts could contribute to this difference. Three species, *Xanthophyllum flavescens*, *Toona ciliata* and *Litsea stocksii* formed 27% of the stand in site UD. The

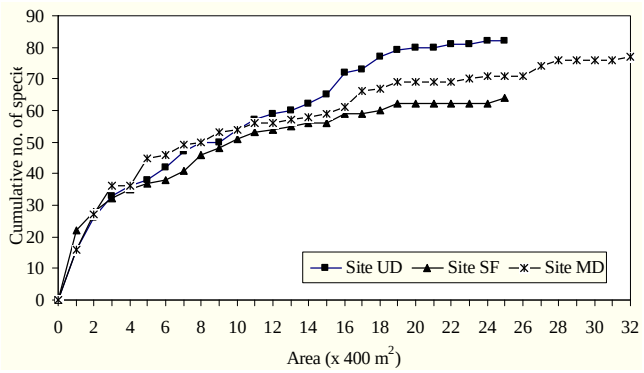

Figure 1. Species-area curves for study plots UD, SF and MD, in the tropical wet evergreen forest of Sengaltheri, KMTR, Western Ghats.

Table 1. Results of woody species inventory in undisturbed (UD), selective-felled (SF) and moderately disturbed (MD) sites in the tropical wet evergreen forest around Sengaltheri, KMTR, Western Ghats, south India

Variable	Site			
	Undisturbed (UD)	Selective felled (SF)	Moderately disturbed (MD)	In all 3-ha
Species richness	82	64	77	125
Shannon index, H	3.69	3.32	3.516	3.898
Stand density (stems ha^{-1})	965	856	852	2673
Stand basal area (m^2 ha^{-1})	55.34	78.32	67.2	
Area of sample plot (ha)	1.0	1.0125	1.125	3.2625
Altitude (m)	1000	1150	920	
Terrain	Steep gradient	Gentle slope	Flat	

latter two species were rare (1 to 3 individuals) in the other two plots. *Myristica dactyloides*, *Dimocarpus longan*, *Mangifera indica* and *Agrostistachys borneensis* together contributed 39% of the stand in SF, while these were occasional to rare in UD. In MD, *Dimocarpus longan*, *Syzygium mundagam*, *Mangifera indica*, *Nothopegia beddomei* and *Myristica dactyloides* formed 37% of the stand and these species characterize the low elevation sites.

Family composition

The number of woody plant families from the three study sites was 42. Lauraceae with 11 species (9%) dominated the forest canopy, followed by Euphorbiaceae (8), Myrtaceae, Meliaceae and Rubiaceae (6 species each), while, density-wise, Myristicaceae (170 trees) and Sapindaceae (244) dominated the stand.

Forest stand density and basal area

The forest stands were dense with 2,673 stems in the 3.14 ha (mean density 851 stems ha^{-1}). Tree density was greatest (965) in site UD while basal area was least in this plot (Table 1), probably due to steep slope. Stand density was more or less similar for sites SF and MD (856 and 852 stems), while SF had 12% greater values than MD.

Forest stand structure

The population structure of the forest stand was reverse J-shaped, with girth frequency and basal area distribution in various size classes similar in all three sites, except for the largest (> 210 cm gbh) size class, which was greatest in SF, least in UD and intermediate in MD (Figure 2).

Stem girth-class diversity and density

Tree species richness, density, and diversity index consistently decreased with increasing stem size classes from 30 cm gbh to 210 gbh, except in the last class of 210 cm gbh (Table 3). The lowest size class captured 89% of species richness, 54% of forest stand density, and there was a 5-fold decrease in richness and about a 40-fold decrease in density in 180–210 cm girth.

Discussion

For the comparable 1-ha scale tree inventories (stems ≥ 30 cm gbh), the species richness of 64–82 species recorded in this study is nearly similar to 64–85 species ha^{-1} recorded in the high elevation forest of Kalakad[5], but lower than that of 57 species ha^{-1} in Mylodai, Courtallum RF, and 30 species ha^{-1} in Nelliampathy, Kerala[9]. Although a few more tree inventories are available from the West-

Table 2. Population density of tree species, most abundant in one or two of the three study sites (undisturbed (UD), selective-felled (SF) and moderately disturbed (MD)) in tropical wet evergreen forest, Sengaltheri, KMTR, Western Ghats

		Number of individuals in		
Species	Family	UD	SF	MD
Acronychia pedunculata (L.) Miq.	Rutaceae	49	0	0
Agrostistachys borneensis Becc.	Euphorbiaceae	41	71	0
Antidesma menasu (Tul.) Miq. ex M. Arg.	Stilaginaceae	34	23	3
Cinnamomum malabatrum (Burm. f.) Bl.	Lauraceae	2	28	31
Cullenia exarillata Robyns	Bombacaceae	44	18	0
Dimocarpus longan Lour.	Sapindaceae	2	74	87
Diospyros sylvatica Roxb.	Ebenaceae	29	0	1
Elaeocarpus serratus L.	Elaeocarpaceae	26	0	1
Filicium decipiens (Wt. & Arn.) Thw.	Sapindaceae	1	15	40
Litsea stocksii (Meisner) Hook. f. var. *glabrescens* (Meisner) Hook. f.	Lauraceae	60	1	0
Mallotus intermedius (Baillon) Balak.	Euphorbiaceae	28	3	0
Mangifera indica L.	Anacardiaceae	1	70	53
Myristica dactyloides Gaertn.	Myristicaceae	2	119	49
Nothopegia beddomei Gamble	Anacardiaceae	3	5	51
Oreocnide integrifolia (Gaud.) Miq.	Urticaceae	0	45	0
Palaquium ellipticum (Dalz.) Baillon	Sapotaceae	1	32	0
Phoebe lanceolata Nees	Lauraceae	0	0	20
Psychotria connata Wall.	Rubiaceae	32	0	2
Syzygium mundagam (Bourd.) Chitra	Myrtaceae	41	14	73
Toona ciliata M. Roem.	Meliaceae	100	0	3
Xanthophyllum flavescens Roxb.	Xanthophyllaceae	100	0	33
Subtotal (21 species)		596	518	447
Remaining (104 species)		369	338	405
Total		965	856	852

ern Ghats area, they cannot be strictly compared (e.g. 45 species ha^{-1} of Kakachi[4]), because of smaller scale and or non-contiguous plots, separated by long distances. Clearly, the wet evergreen forests of Sengaltheri section of KMTR is species-rich compared to other forests of southern Western Ghats. In the wet evergreen forests across the tropics, tree diversity ranges from 20 species ha^{-1} in Rio Xingu, Brazil[10] to 307 species ha^{-1} in Amazonian Ecuador[11]. Thus Kalakad is intermediate in species richness in the tropics. The species diversity of a given forest area, besides climate and geographic location, would also depend on site representativeness, plot dimension, various site attributes, and the extent of human interaction in the past and present.

The influence of small-scale elevation changes on species composition is not well known. The undisturbed site at 1000 m elevation harboured slightly greater number of species than the other two sites. The occurrence of *Toona ciliata*, *Litsea stocksii* as predominants in site UD with the codominants, *Acronychia pedunculata*, *Diospyros sylvatica*, *Mallotus intermedius* and *Psychotria connata* indicates the exposed slopy area of this site, as these are light-demanding species, with the exception of *Xanthophyllum*, which is a lower-storey species. Notably many of these species are long-lived pioneers, unlike the relatively short-lived *Macaranga*. The abundance (26 stems) of *Elaeocarpus serratus*, a riparian zone species, in site UD, compared to SF (0) and MD (1), can be attributed to the location of one side of this plot along the bank of river Pachayar–Manimuthar bifurcation point. *Cullenia exarillata* (whose seeds are a preferred food of the endemic lion-tailed macaque *Macaca silenus*) was recorded in sites UD and SF, due to their relatively higher elevation (> 1000 m). More sampling along the entire elevation gradient of 900–1500 m could reveal the patterns of species diversity.

The mean tree density of 851 trees ha^{-1} in this inventory for the comparable ≥ 30 cm girth threshold, is greater than that of 419 trees ha^{-1} reported as mean tree density for Western Ghats closed-canopy evergreen forest[9] and that of high-elevation forest of Kalakad (716 stems ha^{-1})[5], Mylodai site in Courtallum RF (482 ha^{-1})[12], and Kakachi (583 ha^{-1})[4] in the southern Western Ghats and that of Uppangala, central Western Ghats (635 ha^{-1})[13]. The tree basal area value of Sengaltheri mid-elevation forest in KMTR is well within the range of tropical wet forest: 25.5 m^2 in Rio Xingu, Brazil[10], 82.76 m^2 in the tropical rainforest of Reunion islands[14] to 94.6 m^2 ha^{-1} in the high-elevation forest of Kalakad[5]. The different wet evergreen forests of Agasthyamalai including KMTR are dominated by the families Lauraceae, Euphorbiaceae and Myrtaceae followed by Rubiaceae, Annonaceae (mostly understorey species), Ebenaceae and Meliaceae.

The reverse J-shaped population structure of trees exhibited in all the three study sites is in conformity with many other forest stands in Western Ghats such as Kakachi[4], Uppangala[13], Mylodai-Courtallum RF[12] and high elevation forest of Kalakad[5]. In site SF, selective felling of trees 35 years ago followed by abandonment without any further disturbance, served as a stand-thinning process. This would have probably helped the medium-sized boles to attain greatest biovolume increment due to less competition among saplings and by wider spacing between trees. An alternative and more likely explanation is that for cardamom cultivation, a few larger trees retained as shade trees, appears to have contributed to greater basal area. The fertilizer input to cardamom crops would have probably helped in tree girth increment.

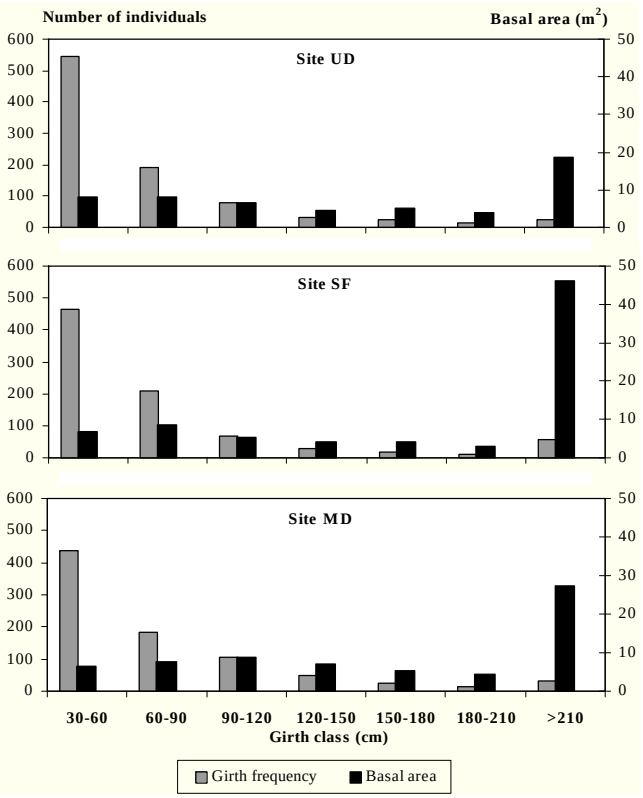

Figure 2. Population structure of woody species in sites UD, SF and MD, based on girth-frequency and basal area.

Table 3. Species richness, stand density and diversity indices for different stem size classes for the whole three hectare area in the tropical wet evergreen forest around Sengaltheri, KMTR, Western Ghats

Girth class (cm)	Species richness	Stand density	Shannon index
30–60	110	1480	3.898
60–90	79	596	3.708
90–120	59	256	3.548
120–150	38	112	3.341
150–180	32	71	3.207
180–210	22	40	2.787
> 210	35	118	3.045

Conclusion

The wet evergreen forests of KMTR, particularly around Sengaltheri and the routes leading to Neterikal, Kuliratti and Kakachi harbour a diverse flora. Previous works in these forests concentrated on quantitative floristic surveys[3,15,16]. This study and an allied one[5] deal with the differences in the diversity as well as abundance of all woody species (≥ 30 cm gbh) inventoried in low, medium and high elevation forests. These differences are related to both natural site variation (small-scale elevation, slope, nearness to water bodies) and human impacts. Evidently, in small areas of wet evergreen forest of Sengaltheri, KMTR, various portions of wet evergreen forest are dominated by different combinations of species, but none of the three study sites is monodominant forest. Data on the population density of some of the important tree species which provide rewards that are preferred by some (key) fauna (for e.g. fruits of *Cullenia* by lion-tailed macaque and that of *Syzygium mundagam* by Nilgiri langur), in the forests would be of immense use in forest conservation. Woody species rarity with greater number of singletons in the site also underlines the need to preserve vast area of this forest, as a single large reserve. The KMTR, besides being biologically an important area with unique flora and fauna, is also a habitat for wild relatives of cultivated plants, such as mango, jack and cardamom, and is a catchment area for more than 6 major river systems. Hence, the protection of this reserve is crucial for biological conservation of species and for human welfare.

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