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Floristic species composition and structure of a mid-elevation tropical montane evergreen forests (sholas) of the western ghats, southern India

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Abstract: The study provides descriptive information of the floristic composition, forest structure and effects of disturbance on forest structure of a mid-elevation (≥ 1800 ≤ 2100 m amsl) tropical montane evergreen forests (sholas) in the Nilgiri Mountains, southern India. Sampling plots of 10 × 100 m (1000 m^2, 0.1 ha) were surveyed in ten different locations within a large patch, giving a total sample area of approximately 1 ha. All individual stems (≥ 1 cm dbh) of trees, shrubs and lianas from these plots were identified to species level and counted. A total of 3896 individuals (≥ 10 cm dbh) comprising 97 species, 79 genera and 45 families were included. On average there were a total of 1246 individual stems of at least 10 cm per hectare with a basal area 53.33 m^2 ha^{-1}. The species abundance distribution did not differ significantly from a log-normal distribution. According to the Importance value index (IVI), five species, namely *Litsea glabrata, Lasianthus venulosus, Meliosma simplicifolia, Daphniphyllum neilgherrense* and *Neolitsea fischeri* were dominant species in the community and influenced forest structure more than any other species present. Lauraceae, Rubiaceae, Euphorbiaceae, Myrtaceae and Symplocaceae were most dominant families according to the Family Importance Value index (FIV). Our results also suggest that disturbance influences tree species richness and density and liana density and basal area, in addition to forest structure and changes species composition. Moreover, the study shows that one-hectare floristic inventories of shola forests can provide a useful tool for assessing plant biodiversity, and provide useful information for effective conservation and management of nature reserves.

Key words: Disturbance factors**,** high-elevation, liana diversity, species abundance, tree diversity.

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Introduction

Large-scale and long-term floristic inventories have been conducted in various tropical forests globally for over a century (Baithalu *et al.* 2013; Ostertag *et al.* 2014; Pragasan & Parthasarathy 2010; Sultana *et al.* 2014). Small-scale floristic inventories provide an effective method to explore forest structure, and tree and liana species composition within tropical forest communities (Castillo-Campos *et al.* 2008; Mohandass & Davidar 2010; Mohandass *et al.* 2014). Comparing forest structure and species composition between one hectare plots has the potential to provide useful insights which can help inform forest conservation and management (Armstrong *et al.* 2011).

Human utilization of forest resources often starts with grazing or subsistence wood collection, followed by small scale forest clearance, then the gradual expansion of these deforested patches causing a cryptic loss of nature reserve forest area (Puyravaud *et al.* 2010). To understand the extent human activity is affecting forest structure and forest biodiversity, small-scale floristic surveys may provide useful information.

The tropical montane rainforests or montane evergreen forests of the upper Nilgiri Mountains (locally called '*sholas*'), include many endemic and endangered plant and animal species (Blasco 1970; Mohandass *et al.* 2008). Local species diversity, community composition and forest structure of shola forests may vary with altitude and local micro-climatic conditions. In former studies 63 plant species were recorded from a one ha plot in Thaishola, Nilgiri mountains (2000 - 2200 m amsl, Narendren *et al.* 2001), and 83 species in a 1.08 ha plot in the Palni hills (1800 and 2005 m amsl) (Davidar *et al.* 2007). Thus species richness and community composition may differ according to elevation (Trigas *et al.* 2013), disturbance (Mohandass *et al.* 2015), and other environmental and climatic conditions (Tielbörger *et al.* 2014).

More floristic surveys are needed in order to understand drivers of variation in forest structure and community composition at a variety of scales across the mid-elevation region. In this study, sampling of floristic composition were conducted in the mid-elevation of the Nilgiris, and the aims of this study were (1) to describe plant community composition, structure and species diversity in mid-elevation tropical montane forest (2) to determine how disturbance influences tree and liana diversity at the local scale (3) to compare species diversity, community composition and forest structure between high-elevation shola forests across the Nilgiri Mountains.

Materials and methods

Study area

The study area was located in the Amaggal Reserve Forest (11° 14. 570´ N and 76° 36. 527´ E) about 4 km away from any human settlement, and about 40 km south-west of Ootacamund in the Nilgiri District (Fig. 1). Amaggal nature reserve includes about 30 ha of continuous forest and is embedded in a planted acacia, tea and eucalyptus mosaic, it also provides a source of fuelwood for local people. The floristic and faunistic diversity of Amaggal is higher than that found in higher elevation forests (> 2200 m) in the nearby Nilgiris (Mohandass *et al.* 2008). Forest structure across the western ghats varies with topography, and shows distinct differences between forest edges and forest interior zones, at different degrees of slope, and in valleys. The elevation of the study area ranges from 1900 - 2033 m amsl. The bedrock is predominently composed of gneisses, charnockites and schists (von Lengerke 1977). The soil is predominantly either a ferrallitic humiferous soil or an andisol, and largely black in colour with a high organic matter content (Blasco 1970; Caner *et al.* 2007).

The climate is cold, wet and windy during the monsoon with a temperature range from below zero to 23 °C, and frost is common between December and February. Amaggal receives monsoonal rainfall twice annually, from both the South West (SW) and North East (NE) monsoons. The mean annual rainfall across a ten year period (1997 - 2007) was 2108 mm at Korakundah Tea Estate, located 10 km away from the Amaggal Reserve Forest. The annual dry season lasts five months, based on the number of sequential months with rainfall under 100 mm.

Methods

From December 2007 to February 2008, we randomly established 0.1 ha (1000 sq. m) plots of 10 × 100 m in 10 different locations within the shola forest of the Amaggal region. Within each 0.1 ha plot we surveyed all plant species including trees, shrubs and lianas of over one cm dbh using the National Inventory Protocol (Muthuperumal & Parthasarathy 2010; Pragasan & Parthasarathy 2010). Sampling was terminated where the species accumulation curves reached an asymptote, and no

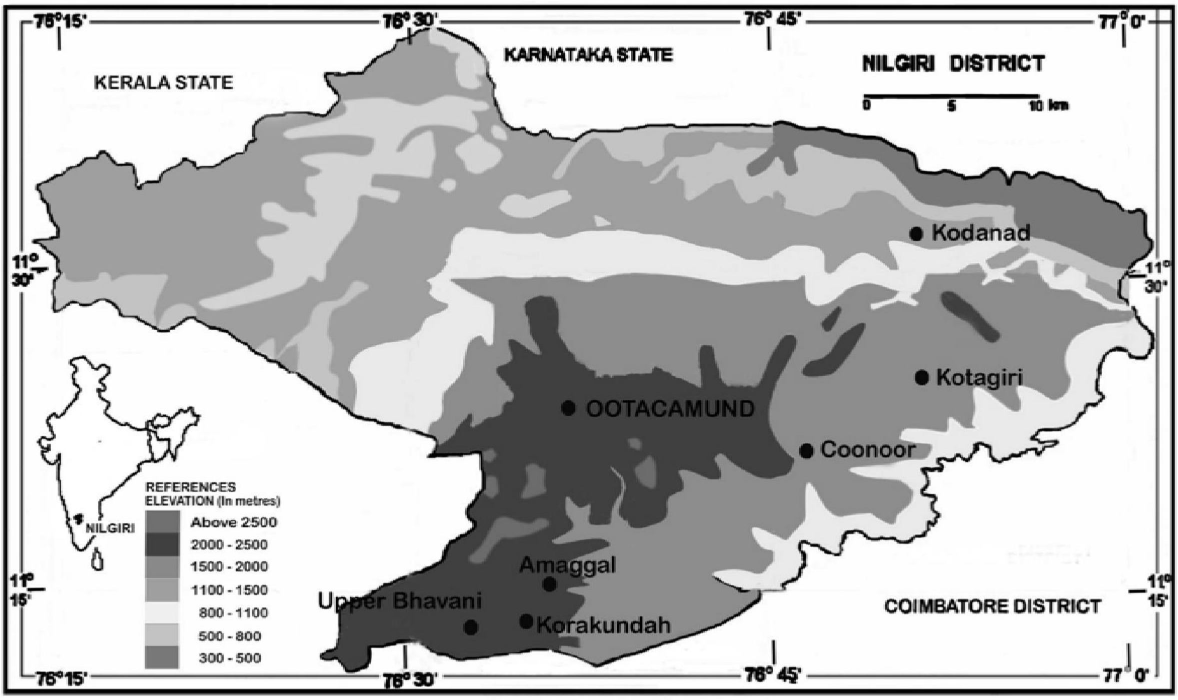

Fig. 1. Location of study site Amaggal Reserve Forest, Nilgiri Mountains, southern India.

additional species were found on further increases in plot area. The slope correction for each plot was made using a slope meter (Mohandass & Davidar 2010). All species were identified and verified using various floral keys, and using the APG III classification scheme (Bremer *et al.* 2009; Fyson 1932; Gamble 1915-1935; Matthew 1999). Identification of specimens was confirmed by the Botanical Survey of India, Coimbatore and the French Institute of Pondicherry. Herbarium specimens were deposited at the Edhkwehlynawd Botanical Refuge (EBR) Centre, Nilgiris.

Biotic richness (at species, genera and family levels), stem density, Fisher's alpha and basal area m^2 ha^{-1} and Importance value index (IVI) were assessed for each of the ten 0.1 ha plots. Fisher's alpha (a measure of diversity) was used to assess species diversity since it is fairly independent of plot size (Condit *et al.* 1998; Fisher *et al.* 1943; Mohandass *et al.* 2015). Shannon and Simpson diversity indices (Da Silva 2014; Magurran 2004) were calculated to determine the species-abundance relationships in plant communities.

To understand floristic structure, the importance value index (IVI) was also calculated by summing up relative frequency, relative density and relative basal area of every species (Curtis & McIntosh 1950; Sultana *et al.* 2014). Taxonomic composition was quantified based on Family importance value (FIV) and was calculated by summing the relative diversity, relative density and relative basal area of each family, according to the formula of Mori *et al.* (1983). The species were arranged in descending order of abundance and the natural logarithm of the total number of stems per species (N) was computed in order to generate the abundance distribution. Based on the number of individuals per species we categorized species into four groups based on frequency of occurrence. The most frequently occurring species (over one hundred individuals per species) were classed as dominant, the next most frequent as common (twenty to one hundred individuals per species), then uncommon (three to nineteen individuals per species) and rare (one to two individuals per species). Mean species richness of the two dbh classes was compared using the one way t-test. The frequency distribution of species and the stem density of various dbh classes was tested by G-test. The association between mean species richness and stand density of various dbh size classes were tested using a G-test.

In the present study we grouped plots within the study area into three distinct disturbance categories, low, moderate and high. Areas with low disturbance (LD) show little or no active human

Table 1. Summary of floristic survey data of various dbh class and different life-forms from a one hectare plot of tropical montane evergreen forest in the Nilgiri Mountains, western ghats, India.

Variables	All species		Trees and shrubs		Lianas	
	≥ 1 cm	≥ 10 cm	≥ 1 cm	≥ 10 cm	≥ 1 cm	≥ 10 cm
Species richness	97	63	75	56	22	7
Number of genera	73	55	61	48	18	7
Number of families	45	35	35	30	14	7
Number of individuals	3896	1246	3694	1224	202	22
Basal area (m^2 ha^{-1})	59.27	53.33	58.07	52.36	1.2	0.97
Fisher's α	18.03	14	13.33	12.11	6.28	3.54
Shannon_H	3.4	3.3	2.24	3.24	2.49	1.69
Simpson_1-D	0.95	0.95	0.94	0.95	0.88	0.77

disturbance. Moderate disturbance (MD) indicates low levels of human disturbance or use, normally only firewood collection. Highly disturbed (HD) areas show high levels of disturbance (possibly over extended portions of time), with regular tree-cutting and other forms of disturbance. Highly disturbed forest plots are also frequently smaller than less disturbed sites, and located near human habitation (Mohandass *et al*. 2014). The study included four relatively undisturbed forest plots (LD), three moderately disturbed forest plots (MD) and three highly disturbed forest plots (HD).

Analysis of co-variance (ANCOVA) was used to analyse the effect of disturbance on tree and liana species richness, density and basal area. Comparison of mean tree and liana species richness, density and basal area between disturbance scores was analysed using one-way t-tests.

Results

Species richness, floristic composition and forest structure

A total of 3896 individuals, including 97 species, 79 genera and 48 families were recorded, these included 62 tree (64 % of species found,), 22 liana (22.6 %) and 13 shrub (13.4 %) species. Analysis based on all plants of at least a 1 cm dbh, the stem density was 3896 ha^{-1} and basal area was 59.27 m^2 ha^{-1} (Table 1). When considering only individuals with a dbh of over 10 cm, the stem density was 1290 stems ha^{-1} and the basal area 53.20 m^2 ha^{-1} (Table 1). With all plant species included, mean species richness was 40.16 ± 8.17 for species with at least 1 cm dbh, and 19.7 ± 3.85 for species with a dbh of at least 10 cm. Trees and shrubs showed a mean species richness of 49.2 ± 10.32 for species with a dbh of over 1 cm and 21.8 ± 4.3 for species with a dbh of over 10 cm. The Fisher's alpha value was 18.03 for all plant species, the Shannon index was 3.40 and the Simpson index was 0.95, diversity values did not vary between the two size classes for any of diversity indices (Table 1).

According to the Importance Value Index (IVI), the ten most dominant species (i.e. with the greatest contribution to floristic species composition and structure) were *Litsea glabrata* (Nees) Hook. f. var. *glabrata* (15.5 %), *Lasianthus venulosus* (Wight & Arn.) Wight (14.4 %), *Meliosma simplicifolia* (Roxb.) Walp. (13 %), *Daphniphyllum neilgherrense* (Wight) K. (12.3 %), *Neolitsea fischeri* Gamble (11.13 %), *Syzygium densiflorum* Wall. ex Wight & Arn. (10.9 %), *Symplocos cochinchinensis* (Lour.) S. Moore (10.8 %), *Tarenna asiatica* (L.) Kuntze ex K. Schum. (10.7 %), *Ilex denticulata* Wall. ex Wight (9.8 %) and *Excoecaria oppositifolia var. crenulata* (Wight) Chakrab. & M. Gangop (9.7 %). *Tetrastigma leucostaphylum* (Dennst.) Alston was the dominant liana representing 2.6 % of the stems. Twenty species had only one record (Appendix Table 1) of which five were lianas, six were shrubs and nine were trees. The genus *Litsea* had greatest number of species (4), followed by *Piper* (3), *Rubus* (3), *Psychotria*, *Cinnamomum*, *Syzygium, Symplocos*, *Celtis, Ilex*, *Hedyotis*, *Crotalaria* and *Neolitsea* (2 species each). Lauraceae was the dominant family with 12 species, followed by Rubiaceae with 10 species (Table 2). The Family Index Value (FIV) indicated that the ten most dominant families (which contributed most to the structural composition), were Lauraceae (49.5 %), Rubiaceae (47.9 %), Euphorbiaceae (23.3 %), Myrtaceae (20.1 %), Symplocaceae (18.6 %), Aquifoliaceae

Table 2. Family diversity, abundance, basal area (m^2 ha^{-1}) and Rank abundance of plots overall (1 ha) in the montane evergreen forest of the Nilgiri Mountains.

Family	Species richness	Stems (ha^{-1})	Basal area (m^2 ha^{-1})	FIV
Lauraceae	12	827	9.45	49.54
Rubiaceae	10	1121	5.22	47.89
Euphorbiaceae	3	496	4.39	23.23
Myrtaceae	3	131	8.1	20.12
Symplocaceae	2	358	4.37	18.62
Aquifoliaceae	2	53	7.27	15.69
Sabiaceae	1	200	3.86	12.68
Staphyleaceae	1	97	3.52	9.46
Celastraceae	4	75	1.86	9.19
Myrsinaceae	3	106	1.34	8.07
Oleaceae	4	29	0.91	6.40
Ulmaceae	2	26	1.38	5.06
Theaceae	3	20	0.58	4.58
Sapotaceae	2	23	0.98	4.31
Rosaceae	4	6	0.01	4.29
Loganiaceae	3	29	0.03	3.89
Vaccinaceae	1	10	1.45	3.73
Leguminosae	3	9	0.19	3.64
Magnoliaceae	1	4	1.4	3.50
Piperaceae	3	8	0.01	3.31
Flacourtiaceae	2	9	0.27	2.75
Araliaceae	1	12	0.79	2.67
Vitaceae	1	51	0.14	2.58
Rutaceae	2	11	0.1	2.51
Compositae	2	6	0.13	2.44
Apocynaceae	2	8	0.01	2.28
Solanaceae	2	5	0	2.19
Anacardiaceae	1	38	0.07	2.12
Melastomaceae	1	28	0.1	1.92
Connaraceae	1	23	0.09	1.77
Rhamnaceae	1	19	0.15	1.77
Elaeocarpaceae	1	5	0.35	1.75
Icacinaceae	1	17	0.12	1.67
Elaeagnaceae	1	12	0.07	1.46
Adoxaceae	1	6	0.16	1.45
Ericaceae	2	11	1.60	5.04
Salicaceae	3	10	0.40	4.03
Pittosporaceae	1	3	0.08	1.24
Erythroxylaceae	1	6	0.03	1.24
Poaceae	1	2	0	1.08
Urticaceae	1	1	0.01	1.07
Berberidaceae	1	1	0	1.06
Hypericaceae	1	1	0	1.06
Arecaceae	1	1	0	1.06
Polygalaceae	1	1	0	1.06

(15.7 %), Sabiaceae (12.7 %), Staphyleaceae (9.5 %), Celastraceae (9.2 %) and Myrsinaceae (8.1 %). Lauraceae (9.45 m^2 ha^{-1}) and Aquifoliaceae (7.27 m^2 ha^{-1}) had the highest basal area values over all the plots (Table 2).

Species-area curve and abundance distribution

The species area curves approached an asymptote (beyond which the number of species does not increase) at 0.8 ha (8 plots, Fig. 2), indicating a satisfactory level of sampling. The species abundance distribution did not differ significantly from a log-normal distribution (Fig. 3a), $\chi^2 = 13.06$, df = 8, $P = 0.05$, (mean = 0.69 and variance = 0.91). Ten percent of species were represented by single individuals, three percent by two individuals and 67 % by between three to one hundred individuals and twenty percent of species had over one hundred individuals (Fig. 3a & 3b). Log frequency of occurrence shows there were ten dominant species (10 %; over 100 stems), 22 common species (23 %; 20 to 99 stems), 36 uncommon species (37 %; 3 to 19 stems) and 29 % rare species (1 to 2 stems).

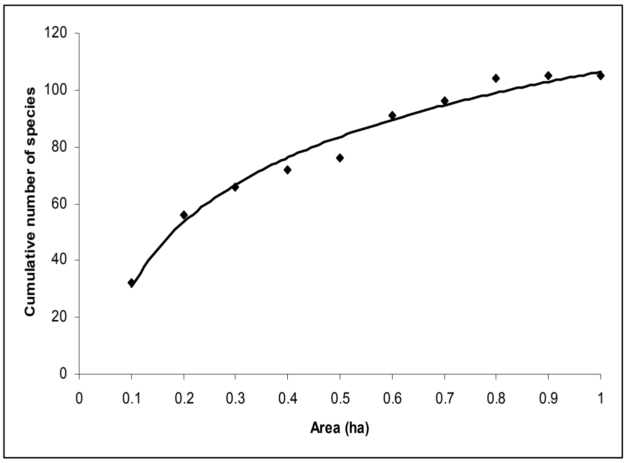

Fig. 2. Mean species-area curve for all 1ha plots.

Forest structure and stem diameter diversity and density

The population size class frequency distribution of the forest stand exhibited a tendency towards a reverse J-shaped distribution (Fig. 4) indicating that the population was skewed towards younger trees, indicating that older individuals were disproportionally represented in the popu-

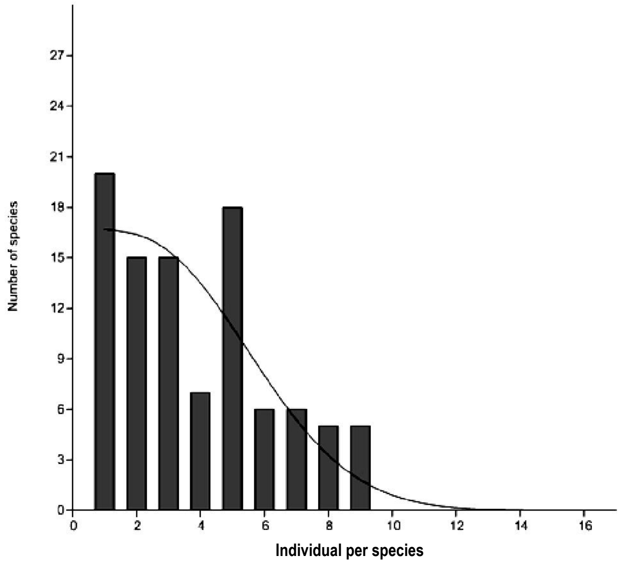

Fig. 3a. Relationship between number of species and species abundance. The exponential pattern suggest a log-normal relationship.

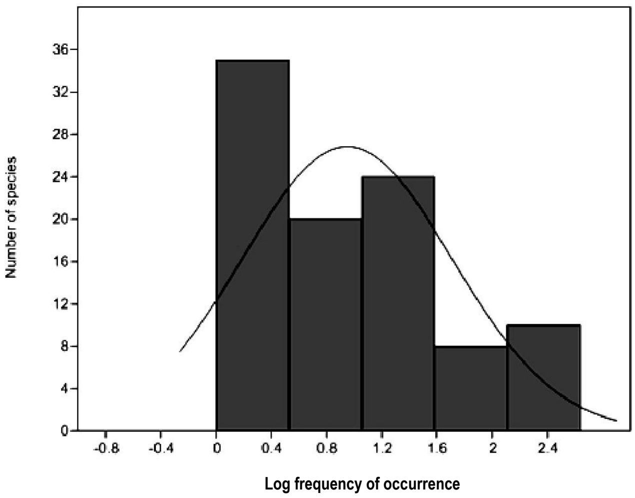

Fig. 3b. Mean frequency (log) distribution and log normal curve of species for all study sites.

lation. Species richness, density and diversity indices consistently decrease with increasing stem size classes from > 1 cm to < 40 cm dbh (Table 3). Basal area increases with increasing dbh class (Table 3). The lowest size class captured (> 1 < 10 cm dbh) 91 % of species richness, 69 % of forest stand density, and 12 % of basal area and there was a 5-fold decrease in richness and about a 40-fold decrease in density from the lowest size (one to five cm dbh) class to the > 20 < 40 cm dbh size class. In each dbh class, species richness and stand density varied together and there was a significant association in the two smallest dbh classes (> 1 < 5 cm dbh: G-test = 48.82, df = 9, $P = 0.0001$) and > 5 <10 dbh: G-test = 22.387, df = 9, $P = 0.01$). However, species richness and stand density were not significantly associated with larger dbh classes, and there was no significant association between tree dbh and metrics of stand structure (i.e. > 10 cm > < 20 cm dbh: G-test = 5.87, df = 9, $P = 0.75$; > 20 < 40 cm dbh: G-test = 13.1, df = 9, $P = 0.16$; and > 40 cm dbh; G-test = 2.25, df = 9, $P = 0.99$).

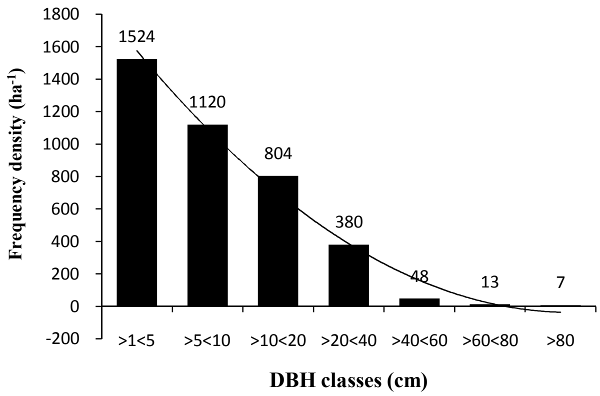

Fig. 4. Diameter size-class frequency distribution of common woody plant populations of the Nilgiri Mountains. Abundance decreases with increasing diameter.

Table 3. Species richness, stand density and diversity indices for different stem size classes for one hectare plot in the shola forest of Amaggal Reserve, Nilgiri Mountains.

Dbh class (cm)	Species richness	Stand density	Fisher's α	Basal area (m^2 ha^{-1})
> 1 < 5	77	1524	17.11	1.98
> 5 < 10	66	1120	15.33	5.04
> 10 < 20	55	804	13.37	12.71
> 20 < 40	42	380	12.07	23.48
> 40	20	62	10.23	16.06

Effect of disturbance on tree and liana species richness, density and basal area

Tree species richness and density were significantly influenced by the disturbance scores ($F_{10,\ 7} = 10.81$; $P = 0.007$; $F_{10,\ 7} = 19.65$, $P = 0.001$), whereas tree basal area was not influenced by disturbance intensity. Liana density and basal area were significantly influenced by disturbance scores ($F_{10,\ 7} = 7.90$, $P = 0.016$; $F_{10,\ 7} = 7.69$, $P = 0.017$) whereas liana species richness was not

Table 4. Effect of disturbance on tree and liana species richness, density and basal area of the tropical montane evergreen forests of the Nilgiri Mountains, southern India. Analysis of co-variance (ANCOVA) was used to analyse the relationship between disturbance and species richness, density and basal area for trees and lianas.

Source of variation	Sum of squares	DF	Mean squares	F	*P*
Intercept	15621.939	1	15621.939	2828.11	< 0.001
Tree species richness	119.433	2	59.717	10.811	0.007
Error	38.667	7	5.524		
Intercept	1324003.03	1	1324003.03	8650.922	< 0.001
Tree density	6017.067	2	3008.533	19.657	0.001
Error	1071.333	7	153.048		
Intercept	321.994	1	321.994	599.736	< 0.001
Tree basal area	4.265	2	2.132	3.972	0.07
Error	3.758	7	0.537		
Intercept	825	1	825	284.016	< 0.001
Liana species richness	11.267	2	5.633	1.939	0.214
Error	20.333	7	2.905		
Intercept	3993	1	3993	217.8	< 0.001
Liana density	289.767	2	144.883	7.903	< 0.016
Error	128.333	7	18.333		
Intercept	0.145	1	0.145	47.726	< 0.001
Liana basal area	0.0466	2	0.0233	7.693	< 0.017
Error	0.0212	7	0.00303		

Table 5. The effect of disturbance on mean tree and liana species richness, density and basal area were tested using a one-sample t-test.

	Trees and shrubs			Lianas		
Vegetation parameters	HD	MD	LD	HD	MD	LD
Species richness	35.67 ± 1.86	41.0 ± 0.58	43.25 ± 1.70**	7.66 ± 1.20	10.33 ± 0.33**	9.5 ± 0.96
Density	332.3 ± 7.62	384.3 ± 10.52	386.0 ± 3.89**	12.7 ± 1.76	26.3 ± 2.33*	21.5 ± 2.53
Basal area	4.95 ± 0.06	5.56 ± 0.05	6.63 ± 0.49**	0.04 ± 0.01	0.21 ± 0.05^{ns}	0.11 ± 0.02

Significant level ns = not significant, *P** < 0.05, *P*** < 0.01.

influenced by disturbance (Table 4). Tree species richness, density and basal area were significantly higher in low disturbed plots than moderate and highly disturbed plots. In contrast, liana species richness and density was significantly higher in moderately disturbed areas than plots with high or low levels of disturbance (Table 5).

Discussion

This report is the first record from this area of community composition from a mid-elevation shola forest. The Amaggal plots had a total species diversity of 97 species, which is higher than that of high-elevation shola forests (i.e. Thaishola Reserve Forest, 67 species ha^{-1}; > 2100 m, and Upper Bhavani Reserve Forest, 87 species in 11.5 ha; > 2200 m; (Table 6), Narendren *et al.* 2001; Mohandass & Davidar 2009). Richness within this study is, however, comparable to that of mid-elevation sholas such as Kukkal forest of Palni hills as recorded 83 species in 1.08 ha (Davidar *et al.* 2007). The mid-elevation shola in our study has a diverse community including 77 tree species ha^{-1}, 13 shrub species ha^{-1} and 22 liana species ha^{-1}. Fisher's alpha at 40 % is greater than in high-elevation sholas (Table 6) such as Upper Bhavani shola of the Nilgiris (Mohandass 2007; Mohandass

Table 6. Comparison on floristic diversity between mid and high-elevation montane evergreen forests (shola) of the Nilgiri Mountains.

Site names	Latitude	Longitude	Altitude (m)	Area sampled (ha)	Total area (ha)	Species number	Number of individuals	Stems (ha^{-1})	Fisher's α	Basal area (m^2 ha^{-1})	Literature
Amaggal	11° 14. 570′ N	76° 36. 526′ E	1900-2033	1	30	97	3896	3896	18.03	59.27	The present study
Goodmorsh	11° 14. 131' N	76° 35. 572' E	2288	1.17	15	44	3079	2632	7.27	66.22	Mohandass (2007)
Paybungalow	11° 13. 624' N	76° 32. 710' E	2302	1.08	9	42	2212	2048	7.36	70.45	Mohandass (2007)
Godown	11° 13. 840' N	76° 35. 189' E	2225	1.08	4	47	3177	2942	7.82	79.13	Mohandass (2007)
Korakundah Estate	11° 13. 712' N	76° 34. 357' E	2250	1.08	3	38	2351	2177	6.44	26.89	Mohandass (2007)
Kolimund	11° 13. 933' N	76° 32. 970' E	2309	0.9	2	37	2034	2260	6.42	54.94	Mohandass (2007)
Forest camp	11° 13. 840' N	76° 35. 115' E	2214	1.26	1.26	49	4269	3388	7.76	68.93	Mohandass (2007)

& Davidar 2009), which indicates that species diversity is higher in the forest of Amaggal region than forests in other parts of the region.

Species diversity may decrease with increasing altitude, through the relationship between diversity and altitude has formerly been found to be very variable based on taxa and region (Lieberman *et al.* 1996; Reddy *et al.* 2011). Variation in tree species composition and the proportion of dominant species may directly be attributed to altitudinal pattern and rainfall distribution as suggested by Reddy *et al.* (2011). However, in high-elevation ranges, mean annual rainfall is higher (2600 mm rainfall) than mid-elevation ranges (1300 - 1500 mm rainfall), which indicates that rainfall may not be as important to increasing the species diversity in the mid-elevation ranges (provided it exceeds certain physiologically important levels). However, the length of dry season may influence the tree species diversity in the mid-elevation of tropical wet evergreen forest of the western ghats (Davidar *et al.* 2005).

Structurally high and mid-elevation shola forests had similar basal area measurements, but Amaggal Reserve Forest is denser and has a denser canopy. Sholas largely made up of large and small trees showed little variation in stand structure between high and mid-elevation shola forests, but higher elevation sites have more large-sized trees. The Amaggal forest basal area values fell within the range of basal areas 59.4 to 66.06 m^2 ha^{-1} reported from high and medium-elevation shola forests of the western ghats (Davidar *et al.* 2007; Mohandass & Davidar 2009). The total basal area of Amaggal (> 10 cm dbh) was 53 m^2 ha^{-1}, which is almost identical to the Upper Bhavani sites value of 53.17 m^2 ha^{-1}. A stem density of 3896 ha^{-1} was recorded for Amaggal; this value is higher than in the Upper Bhavani reserve (2652 ha^{-1}). The likely reason for the differences is because most upper Bhavani study sites are isolated small patches (< 15 ha).

Stem diameter distributions may also indicate the level and form of disturbance within forests, in addition to providing insights into potential regeneration processes (Denslow 1995; Hett & Loucks 1976; Poorter *et al.* 1996; Pragasan & Parthasarathy 2010). In the present study the population density of diameter size class showed a reverse J-shaped distribution or positively skewed, indicating that lower dbh classes are more abundant than might be expected in the population (El-Sheikh 2013; Mohandass *et al.* 2016). Within a plot, large trees (> 40 cm dbh) ranged from two to seven species, and from three to nine individuals of each species. We found maximum dbh size class was 85 to 86 cm (*Syzygium grande* (Wight) Walp. and *Ilex denticulata* Wall. ex Wight), 126 cm (in *Ilex wightiana* Wall. ex Wight) in the upper Bhavani forest. In the Kukkal shola forest, we found 371 cm dbh class in the Palni Hills (*Cassine paniculata* (Wight & Arn.) Lobr.-Callen; Mohandass & Somasundaram *Pers. Obs.*). The present study demonstrated as expected that lower dbh classes exhibited low basal area ranges and dbh classes of 20 to 40 cm had higher basal area values.

The dominant, common and rare species determine the differences in forest species composition between plots at the community level. According to the IVI, the top ten dominant species at Amaggal forest differed slightly between mid and high elevation forests. There were 3 shared dominant species in the mid and high-elevation forests, and the remaining seven species are closely related. The ten most dominant species are, therefore, similar at the species and generic level. Three tree species were the most common (*Litsea glabrata*, *Meliosma simplicifolia*, and *Daphniphyllum neilgherrense*), and the rarest species included *Scolpia crenata* (Wight & Arn.) Clos, *Persea macrantha* (Nees) Kosterm. and *Rhododendron arboretum* Sm. The most common shrubs were *Lasianthus venulosus* and *Psychotria bisulcata* Wight & Arn. and the most common lianas were *Tetrastigma leucostaphylum, Gardneria ovata* Wall. and *Connarus wightii* Hook. f. and rarest liana species were *Rosa leschenaultiana* (Redout & Thory) Wight & Arn. and *Dregea volubilis* (L. f.) Stapf.

Based on the FIV index, Lauraceae was the most abundant family in the study (twelve species) followed by Rubiaceae (ten species). The families Celastraceae, Oleaceae and Rosaceae all had four species. Three species of Euphorbiaceae, Myrtaceae, Myrsinaceae, Theaceae, Loganiaceae, Leguminosae, Piperaceae and Salicaceae occurred in the region. Rubiaceae had the greatest density (1121 ha^{-1}) followed by Lauraceae (827 ha^{-1}), Euphorbiaceae (496 ha^{-1}) and Symplocaceae (358 ha^{-1}). Lauraceae showed the highest basal area 9.45 (m^2 ha^{-1}), followed by Myrtaceae (8.1 m^2 ha^{-1}), and Aquifoliaceae (7.27 m^2 ha^{-1}). However, at family level, variation was similar to other shola forests of high and mid-elevation of the western ghats (Davidar *et al.* 2007; Mohandass & Davidar 2009). Thus family composition appears to be uniform across shola forests of the western ghats (Davidar *et al.* 2007; Mohandass *et al.* 2009; Mohandass *et al.* 2015; Mohandass *et al.* 2016).

However, basal area did not respond significantly to disturbance. Therefore, disturbance reduced diversity and showed negative effects on tree forest structure in the study, it is similar to that of tropical montane forests of Mexico (Cayuela *et al.* 2006). Lianas species richness was not influenced by disturbance scores, whereas liana density and basal area were significantly influenced by disturbances (Mohandass *et al.* 2015). Therefore, disturbance factors may cause changes forest species composition and forest stand structure even at the small scale area in the tropical montane forests of the western ghats.

Conclusions

The present study reveals a high diversity in species composition in mid elevation than high-elevation montane forests of the Nilgiri Mountains. The vegetation of mid-elevation forest in Amaggal is characterised by high diversity, density and similar in basal area as compared to high elevation montane forests. Disturbance may influence diversity and density of trees as well as density and basal area of lianas (Mohandass *et al.* 2015), and had little effect on forest community structure. Therefore, to maintain overall community diversity and structure, human activities should be reduced and regulated in both mid and high elevations regions. We conclude that small scale inventory of plant diversity showed communities with high diversity, densities and basal areas, which supports its value for conservation and has implications for management. The Ghats region is represented by a diverse spectrum of environments, but without understanding the structure and function of these complex ecosystems it is difficult to develop appropriate management plans to best conserve diversity in increasingly threatened regions.

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