

Diversity of understory plants in undisturbed and disturbed tropical lowland forests of Little Andaman Island, India

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Received: 26 November 2007 / Accepted: 19 September 2008 / Published online: 5 October 2008
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Abstract Species richness and density of understory plants were investigated in eight 1 ha plots, distributed one each in undisturbed and disturbed tropical evergreen, semi-evergreen, deciduous and littoral forests of Little Andaman island, India, which falls under one of the eight hottest hotspots of Biodiversity in the world viz. the Indo-Burma. One hundred 1 m⁻² quadrats were established in each 1 ha plot, in which all the understory plants (that include herbs, undershrubs, shrubs and herbaceous climbers) were enumerated. The total density of understory plants was 6,812 individuals (851 ha⁻¹) and species richness was 108 species, representing 104 genera and 50 families. Across the four forest types and eight study plots, the species richness ranged from 10 to 39 species ha⁻¹. All the disturbed sites harbored greater number of species than their undisturbed counterparts. Herbs dominated by species (63%) and density (4,259 individuals). The grass *Eragrostis tenella* (1,860 individuals; IVI 40), the invasive climber *Mikania cordata* (803; IVI 20) and the shrub *Anaxagorea luzonensis* (481; IVI 17.5) were the most abundant species. Poaceae, Asteraceae, Acanthaceae, Orchidaceae and Euphorbiaceae constituted the species-rich families represented by 6 species each. The species-area curves attained an asymptote at 0.8 ha level except in sites DD and DL, indicating 1 ha plot is not sufficient to capture all the understory species in disturbed forests. The alien weeds formed about one-fourth of the species richness (31 species; 28%) and density (1,926 individuals; 28.3%) in the study sites, indicating the extent of weed invasion and the attention required for effective conservation of the native biodiversity of the fragile island forest ecosystem.

Keywords Andaman Islands · Disturbance · Invasive species · Species density · Tropical forest · Understory plants

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Introduction

A defining component of tropical forests is the richness of the plant community (Gentry 1990; Leopold and Salazar 2008). In addition to the trees, the understory of tropical forests has a distinct array of species different from the overstory and is an integral part of the tropical forest community (Bhat and Murali 2001). They may show different patterns of diversity than tree species due to different responses to light level, nutrient availability, and temperature (Siebert 2002; Ramadhanil et al. 2008). However, quantitative inventories on tropical forests have emphasized mainly on tree species and the smaller understory plants are rarely included in such investigations (Poulsen and Pendry 1995; Annaselvam and Parthasarathy 1999; Upadhaya et al. 2006). There are a few quantitative studies on understory plants from neotropics (Smith 1970; Hall and Swaine 1981; Gentry and Dodson 1987; Levey 1988; Poulsen and Balslev 1991; Poulsen and Nielsen 1995; Tuomisto and Poulsen 1996; Tuomisto et al. 1998, 2002; Costa and Magnusson 2002; Leopold and Salazar 2008) and old world tropics (Kiew 1978; Poulsen and Pendry 1995; Poulsen 1996a, b; Newbery et al. 1996; Turner et al. 1996; Laska 1997; Svenning 2000; Bobo et al. 2006; Ramadhanil et al. 2008). In India, the understory plant diversity inventories were mainly focused in the Western Ghats (Gopisundar 1997; Annaselvam and Parthasarathy 1999; Bhat and Utkarsh 1999; Bhat and Murali 2001; Muthuramkumar et al. 2006) and little is known from the Eastern Ghats (Chittibabu and Parthasarathy 2000) and Himalayas (Ram et al. 2004; Upadhaya et al. 2006).

The quantitative plant diversity inventories are the fundamental tool for conservation and management of tropical forests (Campbell 1994), but as far as Andaman and Nicobar Islands are concerned they are limited. Much of the current knowledge is still based on qualitative surveys conducted in the twentieth century, which mainly dealt with the floristic account of trees and climbers (Rao 1986). Padalia et al. (2004) studied the diversity of tree species in the forests of Great Andaman groups and Tripathi et al. (2004) studied the tree diversity in four different altitudes of Saddle Peak National Park, North Andaman Islands. However, quantitative inventories of understory species in Andaman and Nicobar islands are still lacking. Hence, the present investigation was undertaken. The main objectives of the present study are to assess the species richness, abundance and distribution of understory plants in the undisturbed and disturbed evergreen, semi-evergreen, deciduous and littoral forests of Little Andaman Island and to compare the results of these sites with other tropical forests in India and elsewhere in the world.

Study area

The study was conducted in the tropical forests of Little Andaman Island, which is the southern most island of Andaman groups located in the Bay of Bengal, between 10°30'–10°54' N latitude and 92°20'–92°35' E longitude (Fig. 1). The total geographical area of the island is 733 km² with varying width ranging from 20 to 29 km. It is nearly a dumbbell-shaped island with more or less flat terrain, the central and western portions are slightly hilly and the highest elevation is about 210 m above mean sea level. The island was originally inhabited by the Onge community (a Paleolithic negroid tribe) and declared as a tribal reserve in 1957, later the entire forest area was declared as reserve forest. Geologically the island is mainly of thick Eocene sediments deposited on pretertiary fine gray sand stone, shales and slit stones in which basic and ultra-basic igneous rocks are found to be intrusive. Higher elevations are characterized by serpentine and gabbro

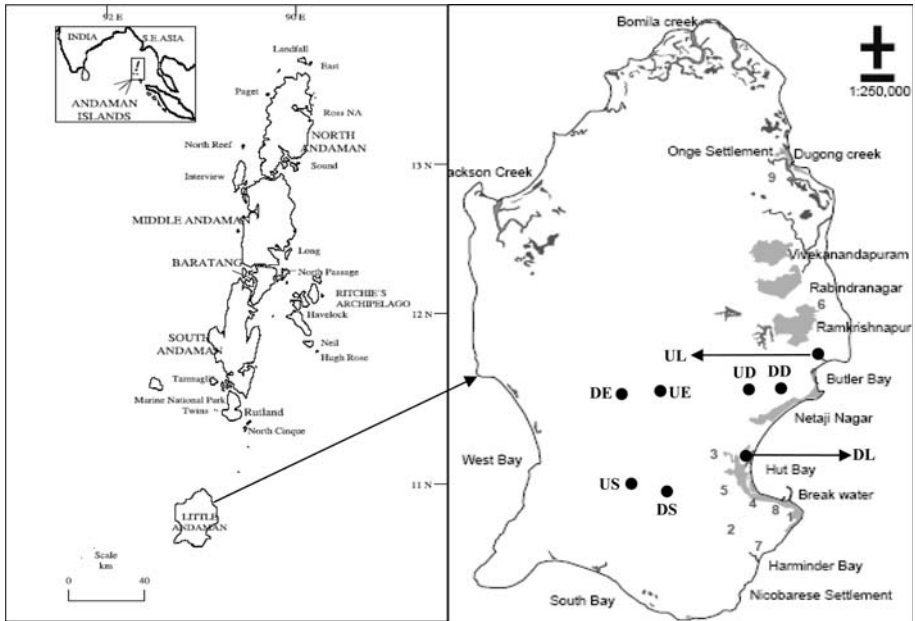


Fig. 1 Map showing the location of Little Andaman Island and eight study sites in the island. For complete names of study sites, refer to ‘Study area’ in text

formations. The soils are immature, loose in texture, poor in drainage and have low moisture retaining capacity (Rao 1986). The island experiences a warm and humid tropical climate with the temperature ranging from 20 to 32°C and mean relative humidity between 82 and 90% throughout the year. It receives heavy rainfall from both south-west and north-east monsoons. January to April show a fairly dry weather with scanty rainfall. The annual average rainfall ranges from 3,000 to 3,500 mm.

An earthquake of 9.0 on the Richter scale, which struck the east coast of Little Andaman Island on 26th December 2004 and the subsequent tsunami have brought about devastating human tragedy and considerable loss to the flora and fauna. In south-east coast the run-up level of sea water rose up to 5 m from the sea level and penetrated 1,200 m into the low-lying areas of inland forest (Ramanamurthy et al. 2005). The sudden surge of sea water has inundated the littoral and inland forests, causing irreparable damage to the littoral and inland plants. The force of the tidal waves uprooted numerous big littoral trees and the high salinity caused mortality of small trees and understory plants. The north-east coast of the island faced another kind of experience, where the sea water level rose up to 5 m without any force, and hence, the damage on the arborescent flora was very less.

The major vegetation types in the island include Andaman tropical evergreen, Andaman semi-evergreen, Andaman moist-deciduous and littoral forests, representing the forest types 1A/C2, 2A/C1, 3A/C1 and 4A/L1 respectively of Champion and Seth (1968). During the tree inventory, a total of 186 species from 125 genera and 56 families (4,252 individuals) were enumerated from the study sites (Rasingam and Parthasarathy 2008). *Pometia pinnata*, *Dipterocarpus* spp., *Knema andamanica*, *Fagraea racemosa*, *Elaeocarpus rugosus*, *Ficus hispida* and *Euodia glabra* dominated the evergreen sites, *Canarium euphyllum*, *Pterocymbium tinctorium*, *Oroxylum indicum*, *Terminalia procera*, *T. bialata*

and *Neonauclea gageana* in semi-evergreen sites, *Tetrameles nudiflora*, *Bombax insigne*, *Terminalia bialata*, *Pterocymbium tictorium* and *Anthocephalus chinensis* in deciduous sites and *Manilkara littoralis*, *Gyrocarpus americanus*, *Pongamia pinnata*, *Terminalia catappa*, *Ficus nervosa* and *Bombax insigne* in the littoral forest.

Eight 1 ha plots were established, one each in undisturbed (site code prefixed with 'U') and disturbed (site code prefixed with 'D') evergreen (UE, DE), semi-evergreen (US, DS), deciduous (UD, DD) and littoral forests (UL, DL). Plots DE and UE are located ~8 km northwest from Hut Bay, the capital town of Little Andaman Island. The inter-distance between these plots is ~1 km. Semi-evergreen forest plots (US, DS) are situated in southwestern part of Hut Bay, plot DS is 2 km away from site US and is located near a metal quarry and subjected to disturbance by the quarry workers and domestic animals. Plot DD is located close to human settlements and disturbed by tourism activity, cattle grazing and illegal timber extraction for house hold materials. The two littoral forest plots were selected based on the destruction by tsunami and human disturbance. Site DL was totally damaged by the December 2004 killer tsunami, and four months later Andaman and Nicobar Island Forest Plantation and Development Corporation Limited extracted all the dead trees. Plot UL is located 10 km away from DL, where the tsunami did not damage the site. The altitude of all the forest plots ranged from 0 to 70 m above mean sea level.

Methods

The eight 1-ha plots, one each in undisturbed and disturbed evergreen, semi-evergreen, deciduous and littoral forests were subdivided into eight hundred 10×10 m quadrats for the quantitative assessment of tree species (≥ 30 cm gbh) in the first phase of the study. Subsequently the understory plant diversity was investigated in the every 1×1 m quadrat laid in the top right corner of eight hundred 10×10 m grids of the total 8-ha study plots. All the understory plants viz. herbs (non-woody small plants ~1–1.5 m tall), undershrubs (small plants of 1–1.5 m tall with moderate stem thickness), shrubs (~1.5–3 m tall with thick stem and branching at ground level without a distinct trunk) and herbaceous climbers were enumerated. This investigation excluded the seedlings and saplings of tall trees and facultative herbs which are generally epiphytes and occasionally encountered in the forest floors. Voucher specimens were collected for each species and identified with local floras (Hooker 1872–1897; Parkinson 1923; Hajra et al. 1999). All the specimens were confirmed with the authenticated old collections deposited in the herbarium of Botanical Survey of India, Andaman and Nicobar Circle, Port Blair (PBL) and deposited in Department of Ecology and Environmental Sciences, Pondicherry University.

Analysis of data

Species diversity indices such as Shannon (H') and Simpson (D) were calculated. Species-area curves were raised using the program EstimateS (version 8, Colwell <http://viceroy.eeb.uconn.edu/estimates>), based on mean species accumulation curve after 100 times randomization of sample order. Spearman rank correlation coefficients were also performed to describe relationships between the species richness, density and site disturbance scores (Systat, SPSS Inc. 2000). A modified importance value index (IVI) of Curtis and McIntosh (1951), for a score of 200, for each understory species was calculated by summing its relative density and relative frequency. The density of species is the total number of individuals in the 8 ha plot sampled and frequency refers to the number of

occurrences in the total quadrats. A modified family importance value (FIV) was calculated by summing the relative diversity (number of species in the family/total number of species $\times 100$) and relative density of the individuals (Mori et al. 1983). The patterns of understory species were examined in the eight sites using non-metric multidimensional scaling (NMS) ordination. The ordination was performed based on the data of species richness, density and disturbance scores, using PC-ORD package.

Results

Species richness and density

A total of 108 species from 104 genera and 50 families were enumerated in the eight 1 ha plots (Table 1). Of these one species was identified up to generic level. The species richness was highest in site DL (39 species ha^{-1}), lowest in site UL (10 species ha^{-1}) and intermediate in the other sites. All the disturbed sites (except the evergreen site) recorded greater number of species than the respective undisturbed sites. Among the 108 species, 77 species (71%) are indigenous to flora of Andaman and Nicobar and the remaining 31 species (29%) are alien weeds. An analysis of species distributions revealed that about 8% of plant species are endemic to the islands, about 73% species distributed in mainland India and other south-east Asian countries. The remaining 19% are not found in mainland India but extend their distribution to south-east Asia including Myanmar, Thailand, Malaya and Indonesia. The number of endemic species is slightly greater in semi-evergreen (6 species) and deciduous forest sites (4 species) than in evergreen and littoral sites (3 species).

Herbs (63 species, 58%) and herbaceous climbers (26 species, 24%) were the most species-rich life-forms, the shrubs and undershrubs ranked next with 16 (15%) and 3 species (3%), respectively (Fig. 2). The Shannon and Simpson indices varied slightly between the undisturbed and disturbed sites (Table 1). Among the understory plants, 25 species (23%) are annuals and 83 species are perennials (77%).

Table 1 Summary of understory plant inventory in eight 1 ha plots, distributed one each in undisturbed and disturbed evergreen (UE, DE), semi-evergreen (US, DS), deciduous (UD, DD) and littoral (UL, DL) forests of Little Andaman Island, India

Variable	Evergreen forest		Semi-evergreen forest		Deciduous forest		Littoral forest		Total for 8 sites
	UE	DE	US	DS	UD	DD	UL	DL	
Species richness	24	17	18	35	26	31	10	39	108
No. of genera	23	17	18	35	26	31	10	38	104
No. of families	17	15	16	25	19	20	9	21	50
Diversity indices									
(i) Shannon	2.4	1.9	2.3	1.9	2.8	1.8	1.8	2.4	
(ii) Simpson	0.1	0.3	0.2	0.3	0.1	0.3	0.2	0.2	
Density (individuals ha^{-1})	619	346	97	1,085	451	2,499	102	1,613	6,812
Disturbance scores	9	18	4	22	16	25	14	33	

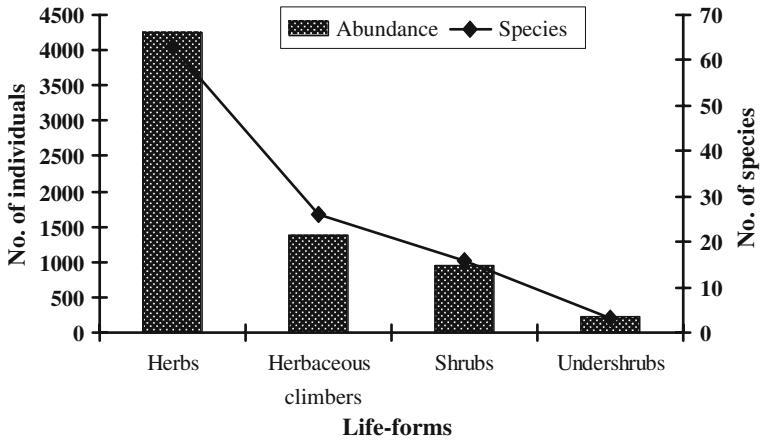


Fig. 2 Species richness and abundance of understory plants by life-forms in Little Andaman Island

Species-area curves

The species-area curves (Chao 1) for all the eight study plots steeply rose up to 0.5 ha. It continued to increase up to 0.8 ha in the disturbed plots DE, DD and DL and there after the species addition was very low to none (Fig. 3). The species-area accumulation curves approach an asymptote at 1 ha level in all the plots except the DL. It indicating that the 1 ha plot is sufficient to capture all the understory species distributed in the forests.

Species richness and density in relations to site disturbance score

The spearman correlation between species richness, species density and site disturbance score revealed that the species richness and density were significantly positively correlated

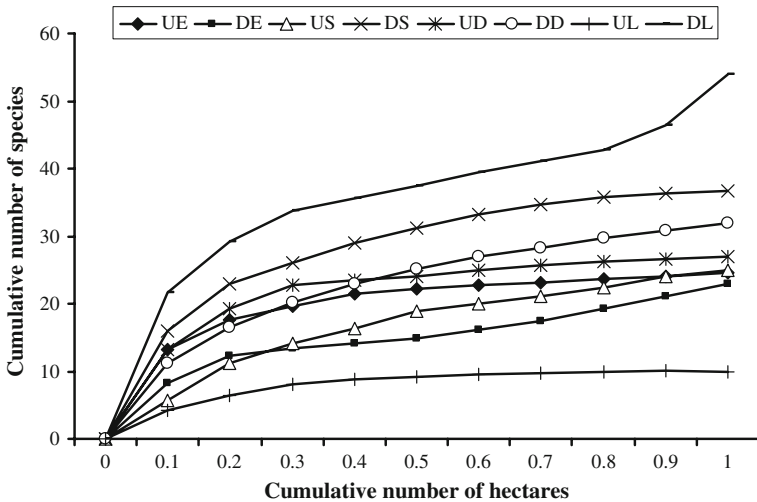
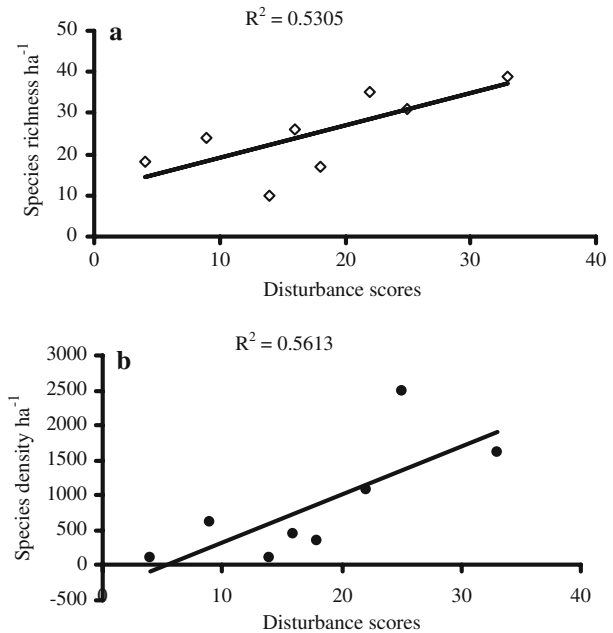


Fig. 3 Species-area curve (Chao 1) for the sites UE, DE, US, DS, UD, DD, UL and DL in Little Andaman Island

Fig. 4 Relationship between species richness, density and site disturbances (a, b) in eight study sites in Little Andaman Island



with the site disturbance scores ($y = 68.86x - 362.16$, $r^2 = 0.53$; $P < 0.05$ and $y = 0.78x + 11.252$, $r^2 = 0.56$; $P < 0.05$). The increasing trend in species richness and density were observed from relatively undisturbed to highly disturbed sites (Fig. 4). The non-metric multidimensional scaling (NMS) ordination, based on the species richness, density and disturbance score distinctly organized the sites UD, DD, DS and DL on the positive coordinates of the NMS axis, mainly because of high species richness and high level of disturbances such as human interference and the impacts of tsunami too. Site UE fell in the middle of the ordination due to the moderate species richness and human interference. Whereas sites DE, US and UL figured on the left of the ordination due to low species richness and the low disturbance level (Fig. 5).

Species density, dominance and rarity

The species density of the 108 understory species varied considerably across eight 1 ha plots and totaled 6,812 individuals (Table 2). The density was greatest in site DD (2,499 individuals ha^{-1}) and lowest in site US (97 individuals ha^{-1}). Among the 6,812 individuals, 1,926 individuals (28%) are alien weeds. Maximum weeds were recorded from the disturbed sites (99%) and few from (1%) the undisturbed deciduous plot (UD). It was completely absent in the plots DE, UE, US and UL. The density of weedy species was very high (51%) in the plot DD (1,265 individuals) and the plots DL and DS ranked next with 468, 107 individuals, respectively.

Family composition

The family diversity of understory plants in the study sites totaled 50 families with 104 genera (Table 3). Among them, 45 families (90%) were angiosperms and 5 families (with

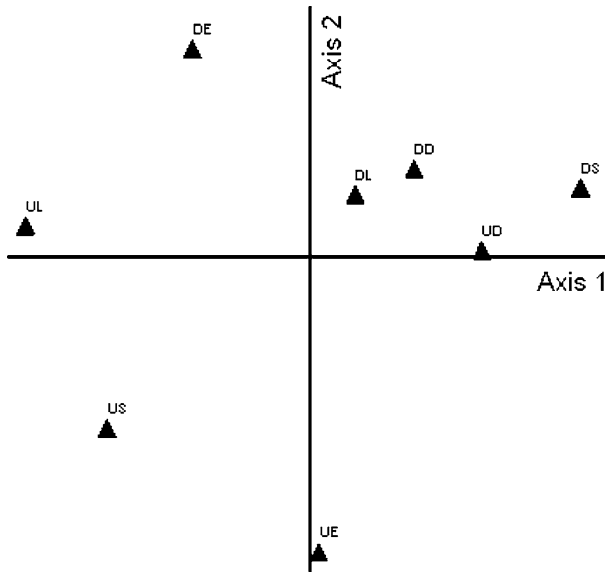


Fig. 5 NMS ordination using the species richness, density and disturbance score of the eight 1 ha plots

5 genera and 5 species; 10%) were pteridophytes. The angiosperms consisted of 32 families with 67 species and 65 genera of dicotyledons (64%), and 13 families with 36 species and 34 genera of monocotyledons (26%). Acanthaceae, Asteraceae, Euphorbiaceae, Orchidaceae and Poaceae were most speciose families represented by 6 species each. Araceae, Commelinaceae and Verbenaceae ranked next with 5 species each. Twenty-seven families were represented by just one species each. The density and family importance values were greatest for Poaceae (2,004 individuals, FIV-35) followed by Asteraceae (1,151 individuals, 22.5) and Acanthaceae (724 individuals, 16.2). Annonaceae (9.6), Orchidaceae (6.8), Rubiaceae (6.5) and Araceae (6.2) also scored high family importance value.

Discussion

The understory species richness of 108 species enumerated in the studied sites of Little Andaman island reflects a medium diversity status of this forest. The human-impacts and the natural disasters considerably increased the species diversity and density of the disturbed sites as compared to the undisturbed sites. The understory species richness ranged from 10 species ha^{-1} in site UL to 39 species ha^{-1} in site DL which was damaged by the 2004 tsunami. After the tsunami Andaman and Nicobar Islands' Forest Plantation and Development Corporation Limited extracted all the dead trees, and this has created lot of open space in the forest and this led to the invasion of other understory plants. As such, the understory richness was low to moderate when compared to the other understory inventories across the tropics (Table 4). In our enumeration understory species richness (108 species) is more than half the total diversity of tree species (for stems ≥ 30 cm gbh; 187 species) enumerated in the same sites (Rasingam and Parthasarathy 2008). The greater density of understory plants in the disturbed sites (mean 1,435 ha^{-1}) as against the

Table 2 Density and importance value index (IVI) of all understory plants encountered in the eight study plots of Little Andaman forests (site abbreviations as in Table 1)

Sl. no.	Species (& family)	Density										IVI
		UE	DE	US	DS	UD	DD	UIL	DL	Total		
1	<i>Eragrostis tenella</i> (L.) Beauv. ex R. & S. (Poaceae)	–	–	–	–	58	1,061	38	703	1,860	33.9	
2	<i>Mikania cordata</i> (Burm.f.) R.L. Robins (Asteraceae)	–	–	–	29	34	621	–	119	803	19.9	
3	<i>Anaxigorea luzonensis</i> A. Gray (Annonaceae)	208	159	19	92	–	–	3	–	481	17.4	
4	<i>Strobilanthes glandulosus</i> Kurz (Acanthaceae)	–	–	–	605	–	–	–	–	605	12.1	
5	<i>Rinorea benghalensis</i> (Wall.) O.K. (Violaceae)	58	61	30	84	16	1	–	–	250	11.1	
6	<i>Chromolaena odorata</i> (L.) King & Robins (Asteraceae)	–	–	–	2	–	194	–	20	216	6.3	
7	<i>Kyllinga brevifolia</i> Rottb. (Cyperaceae)	–	–	–	–	–	219	–	34	253	5.5	
8	<i>Smilax odoratissima</i> Bl. (Smilacaceae)	37	11	3	51	14	–	–	–	116	4.6	
9	<i>Hyptis capitata</i> Jacq. (Lamiaceae)	–	–	–	73	52	–	–	–	125	3.8	
10	<i>Christella parasitica</i> (L.) Lev. (Thelypteridaceae)	38	22	1	1	–	–	–	–	62	3.2	
11	<i>Gonothalamus meeboldii</i> Craib. (Annonaceae)	3	11	2	3	31	–	–	–	50	3.1	
12	<i>Ipomoea pes-caprae</i> (L.) R.Br. (Convolvulaceae)	–	–	–	–	–	–	–	111	111	2.9	
13	<i>Vernonia cinerea</i> (L.) Less. (Asteraceae)	–	–	–	–	–	103	–	–	108	2.8	
14	<i>Gloriosa superba</i> L. (Liliaceae)	–	–	–	–	–	–	–	75	75	2.7	
15	<i>Glycosmis mauritiana</i> (Lam.) Tanaka (Rutaceae)	–	–	–	–	22	27	–	–	49	2.7	
16	<i>Gouania leptostachya</i> DC. (Rhamnaceae)	–	–	10	4	42	3	–	–	59	2.6	
17	<i>Derris scandens</i> (Roxb.) Bth. (Fabaceae)	15	12	5	10	–	–	–	–	42	2.5	
18	<i>Hedyotis corymbosa</i> (L.) Lamk. (Rubiaceae)	–	–	–	–	–	–	–	68	68	2.4	
19	<i>Commelina diffusa</i> Burm.f. (Commelinaceae)	–	–	–	–	–	53	–	37	90	2.4	
20	<i>Amorphophallus longisylus</i> Kurz ex Hk.f. (Araceae)	–	–	–	–	–	–	–	49	49	2.2	
21	<i>Pollia thrysiiflora</i> (Bl.) Steud. (Commelinaceae)	58	–	–	–	–	–	–	–	58	2.1	
22	<i>Spermacoe assurgens</i> Ruiz & Pavon (Rubiaceae)	–	–	–	–	–	26	–	29	55	2.0	
23	<i>Paedertia scandens</i> (Lour.) Merr. (Rubiaceae)	–	–	–	5	–	–	–	45	50	1.8	
24	<i>Nelsonia campestris</i> R.Br. (Acanthaceae)	–	–	–	–	63	18	–	–	81	1.8	

Table 2 continued

Sl. no.	Species (& family)	Density										IVI			
		Density													
		UE	DE	US	DS	UD	DD	UL	DL	Total					
25	<i>Zeuxine nervosa</i> (Wall. ex Lindl.) Trim. (Orchidaceae)	37	10	1	–	–	–	–	–	–	–	–	–	48	1.7
26	<i>Cleome rutidosperma</i> DC. (Capparaceae)	–	–	–	3	–	–	–	–	41	–	–	–	44	1.6
27	<i>Gymnema latifolium</i> Wall. (Asclepiadaceae)	–	–	–	–	5	–	–	–	–	24	–	–	29	1.6
28	<i>Ischaemum rugosum</i> Salisb. (Poaceae)	–	–	–	–	–	–	–	–	–	–	–	61	61	1.5
29	<i>Alocasia decipiens</i> Schott (Araceae)	2	–	3	9	11	–	–	–	–	–	–	–	25	1.5
30	<i>Peperomia pellucida</i> (L.) H.B.K. (Piperaceae)	–	–	–	–	–	–	–	–	–	–	–	38	38	1.5
31	<i>Cucumis callosus</i> (Rottl.) Cogn. (Cucurbitaceae)	–	–	–	–	–	–	–	–	2	–	–	24	26	1.4
32	<i>Donax cannaeformis</i> K. Schum. (Marantaceae)	27	11	1	2	–	–	–	–	–	–	–	–	41	1.4
33	<i>Senna tora</i> (L.) Irwin & Barnbey (Caesalpinaceae)	–	–	–	–	–	–	–	–	19	–	–	17	36	1.4
34	<i>Elatostema integrifolium</i> (D.Don) Wedd. (Urticaceae)	25	24	–	–	–	–	–	–	–	–	–	–	49	1.4
35	<i>Phrynium pubinerve</i> Bl. (Marantaceae)	23	–	–	–	7	–	–	–	–	–	–	–	30	1.3
36	<i>Cayratia trifolia</i> (L.) Domin. (Vitaceae)	–	–	–	3	–	–	–	–	11	6	–	–	20	1.3
37	<i>Rhapidophora laciniata</i> (Burm.f.) Merr. (Araceae)	–	–	–	–	11	–	–	–	–	–	–	–	26	1.2
38	<i>Pavetta graciliflora</i> Wall. ex Ridl. (Rubiaceae)	8	8	–	–	1	–	–	–	–	–	–	–	17	1.2
39	<i>Maesa andamanica</i> Kurz (Myrsinaceae)	–	–	1	4	20	–	–	–	–	–	–	–	26	1.2
40	<i>Eleusine indica</i> (L.) Gaertn. (Poaceae)	–	–	–	–	–	10	–	–	18	–	–	6	34	1.1
41	<i>Physalis minima</i> L. (Solanaceae)	–	–	–	–	–	–	–	–	–	–	–	17	17	1.1
42	<i>Catharanthus roseus</i> (L.) G.Don. (Apocynaceae)	–	–	–	–	–	–	–	–	–	–	–	23	23	1.1
43	<i>Commelina hasskarlii</i> Cl. (Commelinaceae)	–	–	–	–	–	–	–	–	–	–	–	30	30	1.0
44	<i>Cyperus compressus</i> L. (Cyperaceae)	–	–	–	–	–	–	–	–	4	–	–	11	15	0.9
45	<i>Amomum aculeatum</i> Roxb. (Zingiberaceae)	26	–	–	–	–	–	–	–	–	–	–	–	26	0.8
46	<i>Capparis floribunda</i> Wt. (Capparaceae)	–	–	–	–	–	–	–	–	15	2	–	–	17	0.8
47	<i>Eranthemum suffruticosum</i> Roxb. (Acanthaceae)	–	–	–	–	6	15	–	–	–	–	–	–	21	0.8
48	<i>Pilea microphylla</i> (L.) Liebm. (Urticaceae)	–	–	–	–	–	–	–	–	–	–	–	19	19	0.8

Table 2 continued

Sl. no.	Species (& family)	Density										IVI
		UE	DE	US	DS	UD	DD	UL	DL	Total		
49	<i>Ardisia humilis</i> Vahl (Myrsinaceae)	-	-	-	-	10	4	-	-	-	14	0.8
50	<i>Tetrastigma andamanica</i> (King) Suesseng. (Vitaceae)	-	-	-	8	3	-	-	-	-	11	0.7
51	<i>Thunbergia laurifolia</i> Lindl. (Thunbergiaceae)	-	6	-	3	-	-	-	-	-	9	0.7
52	<i>Malaxis andamanica</i> (King & Pantl.) Balakr. & Vasud. (Orchidaceae)	-	1	3	1	6	-	-	-	-	11	0.7
53	<i>Korhalsia laciniosa</i> Mart. (Arecaceae)	7	3	-	-	-	-	-	-	-	10	0.7
54	<i>Cardiospermum helicacabum</i> L. (Sapindaceae)	-	-	-	-	-	16	-	-	-	16	0.6
55	<i>Oplismenus compositus</i> (L.) Beauv. (Poaceae)	5	-	-	14	-	-	-	-	-	19	0.6
56	<i>Dracaena brachyphylla</i> Kurz (Agavaceae)	-	-	6	3	1	-	-	-	-	10	0.6
57	<i>Acclisia secundiflora</i> (Bl.) Bakh.f. (Commelinaceae)	13	4	-	-	-	-	-	-	-	17	0.6
58	<i>Isachne pulchella</i> Roth. ex R. & S. (Poaceae)	-	-	-	17	-	-	-	-	-	17	0.6
59	<i>Anitidesma acuminatum</i> (Wall.) Wt. (Euphorbiaceae)	-	-	-	-	8	-	-	-	-	8	0.5
60	<i>Lygodium circinnatum</i> (Burm.f.) Sw. (Lygodiaceae)	8	-	-	-	-	-	-	-	-	8	0.5
61	<i>Phyllanthus amarus</i> Schum. & Thoms. (Euphorbiaceae)	-	-	-	-	-	2	-	-	6	8	0.5
62	<i>Solanum nigrum</i> L. (Solanaceae)	-	-	-	-	-	-	-	-	7	7	0.5
63	<i>Crinum asiaticum</i> L. (Amaryllidaceae)	-	-	-	-	-	-	6	-	-	6	0.5
64	<i>Dinochola scandens</i> (Bl. ex Nees) O.K. (Poaceae)	-	-	-	-	-	-	13	-	-	13	0.5
65	<i>Piper betle</i> L. (Piperaceae)	-	1	-	-	7	-	-	-	-	8	0.4
66	<i>Jatropha curcus</i> L. (Euphorbiaceae)	-	-	-	-	-	-	-	-	7	7	0.4
67	<i>Stachytarpetta jamaicensis</i> (L.) Vidal. (Verbenaceae)	-	-	-	-	-	-	-	-	10	10	0.4
68	<i>Actephila excelsa</i> (Dalz.) Muell.-Arg. (Euphorbiaceae)	-	-	4	-	1	-	-	-	-	5	0.4
69	<i>Stenochlaena palustris</i> (Burm.f.) Bedd. (Stenochlaenaceae)	-	-	-	9	-	-	-	-	-	9	0.4
70	<i>Nervilia aragoana</i> Gaud. (Orchidaceae)	-	-	-	10	-	2	-	-	-	13	0.4
71	<i>Phyla nodiflora</i> (L.) Greene (Verbenaceae)	-	-	-	-	-	8	-	-	9	17	0.4
72	<i>Achyranthes aspera</i> L. (Amaranthaceae)	-	-	-	-	-	11	-	-	-	11	0.4

Table 2 continued

Sl. no.	Species (& family)	Density										IVI
		UE	DE	US	DS	UD	DD	UL	DL	Total		
73	<i>Caesalpinia bonduc</i> (L.) Roxb. emend Dan. & Excell. (Caesalpiniaceae)	-	-	-	-	-	-	4	1	5	0.3	
74	<i>Lantana camara</i> L. (Verbenaceae)	-	-	-	-	-	-	-	4	4	0.3	
75	<i>Synedrella nodiflora</i> (L.) Gaertn. (Asteraceae)	-	-	-	-	-	-	-	11	11	0.3	
76	<i>Pisonia aculeata</i> L. (Nyctaginaceae)	-	-	-	-	-	-	-	5	5	0.3	
77	<i>Staurogyne lanceolata</i> (Bl.) O.K. (Acanthaceae)	-	-	-	-	5	-	-	-	5	0.3	
78	<i>Tetracera sarmentosa</i> (L.) Vahl. ssp. <i>andamanica</i> (Hoogl.) Hoogl. (Dilleniaceae)	-	1	-	4	-	-	-	-	5	0.3	
79	<i>Cayratia japonica</i> (Thunb.) Gagnep. (Vitaceae)	4	-	-	-	-	-	-	-	4	0.3	
80	<i>Aganosma marginata</i> (Roxb.) G.Don (Apocynaceae)	-	-	1	2	-	-	-	-	3	0.2	
81	<i>Angiopteris evecta</i> (Forst.) Hoffm. (Angiopteridiaceae)	3	-	-	-	-	-	-	-	3	0.2	
82	<i>Carica papaya</i> L. (Caricaceae)	-	-	-	-	-	-	-	3	3	0.2	
83	<i>Pothos scandens</i> L. (Araceae)	-	-	-	1	2	-	-	-	3	0.2	
84	<i>Sida acuta</i> Burm.f. (Malvaceae)	-	-	-	-	-	-	-	3	3	0.2	
85	<i>Ageratum conyzoides</i> L. (Asteraceae)	-	-	-	-	-	7	-	-	7	0.2	
86	<i>Eleutheranthera ruderatis</i> (Sw.) Schulz.-Bip. (Asteraceae)	-	-	-	-	-	6	-	-	6	0.2	
87	<i>Tropidia angulosa</i> (Lindl.) Bl. (Orchidaceae)	6	-	-	-	-	-	-	-	6	0.2	
88	<i>Tropidia curculligoides</i> Lindl. (Orchidaceae)	6	-	-	-	-	-	-	-	6	0.2	
89	<i>Daemonorops manii</i> Becc. (Arecaceae)	-	-	-	-	-	-	5	-	5	0.2	
90	<i>Bridelia ovata</i> Decne (Euphorbiaceae)	-	-	-	-	2	1	-	-	3	0.2	
91	<i>Dioscorea glabra</i> Roxb. (Dioscoreaceae)	-	-	-	2	-	-	-	-	2	0.2	
92	<i>Passiflora foetida</i> L. (Passifloraceae)	-	-	-	-	-	1	-	1	2	0.2	
93	<i>Pteris pellucida</i> Presl. (Pteridiaceae)	-	-	-	2	-	-	-	-	2	0.2	
94	<i>Arisaema</i> sp. (Araceae)	-	-	-	-	-	-	-	3	3	0.1	
95	<i>Murdantia spirata</i> (L.) Brueck (Commelinaceae)	-	-	-	-	-	-	-	3	3	0.1	
96	<i>Alternanthera sessilis</i> (L.) R.Br. (Amaranthaceae)	-	-	-	-	-	2	-	-	2	0.1	

Table 2 continued

Sl. no.	Species (& family)	Density										IVI
		UE	DE	US	DS	UD	DD	UL	DL	Total		
97	<i>Clerodendrum inerme</i> (L.) Gaertn. (Verbenaceae)	-	-	-	-	-	2	-	-	-	2	0.1
98	<i>Acalypha indica</i> L. (Euphorbiaceae)	-	-	-	-	-	-	-	-	1	1	0.1
99	<i>Calamus baratangensis</i> Renuka & Vijayak. (Arecaceae)	1	-	-	-	-	-	-	-	-	1	0.1
100	<i>Clerodendrum paniculatum</i> L. (Verbenaceae)	-	1	-	-	-	-	-	-	-	1	0.1
101	<i>Clitoria ternatea</i> L. (Papilionaceae)	-	-	-	-	-	-	1	-	-	1	0.1
102	<i>Cnestis palala</i> (Lour.) Merr. (Connaraceae)	-	-	-	1	-	-	-	-	-	1	0.1
103	<i>Datura metel</i> L. (Solanaceae)	-	-	-	-	-	-	-	-	1	1	0.1
104	<i>Eulophia spectabilis</i> Suresh (Orchidaceae)	1	-	-	-	-	-	-	-	-	1	0.1
105	<i>Myxopyrum smilacifolium</i> Bl. (Oleaceae)	-	-	1	-	-	-	-	-	-	1	0.1
106	<i>Phaulopsis imbricata</i> (Forsk.) Sw. (Acanthaceae)	-	-	-	1	-	-	-	-	-	1	0.1
107	<i>Pouzolzia zeylanica</i> (L.) Benn. (Urticaceae)	-	-	-	-	-	-	-	-	-	1	0.1
108	<i>Zingiber squarrosum</i> Roxb. (Zingiberaceae)	-	-	1	-	-	-	-	-	-	1	0.1
	Total	619	346	97	1,085	451	2,499	102	1,613	6,812	200	

Table 3 Family diversity (richness of genera and species), density and family importance value (FIV) of understory plants in the total 8 ha plots in Little Andaman Island

Sl. no.	Family	Genera	Species	Density	FIV
1	Poaceae	6	6	2,004	35.0
2	Asteraceae	6	6	1,151	22.5
3	Acanthaceae	6	6	724	16.2
4	Annonaceae	2	2	531	9.6
5	Cyperaceae	2	2	268	5.8
6	Violaceae	1	1	250	4.6
7	Commelinaceae	4	5	198	7.5
8	Rubiaceae	4	4	190	6.5
9	Lamiaceae	1	1	125	2.8
10	Smilacaceae	1	1	116	2.6
11	Convolvulaceae	1	1	111	2.6
12	Araceae	5	5	106	6.2
13	Orchidaceae	5	6	85	6.8
14	Liliaceae	1	1	75	2.0
15	Marantaceae	2	2	71	2.9
16	Urticaceae	3	3	69	3.8
17	Thelypteridaceae	1	1	62	1.8
18	Capparaceae	2	2	61	2.7
19	Rhamnaceae	1	1	59	1.8
20	Rutaceae	1	1	49	1.6
21	Piperaceae	2	2	46	2.5
22	Fabaceae	2	2	43	2.5
23	Caesalpiniaceae	2	2	41	2.5
24	Myrsinaceae	2	2	40	2.4
25	Vitaceae	2	3	35	3.3
26	Verbenaceae	4	5	34	5.1
27	Euphorbiaceae	6	6	32	6.0
28	Asclepiadaceae	1	1	29	1.4
29	Zingiberaceae	2	2	27	2.2
30	Apocynaceae	2	2	26	2.2
31	Cucurbitaceae	1	1	26	1.3
32	Solanaceae	3	3	25	3.1
33	Arecaceae	3	3	16	3.0
34	Sapindaceae	1	1	16	1.2
35	Agavaceae	1	1	10	1.1
36	Thunbergiaceae	1	1	9	1.1
37	Stenochlaenaceae	1	1	9	1.1
38	Lygodiaceae	1	1	8	1.0
39	Amaryllidaceae	1	1	6	1.0
40	Dilleniaceae	1	1	5	1.0
41	Nyctaginaceae	1	1	5	1.0
42	Caricaceae	1	1	3	1.0
43	Malvaceae	1	1	3	1.0
44	Angiopteridaceae	1	1	3	1.0

Table 3 continued

Sl. no.	Family	Genera	Species	Density	FIV
45	Amaranthaceae	1	1	2	1.0
46	Dioscoreaceae	1	1	2	1.0
47	Passifloraceae	1	1	2	1.0
48	Pteridaceae	1	1	2	1.0
49	Connaraceae	1	1	1	0.9
50	Oleaceae	1	1	1	0.9
	Total	104	108	6,812	200

undisturbed sites (mean 317 ha⁻¹) is contrary to the value obtained for tree inventory (mean 413 stems ha⁻¹ in disturbed sites and 649 stems ha⁻¹ in undisturbed sites).

The diversity indices of understory plants did not vary much in all the study sites and the Shannon index (H') ranged from 1.8 to 2.8. The species-area curves for all the undisturbed sites attained an asymptote in the 1 ha level, but in disturbed sites particularly, in sites DL and DD, the curves did not reach an asymptote at 1 ha level. It continuously raised even after the 1 ha area. The effect of tsunami, cattle grazing and human-impacts all led to high density and diversity in the disturbed sites. For understory plants, a significant positive correlation was obtained between the site disturbance scores and both species richness and density. An increasing trend in species richness and density from the undisturbed sites to disturbed sites is contrary to trend obtained for tree diversity inventory, in which correlation between the species richness and density and disturbance score was significantly negative ($y = -2.2375x + 94.81$, $r^2 = 0.77$; $P < 0.01$ and $y = -20.188x + 887.31$, $r^2 = 0.58$; $P < 0.05$).

The distribution of monocot species *Tropidia angulosa*, *T. curculigoides*, *Eulophia spectabilis*, *Pollia secundiflora*, *P. thrysiflora*, and *Amomum aculeatum* exclusively in the evergreen forest plots indicates their occurrence in specific habitats of humid and shady environments of tropical forests. The occurrence of *Rinorea benghalensis* in six study sites could explain its environmental plasticity, being both shade and light tolerant. The vegetative spread gives herbs on the ground a mobility to find suitable edaphic and climatic microhabitats (Poulsen and Balslev 1991). The prostrate, salt tolerant *Ipomoea pes-caprae* and the grass *Eragrostis tenella* spread vegetatively and formed a carpet on the littoral forest floor in the tsunami-affected area due to availability of open space, high nutrients and less competition.

The absence of annuals is a general characteristic of tropical rainforests (Hall and Swaine 1981; Poulsen and Balslev 1991) and in the present inventory annuals contributed nearly 23% (25 species) of the total understory diversity and all they were from the disturbed sites. Annaselvam and Parthasarathy (1999) in Anamalais, Western Ghats and Chittibabu and Parthasarathy (2000) in Kolli hills, Eastern Ghats recorded high annuals in the human-impacted sites. However, 100% perennials were recorded in Ghana (Hall and Swaine 1981) and Amazonian Ecuador (Poulsen and Balslev 1991). Among the four life-form categories, the herbs dominated by means of species richness (63 species) and density (4,259 individuals), similar observations were also made from Anamalais of Western Ghats (Annaselvam and Parthasarathy 1999) and Kolli hills of Eastern Ghats (Chittibabu and Parthasarathy 2000).

Nearly 41% of species (45 species) were represented by less than 10 individuals and it was slightly less than that of the rare tree species enumerated in the same study sites (44 species; 23%) and it was more or less equal to the species rarity recorded in Amazonian

Table 4 Summary of understory plant inventories in various tropical forests (H-Herbs; S-Shrubs)

Forest type	Location	Plot size & sub-samples	Number of		Dominant		Reference
			Plants	Species	Families	Families	
Tropical forest	El verde, Puerto Rico	0.1 ha		48			Smith (1970)
Tropical wet evergreen	Nueng F.R., Ghana	0.1 ha		47			Hall and Swaine (1981)
Tropical dry forest	Capeira, Ecuador	0.1 ha	2,854 H 742 S	50 29			Gentry and Dodson (1987)
Tropical wet forest	Rio Palengue, Ecuador	0.1 ha	1,220 H 531 S	39 18			Gentry and Dodson (1987)
Tropical moist forest	Jauneche, Ecuador	0.1 ha	944 H 219 S	18 16			Gentry and Dodson (1987)
Moist tropical forest	Cuyabeno, Amazonian Ecuador	1 ha; hundred 10 m ² quadrats	10,960	96	25	Peridophytes Araceae Marantaceae	<i>Puriana radiciflora</i> Poulsen and Balslev (1991)
Moist tropical forest	Cuyabeno, Amazonian Ecuador	1 ha; 10 m ² subplots	4,637	50			<i>Adiantum terminatum</i> Poulsen and Nielsen (1995)
Evergreen lowland & lower montane forest	Brunei	0.75 ha; three 50 m ² plots	9,431	121	26	Zingiberaceae (24) Araceae (14) Gesneriaceae (10)	<i>Ptyssiglottis psychotriifolia</i> <i>Begonia</i> sp. <i>Selaginella dielsii</i> Poulsen and Pendry (1995)
Dipterocarp forest	Batu Apoi, Brunei	1 ha; three 20 m ² subplots	6,264	92	13	Peridophytes (21) Zingiberaceae (18) Araceae (17) Zingiberaceae (46)	<i>Mapania monostachya</i> Poulsen (1996a)
Dipterocarp forest	Batu Apoi, Brunei	Two 1 ha plots	6,264				Poulsen (1996b)

Table 4 continued

Forest type	Location	Plot size & sub-samples	Number of		Dominant		Reference
			Plants	Species	Families	Species	
Tropical rain forest	Central catchment nature reserve, Singapore	0.2 ha	59		Araceae (10) Cyperaceae (6)	<i>Taenitis bleshnoides</i>	Turner et al. (1996)
Lowland tropical rainforest	Peru	Three 500 × 5 m and three 1,300 × 5 m	27,000	83		<i>Lamaritopsis japurensis</i> <i>Danaea nodosa</i> <i>Cycloclium meniscioides</i>	Tuomisto and Poulsen (1996)
	Ecuador	One 100 × 100 m					
Tropical lowland evergreen forest	Agumbe, Central Western Ghats, India	Three 1 ha plots	3,965	29	Rubiaceae (7)	<i>Psychotria nigra</i>	Gopisundar (1997)
			7,067	29	Piperaceae (3)	<i>P. dalzellii</i>	
			16,358	21	Verbenaceae (3)	<i>Bolbitis suberenatus</i>	
Tropical evergreen forest	Anamalais, Western Ghats, India	Total 30 ha; 3,000, 4 m ² nested quadrats covering 4.8 ha	27,390	55	28		
			218,471	155	53	Acanthaceae (15) Papilionaceae (12) Asteraceae (9) Zingiberaceae (8)	<i>Nilgiranthus barbatus</i> <i>Pellionia heyneana</i> <i>Echolium viride</i>
Tropical evergreen forest	Kolli hills, Eastern Ghats, India	8 ha; eight hundred 4 m ² plots covering 0.32 ha	9,680	52	35		
						Lamiaceae (4) Acanthaceae (3) Asteraceae (3)	<i>Cyrtococcum trigonum</i> <i>Arisaema leschenaultia</i>
Non-flooded Evergreen rainforest	Brazil	Four 80 × 0.5 m	45	23			
Yasuni National Park	Amazonian Ecuador	Twenty-seven 500 × 5 m	50,501	229			
						Marantaceae (12) Cyperaceae (5)	<i>Trichomanes pinnatum</i> <i>Monatagma spicatum</i>
						<i>Adiantum humile</i> <i>Miconia triplinervis</i>	Tuomisto et al. (2002)

Table 4 continued

Forest type	Location	Plot size & sub-samples	Number of		Dominant		Reference
			Plants	Species	Families	Species	
Mixed broad leaved forest	Central Himalaya	Ten 1 m ² plots Ten 25 m ² plots		67 H 43 S			Ram et al. (2004)
Subtropical humid forest	Jaintia hills, Meghalaya	Thirty 1 m ² plots	8,436 H	91	Rubiaceae (8)	<i>Glabba clarkei</i>	Upadhaya et al. (2006)
			36,210 S	89	Lamiaceae (8) Rosaceae (6) Rubiaceae (6)	<i>Psychotria erratica</i>	
Tropical rainforest	Valparai plateau, Western Ghats	0.16 ha	6,123	108		<i>Elatostemma lineolatum</i> <i>Coffea canephora</i> <i>Cyrtococcum trigonum</i>	Muthuramkumar et al. (2006)
Tropical rain forest	Little Andaman, Andaman & Nicobar islands	8 ha; eight hundred 1 m ² plots	6,812	108	50	Acanthaceae (6) Asteraceae (6) Euphorbiaceae (6)	Present study

rainforest (50%; Poulsen and Balslev 1991). While in the Kolli hills of Eastern Ghats it was two fold higher (75%; Chittibabu and Parthasarathy 2000) and very less (21%) at Varagalaiar site, Western Ghats (Annaselvam and Parthasarathy 1999).

In the present enumeration, Poaceae, Asteraceae, Acanthaceae, Orchidaceae and Euphorbiaceae were the dominant plant families and this is in conformity with results of Anamalais of Western Ghats (Annaselvam and Parthasarathy 1999) and Kolli hills of Eastern Ghats (Chittibabu and Parthasarathy 2000). According to Richards (1996) Acanthaceae, Poaceae and Asteraceae form predominant plant families of ground herbs in tropical rainforests. While in Amazonian rainforests Araceae, Marantaceae and Poaceae are dominant. The disturbances such as cattle grazing and human influences led to increased representation of Asteraceae as one of the dominant families in the present study. Muthuramkumar et al. (2006) made similar findings in the unprotected disturbed forest of Valparai in Indian Western Ghats.

The representation of alien weeds was greater in the disturbed forest sites (DD, DL and DS) as compared to the undisturbed forest sites. It was completely absent in the disturbed evergreen forest site (DE), as this site is located far away from human settlements and also interior to the forest roads. The tropical forest of Little Andaman Island was preserved in the past by the establishment of the tribal reserve for Onges (Paleolithic negroid tribes), but in the recent past disturbance by the tsunami and non-tribal settlers led to an increase in species richness of understory plants due to colonization of fast growing weedy species like *Mikania cordata*, *Ageratum conyzoides*, *Chromolaena odorata*, *Vernonia cinerea* and *Hyptis capitata*. Such a change in species richness has been attributed to disturbance that alters equilibrium in the plant community and provides suitable microhabitats for fast colonizing species (Connell 1978). In the present inventory, the species richness was comparatively higher in the disturbed sites DL (23 species out of 39; 59%) and DD (13 out of 31; 42%), most of them being invasive species. Overall, one-fourth of the understory plants (31 species, 28%; 1,926 individuals, 28.3%) are weeds and they were all reported from the disturbed sites.

Conclusion

The international community began to pay increasing attention to biodiversity loss and tropical deforestation in 1980s, and taking the biodiversity inventory as a tool for guiding conservation planning at a local scale is under-used, especially in tropical countries where technical capacity is often limited (Gordon and Newton 2006). A century old cultural history of human occupation in the Andaman and Nicobar islands and the indiscriminate utilization of plant resources by humans in the recent past have posed a threat to the biodiversity of islands (Padalia et al. 2004). The decreasing species richness and density from undisturbed to disturbed forests for trees and an opposite trend for understory plants are attributed to the effect of human-impacts including forest logging in the past and invasion of alien species. Apart from the representation of greater number rare species (45 species; 41%) in all the sites and the presence of greater number of alien species (31 of 108 species) in disturbed sites, call attention for conservation priorities. Sustainability of forest biodiversity is critical for existence of tribal races and overall environmental conditions in these islands. Hence, special priority should be given to conserve these fragile island biodiversity, which are facing pressure from increasing population which needs a check in the island ecosystem and so also sufficient care needed in implementing various developmental activities.

Acknowledgments We thank the Director, Botanical Survey of India, Kolkata and Joint Director, Botanical Survey of India, Andaman and Nicobar Circle, Port Blair for allowing us to consult the herbaria and officials of Andaman and Nicobar Island Forest Plantation and Development Corporation Limited, Port Blair for field support.

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