

Understory Plant Diversity in Tropical Dry Evergreen Forests on the Coromandel Coast of India Under Various Disturbance Regimes

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ABSTRACT

Tropical forest vegetation and community research have largely tended to focus on the tree component, and limited attention has been paid to understory vegetation. Species richness and density of understory plants were studied in disturbed and undisturbed sites of tropical dry evergreen forests on the Coromandel Coast of India. A total of 400 quadrats distributed hundred each in four forest categories and ten replicate sites of each of them. We found 4870 individuals of understory plants belonging to 59 species, 51 genera and 24 families. Across the four forest disturbance categories, the species richness ranged from 14 to 43 species. The HD sites harbored greater number of species and density than other forest categories. Herbs dominated by species and density than the other habit types. Acanthaceae, Euphorbiaceae and Papilionaceae constituted the species-rich families represented by 6 species each. The abundance and species richness of invasive species strongly correlated with disturbance scores ($R^2= 0.977$; $R^2= 0.94$). The invasive species richness was highest in the HD sites (17 species) and least in RD sites). The present study indicates the increasing invasion in disturbed sites and hence undisturbed sites call for conservation efforts and the disturbed sites warrant eco-restoration by way of better protection to save the native biodiversity of this understudied forest type.

Key Words: Tropical forest; Understory plants; Disturbance; Non-native species; Species density

INTRODUCTION

Understory vegetation in forest ecosystems plays a crucial role in regulating succession (Royo and Carson 2006), accounts for the majority of floristic diversity (Halpern and Spies 1995, Roberts and Gilliam 2003), and facilitating nutrient cycling and energy flow as ecosystem drivers (Nilson and Wardl 2005). Further, understory as an integral component of forest ecosystems supports a large fraction of total forest community and provide habitat and food sources for many kinds of animals (Gentry and Emmons 1987, Hirao et al. 2009, Lu et al. 2011). Understory vegetation generally varies considerably among different forest types (Hart and Chen 2008). Several factors have been reported to account for this variation, including overstory structure and species composition (Hart and Chen 2008, Sangar et al. 2008), soil nutrient availability and moisture level

(Poulsen and Pendry 1995, Newbery et al. 1996), forest succession history and forest fragmentation (LaFrankie et al. 2006, Benitez-Malvido and Martinez and Ramos 2003, Rasingam and Parthasarathy 2009).

Many studies on vascular plants in tropical forests have focused on trees and lianas, whereas the understory remains the least understood. There are few quantitative studies on understory plants from various tropical forests (Smith 1970, Hall and Swaine 1981, Gentry and Dodson 1987, Poulsen and Neilsen 1995, Tuomisto and Poulsen 1996, Tuomisto et al. 1998, Costa and Magnusson 2002, Kiew 1978, Bobo et al. 2006, Lu et al. 2011). In India, the understory plant diversity inventories available from the Western Ghats (Gopisundar 1997, Bhat and Utkarsh 1999, Bhat and Murali 2001, Muthuramkumar et al. 2006), Eastern Ghats (Chittibabu and Parthasarathy 2000), Himalaya (Ram et al. 2000, Upadhaya et al. 2006) and Andaman Islands (Rasingam and Parthasarathy

2009). The tropical dry evergreen forests (TDEF) on the Coromandel Coast of India which occurs as patches are short-statured, largely three-layered, tree-dominated evergreen forests with a sparse ground flora and dense lianas. Only about 4 to 5% of the original TDEF patches exist today. Although over two decades many studies have been conducted on the biodiversity and ecology of tropical dry evergreen forests in selected sites (Parthasarathy et al. 2008, Mani and Parthasarathy 2006, Selwyn and Parthasarathy 2006; 2007, Reddy and Parthasarathy 2003, Venkateswaran and Parthasarathy 2003), investigation on the understory diversity is lacking. The main objectives of this study was to analyze the patterns of species richness, abundance, species composition and distribution of understory plants in tropical dry evergreen forests experiencing different degrees of human disturbance.

MATERIALS AND METHODS

Study Area

The present study was undertaken in total of 40 tropical dry evergreen forest sites, which are classed into four categories based on the forest disturbance scores. They are located around Puducherry ($11^{\circ} 56' N$ and $79^{\circ} 53' E$), Villupuram ($11^{\circ} 93' N$ and $79^{\circ} 48' E$), Cuddalore ($11^{\circ} 43' N$ and $79^{\circ} 49' E$) and Pudukottai ($10^{\circ} 23' N$ and $78^{\circ} 52' E$) towns on the Coromandel Coast peninsular India (Figure 1). The total of 40 sites were selected ten for each of the four category of forests (relatively undisturbed-RD, moderately disturbed- MD, much disturbed-MU and heavily disturbed-HD) to serve as replicates chiefly based on the extent of human disturbance and further to discern variation within and

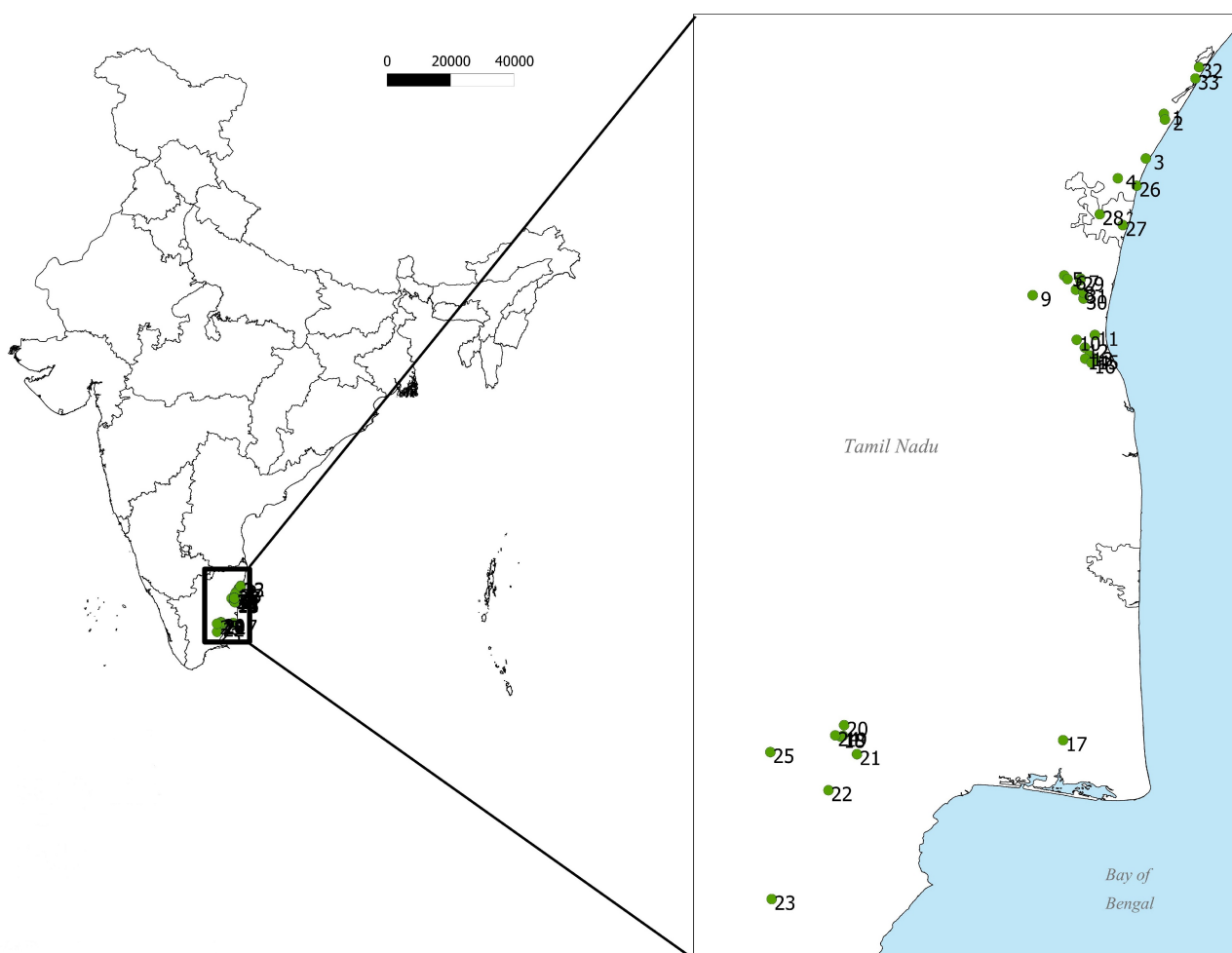


Figure 1. Location of the 40 tropical dry evergreen sites on the Coromandel Coast of India

across the four forest categories. Study sites were classified into four disturbance categories based on their disturbance scores. Site disturbance scores were determined based on the extent of various anthropogenic activities such as signs of temple visitors' impact, grazing by cattle and goats, illegal timber felling, fuel wood collection, fodder leaf collection, soil removal for house and road construction, the number and width of trails made inside the forest, road construction, litter clearance, edible fruit collection, medicinal plant removal, human occupation, extent of bioinvasion and cultural attachment of the local people as sacred groves. The semi-qualitative assessment of various types of disturbance was ranked as rare (1), occasional (2) or frequent (3). The sum of all the scores that had high ranks (31-40) was designated as heavily disturbed sites, 21 to 30 as much disturbed sites, 11 to 20 as moderately disturbed sites and 1 to 10 as relatively undisturbed sites. Soils are basically red lateritic and sand to sandy loam in texture in all the study sites. The climate is tropical dissymmetric type with most rainfall received during the northeast monsoon (October to December) and little and inconsistent in the southwest monsoon (June to September). The mean annual rainfall for the twenty-year period (1991-2011) is 1,282, 1,074 and 1,033 mm for Puducherry, Cuddalore and Pudukottai towns respectively. The mean annual maximum and minimum temperatures for the same period are 32.9 °C and 24.5 °C in Puducherry, 33.6 °C and 22.8 °C in Cuddalore and 33.4 °C and 25.4 °C Pudukottai. The vegetation of this region is described as tropical dry evergreen forest (Type 7/C1 of Champion and Seth 1968, Venkateswaran and Parthasarathy 2003, Parthasarathy et al. 2008).

Data Collection

The field work was carried out between March to December 2010. Ten 2 × 2 m quadrats were established in each site and these total to 100 plots for each of the four forest disturbance categories. All the understory plants viz. grasses and sedges, herbs (forbs) and undershrubs (small plants with moderate stem thickness) were enumerated. All the specimens were identified and verified with regional floras (Gamble and Fischer 1915-1935, Matthew 1991).

Data Analysis

Diversity indices such as Shannon (H') and Simpson (D) were calculated following Magurran (2004). We used

one-way analysis of variance (ANOVA) to check for significance differences in understory variables across the four forest categories. Spearman correlation coefficients were also estimated to describe the relationship between species richness and density, and site disturbance scores (Systat. SPSS Inc. 2000).

RESULTS

A total of 59 species of understory plants from 51 genera and 24 families were encountered in the total 400 sample plots of tropical dry evergreen forest (distributed 100 in each of the four categories of forest disturbance-Relatively undisturbed, Moderately disturbed, Much disturbed and Heavily disturbed) on the Coromandel Coast of India. Understory species richness did not differ significantly across the four forest categories ($P > 0.05$). The maximum species richness was recorded in the HD sites with 43 species, followed by MU (40 species), MD (28 species) and RD sites (14 species). The abundance of understory species did not differ significantly across the four disturbance categories ($P > 0.05$) and the abundance was greater in HD (1824 individuals) and MU (1445) than in MD (855) and RD (746) sites (Table 1). The diversity index values increases with increasing forest disturbance. The Shannon index was higher in MU and HD than in MD and RD sites, while the Simpson index was higher in RD sites than the other three forest disturbance categories.

Table 1. Summary of understory plant diversity inventory in four categories of tropical dry evergreen forest on the Coromandel Coast of India (data pooled for 100 quadrats (2x2 m each) in ten sites for each of the four categories of forests. RD- relatively undisturbed; MD- moderately disturbed; MU- much disturbed; HD- heavily disturbed).

	RD	MD	MU	HD	Total
Species richness	14	28	40	43	59
Abundance					
(No. of individuals)	746	855	1445	1824	4870
No. of genera	14	27	34	41	51
No. of families	9	17	23	21	24
Diversity indices					
Shannon	1.88	2.56	3.34	3.32	
Simpson	0.27	0.15	0.04	0.04	

Of the total 59 understory species enumerated, three species (*Sansevieria roxburghiana*, *Desmodium triflorum* and *Boerhaavia diffusa*) were common to all the four forest disturbance categories and figured within the top ten abundant understory species of the four forest categories (Table 2). The most abundant understory species was *Sansevieria roxburghiana* in RD and MD, *Achyranthes aspera* in MU and HD sites. Among the other species 17 species occurred only in MU and HD sites and 2 species were confined to RD and MD sites. The abundance of *Sansevieria roxburghiana* was greater in RD sites, but abundance decreased drastically with increasing forest disturbance.

The correlation between total understory species richness, their species density and site disturbance scores revealed that the species richness and density were significantly positively correlated with the site disturbance scores ($r^2= 0.917$; $r^2= 0.956$) in all the four forest disturbance categories. The increasing trend in species richness and density were observed from RD to HD sites (Figure 2a). The invasive species richness and abundance was greater in HD and MU than the MD and RD sites. The abundance and species richness of invasive species strongly correlated with disturbance scores ($r^2= 0.977$; $r^2= 0.94$; Figure 2b).

Table 2. Understorey plant species abundance and habit types of four categories of tropical dry evergreen forest on the Coromandel Coast of India (data pooled for 100 quadrats of 2m × 2m in ten sites for each of the four category of forests- RD-relatively undisturbed; MD-moderately disturbed; MU-much disturbed; HD-heavily disturbed).

No	Species	Family	N/I	Habit	RD	MD	MU	HD	Total
1	<i>Sansevieria roxburghiana</i> Schultes & Schultes f.	Agavaceae	N	H	367	313	115	86	881
2	<i>Achyranthes aspera</i> L.	Amaranthaceae	I	H	-	41	118	213	372
3	<i>Desmodium triflorum</i> (L.) DC.	Papilionaceae	N	H	57	65	88	113	323
4	<i>Cyperus rotundus</i> L.	Cyperaceae	N	G	-	-	99	103	202
5	<i>Chloris inflatus</i> Link	Poaceae	N	G	-	27	75	98	200
6	<i>Anisomeles indica</i> (L.) Kuntze	Papilionaceae	N	US	-	43	76	67	186
7	<i>Hyptis suaveolens</i> (L.) Poir.	Lamiaceae	I	US	-	-	69	88	157
8	<i>Aristida setacea</i> Retz.	Poaceae	N	G	-	-	66	89	155
9	<i>Boerhaavia diffusa</i> L.	Nyctaginaceae	I	H	14	17	38	77	146
10	<i>Tribulus terrestris</i> L.	Zygophyllaceae	I	H	-	18	53	75	146
11	<i>Croton bonplandianum</i> Baillon	Euphorbiaceae	I	H	-	3	55	86	144
12	<i>Triumfetta rhomboidea</i> Jacq.	Tiliaceae	N	US	8	-	39	78	125
13	<i>Dipteracanthus prostratus</i> (Poir.) Nees	Acanthaceae	N	H	77	45	-	-	122
14	<i>Indigofera aspalathoides</i> Vahl ex DC.	Papilionaceae	I	US	-	-	53	67	120
15	<i>Tridax procumbens</i> L.	Asteraceae	I	H	-	-	49	67	116
16	<i>Kyllinga bulbosa</i> P. Beauv.	Cyperaceae	I	G	-	-	46	53	99
17	<i>Phyllanthus virgatus</i> Forster f.	Euphorbiaceae	N	H	-	8	37	41	86
18	<i>Amorphophallus sylvaticus</i> (Roxb.) Kunth	Araceae	N	H	45	32	-	-	77
19	<i>Alysicarpus monilifer</i> (L.) DC.	Papilionaceae	N	H	-	19	17	29	65
20	<i>Asystasia gangetica</i> (L.) T. Anderson	Acanthaceae	N	H	23	-	11	28	62
21	<i>Scoparia dulcis</i> L.	Scrophulariaceae	I	H	-	-	22	36	58
22	<i>Spermacoce ocymoides</i> Burm.f.	Rubiaceae	N	H	-	29	28	-	57
23	<i>Commelina benghalensis</i> L.	Commelinaceae	N	H	23	17	-	16	56
24	<i>Phyla nodiflora</i> (L.) E. Greene	Verbenaceae	I	H	-	-	19	35	54
25	<i>Kyllinga monocephala</i> Rottb.	Cyperaceae	N	G	35	-	12	-	47
26	<i>Mollugo oppositifolia</i> L.	Molluginaceae	N	H	-	11	33	-	44
27	<i>Psilotrichum nudum</i> (Wallich) Moq.	Amaranthaceae	N	H	-	-	44	-	44
28	<i>Ecbolium viride</i> (Vahl) Vollesen	Acanthaceae	N	H	42	-	-	-	42
29	<i>Andrographis paniculata</i> (Burm.f.) Wall. ex Nees	Acanthaceae	N	US	18	23	-	-	41
30	<i>Catharanthus roseus</i> (L.) Don	Apocynaceae	I	US	-	-	13	28	41

Table 2. (continued)

No	Species	Family	N/I	Habit	RD	MD	MU	HD	Total
31	<i>Euphorbia hirta</i> L.	Euphorbiaceae	N	H	-	-	12	29	41
32	<i>Waltheria indica</i> L.	Sterculiaceae	N	US	-	7	14	17	38
33	<i>Oldenlandia umbellata</i> L.	Rubiaceae	N	H	-	15	11	8	34
34	<i>Acalypha indica</i> L.	Euphorbiaceae	N	US	-	18	-	15	33
35	<i>Alternanthera sessilis</i> (L.) R. Br. ex DC.	Amaranthaceae	N	H	-	33	-	-	33
36	<i>Spermacoce hispida</i> L.	Rubiaceae	N	H	-	-	33	-	33
37	<i>Evolvulus alsinoides</i> L.	Convolvulaceae	N	H	13	-	18	-	31
38	<i>Evolvulus nummularius</i> L.	Convolvulaceae	N	H	-	17	12	-	29
39	<i>Vernonia cinerea</i> (L.) Less.	Asteraceae	I	H	-	-	6	23	29
40	<i>Sida cordifolia</i> L.	Malvaceae	N	US	-	-	10	16	26
41	<i>Mollugo pentaphylla</i> L.	Aizoaceae	N	H	-	-	11	13	24
42	<i>Trianthema portulacastrum</i> L.	Aizoaceae	I	H	-	-	9	15	24
43	<i>Therioiphonum minutum</i> (Willd.) Baillon	Araceae	N	H	18	-	5	-	23
44	<i>Aeschynomene aspera</i> L.	Papilionaceae	N	US	-	17	-	4	21
45	<i>Sida rhombifolia</i> L.	Malvaceae	I	US	-	-	8	13	21
46	<i>Urena lobata</i> L.	Malvaceae	I	US	-	-	8	12	20
47	<i>Cleome viscosa</i> L.	Capparaceae	I	H	-	-	8	11	19
48	<i>Becium filamentosum</i> (Forsskal) Chiov.	Lamiaceae	N	H	-	3	-	15	18
49	<i>Perotis indica</i> (L.) Kuntze	Poaceae	N	G	-	18	-	-	18
50	<i>Blainvillea acmella</i> (L.) Philipson	Asteraceae	N	H	-	2	-	15	17
51	<i>Melochia corchorifolia</i> L.	Sterculiaceae	I	H	-	-	-	17	17
52	<i>Tephrosia purpurea</i> (L.) Pers.	Papilionaceae	N	US	-	-	-	17	17
53	<i>Blumea obliqua</i> (L.) Druce	Asteraceae	N	H	-	11	-	2	13
54	<i>Blepharis maderaspatana</i> (L.) Roth	Acanthaceae	N	H	6	-	-	1	7
55	<i>Andrographis serphyllifolia</i> (Vahl) Wight.	Acanthaceae	N	H	-	1	-	5	6
56	<i>Euphorbia rosea</i> Retz	Euphorbiaceae	N	H	-	-	5	-	5
57	<i>Gisekia pharnaceoides</i> L.	Aizoaceae	N	H	-	2	-	-	2
58	<i>Zornia diphylla</i> (L.) Pers.	Papilionaceae	N	H	-	-	-	2	2
59	<i>Acalypha alnifolia</i> Klien ex Willd.	Euphorbiaceae	N	US	-	-	-	1	1
					746	855	1445	1824	4870

(H- Herb; G-Grass; US-Undershrub; N- Native; I- Invasive)

The species richness and abundance of different habit types of understory species (grasses, herbs and undershrubs) did not differ significantly across the four forest disturbance categories ($P > 0.05$). Species richness and abundance of herbs were greater in all the four forest disturbance categories, followed by undershrubs (Table 2). Species richness and abundance of all habit types increased with increasing forest disturbance. In HD sites herb species diversity and abundance were greater than the other three forest categories.

In the present study, the contribution of 24 plant families towards understory taxa diversity (genera and

species) and stand density varied across the four forest categories (Table 3). The most speciose families in our sites include Acanthaceae (6 species and 4 genera), Euphorbiaceae (6 species and 4 genera) and Papilionaceae (6 species and 6 genera). Seven families were represented by 3 species, and 10 families were represented by single species each. In terms of understory abundance, Agavaceae was represented by just one species, *Sansevieria roxburghiana* in four forest categories with a total of 881 individuals, followed by Papilionaceae (548) and Amaranthaceae with 449 individuals.

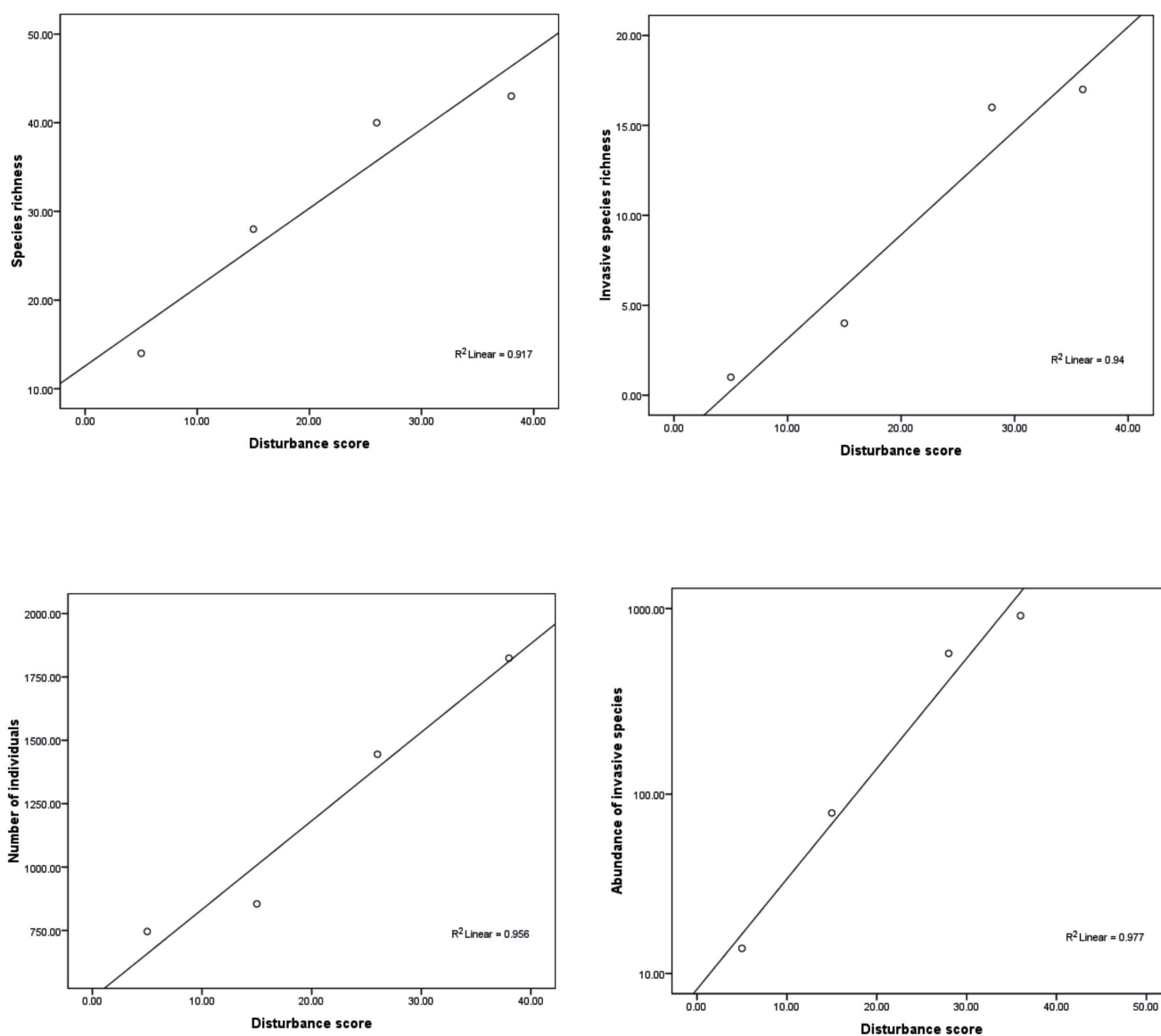


Figure 2. Relationship between species richness, density and site disturbances (a,b) in four forest disturbance categories.

DISCUSSION

The species richness of understory plants was greater in the disturbed sites than in undisturbed sites and this is in agreement with the reports of many other studies (Rasingam and Parthasarathy 2009, Lalfakawma et al. 2010, Chittibabu and Parthasarathy 2003). Svenning (2000) found that space created by small canopy gaps and environmental and historical factors were of comparable importance for controlling herb species composition and distribution. Understory plants are

limited by light availability under closed and stratified canopies in mature and undisturbed forest stands. The limited light availability with forest canopy closure may result in decline in understory species richness (Samule et al. 2010).

The greater abundance of shade tolerant, native and endemic understory species *Sanseveria roxburghiana* in relatively undisturbed sites can be related with dense canopy and the resulting shade available in the forest floor which is as indicator of little disturbance prevailing in these sites. In contrast, the decrease in its abundance

Table 3. Contribution of families of understory plants to generic and species richness and abundance, arranged in decreasing order of total abundance of all forest disturbance categories (RD- relatively undisturbed; MD- moderately disturbed; MU- much disturbed; HD- heavily disturbed)

Family	Species richness				Abundance				Total
	RD	MD	MU	HD	RD	MD	MU	HD	
Agavaceae	1	1	1	1	367	313	115	86	881
Papilionaceae	1	3	3	6	57	101	158	232	548
Amaranthaceae	-	2	2	1	-	74	162	213	449
Poaceae	-	2	2	2	-	45	141	187	373
Lamiaceae	-	2	2	3	-	46	145	170	361
Cyperaceae	1	-	3	2	35	-	157	156	348
Euphorbiaceae	-	3	4	5	-	29	109	172	310
Acanthaceae	5	3	1	3	166	69	11	34	280
Asteraceae	-	2	2	4	-	13	55	107	175
Nyctaginaceae	1	1	1	1	14	17	38	77	146
Zygophyllaceae	-	1	1	1	-	18	53	75	146
Tiliaceae	1	-	1	1	8	-	39	78	125
Rubiaceae	-	2	3	1	-	44	72	8	124
Araceae	2	1	1	-	63	32	5	-	100
Malvaceae	-	-	3	3	-	-	26	41	67
Convolvulaceae	1	1	2	-	13	17	30	-	60
Scrophulariaceae	-	1	1	-	-	22	36	58	116
Commelinaceae	1	1	-	1	23	17	-	16	56
Sterculiaceae	-	1	1	2	-	7	14	34	55
Verbenaceae	-	-	1	1	-	-	19	35	54
Aizoaceae	-	1	2	2	-	2	20	28	50
Molluginaceae	-	1	1	-	-	11	33	-	44
Apocynaceae	-	-	1	1	-	-	13	28	41
Capparaceae	-	-	1	1	-	-	8	11	19

with increasing disturbance makes this species an indicator of forest disturbance (Table 2). Other native and shade tolerant species such as *Amorphophallus sylvaticus* and *Ecbolium viride* also occurred only in the undisturbed or less disturbed sites indicating that the undisturbed forests are dense and cast more shade on the forest floor. Whereas thirteen invasive species that occurred only in the disturbed sites indicates that more canopy opening due to tree or branch felling. Fischer et al. (2006) and Ries et al. (2004) reported that the presence of disturbance in the form of canopy openings increases resource availability and also modifies the microclimate. Many of exotic plants benefit from edge environments and exert substantial pressures, including competition, on the range of native species.

Acanthaceae, Euphorbiaceae and Papilionaceae constituted the dominant plant families as also reported

in Anamalais, Western Ghats (Annaselvam and Parthasarathy 1999), Kolli hills of Eastern Ghats (Chittibabu and Parthasarathy 2000) and Andaman Islands (Rasingam and Parthasarathy 2009). Whereas, Acanthaceae, Poaceae and Asteraceae formed predominant plant families of ground herbs in tropical rain forests (Richards 1996). While Araceae, Marantaceae and Poaceae are dominant in Amazonian rainforests. The present inventory of 59 species in our sites is moderate when compared to other tropical forests. In India, Annaselvam and Parthasarathy (1999) reported 155 species in three thousand 4 m² quadrats in a 30 ha plot of Anamalais Western Ghats, and in Kolli hills (52 species in eight hundred 4 m² quadrats in a 8 ha plot; Chittibabu and Parthasarathy 2000) and in tropical lowland forest of Little Andaman Islands (108 species in 800 1m² quadrats in 8 ha plots; Rasingam and Parthasarathy 2009). In the

tropical wet forest of Rio Palenque in Ecuador, 176 species were recorded in the understory in a 0.1 ha plot (Gentry and Dodson 1987). Similarly 121 herb species were enumerated in three 500 m² plots in the tropical forests of Brunei (Poulsen and Pendry 1995).

The diversity and abundance of non-native species was greater in the disturbed forests (HD, MU and MD) as compared to the relatively undisturbed sites. The tropical dry evergreen forests are mostly sacred groves preserved as a result of the religious belief of the local people (Parthasarathy and Karthikeyan 1997), but in recent times many forests are highly threatened by various human activities and these led to an increase in species richness of understory plants due to colonization of fast growing weed species like *Achyranthes aspera*, *Hyptis suaveolens*, *Croton bonplandianum* and *Vernonia cinerea*. Most invasive species spread rapidly and are fast growing, utilizing available resources and possess greater ecological plasticity than native species.

Tropical dry evergreen forests of peninsular India with restricted geographical distribution are threatened by disturbance due to various human activities. The increase in species richness and density of understory plant community due to disturbance could effect regeneration of tree species, which ultimately leads to reduction in plant diversity. On the other hand species richness and abundance of invasive species increased with increasing forest disturbance and this indicates that the disturbed sites demand greater attention for conservation priorities.

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