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Diversity and population characteristics of woody species in subtropical humid forests exposed to cultural disturbances in Meghalaya, Northeast, India

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Abstract: The study was carried out to assess the impact of anthropogenic disturbances of mild intensity on diversity and phytosociological attributes of tree species in two subtropical forest stands, represented by Ialong and Raliang sacred groves in Jaintia hills of Meghalaya, northeast India. A total of 159 woody species (≥ 5 cm dbh) of 107 genera was identified in the two groves spreading over an area of 2 ha. The richness of woody species in 0.5 ha study plots increased from 80-82 in the protected stands to 92-93 in the disturbed stands of the two groves. In case of Ialong sacred grove, their density decreased from 1476 stems ha^{-1} in the protected stand to 1340 stems ha^{-1} in the disturbed stand whereas, in the Raliang sacred grove, it increased from 938 stems ha^{-1} in the protected stand to 1308 stems ha^{-1} in the disturbed stand. The basal area was higher in the undisturbed stands (57 to 71 m^2ha^{-1}) than the disturbed stands (36 to 49 m^2h^{-1}) in both the groves. Its distribution in different dbh classes resulted in a J-shaped curve in all but one stand. On the contrary, distribution of both species richness as well as their density in different dbh classes yielded a reverse J-shaped curve. Results revealed that the disturbance of mild intensity, to which these forests were exposed, enhanced species richness without altering tree population structure of the community.

Resumen: Este estudio se llevó a cabo con el fin de evaluar el impacto de disturbios antropogénicos de intensidad moderada sobre la diversidad y los atributos fitosociológicos de especies arbóreas en dos rodales de bosque subtropical: los bosques sagrados Ialong y Raliang en las colinas Jaintia de Meghalaya, noreste de la India. En estos dos bosques, que cubren un área de 2 ha, se registraron en total 159 especies leñosas (≥ 5 cm dap) de 107 géneros. La riqueza de las especies leñosas en parcelas de estudio de 0.5 ha incrementó de 80 a 82 en los rodales protegidos, hasta 92-93 en los rodales perturbados de los dos bosques. En el caso del bosque sagrado de Ialong, su densidad decreció de 1476 troncos ha^{-1} en el sitio protegido hasta 1340 troncos ha^{-1} en el sitio perturbado, mientras que en el bosque sagrado Raliang, ésta incrmentó de 938 troncos ha^{-1} en el sitio protegido a 1308 troncos ha^{-1} en el rodal perturbado. El área basal fue mayor en los rodales no perturbados (57 a 71 m^2 ha^{-1}) que en los perturbados (36 a 49 m^2 h^{-1}) en ambos bosques. Su distribución en diferentes clases de dap resultó en una curva con forma de J en todos los rodales menos en uno. Por el contrario, la distribución tanto de la riqueza de especies como de su densidad en diferentes clases de dap produjo una curva con forma de J-invertida. Los resultados revelaron que el disturbio de intensidad moderada, al que estos bosques están expuestos, aumenta la riqueza de especies, sin alterar la estructura poblacional arbórea de la comunidad.

Resumo: O estudo foi levado a feito para avaliar o impacte dos distúrbios antropogénicos de média intensidade na diversidade e atributos fitosociológicos das árvores florestais em duas parcelas subtropicais, representada pelos hortos sagrados em Ialong e Raliang nas colinas de Jaintia em Meghalaya, nordeste da Índia. Nos dois hortos que se estendem por uma área de 2 hectares foram identificadas 159 espécies lenhosas (dap ≥ 5 cm) pertencentes a 107 géneros. A riqueza em espécies lenhosas em parcelas de 0,5 ha cresceu de 80-82 nas parcelas protegidas para as 92-93 nas parcelas disturbadas dos dois hor-

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tos. No caso do horto sagrado de Ialong a sua densidade decresceu dos 1476 troncos ha^{-1} na parcela protegida para os 1340 troncos ha^{-1} na parcela disturbada valores que para a parcela sagrada em Raliang subiram de 938 troncos ha-1 na parcela protegida para os 1308 troncos ha^{-1} na parcela disturbada. A área basal foi maior nas parcelas não disturbadas (57 – 71 m^2ha^{-1}) quando comparada com as disturbadas (36 a 49 m^2ha^{-1}) nos dois hortos. A sua distribuição em diferentes classes de dap é representada por uma curva com um andamento J em todas excepto uma parcela. Pelo contrário, a distribuição, quer da riqueza específica quer da sua densidade em diferentes classes de dap produziram um curva do tipo J invertido. Os resultados revelaram que um distúrbio de intensidade média, conforme estas florestas estiveram expostas, promoveram a riqueza específica sem alterarem a estrutura da população de árvores da comunidade.

Key words: Disturbance, northeast India, sacred grove, species richness, subtropical humid forest, tree diversity, tree population.

Introduction

The effect of human disturbances on species diversity is an issue that has engaged the attention of ecologists both from theoretical and applied standpoints (Stapanian *et al.* 1997). The empirical studies of Hurd *et al.* (1971), McNaughton (1977, 1985), Tilman (1988), Frank & McNaughton (1991), Tilman & Downing (1994), support the hypothesis that ecosystems with high species diversity are more stable and resilient to environmental disturbances than those, which have low species diversity. It is argued that diverse systems are likely to contain some species that can thrive during perturbation and, therefore, may compensate for those members of the community that are reduced or eliminated by the disturbance (Ehrlich & Wilson 1991; Lawton & Brown 1994; Pimm 1984). Contrary to this view, Connell (1978), drawing analogy between coral reefs and tropical forests, proposed that species diversity in rain forest will be greatest where disturbances are moderate in intensity and frequency. Collins *et al.* (1995) argued that richness should be highest at intermediate frequencies of disturbances when condition favours competitive species and those that tolerate disturbance. Thus, the intensity and frequency of disturbance are important determinants of plant diversity in a community.

In northeast India, in general, and Meghalaya in particular, species-rich virgin forest patches have been preserved through ages in the form of sacred groves due to strong religious beliefs of different tribes living in the region (Tiwari *et al.* 1999). A portion of these forests is often converted into village reserve forest to meet timber, fuel wood and other requirements of the village community in the vicinity of these forests (Khiewtam & Ramakrishnan 1989; Upadhaya 2002). The periphery of village reserve forest is annually burnt during dry winter season to promote herbage growth in the ensuing spring season for cattle grazing (Pandey *et al.* 1993; Upadhaya 2002). The present study was undertaken in two well protected sacred groves and their adjoining village reserve forests located in Jaintia hills of Meghalaya to assess the impact of these cultural disturbances on species richness, density and population structure of woody species in the two groves that represent the subtropical humid forest of the site.

Materials and methods

Study area and climate

The study was conducted at Ialong and Raliang in Jaintia hills district of Meghalaya in northeast India during 1999-2001. Ialong is located about 8 km east (latitude 25° 28′ N, longitude 92° 16′ E, altitude 1350 m asl), and the Raliang (latitude 25° 30′ N and longitude 92° 28′ E, altitude of 1300 m asl) is located 28 km northeast of Jowai town in Jaintia hills district. The sacred groves at Ialong and Raliang are called '*Khloo blai*' (meaning religious forest) and '*Khloo Lyngdoh*' or *Khloo Poh Lyngdoh*' (meaning forest looked after by the *Lyngdoh* or preist), respectively. These groves are well protected on account of the strong religious

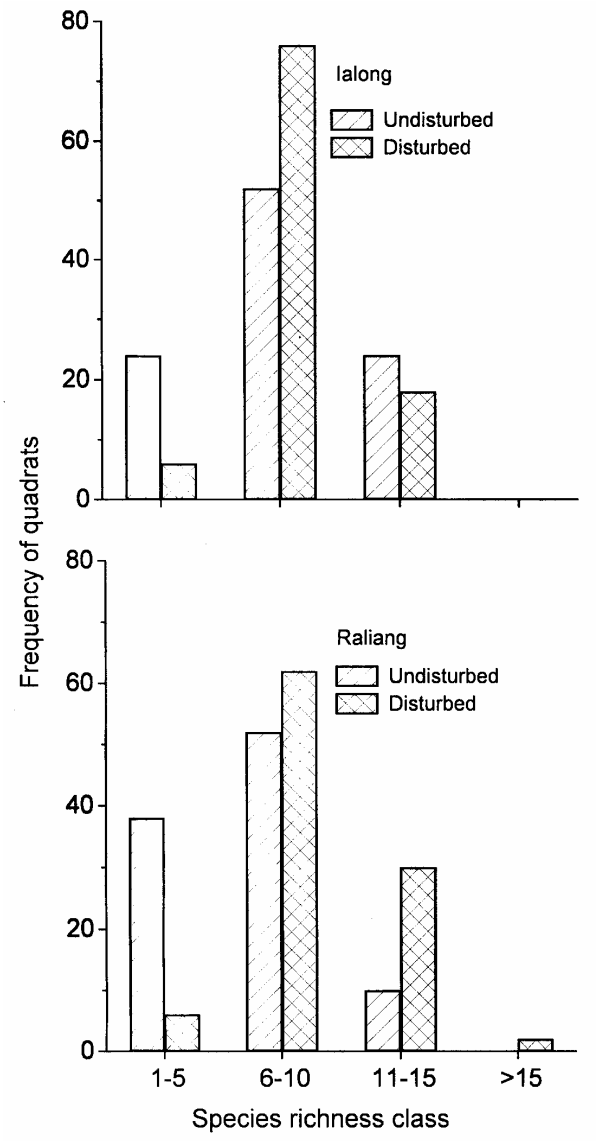

Fig. 1. Spatial distribution of species richness in undisturbed and disturbed stands at Ialong and Raliang sacred groves.

beliefs of the Jaintia tribe and represent the climax montane forests found between 1000-2000 m asl in northeast India. In each of the two sacred groves about 20-30 ha area is well protected and undisturbed, while ca. 30-40 ha area is converted into village reserve forest. The village reserve forest is mildly disturbed due to selective felling and lopping of trees for timber and fuelwood requirements of nearby villages and grazing by cattle and goats. About 20-30 animals were observed grazing in the periphery of the village forest during field visits. The periphery of the village forests is burnt during dry winter to promote herbage growth for the purpose of forage to domestic cattle during ensuing spring season. However, the intensity of disturbance and fire was not enough to cause serious damage to the village forest, which was quite dense and similar to the undisturbed portion due to abundant coppicing.

The climate of the area is monsoonic with distinct wet and dry seasons. The wet season extends from April to October, followed by a dry period from November to March. During wet season monthly rainfall ranged from 131 mm to 1557 mm, while in dry period it was usually <50 mm per month. The annual rainfall was 6539 mm during the year 2000. The mean monthly temperature varied from a maximum of 26°C in the month of April to a minimum of 5°C in January.

Methodology

The forest stands at Ialong and Raliang were classified on the basis of disturbance index calculated as the basal area of cut trees measured at ground level expressed as a fraction of total basal area of all trees, including felled ones (Rao *et al.* 1990). The disturbance index was 0% in the undisturbed sacred grove while it was 20% in the village forests. The woody vegetation was sampled by laying fifty randomized quadrats of 100 m^2 size in the undisturbed as well as mildly disturbed stands of both the groves during 1999-2001. All species (≥ 5 cm dbh) in each quadrat were tagged. They were identified with the help of the Flora of Jowai (Balakrishnan 1981-1983), Forest Flora of Meghalaya (Haridasan & Rao 1985-1987) and Flora of Assam (Kanjilal *et al.* 1934-1940). The Herbaria of Botanical Survey of India, Eastern Circle, Shillong and Botany Department, NEHU, Shillong were consulted for correct identification of plant specimens. The nomenclature of the species follows the regional flora.

The height and dbh of stems of each species were measured in all plots and they were grouped into three height classes (large tree ≥ 15 m, medium tree 8-15 m, small tree < 8 m) and seven dbh classes (5-15, 16-25, 26-35, 36-45, 46-55, 56-65 and > 65 cm). The density and basal area of each species were determined in different dbh classes according to Muller-Dombois & Ellenberg (1974). The population structure was analyzed at the

community level with the help of density-diameter curve. Whitford index was used to study dispersion pattern (Whitford 1948). Shannon index of diversity ($\bar{H}$) (Magurran 1988), evenness index (Pielou 1975) and Simpson dominance index (D) (Simpson 1949) were calculated to analyze species diversity and dominance in the community.

Results

Species richness and its distribution pattern

A total of 159 (4 unidentified) woody species (≥ 5 cm dbh) were identified in 2 ha area of the two sacred forests. Out of these, 39 species (24.5%) were canopy trees (≥ 15 m height), 45 species (28.3%) were subcanopy trees (8-15 m height), and the rest (37.7%) were small trees and tall shrubs (< 8 m height). Lianas contributed only 9.4% (15 species) to the total species richness (Table 1).

The undisturbed forest stands at Raliang and Ialong had 80 and 82 species, respectively in 0.5 ha area. The corresponding values for the disturbed stands were 92 and 93 species (Table 1). Twenty-four species were common to all four stands. Ten secondary colonizing species viz., *Euodia trichotoma* (large tree), *Glochidion lanceolarium, Litsea citrata* (medium sized tree) and *Ligustrum robustrum, Lindera caudata, Lyonia ovalifolia, Rhus hookeri, Rhus javanica, Saurauria nepaulansis* and *Symplocos crataegoides* (small tree or large shrub) were present exclusively in the disturbed stands.

The identified species belonged to 59 plant families. Lauraceae with 24 species was the dominant family followed in descending order by Araliaceae and Moraceae (9 species each). Euphorbiaceae and Fagaceae (8 species each), Theaceae (7 species), Rutaceae (6 species), Anacardiaceae, Myrsinaceae and Rubiaceae (5 species each), Rosaceae (4 species) and Clusiaceae and Symplocaceae (3 species each). Thirteen families were represented by two species and thirty-three families were monospecific. In terms of stem density per 0.5 ha, Fagaceae (16-142 stems) and Lauraceae (51-126 stems) were dominant families in all the stands (Table 2). Sapotaceae, a common family at Raliang, was absent in Ialong. Arecaceae, the only monocot family was represented by *Caryota urens*. Two gymnospermic families namely, Pinaceae and Podocarpaceae were represented by *Pinus kesiya* and *Podocarpus neriifolia*, respectively.

The spatial distribution of species richness in each stand was studied by determining species density per 100 m^2 plot. The results revealed that in the undisturbed stands, 25-40% of the plots had 1-5 species, 50% plots had 6-10 species and the rest (10-25%) had 11-15 species. In the disturbed stands the percentage of plots having 6-10 species increased to 60% - 75% while those having 1-5 species declined to about 5% (Fig. 1).

In all the four forest stands, majority of the species (90-95%) were contagiously distributed and only 5-8% of the species showed random distribution pattern. Regular distribution was observed only in the case of *Sarcosperma griffithii* in the undisturbed stand at Raliang (Table 3).

Species diversity and dominance

Shannon-Wiener's diversity index computed using proportional number varied from a minimum of 3.42 in Ialong undisturbed stand to a maximum of 3.87 in Raliang disturbed stand. Evenness index varied from 0.53 to 0.61 in the four stands (Table 4).

Density concentration

The stand density in the four stands ranged from 938 to 1476 individuals ha^{-1} with a mean

Table 1. Distribution of species richness in undisturbed and disturbed stand in Ialong and Raliang sacred groves.

Growth form	Ialong		Raliang		Overall
	Undisturbed	Disturbed	Undisturbed	Disturbed	
Large trees (> 15 m height)	22	20	29	25	39
Medium trees (8-15 m height)	27	27	26	26	45
Small trees (< 8 m height)	28	41	18	34	60
Lianas	5	4	7	8	15
Total	82	92	80	93	159

Table 2. Number of woody species and their density (individuals/0.5 ha) in different families in undisturbed and disturbed stands of Ialong and Raliang sacred groves.

Families	Ialong				Raliang				Overall	
	Undisturbed		Disturbed		Undisturbed		Disturbed			
	Species	Density	Species	Density	Species	Density	Species	Density	Species	Density
Acanthaceae	-	-	1	6	-	-	-	-	1	6
Aceraceae	1	3	1	1	2	14	1	10	2	28
Anacardiaceae	1	18	4	33	2	11	5	32	5	94
Annonaceae	-	-	-	-	2	10	1	7	2	17
Apocynaceae	-	-	-	-	1	1	-	-	1	1
Aquifoliaceae	-	-	-	-	1	2	1	2	1	4
Areciaceae	-	-	-	-	1	4	1	1	1	5
Araliaceae	5	17	4	12	4	17	5	25	9	71
Betulaceae	1	6	1	6	1	2	1	2	1	16
Buxaceae	1	5	1	9	1	4	1	11	1	29
Capparaceae	-	-	-	-	1	14	1	3	1	17
Caprifoliaceae	1	1	2	11	-	-	-	-	2	12
Celastraceae	1	149	1	1	-	-	1	5	2	155
Clusiaceae	2	4	-	-	2	3	1	1	3	8
Conanaceae	1	22	-	-	1	6	1	10	1	38
Coranaceae	1	8	1	3	-	-	-	-	1	11
Cyatheaceae	-	-	1	5	-	-	-	-	1	5
Ebenaceae	1	4	1	16	1	1	1	5	1	26
Elaeocarpaceae	-	-	-	-	2	2	1	9	2	11
Ericaceae	1	1	2	15	-	-	1	9	2	25
Erythroxylaceae	1	1	1	2	1	1	1	1	1	5
Euphorbiaceae	4	5	4	10	2	3	3	22	8	40
Fabaceae	1	1	1	2	-	-	1	2	2	5
Fagaceae	8	77	6	142	4	16	4	111	8	346
Hamamelidaceae	-	-	1	4	-	-	-	-	1	4
Iteaceae	1	1	-	-	1	1	2	18	2	20
Juglandaceae	1	20	1	28	1	4	1	12	1	64
Lamiaceae	-	-	1	3	-	-	-	-	1	3
Lauraceae	10	51	11	73	17	126	18	61	24	311
Lardizabalaceae	-	-	-	-	-	-	1	1	1	1
Magnoliaceae	1	1	-	-	2	5	1	3	2	9
Meliaceae	-	-	-	-	2	32	1	13	2	45
Mimosaceae	1	25	2	23	1	9	1	20	2	77
Moraceae	8	38	6	8	4	10	3	7	9	63
Myricaceae	1	3	1	13	1	1	1	16	1	33
Myristicaceae	-	-	-	-	1	14	-	-	1	14
Myrsinaceae	3	10	4	11	1	1	4	6	5	27
Myrtaceae	1	30	1	11	1	7	1	6	1	54
Oleaceae	-	-	1	4	-	-	1	5	1	9

Table 2 *(contd.)*

Pinaceae	1	1	1	3	-	-	1	2	1	6
Pittosporaceae	-	-	-	-	1	3	1	2	1	5
Podocarpaceae	-	-	-	-	1	1	-	-	1	1
Proteaceae	1	31	1	16	1	14	1	38	1	99
Rosaceae	1	10	4	11	2	42	1	9	4	72
Rubiaceae	5	64	5	35	3	9	4	21	5	129
Rutaceae	2	7	4	34	2	6	3	14	6	61
Santalaceae	1	10	1	7	-	-	1	1	1	18
Sapindaceae	-	-	-	-	1	1	1	3	1	4
Sapotaceae	-	-	-	-	1	58	1	22	1	80
Saurauriaceae	-	-	1	8	-	-	1	3	1	11
Semaroubaceae	1	4	-	-	-	-	-	-	1	4
Sterculiaceae	-	-	-	-	1	3	-	-	1	3
Styracaceae	2	6	2	4	1	3	1	44	2	57
Symplocaceae	1	5	2	5	2	4	3	10	3	24
Theaceae	5	88	6	86	1	2	3	39	7	215
Urticaceae	1	1	-	-	-	-	-	-	1	1
Vacciniaceae	1	2	1	2	-	-	-	-	1	4
Verbenaceae	1	1	1	4	-	-	1	6	1	11
Vitaceae	1	7	1	1	1	1	1	2	2	11
Unidentified	-	-	1	2	1	1	2	2	4	6
Total	82	738	92	670	80	469	93	654	159	2531

– indicates absence

value of 1265 ± 132 stems ha^{-1} (Table 4). At Ialong the density decreased from 1476 stems ha^{-1} in the protected stand to 1340 ha^{-1} in the disturbed stand whereas, at Raliang it increased from 938 stems ha^{-1} in the protected stand to 1308 stems ha^{-1} in the disturbed stand. In the undisturbed stand at Ialong, *Microtropis discolors* was the dominant species in terms of density (298 stems ha^{-1}) followed by *Camellia caudata* with 136 stems ha^{-1} (Table 5). These two species together constituted 29% of the stand density in the forest. At Raliang, *Sarcosperma griffithii* had the highest number of individuals (116 stems ha^{-1}) followed by *Actinodaphne obovata* (108 stems ha^{-1}) in the undisturbed stand. Together they constituted about 23% of the stand density. *Castanopsis purpurella* was the most abundant species with 224 and 130 stem ha^{-1} in the disturbed stands at Ialong and Raliang respectively (Table 5).

Species – individual relationship

The relationship between the number of species and the number of individuals is shown in the Fig. 2. In all stands majority of the species was represented by few individuals whereas, few species had relatively large population density. In the undisturbed stands, 28-29 species (35%) were represented by one individual each and 10-14 species (12-17%) were represented by two stems each. While in the disturbed stands 25% of the species were represented by one individual each and 17% by two stems each.

Population structure

Distribution of species richness in different dbh classes showed high richness in 5-15 cm dbh class, which sharply declined in 16-25 cm dbh class followed by a gradual decrease up to 65 cm dbh class in all the stands. However, in the disturbed stands, the species richness in 5-15 cm and 16-25 cm dbh classes was markedly high than the undisturbed stands (Fig. 3).

The density-diameter distribution yielded reverse J-shaped curves in all stands (Fig. 3). However, at Raliang stem density in 5-15 cm and 16-25 cm dbh classes was markedly high in the disturbed

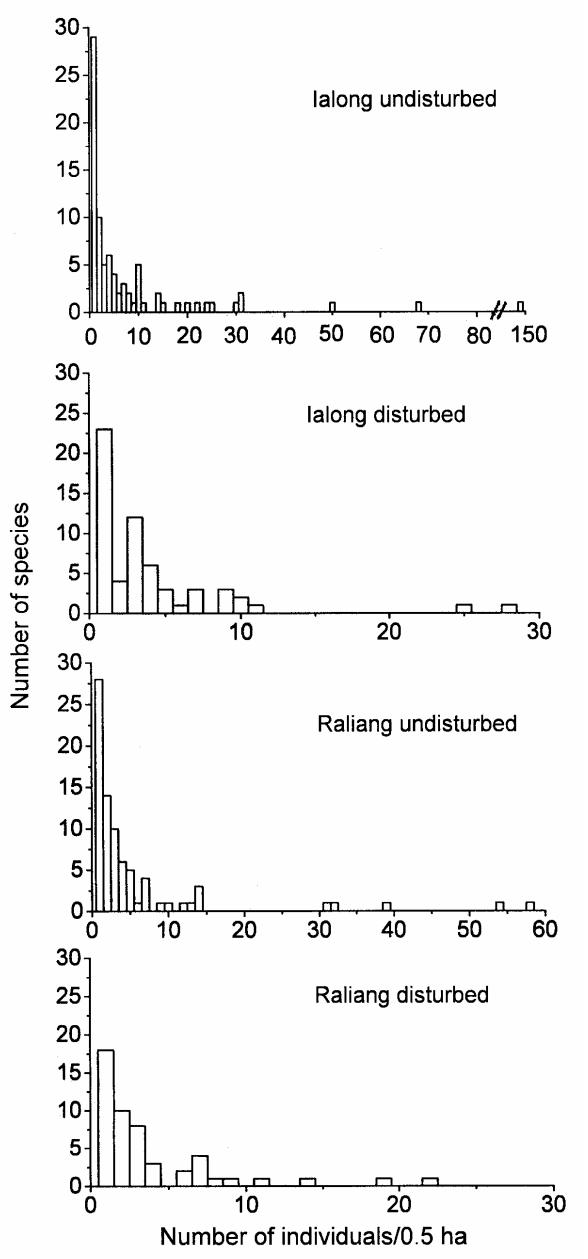

Fig. 2. Species individual relationship in a 0.5 ha area of the undisturbed and disturbed stands at Ialong and Raliang sacred groves.

village forest than the undisturbed scared groves, but at Ialong such an increase was observed only in 16-25 cm dbh class.

The tree basal cover in the undisturbed stands of both the groves was comparatively greater than the disturbed stands. Despite the fact that density of young trees (5-15 cm dbh) was very high, their total basal cover was much less than the cover of mature trees, thereby resulting into a J-shaped distribution of basal cover. Old trees (≥ 26-35 cm dbh class) had less basal cover in the disturbed stands than the undisturbed stands of both the groves, indicating the extraction pattern of trees in the former stands (Fig. 3).

Table 3. Distribution pattern of woody species in the four stands.

Sites	Distribution pattern (Number of species)		
	Regular	Random	Contagious
Ialong			
Undisturbed	0	8 (10)	74 (90)
Disturbed	1 (1)	5 (6)	74 (93)
Raliang			
Undisturbed	0	5 (5)	87 (95)
Disturbed	0	7 (8)	86 (92)

The number in parentheses is the percentage of the total.

Table 4. Consolidated summary of plant diversity and community characteristics of all woody species ≥ 5 cm dbh in undisturbed and disturbed stands in Ialong and Raliang sacred groves.

Variables	Ialong		Raliang	
	Undisturbed	Disturbed	Undisturbed	Disturbed
Area sampled (ha)	0.5	0.5	0.5	0.5
Species richness	82	92	80	93
Number of families	39	39	41	46
Number of genera	59	69	62	71
Density (ha^{-1})	1476	1340	938	1308
Basal area ($m^2\ ha^{-1}$)	57.46	49.64	71.44	36.52
Diversity indices:				
Shannon diversity index	3.42	3.78	3.55	3.87
Evenness index	0.53	0.61	0.56	0.61
Simpson dominance index	0.067	0.047	0.052	0.034

Discussion

The sacred groves at Ialong and Raliang are multilayered subtropical humid forest communities composed of large, medium and small trees

Table 5. Density (individuals ha^{-1}) of dominant species (≥ 5 cm dbh) in undisturbed and disturbed stands of Ialong and Raliang sacred forests.

Name of species	Family	Growth form	Density			
			Ialong		Raliang	
			Undisturbed	Disturbed	Undisturbed	Disturbed
Acer laevigatum Wall.	Aceraceae	LT	6	2	26	20
Actinodaphne obovata (Nees) Kosterm	Lauraceae	LT	-	-	108	2
Camellia caudata Wall	Theaceae	ST	136	48	-	-
Castanopsis purpurella (Miq.) Balakr.	Fagaceae	LT	62	224	14	130
Citrus latipes (Swingle) Tanaka	Rutaceae	MT	8	52	6	-
Coffea khasiana Hook.f.	Rubiaceae	ST	100	26	4	6
Diospyros kaki L.f.	Ebenaceae	MT	8	32	2	10
Dysoxylon gobara (Buch-Ham) Merr	Meliaceae	MT	-	-	62	26
Engelhardtia spicata Bl.	Juglandaceae	LT	40	56	8	24
Helecia nilagirica Bedd	Proteaceae	MT	62	32	28	76
Itea macrophylla Wall.	Iteaceae	ST	2	-	-	34
Knema angustifolia (Roxb.) Warb.	Myristicaceae	LT	-	-	28	-
Lindera latifolia Hook.f.	Lauraceae	MT	28	48	10	18
Lithocarpus elegans Soepadmo	Fagaceae	LT	28	12	14	82
Macropanax dispermus (Bl.) O. Ktze	Araliaceae	MT	2	-	24	16
Microtropis discolor (Wall.) Arn	Celastraceae	ST	298	2	-	-
Myrica esculenta Buch-Ham	Myricaceae	MT	6	26	2	32
Neolitsea cassia (L.) Kosterm.	Lauraceae	LT	-	-	64	12
Pithecellobium monodelphum (Roxb.) Kaster	Mimosaceae	MT	50	30	18	40
Prunus jenkensii Hk.f.	Rosaceae	LT	20	4	78	18
Pseudostreblus indica Bur	Moraceae	LT	48	-	-	-
Rhus acuminata DC	Anacardiaceae	MT	36	50	-	38
Rourea minor (Gaertn.) Leenh	Connanaceae	L	44	-	12	20
Sarcosperma griffithii Clarke	Sapotaceae	LT	-	0	116	44
Schima wallichii Dyer	Theaceae	LT	20	88	4	66
Styrax serrulatum Roxb.	Styracaceae	MT	10	2	6	88
Syzygium tetragonum (Wt) Kurz	Myrtaceae	LT	60	22	14	12
Others			402	584	290	494
Total			1476	1340	938	1308

LT – large size tree, MT = medium size tree, ST = small size tree, L = liana.

distributed in three distinct strata. The under-canopy layer composed of medium and small trees and shrub had highest concentration of species. High species richness of understory is attributed to the presence of individuals of canopy species, which were either young or whose growth was arrested due to shade cast by overhead canopy as well as understory species. Similar observation has been reported by Jamir & Pandey (2003) from three other sacred groves of Jaintia hills and Quigley & Platt (2003) from nine seasonally deciduous forests in the Americas. The species richness was high in the understory layer in the disturbed village forest and is similar to those reported by Quigley & Platt (2003), who observed rapid recovery of damaged trees and release of smaller trees in seasonal forests damaged by hurricane.

High species richness of the grove is also due to geographical location of the northeastern region at the confluence of Indo-Malayan and Indo-Chinese biogeographical region (Rao 1944), and favourable climatic condition and protection over a

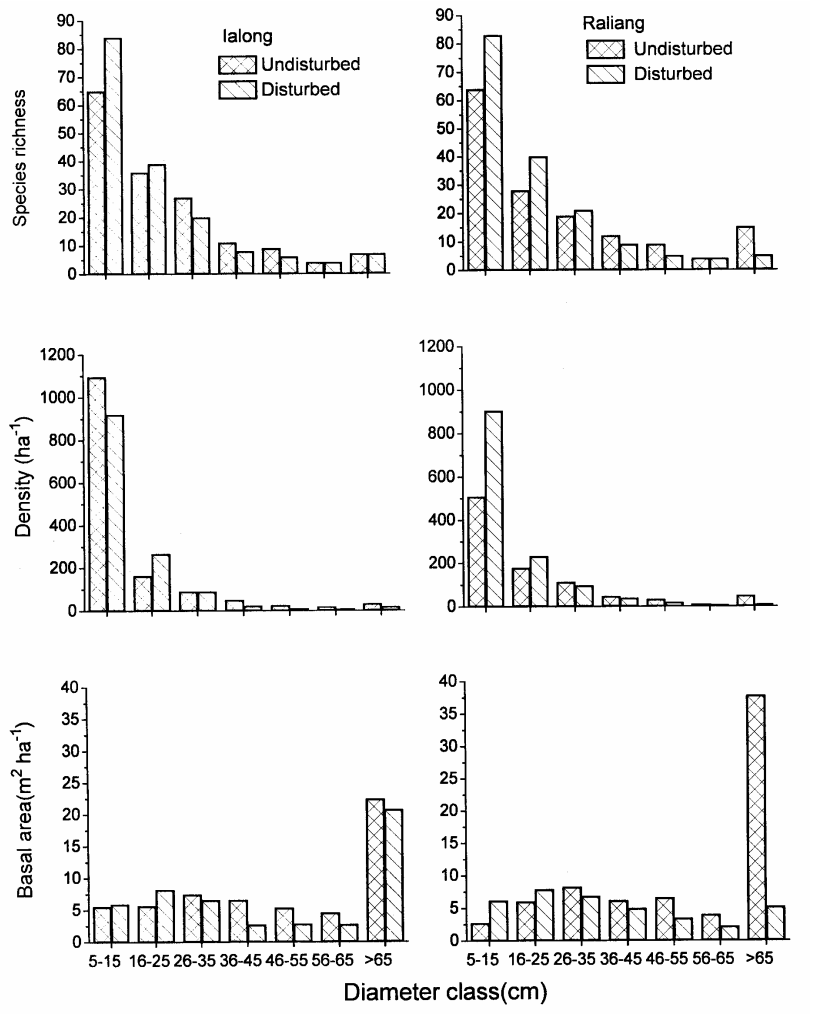

Fig. 3. Distribution of species richness, density and basal area in different diameter classes in the undisturbed and disturbed stands of Ialong and Raliang sacred groves.

long period of time. Their species richness is comparable to the tropical forests at Luquillo Mountains in Puerto Rico (Weaver & Murphy 1990), and Yanamono, Peru (Gentry 1988). Connell (1978) argued that disturbance of mild intensity creates an alternative non-equilibrium situation that brings variation or change (increase) in species diversity by providing opportunity to fast colonizing species to establish in a community. The studies of Connell (1978), Sousa (1979), Paine & Levin (1981) and Hobbie *et al.* (1994) clearly demonstrated that maximal species diversity occurs under intermediate disturbance regime. In the present case increase in species diversity in the village forest was due to colonization by fast growing secondary species like *Corylopsis himalayana, Litsea citrata, Lyonia ovalifolia* and *Saurauria nepaulensis* in the open spaces created by selective tree cutting.

Species richness was not uniformly distributed in the forest; rather both the forests were mosaic of low and high diversity patches. This appears to be the result of the combined effect of non-extreme stable environmental conditions and gap phase dynamics within the forest (Whittaker 1972). In this respect, also the studied forests are similar to the tropical rain forests, which have often been described as highly patchy communities (Ashton

1969; Herwitz 1981; Poore 1968) primarily due to gap-phase dynamics. Contagious distribution of species as observed in the majority of cases in the present study, may be related to seed dispersal mechanism of the species and gap formation (Barik *et al.* 1996). On the basis of a comparative study of the dispersion pattern of trees in tropical and temperate forests Armesto *et al.* (1986) concluded that clumping is characteristic of those forests in which formation of canopy gaps is the chief source of disturbance. Our result shows that contagious distribution of species was not influenced by disturbance, but the patchiness of the community increased due to increase in frequency of species-rich pockets. This could be the result of selective cutting of older trees in the village forest that might have favoured the establishment of shade intolerant species like *Castanopsis purpurella, Engelhardtia spicata, Lithocarpus elagans* and *Schima wallichii* in the open spaces.

The density (938-1476 stems ha^{-1}) of woody species (≥ 5 cm dbh) recorded at the present study sites is close to those reported from lowland tropical forests (716-1440 stems ha^{-1}) in Kurupukari, Guyana (Johnston & Gillman 1995), terra firme forest (1561 stems ha^{-1}) in Amazonian Ecuador (Valencia *et al.* 1994) and subtropical humid forest (1176-1496 stems ha^{-1}) in the Jaintia hills, Meghalaya (Jamir 2000). Selective cutting of straight boles of *Microtropis discolor* and *Camellia caudata* for use as poles by villagers was the main reason for the lower stem density in Ialong disturbed stand whereas, at Raliang, large trees of *Actinodaphne obovata, Sarcosperma griffithii, Neolitsea cassia, Prunus jenkinsii* were selectively felled few years ago for construction purposes. The creation of forest opening lead to colonization by shade intolerant species such as *Castanopsis purpurella, Engelhardtia spicata, Lithocarpus elagans, Schima wallichii* and concomitant increase in stem density in the disturbed stand.

About 42% to 53% of the total species were represented by one or two individuals in each stands. The numbers of individuals of such species are kept low by a combination of unfavourable regeneration conditions, lack of appropriate habitat, or both (Hubbell 1979). In this respect also the sacred groves are similar to tropical forests, which are known to possess large number of tree species that have few individuals as reported by Thorington *et al.* (1982), from Barro Colorado Island, Panama and Parthasarathy & Karthikeyan (1997) from western ghats. However, with disturbance number of such species decreased as there was an increase in number of individuals of those species *(Castanopsis purpurella, Engelhardtia spicata, Myrica esculanta, Schima wallichii*) which are resistant to damage or to death caused by physical extremes or natural enemies that eventually fill much of the space after disturbances (Connell 1978).

The tree population structure observed in the present study is similar to those reported from the forests at Costa Rica (Nadkarni *et al.* 1995), Brazalian Amzon (Campbell *et al.* 1992) and Eastern Ghats (Kaduval & Parathasarathy 1999), all of them have the preponderance of young individuals. Whitmore (1975) has ascribed such a tree population structure in the mature forest to the fast rate of turnover of the gaps. The tree basal cover measured at the present study site (36-71 m^2 ha^{-1}) is close to the equatorial forest (10-45 m^2 ha^{-1}) in Kango Island, Zaire (Mosango 1991), tropical rain forest (78 m^2 ha^{-1}) in Amazonia (Campbell *et al.* 1992), lower montane forest (62 m^2 ha^{-1}) in Costa Rica (Nadkarni *et al.* 1995), and evergreen forest (55-94 m^2 ha^{-1}) of Kalakad in western ghats (Parthasarathy *et al.* 1992), but higher than the dry evergreen forest (32.8 m^2 ha^{-1}) of Puthupet, South India (Parthasarathy & Sethi 1997). A gradual decrease in basal area and the density of trees beyond 16-25 cm dbh class indicated extraction pattern of trees in the village forest. Such a selective extraction of trees led to tree regeneration either through coppice or new recruitments by seeds or both in the disturbed stands where population density of young individuals (5-15 cm and or 16-25 cm) was high and their contribution to stand basal cover was more.

Conclusions

The virgin subtropical humid forests of Meghalaya represented by sacred groves at Ialong and Raliang are still preserved by the Jaintia tribe. One portion of these groves is mildly disturbed due to use by the local village community for their timber and fuel wood requirements as well as grazing by their cattle and goat. In spite of these disturbances, tree regeneration was not adversely affected in the village forest as was evident from high density of young trees in the stand. These

disturbances, however, have led to an increase in species richness due to colonization by secondary species like *Litsea citrata, Ligustrum robustrum, Rhus javanica* and *Symplocos crataegoides* in the disturbed stands.

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References

Armesto, J.J., J.D. Mitchell & C. Villogram. 1986. A comparison of spatial patterns of trees in tropical and temperate forests. *Biotropica* **18**: 1-11.

Ashton, P.S. 1969. Speciation among tropical forest trees: some deductions in the light recent evidence. *Biological Journal of Linnaean Society* **1**: 155-196.

Balakrishnan, N.P. 1981-1983. *Flora of Jowai.* 2 Vols. BSI, Hawrah.

Barik, S.K., R.S. Tripathi, H.N. Pandey & P. Rao. 1996. Tree regeneration in a subtropical humid forest: effect of cultural disturbance on seed production and germination. *Journal of Applied Ecology* **33**: 1551-1560.

Campbell, D.G., J.L. Stone & A. Jr. Rosas. 1992. A comparison of the phytosociology and dynamics of three flood plain (Varzae) forests of known ages, Rio Jurua, Western Brazilian Amazon. *Botanical Journal of Linnaean Society* **108**: 213-237.

Collins, S.L., S.M. Glenn & D.J. Gibson. 1995. Experimental analysis of intermediate disturbance and initial floristic composition: decoupling cause and effect. *Ecology* **76**: 486-492.

Connell, J.H. 1978. Diversity in tropical rain forest and coral reefs. *Science* **199**: 1302-1310.

Ehrlich, P.R. & E.O. Wilson. 1991. Biodiversity studies; science and policy. *Science* **253**: 758-762.

Frank, D.A. & S.J. McNaughton. 1991. Stability increases with diversity in plant communities: empirical evidence from the 1998 Yellow Stone Drought. *Oikos* **62**: 360-362.

Gentry, H.A. 1988. Tree species richness of upper Amazon forests. *Proceedings of National Academy of Sciences* USA **85**: 156-159.

Haridasan, K. & R.R. Rao. 1985-1987. *Forest Flora of Meghalaya.* 2 Vols. Bishen Singh Mahendrapal Singh, Dehra Dun, India.

Herwitz, S.R. 1981. *Regeneration of Selected Tropical Tree Species in Corcovado National Park, Costa Rica.* University California Publication in Geography 24, Berkeley, California.

Hobbie, S.E., D.B. Jensen & F.S. III. Chapin. 1994. Resource supply and disturbance as controls over present and future plant diversity. pp. 385-480. *In:* E.D. Schulze & H.A. Mooney (eds.) *Biodiversity and Ecosystem Function.* Springer Verlag, Berlin, Heidelberg.

Hubbell, S.P. 1979. Tree dispersion, abundance and diversity in a tropical dry forest. *Science* **203**: 1299-1309.

Hurd, L.E., M.V. Mellinger, L.L. Wolf & S.J. McNaughton. 1971. Stability and diversity at three trophic levels in terrestrial systems. *Science* **173**: 1134-1136.

Jamir, S.A. 2000. *Studies on Plant Biodiversity, Community Structure and Population Behaviour of Dominant Tree Species of Some Sacred Groves of Jaintia Hills, Meghalaya.* Ph.D. Thesis. North Eastern Hill University, Shillong, India.

Jamir, S.A. & H.N. Pandey. 2003. Vascular plant diversity in the sacred groves of Jaintia Hills in northeast India. *Biodiversity and Conservation* **12**: 1497-1510.

Johnston, M. & M. Gillman. 1995. Tree population in low-diversity forests, Guyana. I. Floristic composition and stand structure. *Biodiversity and Conservation* **4**: 339-362.

Kadavul, K. & N. Parthasarathy. 1999. Structure and composition of woody species in tropical semievergreen forest of Kalrayan hills, Eastern Ghats, India. *Tropical Ecology* **40**: 247-260.

Kanjilal, V.N., P.C. Kanjilal, A. Das, R.N. De & N.L. Born. 1934-1940. *Flora of Assam.* 5 Vols. Government Press, Shillong.

Khiewtam, R.S. & P.S. Ramakrishnan. 1989. Sociocultural studies of the sacred groves at Cherrapunji and adjoining areas in north-eastern India. *Man in India* **69**: 64-71.

Lawton, J.H. & V.K. Brown. 1994. Redundancy in ecosystems. pp. 255-270. E.D. Schulze & H.A. Mooney (eds.) *Biodiversity and Ecosystem Function.* Springler Verlag, Berlin, Heidelberg.

Magurran, A. 1988. *Ecological Diversity and its Measurement.* Princeton University Press, New Jersey.

McNaughton, S.J. 1977. Diversity and stability of ecological communities; a comment on the role of empiricism in ecology. *American Naturalists* **111**: 515-525.

McNaughton, S.J. 1985. Ecology of a grazing system; the Serengeti. *Ecological Monograph* **55**: 259-294.

Mosango, M. 1991. Contribution 'AI' etude botanique biogeochemicque de I ecosystem forest region equatoriale (IFBe Kongalo, Zaire). *Belgian Journal of Botany* **124**: 167-194.

Muller Dombois, D. & H. Ellenberg. 1974. *Aims and Methods of Vegetation Analysis*. John Wiley and Sons, New York.

Nadkarni, N.M., T.J. Matelson & W.A. Haber. 1995. Structural characteristic and floristic composition of neotropical cloud forest, Montenerde, Costa Rica. *Journal of Tropical Ecology* **11**: 482-495.

Paine, R.T. & S.E. Levin. 1981. Intertidal landscapes: disturbance and the dynamics of patterns. *Ecological Monograph* **51**: 145-178.

Pandey, H.N., R.S. Tripathi & Uma Shanker. 1993. Nutrient cycling in a excessively rainfed subtropical grassland in Cherrapunji. *Journal of Biosciences* **3**: 395-406.

Parthasarathy, N. & R. Karthikeyan. 1997. Plant biodiversity inventory and conservation of two tropical dry evergreen forests on the Coromandal Coast, South India. *Biodiversity and Conservation* **6**: 1063-1083.

Parthasarathy, N., V. Kindal & K.L. Praveen. 1992. Plant species diversity and human impacts in the tropical wet evergreen forest of southern Western Ghats. *In*: *Indo-French Workshop on Tropical Forest Ecosystem: Natural Functioning and Anthropogenic Impact*. 26-27 Nov. French Institute, Pondicherry.

Parthasarathy, N. & P. Sethi. 1997. Trees and lianas species and population structure in a tropical dry evergreen forest in South India. *Tropical Ecology* **38**: 19-30.

Pimm, S.L. 1984. The complexity and stability of ecosystems. *Nature* **307**: 312-326.

Pielou, E.C. 1975. *Ecological Diversity*. John Wiley and Sons Inc. New York.

Poore, M.E.D. 1968. Studies in Malaysian rain forest. I. The forest on Trassic sediments in Jengka forest reserve. *Journal of Ecology* **56**: 143-196.

Quigley, M.F. & W.J. Platt. 2003. Composition and structure of seasonally deciduous forests in the Americas. *Ecological Monographs* **73**: 87-106.

Rao, R.R. 1994. *Biodiverstiy in India, Floristic Aspects*. Bishen Singh Mahendra Pal Singh, Dehradun, India.

Rao, P., S.K. Barik, H.N. Pandey & R.S. Tripathi. 1990. Community composition and tree population structure in a subtropical broad-leaved forest along a disturbance gradient. *Vegetatio* **88**: 151-162.

Simpson, E.H. 1949. Measurement of diversity. *Nature* **163**: 688.

Sousa, W.P. 1979. Disturbance in marine intertidal boulder fields: non-equilibrium maintenance of species diversity. *Ecology* **60**: 1225-1239.

Stapanian, M.A., D.L. Cassell & S.P. Cline. 1997. Regional patterns of local diversity of trees: associations with anthropogenic disturbance. *Forest Ecology and Management* **93**: 33-44.

Thorington, Jr. R.W., B. Tannenbaum, A. Tarak & R. Rudran. 1982. Distribution of trees on Barro Colorado Island: A five hectarer sample. pp. 83-94. *In*: E.G. Leigh, Jr. A.S. Rand & D.M. Windror (eds.) *The Ecology of Tropical Forest-Seasonal Rhythms and Long-Term Changes*. Smithsonian Institution Press, Wshington, DC.

Tilman, D. (ed.). 1988. *Plant Strategies and the Dynamics and Structure of Plant Communities*. Princeton University Press, Princeton.

Tilman, D. & J.A. Downing. 1994. Biodiversity and stability in grasslands. *Nature* **367**: 363-365.

Tiwari, B.K., S.K. Barik & R.S. Tripathi. 1999. *Sacred Forests of Meghalaya. Biological and Cultural Diversity*. Regional Centre, National Afforestation and Eco-Development Board, North Eastern Hill University, Shillong.

Upadhaya, K. 2002. *Study on Plant Diversity and Ecosystem Function in Sacred Groves of Meghalaya*. Ph.D. Thesis. North Eastern Hill University, Shillong, India.

Valencia, R., H. Balslev, Y. Paz & G.C. Mino. 1994. High tree alpha-diversity in Amazonian Ecuador. *Biodiversity and Conservation* **3**: 21-28.

Weaver, P.L. & P.G. Murphy. 1990. Forest structure and productivity in Puerto Rico's Luquillo Mountains. *Biotropica* **22**: 69-82.

Whitford, P.B. 1948. Distribution of woodland plants in relation to succession and clonal growth. *Ecolgoy* **30**: 199-208.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. *Taxon* **21**: 213-251.

Whitemore, T.C. 1975. *Tropical Rain Forest of the Far East*. Oxford University Press. Oxford.