Tropical Ecology 47(1): 47-55, 2006 ISSN 0564 -3295

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Evaluation of disturbance in a tropical dry deciduous forest of Alagar hill (eastern ghats), South India

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Abstract: Disturbance to a tropical dry deciduous forest of Alagar hill (eastern ghats), Madurai (12°18′N; 76°42′E), south India was assessed comparatively at foot (275 m), mid (350 m) and top (550 m) hill locations with differential intensity of disturbance. The selected measures were broadly pertained to tree density, canopy thickness, abundance of herbs and insects, cattle grazing and human intervention. Sampling was performed during post monsoon (October-November) seasons of 1999 and 2000 and summer (March-May) season of 2003. Number of trees with multiple stems, number of crossing branches, abundance of herbs, foliage insects and butterflies and thickness of canopy cover were highest at top-hill and lowest at foot-hill. Number of man made tracks and number of human intruders were highest at foot-hill while lowest at top-hill. One way ANOVA revealed significant differences in all measures between locations at three different altitudes. Our data revealed that dry deciduous forest of Alagar hill, south India is being subjected to heavy disturbance at foot and mid-hill locations. Top-hill is relatively relieved from such disturbance.

Resumen: La perturbación en un bosque tropical seco caducifolio del Cerro Alagar (Gates Orientales), Madurai (12°18′N; 76°42′E), en el sur de la India, fue evaluada de manera comparativa en localidades de piedemonte (275 m), elevación media (350 m) y cima (550 m) que presentan diferentes intensidades de disturbio. Las medidas seleccionadas tuvieron que ver en general con la densidad de árboles, el espesor del dosel, la abundancia de hierbas e insectos, el pastoreo por el ganado y la intervención humana. El muestreo se llevó a cabo durante las temporadas post-monzónicas (octubre-noviembre) de 1999 y 2000, y la temporada de verano (marzo-mayo) de 2003. El número de árboles con numerosos tallos, el número de ramas que se atravesaban, la abundancia de hierbas, de insectos del follaje y de mariposas, así como el espesor del dosel, tuvieron sus valores más altos en la cima y los más bajos en el piedemonte. El número de rastros de origen humano así como el número de intrusos humanos alcanzaron sus picos en el piedemonte y sus mínimos en la cima. Un análisis de varianza de una vía reveló diferencias significativas para todas las variables entre localidades ubicadas a las altitudes diferentes. Nuestros datos mostraron que el bosque seco deciduo del Cerro Alagar, en el sur de la India, está siendo sujeto a un régimen intenso de disturbio en sus localidades de piedemonte y de altitud intermedia, mientras que la cima está relativamente libre de dicho disturbio.

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Resumo: Os distúrbios a uma floresta tropical seca decídua na colina de Alagar (Gates Orientais), Madurai (12°18′N; 76°42′E), no sul da Índia, foram avaliados comparativamente no sopé - (275m), na meia encosta - (350m) e no topo (550m) da encosta com intensidades diferenciais de distúrbio. As medidas efectuadas abrangeram a densidade arbórea, a espessura do copado, a abundância das ervas e insectos, apascentamento de gado e intervenção humana. A amostragem foi efectuada durante a estação da pós-monção (Outubro-Novembro) em 1999 e 2000, e na estação de verão (Março-Maio) de 2003. O número de árvores com troncos múltiplos, número de ramos entrecruzados, abundância de ervas, insectos e borboletas na folhagem e espessura da cobertura do copado era o mais elevado no sopé da colina e o mais baixo no topo. A análise de variância "one way" revelou diferenças significativas em todas as medidas efectuadas entre localizações nas três altitudes. Os dados revelam que a floresta seca decídua da colina de Alagar, sul da Índia vem sendo sujeita a distúrbios pesados no sopé e meia encosta. O topo está relativamente liberto de tais distúrbios.

Key words: Alagar hill, altitude, canopy thickness, disturbance, dry deciduous forest, insect abundance, tree density.

Introduction

Connell's (1978) paper on species diversity of tropical rain forests and coral reefs in relation to disturbance has stimulated much scientific interest on the significance of disturbance in community ecology and conceptual development of the intermediate disturbance hypothesis. Disturbance to an ecosystem means any discrete event that disrupts ecosystem, community or population structure, or the physical environment (Pickett & White 1985). Species composition, community dynamics and human welfare services of forest ecosystems become adversely affected by disturbances of both natural and anthropogenic origin (Sousa 1984). Whitemore & Burslem (1996) classified disturbance into large scale or community wide (landslides, volcanoes, drought, lighting, forest fire and various human activities) and small-scale disturbances such as mortality of few trees. In fact many kind of disturbances both natural and anthropogenic are amenable to scientific experimentation and immeasurable directly. Most of the studies on forest ecosystems in relation to disturbance were focused on species-rich tropical rain forests (Ashton 1993; Aravind *et al.* 2001; Bhuyan *et al.* 2001; Whitemore & Burslem 1996) or temperate forests (Gilliam 2002; Schumann *et al.* 2003). Dry deciduous forests of tropical areas are under constant disturbances of both climatic and anthropogenic origin. In India, habitat destruction, over exploitation, environmental pollution and anthropogenic pressure are the major disturbances to forest ecosystems (UNEP 2001). Most of the above mentioned studies have governed these factors in their analysis. Recently invasion of exotic species especially weeds in the forest ecosystems and its ecological impacts on community structure and dynamics of native species also received greater scientific attention as disturbance (Chandrasekaran & Swamy 1995; 2002; Sagar *et al.* 2003; Sagar & Singh 2004, 2005). The dry tropical forest accounts for 38.2% of the total forest cover of India (MoEF 1999), which is largely disturbed by lopping, burning, overgrazing and clearing for cultivation. Such disturbances leads to their conversion into species-poor forest ecosystems. Habitat destruction is the leading cause of species extinction and biodiversity loss in natural ecosystems (Koh *et al.* 2004; Pimm & Raven 2000). Unfortunately, studies on tropical dry deciduous forests in relation to disturbances were much limited in India (Khera *et al.* 2001; Puyravaud *et al.* 1995) particularly, on eastern ghats in south India (Rajan *et al.* 1995). Thus, the present study evaluated the disturbance to a tropical dry deciduous forest of Alagar hill (eastern ghats), Madurai, south India using selected direct (number of trees, number of butterflies and herb density) and indirect (number of sunspots and number of man-made tracks) measures.

Materials and methods

Alagar hill forms a discontinuous minor range in the Deccan plain and appears as an extension of eastern ghats. It is located 22 km northeast of Madurai city (12°18′N; 76°42′E; altitude 275 m). The dry deciduous forest of Alagar hill is composed of both highly disturbed and protected vegetation, which varies with topography of the area and degree of anthropogenic pressure. Sriganesan (1984, 1987) described the vegetation and soil characteristics of this forest. By following Krishnankutty *et al.* (2000), three different altitudes viz., 275 m, (foot-hill - Silambar Valley), 350 m (mid-hill - Palamutheer solai - middle of Silambar Valley) and 550 m (top-hill–above Nupuragangai towards Bison Valley) were selected to study the disturbances to this dry deciduous forest. The present study was carried out during post monsoon (October-November) seasons of 1999 and 2000 and summer (March-May) season of 2003. Both summer and monsoon seasons were considered for sampling to reduce the confounding effect of seasons on selected measures of disturbance.

Tree density at selected three altitudes was estimated by two measures viz., number of trees with multiple stems and number of crossing branches. To estimate the former, all trees occurring in 10 m × 10 m randomly placed quadrats were tagged with fluorescent sticker to differentiate them from others. Numbers of trees with multiple stems (two or more) among these tagged trees were counted. At each altitude, ten quadrats were counted, five for each season. To estimate the second parameter, the estimator walked along transect of 3 m length towards the double-storey vegetational growth in the interior areas of the forest and counted the branches of trees and shrubs crossed above his chest and resisted his entry into the forest. No distinction was made either on the thickness or species of the counted branches. Total ten transects were walked at each altitude, five for each season.

Thickness of tree canopy was assessed by a unique and indirect measure. Quadrats of 3 m^2 size were randomly placed on the forest floor. The numbers of 'sunlight spots' falling within the quadrats through canopy cover were counted. Spots clearly separated by complete shade were counted alone. Total ten quadrats were counted at each altitude, five for each season. It was estimated at 12.00 noon on sunny days when sun is directly overhead.

Anthropogenic disturbance was evaluated by three measures viz., number of man-made tracts, number of intruders and number of grazing cattle. The estimator walked in the main track of the forest in interior areas for 15 minutes and counted the number of man-made sidetracks that he encountered within 15 minutes of walking. Each 15 minutes walk constitutes a single sample and total 10 samples are collected at each altitude, five for each season. During this sampling, number of intruders and number of grazing cattle noticed at interior areas of forest were also counted separately (n = 10). In both measures, each 15-minute count constitutes a single sample. Five samples were collected per each season.

To estimate the herbal density, 1 m × 1 m quadrats were randomly placed on the forest floor at selected altitudes. The number of herbs occurred within the quadrats were counted and no taxonomic distinction was made in these samples. Abundance of foliage insects and butterflies were quantified by sweep net sampling. Each sweeping operation lasted five minutes over the under-storey vegetation cover and in air, if butterflies were noticed. Sampling foliage insects was mostly done by sweeping the net over the under-storey vegetation cover. For these three measures, ten samples were collected, five per each season. Results are expressed in mean, standard deviation and coefficient of variation. Comparison of the means of selected parameters between altitudes was done by t test (for small samples i.e. n = >30) and by one way ANOVA (Misra & Misra 1989).

Results and discussion

Table 1 presents the quantitative data on disturbance based measures in Alagar hill. Table 2 indicates the t values for comparison of the means between altitudes. The results of ANOVA are given in Table 3. The top-hill showed highest abundance of butterflies compared to mid and foot-hills. The lowest abundance of butterflies was recorded at foot-hill with relatively high coefficient of variation (28.12%) suggesting a wide inter-sample variability (Table 1). Butterflies are frequently used as indicators of disturbance to forest ecosystems. Data from tropical rain forests have shown that logging due to disturbance reduces both diversity and abundance of butterflies (Daily & Ehrlich 1995; Hamer *et al.* 1997; Hill *et al.* 1995). The undisturbed Maha Maya forest of Jammu supported maximum abundance (range 8-890; mean 449) of butterflies when compared to disturbed urban ecosystems (range 3-189; mean 96) of Bangalore City (Geetha *et al.* 2000). In northern western ghats, forest fire played a significant role as disturbance in determining the diversity of butterflies. Larvae of the families Lycaenidae and Nymphalidae, feed on herbs, were dominated in the grazed areas of the forest (Kunte 1997). Evidently reduction in abundance of butterflies at foot and mid hills may be a surrogate of disturbance. The difference in mean abundance of butterflies at foot and mid hills was statistically insignificant. This is possibly due to more or less similar degree of reduction in vegetation cover, fragmentation of forest and formation of gaps, all mainly by anthropogenic disturbances. According to Ghazoul (2001), human disturbances in dry deciduous forest of Thailand have changed the pollinating behaviour of butterflies rather than their abundance. In contrast, no discernible patterns of butterfly diversity were noticed along five disturbance gradients in wet evergreen forest of western ghats. However, as in the present study, less disturbed sites in dry deciduous forest and scrub jungle also harboured higher diversity of butterflies (Aravind *et al.* 2001). Conversely, disturbances have increased the butterfly diversity in Madagascar Island (Kremen 1992). This is possible because moderate disturbance would favour species diversity, immigration of species in gaps and reduces the chance of extinction (Connell 1978).

Table 1. Disturbance based measuring at different altitudes in a tropical dry deciduous forest of Alagar hill, South India (n = 10)

Parameters	Foot-hill (275 m)	Mid-hill (350 m)	Top-hill (550 m)
Number of trees / 10 m^2	13.2 ± 2.53(19)	21.3 ± 2.97(14)	28.4 ± 19.50(7)
Number of crossing branches / 3 m^2	11.4 ± 3.99(35)	18.3 ±17.90(10)	23.1 ± 2.32(10)
Number of sunspots / 3 m^2	25.1 ± 3.78(15)	18.3 ± 4.37(24)	10.1 ± 2.47(24)
Number of cattle/ 15 minutes walk	12.4 ± 4.36(35)	14.5 ± 3.20(22)	19.9 ± 3.45(17)
Number of man-made tracks / 15 minutes walk	10.2 ± 2.65(26)	5.9 ± 1.99(8)	2.8 ± 1.08(38)
Number of foliage insects / 5 minutes sweep	15.7 ± 3.44(22)	24.1 ± 3.56(15)	40.1 ± 6.32 (15)
Number of butterflies/ 5 minutes sweep	12.8 ± 3.60(28)	19.3 ± 2.92(15)	30.2 ± 5.67 (19)
Density of herbs / m^2	35.5 ± 6.34(17)	28.2 ± 3.03(11)	18.3 ± 2.73 (15)
Number of intruders / 15 minutes walk	70.4 ±14.73(21)	67.2 ±12.76(19)	13.1 ± 3.62 (28)

Values are expressed in mean ± SD (coefficient of variation in %)

Table 3. One way ANOVA indicating the effect of altitudes on the different studied parameters in a tropical dry deciduous forest of Alagar hill, South India. SV= sources of variation, BS= between samples, WS= within samples; SS= sum of squares; MS= mean squares.*All values are significant at P<0.001

Parameters	SV	SS	MS	$F_{2,27}$
Number of trees / 10 m^2	BS	1155	577.5	81.2*
	WS	192	7.1	
Number of crossing branches / 3 m^2	BS	680	340	33.3*
	WS	276	10	
Number of sunspots / 3 m^2	BS	1216	608	48.3*
	WS	325	12	
Number of cattle/ 15 minutes walk	BS	299	149.5	23.4*
	WS	174	6.4	
Number of man-made tracks / 15 minutes walk	BS	276	138	37.7*
	WS	99	3.6	
Number of foliage insects / 5 minutes sweep	BS	3293	1646.6	69.3*
	WS	641	23.7	
Number of butterflies / 5 minutes sweep	BS	1545	772.5	36.9*
	WS	565	20.9	
Density of herbs / m^2	BS	1659	829.5	24.4*
	WS	1000	37.1	
Number of intruders / 15 minutes walk	BS	20734	10367	61.3*
	WS	4575	169	

Table 2. 't' values between the altitudes of different studied parameters in a tropical dry deciduous forest of Alagar hill, South India. Foot, mid and top are the site locations respectively at 275 m 350 m and 550 m altitudes (n = 10).

Parameters	Foot vs Mid	Foot vs Top	Mid vs Top
Number of trees / 10 m^2	4.658**	10.746***	4.567**
Number of crossing branches / 3 m^2	3.771**	5.856***	3.688**
Number of sunspots / 3 m^2	2.716*	7.689***	3.789**
Number of cattle/ 15 minutes walk	0.877 NS	3.035*	2.566*
Number of man-made tracks / 15 minutes walk	2.926*	6.273***	3.197*
Number of foliage insects / 5 minutes sweep	3.794**	8.172***	5.377***
Number of butterflies/ 5 minutes sweep	1.548 NS	5.938***	4.013**
Density of herbs / m^2	2.802*	6.328***	5.445**
Number of intruders / 15 minutes walk	0.368 NS	9.874***	1.010 NS

Key: *Significant at $P<0.05$; **Significant at $P<0.01$; ***Significant at $P<0.001$;NS= not significant

The present study estimated total abundance of foliage insects without any taxonomic resolution of the sample. In general disturbances to forest ecosystems have caused a reduction in abundance and diversity of insects (Daily & Ehrlich 1995; Hill *et al.* 1995). The number of foliage insects were highest at top-hill, and lowest at foot-hill. Disturbances in Atlantic coastal forest of Brazil have resulted in forest gaps where abundance of bees diminished significantly (Raw & Santos 2001). Similarly reduction in abundance of dung beetle communities was reported at disturbed coffee estate sites of western ghats. Dung beetles abundance was highest in the forests, followed by polyculture-shade coffee plantations, and much lower in the monoculture coffee (Badrinarayanan *et al.* 2001). In contrast, Dharmarajan *et al.* (2001) have reported that abundance of ants and dung beetles increased with the intensity of disturbance in moist deciduous forests of western ghats. The most disturbed sites showed highest abundance of dung beetles (616) than less disturbed sites (373). Similar trend was also recorded in abundance of ants. It was assumed that both plant species diversity and total vegetation cover get reduced by severe disturbances at foot and mid-hill, in turn total abundance of foliage insects.

Maximum number of trees with multiple branches were recorded at top-hill, followed by mid-hill of the forest. It is an evidence for better tree growth at least disturbed top-hill. In contrast, minimum numbers of trees with multiple branches at foot-hill suggested a reduction in tree growth at highly disturbed zone. The number of crossing branches is an index for closeness between trees and shrubs. This estimate was also highest at top-hill when compared to other two altitudes. In brief, tree growth and cover of vegetation are in better condition at less disturbed top-hill. Aravind *et al.* (2001) showed that anthropogenic disturbances in a tropical evergreen forest of western ghats reduced the tree density and increased the broken stems. The highly disturbed zones had 200 trees ha^{-1} which increased abruptly to 1200 trees ha^{-1} at least disturbed zones of the forest. According to Parthasarathy (1999), the mean stem density of woody species in a tropical wet evergreen forest was reduced at frequently disturbed sites. Visitors and pilgrims frequently disturb the foot and mid-hill areas. According to Sagar *et al.* (2003), stem density declined along the disturbance gradient mainly due to a gradual increase in the extraction of timber and debarking in a dry tropical forest region of India. Bhuyan *et al.* (2001) from their study on wet evergreen forest in relation to disturbance showed that the forest tree as well as shrub densities were highest in undisturbed and lowest in highly disturbed sites. The maximum number of crossing branches at top-hill suggested a high degree of tree-cum-shrub density, when compared to foot and mid-hill.

Canopy is an aggregate of every tree crown in the forest including foliage, branches, fine twigs and epiphytes. Canopy ecology in tropical rain forests is receiving a considerable scientific attention (Devy & Ganesh 2003). The dry deciduous forest of Alagar hill exhibits poor canopy at foot and mid-hill in terms of maximum number of sun-spot counts on the forest floor. This estimate was inversely related to thickness of the canopy. At foot and mid-hill areas, severe anthropogenic and unestimated climatic disturbances have resulted in reduced foliage growth and mortality of trees. This leads to discontinuous as well as less-dense canopy at foot and mid-hills. Rajan *et al.* (1995) studied the soil seed bank of disturbed sites at mid-hill area of the present study and concluded that there was no regeneration at disturbed sites due to smaller seed bank. This could be another reason for the formation of wide gaps and discontinuity in canopy cover at both mid- and foot-hills. Hare *et al.* (1997) studied the structure and species composition of a subtropical dry forest in the Dominican Republic in relation to disturbance. Their data revealed that trees were more widely spaced and canopy was more open at disturbed forest. Kumar & Shahabuddin (2005) also revealed a significant decline in the mean canopy cover in the forests of Sariska Tiger Reserve, India, due to widespread biomass extraction such as grazing and firewood collection. Similar conditions were noticed at foot and mid-hill areas. In tropical evergreen forest of western ghats, relatively small scale disturbance such as lopping of plants for fuel wood collection significantly reduced canopy continuity and its cover (Gupta 2001). Fuel wood collection was the common disturbance at all selected altitudes especially at foot and mid-hills, which could reduce the canopy cover. Recently, Ram *et al.* (2004) have shown that human disturbances to mixed-broad leaf forests of Himalayas resulted in low crown cover and enhanced penetration of light while high crown cover characterized forests away from human habitats. This observation on increased light penetration through low crown cover supported our data on maximum sun light spots at foot-hill with thin and discontinuous canopy.

The highest number of man made tracks at foot-hill, indicate the high degree of intervention by local inhabitants and visitors into the interior areas of the protected forest. Local people reach the top-hill through the Periya Aruvi Valley while at foot and mid-hill via Silambar Valley. The foot-hill and a temple of Lord Muruga at mid-hill are connected by an old hilly track and a motorable road and these tracks pass through Silambar Valley. Anthropogenic disturbances caused by visitors travelling through these tracks are diverse and unaccountable. However, the numbers of man-made tracks were minimum at top-hill with relatively low degree of disturbances. This estimate falls between these two extremities at mid-hill. These side tracks are characterized by narrow-width, damage to shrubs and lack of herbs. They may lead to other interior areas as short-cut routes or with dead ends. They were mostly used for collection of minor forest produce, extraction of fuel wood and defecation. Around these side tracks, we also often noticed evidences for fire set by human activity at all three altitudes.

Maximum number of intruders was recorded at foot- and mid-hills possibly due to the significance of these areas as popular pilgrim as well as picnic center of south India. Top-hill is also not exclusively free from human intrusion, but only to lesser degree when compared to foot- and mid-hills. It was disturbed mainly for the extraction of fuel wood and collection of minor forest produce. Human intruders from the foot- and mid-hill areas reach the top-hill for recreation by trekking. The intensity of human intrusion to top-hill reached the peak during the monsoon seasons, when drinking sources are naturally repleshnished at top-hill. According to Aravind *et al.* (2001), most disturbed sites in the wet evergreen forest of western ghats were located immediately surrounding the human settlements and least disturbed sites were much away from them. In the present study, the highly disturbed foot-hill is located very nearer to the village called Alagar Koil while top-hill is far away from this village at 550 m altitude. Similarly in USA, increase in recreational pressure on the forest habitats was measured by human intervention measures such as number of visitors-days, which means the number of people visiting a forest area per unit time (Berwick & Berwick 1995).Maximum number of cattle was recorded at top-hill, when compared to foot- and mid-hill, possibly due to the availability of thick vegetation cover and lack of human disturbances. There was no statistically significant difference between foot- and mid-hills with reference to this measure. Cattles are brought to top-hill for grazing by local people via Periya Aruvi Valley while to the foot- and mid-hills via Silambar Valley. Infact a considerable number of cattle was dedicated to Lord Alagar and left in the forest areas by pilgrims. This recurrent and religious activity increased the population of cattle in the forest zone considerably. Data collected by Abraham & Balakrishnan (1993) in forest habitats of Wynad, Kerala, has shown excessive grazing by the domesticated cattle and goats in the forest area, is one of the serious disturbance to vegetation inspite of the legal restrictions. According to Pandey & Shukla (1999), the recurrent human intervention like practice of grazing may change the habitat fitness of many native species. Similar violation of law is a common event in Alagar hill. The reduction in green cover at foot-hill could be considerable due to grazing by free ranging cattles.

Herb density was maximum at foot-hill, followed by mid-hill. Top-hill showed minimum density of herbs. Generally, increase in density and diversity of herbaceous species in forest ecosystems reflects the degree of natural or anthropogenic disturbances. As in the present study, Chandrashekara & Ramakrishnan (1994) also reported greater herbal density at disturbed sites compared to an undisturbed site in tropical evergreen forests of western ghats. In contrast, Parrotta (1995) quantified lower herb density in the undisturbed forest sites with dense canopy cover. According to Ghazoul (2001), disturbance by tree logging in tropical forest of Thailand has resulted in a marked increase in the under storey herbaceous flora. Ram *et al.* (2004) reported the enhanced growth of under-storey species at disturbed forest of central Himalaya, especially under open canopy. They attributed it to increased light penetration and heterogeneity in climatic and soil factors at gaps. The present study confirmed maximum light penetration at foot- and mid-hill areas in terms of maximum number of sun spots per unit area of forest floor. Rajan *et al.* (1995) have reported the low rate of woody species regeneration as a function of small soil seed banks at disturbed mid-hill area of the Alagar hill. Thus, in the absence of woody species regeneration, enhanced growth of herbs could be possible at mid- and foot-hill areas due to availability of radiant energy. According to Kunte (1997), grazed sites of northern western ghats are dominated by herbaceous vegetation. A considerable density of herbs at top-hill was possibly due to this fact. Conversely, Bhuyan *et al.* (2001) showed highest herb and vine densities in undisturbed sites of tropical wet evergreen forest of northeast India. Our results emphasize the need for increased legal protection, well designed management practices and intensive afforestation at selected altitudes especially foot- and mid-hill areas for the sustainable utilization of the dry deciduous forests.

Acknowledgements

We are indebted to an anonymous reviewer and Prof. A.S. Raghubanshi for their constant encouragement and helpful comments.

References

Abraham, N.P. & M. Balakrishnan. 1993. Human interactions in forest habitats in Wynad, Kerala. *Journal of Zoological Society of Kerala* **3**: 35-41.

Aravind, N.A., D. Rao, G. Vanaraj, J. Poulsen, R. Uma Shankar & K.N. Ganeshaiah. 2001. Anthropogenic pressure in a tropical forest ecosystem in western ghats, India: are they sustainable? pp. 125-128. *In*: K.N. Ganeshaiah, R. Uma Shankar & K.S. Bawa (eds.) *Tropical Ecosystems: Structure, Diversity and Human Welfare.* Oxford & IBH, New Delhi.

Ashton, P.S. 1993. The community ecology of Asian rain forests in relation to catastrophic events. *Journal of Biosciences* **18**: 501-514.

Badrinarayanan, S., J. Krishnaswamy, S. Lele & K. Chandrasekara. 2001. Consequences of forest conservation to coffee plantation on litter beetles and ant communities. pp. 162-163. *In*: K.N. Ganeshaiah, R. Uma Shankar & K.S. Bawa (eds.) *Tropical Ecosystems: Structure, Diversity and Human Welfare.* Oxford & IBH, New Delhi.

Berwick, N.L. & S. Berwick. 1995. Assessing impact of development of wilderness. pp. 449 - 472. *In*: S.H. Berwick & V.B. Saharia (eds.) *Wildlife Research and Management.* Oxford University Press, New Delhi.

Bhuyan, P., M.L. Khan & R.S. Tripathi. 2001. Tree diversity and population structure in undisturbed and human impacted tropical wet evergreen forests of Arunachal Pradesh, northeast India. pp. 114-115. *In*: K.N. Ganeshaiah, R. Uma Shankar & K.S. Bawa (eds.) *Tropical Ecosystems: Structure, Diversity and Human Welfare.* Oxford & IBH, New Delhi.

Chandrasekaran, S. & P.S. Swamy. 1995. Changes in herbaceous vegetation following disturbance due to biotic interference in natural and man-made ecosystem in western ghats. *Tropical Ecology* **36**: 213-220.

Chandrasekaran, S. & P.S. Swamy. 2002. Biomass, litterfall and aboveground net primary productivity of herbaceous community in varied ecosystems at Kodayar in the western ghats of Tamilnadu. *Agriculture, Ecosystems and Environment* **88**: 61-67.

Chandrashekara, U.M. & P.S. Ramakrishnan. 1994. Vegetation and gap dynamics of a tropical wet evergreen forest in the western ghats of Kerala, India. *Journal of Tropical Ecology* **10**: 337-354.

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

Daily, G. & P.R. Ehrlich. 1995. Preservation of biodiversity in small rain forests patches: rapid evaluation using butterfly trapping. *Biodiversity and Conservation* **4**: 35-45.

Devy, M.S. & T. Ganesh. 2003. Canopy science and its relevance in India. *Current Science* **85**: 581-584.

Dharmarajan, P., K.N. Ganeshaiah, R. Uma Shankar, T.M. Musthak Ali & K. Chandrashekara. 2001. Impact of human disturbances on the diversity of dung beetles (Coleoptera: Scarabaeidae) and ants (Hymenoptera: Formicidae). pp. 129-132. *In*: K.N. Ganeshaiah, R. Uma Shankar & K.S. Bawa (eds.) *Tropical Ecosystems: Structure, Diversity and Human Welfare.* Oxford & IBH, New Delhi.

Geetha, V., R. Poornima & H. Singh. 2000. Comparative study of biodiversity of butterflies between Bangalore and Jammu region. *Indian Journal of Environment and Ecoplanning* **3**: 599-604.

Ghazoul, J. 2001. Direct and indirect effects of human disturbance on the reproductive ecology of tropical forest trees. pp. 97-100. *In*: K.N. Ganeshaiah, R. Uma Shankar & K.S. Bawa (eds.) *Tropical Ecosystems: Structure, Diversity and Human Welfare.* Oxford & IBH, New Delhi.

Gilliam, F.S. 2002. Effects of harvesting on herbaceous layers diversity of a central Appalachian hard wood forest in west Virginia, USA. *Forest Ecology and Management* **155**: 33-43.

Gupta, K.K. 2001. Importance of canopy continuity conservation of slendar loris (*Loris tardigradus*). pp. 434-435. *In*: K.N. Ganeshaiah, R. Uma Shankar & K.S. Bawa (eds.) *Tropical Ecosystems: Structure, Diversity and Human Welfare.* Oxford & IBH, New Delhi.

Hamer, K.C., J.K. Hill, L.A. Lace & A.M. Longan. 1997. Ecological and biogeographical effects of forest disturbance on tropical butterflies of Sumatra, Indonesia. *Journal of Biogeography* **24**: 67-75.

Hare, M.A., D.O. Lantagne, P.G. Murphy & H. Checo. 1997. Structure and tree species composition in a subtropical dry forest in the Dominican Republic: comparison with a dry forest in Puerto Rico. *Tropical Ecology* **38**: 1-17.

Hill, J.K., K.C. Hamer, L.A. Lace & W.M.T. Banham. 1995. Effects of selective logging on tropical forest butterflies on Buru, Indonesia. *Journal of Applied Ecology* **32**: 754-760.

Khera, N., A. Kumar, J. Ram & A. Tewari. 2001. Plant biodiversity assessment in relation to disturbances in mid elevational forest of Central Himalaya, India. *Tropical Ecology* **42**: 83-95.

Koh, L.P., R.R. Dunn, N.S. Sodhi, R.K. Colwell, K.C. Proctor & V.S. Smith. 2004. Species coextinctions and biodiversity crisis. *Science* **305**: 1632-1634.

Kremen, C. 1992. Assessing the indicator properties of species assemblages for natural areas monitoring. *Ecology Applications* **2**: 203-217.

Krishnankutty, N., A. Jeyachandran & N. Nagendran. 2000. Effect of seasonal and altitudinal variations on growth performance of *Acalypha indica* Linn. in Alagar Hill (eastern ghats), South India. *Tropical Ecology* **41**: 41-45.

Kunte, K.J. 1997. Seasonal patterns in butterfly abundance and species diversity in four tropical habitats in northern western ghats. *Journal of Biosciences* **22**: 593-603.

Kumar, R. & G. Shahabuddin. 2005. Effects of biomass extraction on vegetation structure, diversity and composition of forests in Sariska tiger reserve, India. *Environmental Conservation* **32**: 248-259.

Misra, B.N. & M.K. Misra. 1989. *Introductory Practical Biostatistics.* Naya Prakash, Calcutta.

MoEF. 1999. *National Policy and Macrolevel Action Strategy on Biodiversity.* Ministry of Environment and Forest, Government of India, New Delhi.

Pandey, S.K. & R.P. Shukla. 1999. Plant diversity and community patterns along the disturbance gradient in plantation forests of sal (*Shorea robusta* Gaertn.). *Current Science* **77**: 814-818.

Parrotta, J.A. 1995. Influence of overstorey composition and understory colonization by native species in plantations on a degraded tropical site. *Journal of Vegetation Science* **6**: 626-636.

Parthasarathy, N. 1999. Tree diversity and distribution in undisturbed and human impacted sites of tropical wet evergreen forest in southern western ghats, India. *Biodiversity and Conservation* **8**: 1365-1381.

Pickett, S.T.A. & P.S. White. 1985. *The Ecology of Natural Disturbance and Patch Dyanamics.* Acadimic Press, Orlando, Florida.

Pimm, S.L. & P. Raven. 2000. Extinction by numbers. *Nature* **403**: 843-844.

Puyravaud, J.P., D. Shridhar, A. Gaulier, S. Aravajy & S. Ramalingam. 1995. Impacts of fire on a dry deciduous forest in the Bandipur National Park. southern India: preliminary assessment and simplification for management. *Current Science* **68**: 745-748.

Rajan, P., S.M. Sundarapandian, S. Chandarasekaran & P.S. Swamy. 1995. Variations in soil seed bank at different microsites in a deciduous forest near Madurai, south India. *International Journal of Ecology and Environmental Sciences* **21**: 263-272.

Ram, J., Arvind Kumar & J. Bhat. 2004. Plant diversity in six forest types of Uttaranchal, Central Himalaya, India. *Current Science* **86**: 975-978.

Raw, A. & M.E. de Silva Santos. 2001. Forest disturbances and native bees in Brazil's Atlantic coastal forest. pp. 193-195. *In*: K.N. Ganeshaiah, R. Uma Shankar & K.S. Bawa (eds.) *Tropical Ecosystems: Structure, Diversity and Human Welfare.* Oxford & IBH, New Delhi.

Sagar, R., A.S. Raghubanshi & J.S. Singh. 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. *Forest Ecology and Management* **186**: 61-71.

Sagar, R. & J.S. Singh. 2004. Local plant species depletion in a tropical dry deciduous forest of northern India. *Environmental Conservation* **3**: 55-62.

Sagar, R. & J. S. Singh. 2005. Structure, diversity and regeneration of tropical dry deciduous forest of northern India. *Biodiversity and Conservation* **14**: 935-959.

Schumann, M.E., A.S. White & J.W. Witham. 2003. The effects of harvest created gaps on plant species diversity, composition and abundance in a Maine Oak-pine forest. *Forest Ecology and Management* **176**: 543-561.

Sousa, W.P. 1984. The role of disturbances in natural communities. *Annual Review of Ecology and Systematics* **15**: 353-391.

Sriganesan, T. 1987. On the biological spectrum of Alagar hill complex. *Science Literature Arts Search* **6**: 18-23.

Sriganesan, T. 1984. *Flora of Alagar Hill.* Ph.D. Thesis. Madurai Kamaraj University, Madurai, India.

UNEP, 2001. *India: State of the Environment-2001.* United Nations Environment Programme. Nairobi.

Whitemore, T.C. & D.F.R. Burslem. 1996. Major disturbances in tropical rain forests. pp. 549-565. *In*: D.M. New Berry, H.H.T. Pains & N.D. Brown (eds.) *Dynamics of Tropical Communities*. Blackwell, Cambridge.