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Diversity, Dominance and Population Structure of Tree Species along Fragment-Size Gradient of a Subtropical Humid Forest of Northeast India

O.P. Tripathi, K. Upadhaya, R.S. Tripathi and H.N. Pandey
Department of Forestry, North Eastern Regional Institute of Science and Technology, Deemed University, Nirjuli-791 109, Arunachal Pradesh, India

Abstract: The present study was carried out in forest fragments of 1, 2, 5 and >5-ha of a subtropical humid forest in Meghalaya, northeast India to analyze the impact of fragment size on tree diversity and population structure and regeneration status of important trees. The intensity of disturbance steadily decreases with increase in size of the fragment. The study revealed that tree species richness increased from 49 species in 1-ha fragment to 64 species in >5-ha fragment. Tree species richness was positively related to fragment size, but was inversely related to the degree of disturbance. Impact of fragment size on density and basal cover did not differ much between the fragments. Diversity and dominance indices did not varied much along the fragment size gradient. Out of ten most dominant species, dominance of four species decreased along increasing size gradient while dominance of remaining species consistently decreased from 1-ha to >5-ha fragments. Overall tree population structure was pyramid shaped in all the fragments. About 16-25% species showed good regeneration in all the fragments. Percentage of species showing fair, poor and no regeneration progressively increases with increase in size of the fragments. Large percentages (44%) of new species were found regenerating in small fragments compared to large fragments where only 3 new species were regenerating. This revealed that fragments of smaller area might have given a favourable micro-environmental condition for seedling survival.

Key words: Fragment-size gradient, Northeast India, population structure, regeneration status, subtropical humid forest, tree diversity

INTRODUCTION

One of the important causes of biodiversity loss is the fragmentation of large blocks of natural forest landscapes into small isolated patches of native vegetation surrounded by a matrix of agricultural or other developed land. The large forest fragments are characterized by better soil and greater geomorphologic and microhabitat diversity which ultimately favours regeneration and co-existence of species (Veblen *et al*. 1996; Molino and Sabatier, 2001) and thereby contribute to greater species diversity (Dzwonko and Loster 1989; Honnay *et al*., 1999). Several studies have emphasized the role of habitat quality and habitat diversity in determining the species occurrence. Greater extinction rates of some species in small forest fragments could be related to the change in quality and diversity of habitats (Dupre and Ehrlen, 2002; Jacquemyn *et al*., 2003; Kolb and Diekmann, 2004).

Forest destruction and fragmentation increases vulnerability of forest community which leads to micro-environmental changes that drastically influences the composition forest under-storey (Chen *et al*., 1992; Matlack, 1994; Kapos *et al*., 1995). After fragmentation, the remaining forest patches are surrounded by different communities, therefore, creating an abrupt edge between forests and surrounding vegetation. These edges influence abundance and distribution of organisms across the landscape (Murcia, 1995; Mills, 1995). High stem density, high immigration and edge-core characteristics are the three mechanisms of species enrichment in natural fragments (Brokaw, 1998), which do not generally operate in the recently created forest fragments. Fire, light penetration and tree-fall rates are higher on edges of recent anthropogenic fragments which promotes invasion by weeds, pioneer trees and vines that disrupt regeneration of diverse shade tolerant species (Laurance and Bierregaard, 1997). Forest fragments formed abruptly due to human activities changes the condition, leading to a rapid collapse in community organization and richness (Brokaw, 1998).

The state of Meghalaya, northeast India is characterized by highly dissected and irregular topography with wide variations in altitude, rainfall, temperature and soil conditions. The state, like other parts of the country is under going rapid transformation due to urbanization, mining and extraction of forest products, besides continuance age-old practice of shifting cultivation. Due to these activities, natural forests are getting fragmented into small (<1sq. km) patches (Tripathi, 2002). Fragmentation of these forests has

Corresponding Author: O.P. Tripathi, Department of Forestry, North Eastern Regional Institute of Science and Technology, Deemed University, Nirjuli-791 109, Arunachal Pradesh, India

serious ecological and environmental implications such as elimination of native species and development of degraded forest-covered landscape dominated by exotic invasive species from the surrounding areas (Pandey *et al*., 2003).

Diversity of tree species, population structure and regeneration behaviour have been studied in different forest stands of humid subtropical forest in the state by several workers (Khan *et al*., 1987; Rao *et al*., 1990; Barik *et al*., 1992; Tripathi, 2002; Upadhaya *et al*., 2003; Mishra *et al*., 2004; Tripathi *et al*., 2004) but none of these studies has examined the effect of fragment size on the above aspects. Therefore, a study was undertaken to examine whether or not the fragment size influences tree diversity and population structure and regeneration status of dominant trees in humid subtropical forest of the state. For this purpose, a well-preserved subtropical forest (sacred forest) that was a continuous block of about 20-ha during 1989 (Khiewtam and Ramakrishnan, 1989) and now fragmented into several patches, was selected for the study. Our specific objectives were; to assess the level of disturbance in the forest patches and to examine the effect of disturbance and patch size on diversity, population structure and regeneration status of tree species.

MATERIALS AND METHODS

The study was conducted in a sacred forest for a period of two years (2005-2007), which was spread over an area of more than 20 ha (latitude 25º 19.72′ N, longitude 91º 43.61′ E, 1645 m asl) on the gentle slope in East Khasi hill district of Meghalaya, northeast India. About 15-ha area was covered by dense forest fragments of varying sizes ranging from 0.01ha to >5-ha (7.5-ha) and remaining areas were open grazing land. Fragments of 2-ha and >5-ha size were closer to each other than the other fragments (distance between the fragments ranged between 5 and 50 m). Since fuel-wood collection by nearby villagers was allowed, the forest was moderately disturbed. The climate of the area under study was monsoonic with an average annual rainfall of about 9758mm, most of which (84%) occurs during rainy season (May-September). Ground frost was common during winter (November-January) season. The mean minimum and maximum temperature ranges between 4.3 to 29.2ºC.

Four forest fragments (1, 2, 5 and >5-ha area) were selected for detailed Fig 1. The intensity of disturbance was calculated based on the number of cut stumps divided by total number of stems of all tree species including cut stumps in each fragment (Rao *et al*., 1990). The number of cut stumps under different forest fragments is presented in the table along with disturbance index. Thirty quadrates of 10x10 m size were placed randomly in each fragment. All individuals having ³5 cm diameter at breast height (dbh) in each quadrate were recorded and species were identified with the help of regional floras (Balakrishnan, 1981-1983; Haridasan and Rao, 1985-1987). Frequency, density and basal cover of trees were calculated according to Misra (1968) and Mueller-Dombois and Ellenberg (1974). Species diversity indices were calculated following Magurran (1988). Tree seedlings (<1 m height) and saplings (<5 cm dbh and >1 m height) were studied by laying 30 quadrats of 2m x 2m size in each fragment.

All individuals were grouped into seedlings, saplings, young (5-35 cm dbh), adult (36-65 cm dbh) and mature (>65 cm dbh) trees for analysis of their population structure. The regeneration status of dominant trees was assessed based on density of their seedling, sapling and adult tree. The species were categorized as (i) good, if seedlings>saplings>adult (ii) fair, if seedling>sapling≤ adult (iii) poor, if species survives in only saplings stage but not as seedlings (though saplings may be less or equal to adult), (iv) none, if a species was absent both in seedling and sapling stage but present as adult, and (v) new, if a species was present only in seedling/sapling stage but not as adult trees (Uma Shankar 2001). SYSTAT (ver. 6.0) statistical software was used to find out the significant correlation between sizes of the forest fragment and different community parameters.

RESULTS

Tree species richness: Altogether 103 tree species were recorded from studied forest fragments. Among them, 54 species were common in all the fragments, seventeen species were restricted to the small (1 and 2-ha) fragments and 32 species were confined to the larger (5 and >5-ha) fragments. The forest canopy was mainly composed of species like *Castnopsis purpurella, Elaeocarpus lancifolius, Quercus kamrupii, Persea gamblei* and *Schima khasiana.* Sorensen's similarity index ranges from 54 to 62%. Lauraceae and Fagaceae were the most species-rich families followed by Araliaceae, Symplocaceae and Theaceae in the forest fragments. Large numbers of families (16 to 22 families) were represented by one species.

Species-area curves showed a sharp increase in tree species richness with increase in fragment size, reaching to asymptotic level between 0.20-0.25 ha areas. At this level number of tree species was maximum (60-63 species) in >5-ha fragment and minimum (42-45 species) in 1-ha fragment (Fig. 2). Tree species richness was maximum (64 species) in >5-ha fragment followed by 5-ha (58 species), 2-ha (54 species) and 1-ha (49 species) fragments (Table 1). Pearson correlation matrix revealed that there was a significant positive correlation between forest fragment size and species richness ($r = 0.992$, $p<0.05$) and basal area ($r = 0.973$, $p<0.05$). Positive

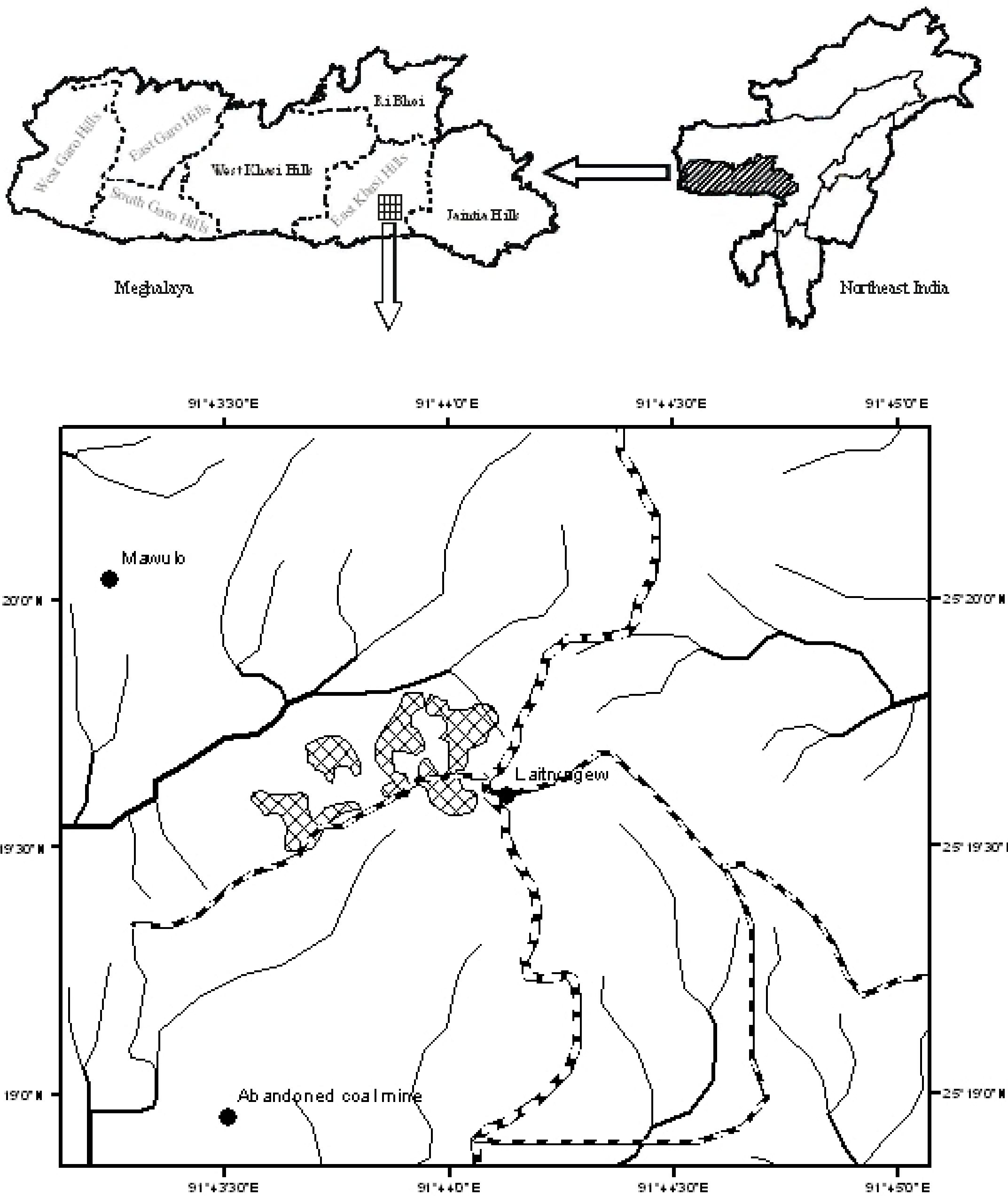

Fig 1: Location of the study area in northeast India

correlation (r = 0.978, $p<0.05$) was also observed between stand density and Shannon's diversity index. However, negative correlation was observed in case of disturbance index and Simpson's dominance index. Other community parameters did not showed significant relationship with the size of the fragments (Table 2).

Stand density, diversity and dominance: The maximum stand density (1620 individuals ha^{-1}) was recorded in >5-ha fragment followed by 2-ha (1290 individuals ha^{-1}), 1-ha (1280 individuals ha^{-1}), and 5-ha (1203 individuals ha^{-1}) fragments. Basal cover of forest community increases with increase in size of the forest fragment and

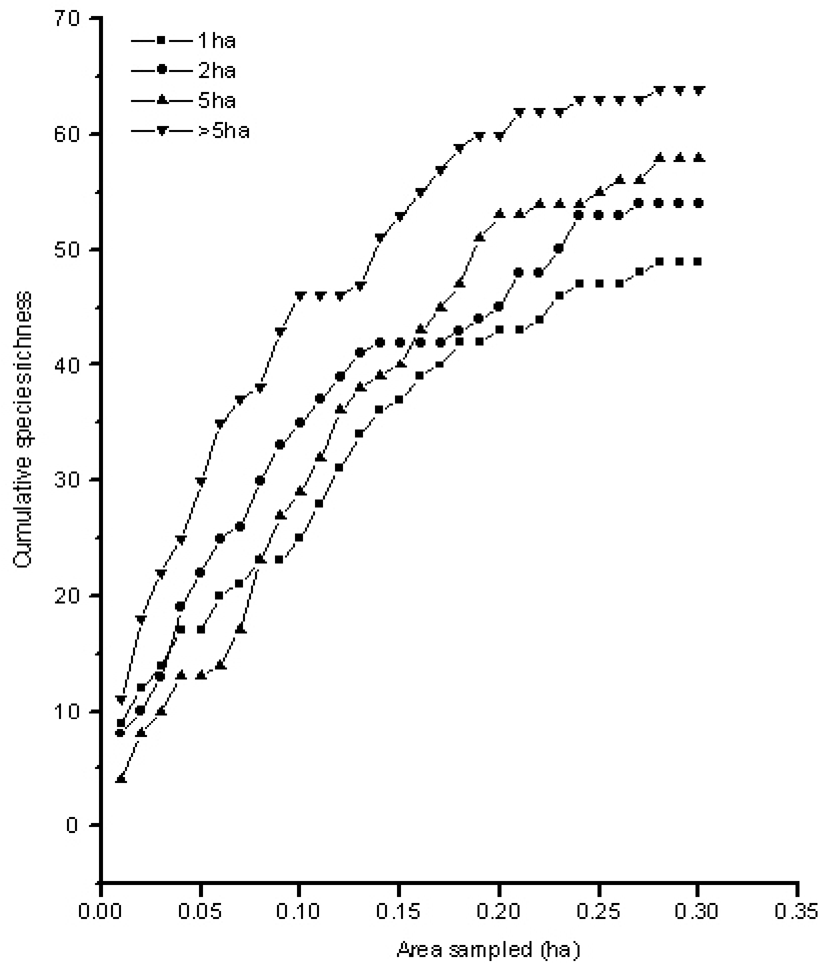

Fig 2: Species-area curves of the forest fragments.

Table 1: Community characteristics of the different forest fragments

Parameters	Fragment size 1 ha	2 ha	5 ha	>5 ha
Species richness	49	53	58	64
Number of genera	41	46	44	51
Number of families	28	31	29	35
Stand density (individual ha^{-1})	1280	1290	1203	1620
Basal area (m^2ha^{-1})	35.12	33.89	40.63	45.11
Number of cut stumps (ha^{-1})	285	161	129	160
Disturbance index (%)	18.20	11.09	9.62	8.99
Shannon diversity index	3.21	3.30	3.16	3.57
Simpson's dominance index	0.07	0.06	0.08	0.05

ranged from 33.9 to 45.1 m^2 ha^{-1}. The Shannon's diversity index was maximum (3.57) in >5-ha fragment followed by 2, 1 and 5-ha fragments. In contrast, Simpson dominance index showed a reverse trend (Table 1). Based on density and basal cover, *Quercus kamrupii* was either dominant or co-dominant species in all the forest fragments. Beside this species like *Lithocarpus dealbata*, *Helicia nilagirica*, *Castanopsis purpurella* and *Myrica esculenta* were frequently found in the fragments. There was a marked reduction in the density and basal area of *Elaeocarpus lancifolius, Glochidion acuminatus, Helicia nilagirica, Lithocarpus dealbata, Neolitsea cassia* and *Persea odoratissima* with increase in forest fragment size. On the other hand, *Castanopsis purpurella, Myrica esculenta, Persea gamblei* and *Quercus kamrupii* showed a distinct increase in their dominance with increase in size of the fragments (Table 3).

Population structure: The age structure of tree population in all the fragments was pyramidal in shape. Young individuals (≤35 cm dbh) contributed 84-91%, older (>35 cm dbh) individuals 6-14% and the mature trees (≥65 cm dbh) accounted for only 2-3% of the total stand densities in the fragments (Fig. 3). The proportion of young and old individuals was comparatively more in the large fragments (5 and > 5-ha) than the small fragments. In most cases, seedling recruitment of dominant species was better in the small fragments thanthe larger ones, but conversion from sapling to adult

Table 2: Pearson correlation matrix between size of the forest fragments and different community variables

	Forest	Species	Stand	Basal	Disturbance	Shannon's diversity
Parameters		area	richness	density	area	index index
Species richness	0.992*	-	-	-	-	-
Stand density	0.686	0.704	-	-	-	-
Basal area	0.973*	0.939	0.690	-	-	-
Disturbance index	- 0.790	- 0.843	- 0.355	- 0.633	-	-
Shannon's diversity index	0.752	0.788	0.978*	0.711	- 0.530	-
Simpson's dominance index	- 0.371	- 0.438	- 0.879	- 0.306	0.271	- 0.887

*: $p<0.05$ level

Table 3: Impact of fragment size on dominance (based on density ha^{-1}) of ten important tree species of the forest. Values in parentheses are basal area ($m^2\ ha^{-1}$) of the species.

	Fragment size				
Plant species	1ha	2ha	5ha	>5ha	Status
Castanopsis purpurella	101 (3.21)	113 (5.21)	130 (4.53)	253 (12.21)	Increasing
Myrica esculenta	40 (2.97)	50 (3.12)	70 (4.51)	107 (1.75)	Increasing
Persea gamblei	27 (1.38)	60 (1.44)	83 (2.13)	110 (1.73)	Increasing
Quercus kamrupii	113 (7.56)	128 (8.07)	150 (11.13)	167 (9.99)	Increasing
Elaeocarpus lancifolius	46 (1.13)	30 (0.88)	7 (0.24)	10 (0.33)	Decreasing
Glochidion acuminatus	47 (0.86)	40 (0.59)	17 (0.57)	19 (0.18)	Decreasing
Helicia nilagirica	99 (1.09)	93 (0.79)	64 (0.58)	47 (1.09)	Decreasing
Lithocarpus dealbata	218 (1.76)	87 (0.20)	23 (0.98)	17 (1.27)	Decreasing
*Neolitsea cassia*1	43 (3.52)	73 (3.14)	53 (2.12)	30 (0.84)	Decreasing
Persea odoratissima	39 (1.05)	23 (0.72)	23 (0.82)	20 (0.51)	Decreasing

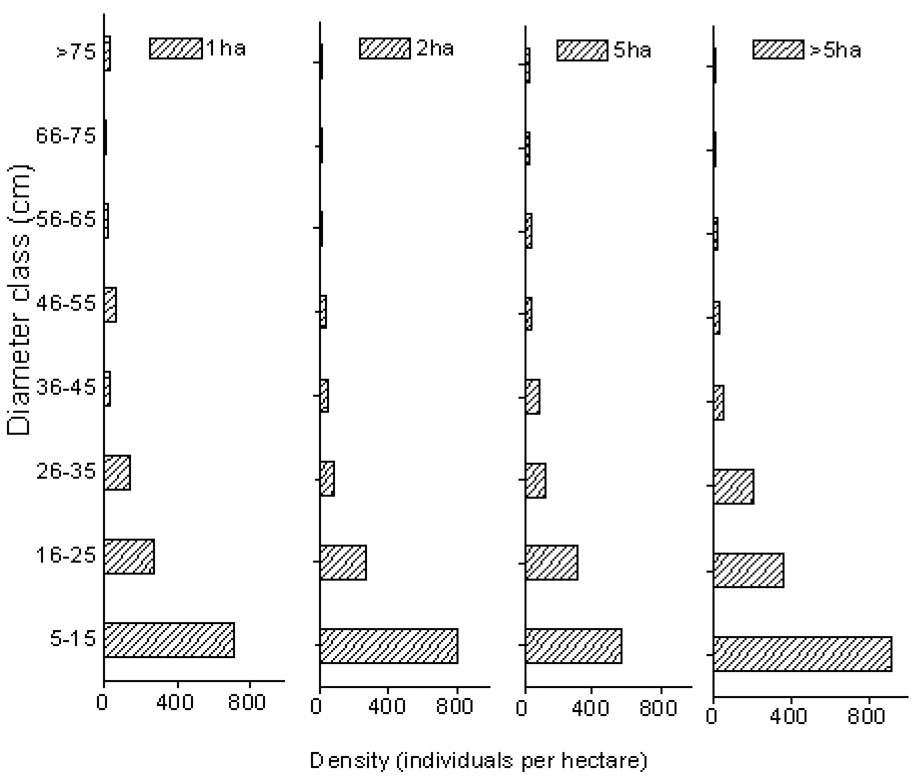

Fig. 3: Tree population structure in different forest fragments

stage was better in large fragments than the small ones. The two species viz., *Castanopsis purpurella* and *Quercus kamrupii* were exception in this regard (Fig. 4).

The overall density of seedlings and saplings decreases with increase in size of the fragments, but density of trees did not differ between the fragments except >5-ha fragment. The seedling to sapling ratio and sapling to adult ratio was higher in large fragments than small fragments. The number of species whose seedling, sapling and adult trees were present in different forest

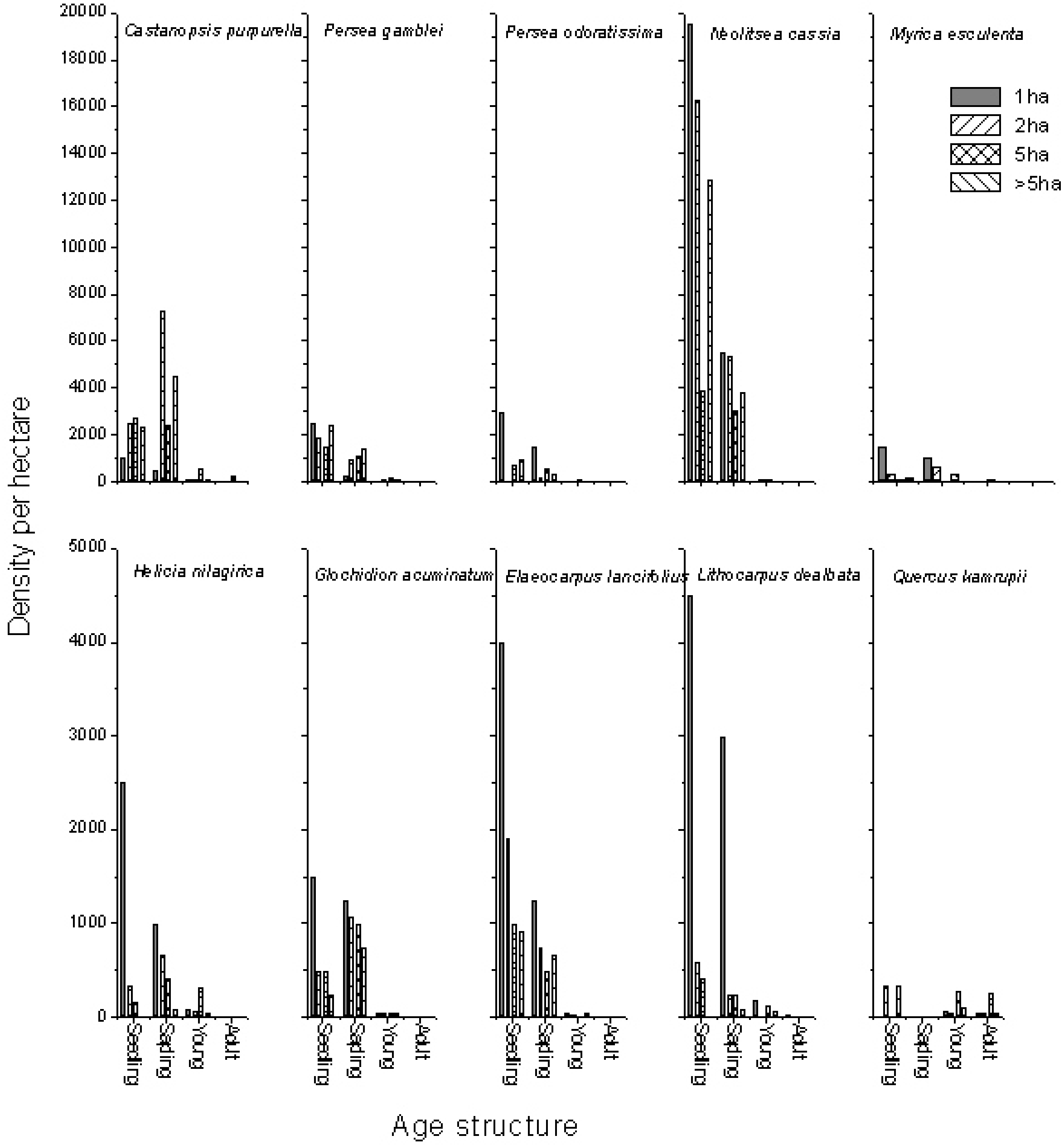

Fig. 4: Population structure of dominant tree species in different forest fragments

Table 4: Number of tree species showing different regeneration status in forest fragments. Values in parentheses are the percentage of total number of species in the fragment

	Fragment size			
Regeneration status	1 ha	2 ha	5 ha	>5 ha
Good1	3 (25)	15 (23)	12 (18)	11 (16)
Fair	6 (12)	8 (13)	9 (13)	15 (22)
Poor	6 (12)	12 (19)	20 (29)	17 (26)
None	4 (7)	19 (30)	16 (24)	21 (31)
New	23 (44)	10 (15)	11 (16)	3 (5)
Total	52 (100)	64 (100)	68 (100)	67 (100)

fragments was higher (68 species) in 5-ha fragment than 1-ha (52 species) fragment. About 16-25% species howed good regeneration in all the fragments and percentage of species showing fair, poor and no regeneration progressively increases with the increase in fragment size. The most noticeable increase was in no regeneration category of species. On the contrary, a large percentage (44%) of new species were trying to establish in 1-ha forest patch, percentage of such species sharply declined with increase in the size of the forest fragments (Table 4).

DISCUSSION

Fragmentation of natural forests due to anthropogenic pressure is a common phenomenon. The present study site was covered by a continuous forest patch of 15-ha about two decades ago. This forest has been broken into small fragments of varying sizes separated by 5-50 m grass-covered corridors due to human disturbances such as tree cutting for fire-wood, grazing and fire during dry winter. The intensity of disturbance indicates that though all fragments were mildly disturbed, the smaller patches were relatively more disturbed than the larger ones. The findings of the present study revealed that the size of forest fragment does not have much impact on species composition of dominant trees and family composition. However, a close examination of community parameters such as density, basal cover and diversity indices revealed changes in these parameters, which seems to be the result of forest fragmentation and associated micro-environmental changes.

Tree species richness and diversity showed an increasing tendency with increase in fragment size and decrease in the degree of disturbance in the forest fragments. Though the dominance among the constituent's species of the community was similar in all the fragments, but the dominance of few species showed a progressive decrease with increase in patch size. Several factors such as surrounding vegetation by means of inter-specific interactions, environmental modification; seedling bank; availability of resources; disturbance levels together with stochastic factors like random climatic variability, fluctuations of resources and dispersal limitation may influence the vegetation composition (Connell, 1989; Hubbell *et al.*, 1999; Dalling *et al.*, 2002).

Diversity and dominance varied along the size of forest fragment and level of disturbance. In communities under stress, one or a few ecological resources can have disproportional importance in the determination of species abundance. Species with different competitive abilities in relation to these resources/factors can divide the niche space in a quite hierarchical manner (May, 1975). Grime (1983) has reported that the decrease in community niche space will reduce the number of species due to eco-physiological constraints. On the other hand, in communities of mesic environments, differences in the competitive ability of the species in relation to different resources would allow each species to consume maximum of the resource that limits it most, and this would result in the co-occurrence of more species with low dominance (Tilman, 1982).

The tree population density and basal cover in >5-ha fragment was comparatively higher than the other fragments due to presence of large number of young as well as old individuals in the community. The small sapling population of dominant species in small fragments compared to the large seedling populations, was due to higher seedling mortality caused by trampling of grazing cattle and other unfavourable microclimatic conditions under forest canopy such as competition, predation etc. The poor seedling and sapling density of some species in large fragments is attributed to low light intensity on the forest floor due to dense overhead canopy (Barik, 1992; Tripathi, 2002). Recruitment failure of native species due to shading has been emphasized by a number of workers (Davies, 2001; Levine *et al.*, 2003; Lichstein *et al.*, 2004). Reduced abundance of shade-tolerant understory seedlings in forest fragments could result from both limited seedling recruitment and increased mortality of established seedlings (Santos *et al.*, 1999; Bruna, 2002). Seedlings have a limited tolerance range of light, temperature and humidity (Rees 1997), which are strongly altered in the forest fragments (Gehlhausen *et al.*, 2000). However, the effects of fragmentation on tropical plants are not uniformly detrimental. Some of the taxa show enhanced reproduction and growth in the fragments (Sizer and Tanner, 1999; Dick, 2002).

Fairly large number of species had good regeneration in large fragments where light intensity was low, soil moisture level was high and intensity of disturbance was low. On the contrary, percentage of those species that showed fair, poor and no regeneration progressively increased with the increase in fragment size suggesting that low light, high soil moisture and low disturbance did not favour their regeneration. Inadequate regeneration of the constituent's species is a general phenomenon in Indian forests because of grazing, fire, extraction of timber and fuel-wood and cultivation (Uma Shankar *et al.*, 1998; Uma Shankar, 2001). A large percentage of species that occurred only in seedling or sapling stages without any adult plant in 1-ha forest patch may be viewed as colonization effort by those species which require better light condition and have ability to tolerate greater degree of disturbance.

CONCLUSION

Forest fragmentation leads to reduction of total amount of forest areas, isolation of smaller patches, habitat loss and increase in disturbance level. All these were responsible for decrease in tree diversity in the smaller fragments. Large fragments which were less disturbed than small forests harboured such species which were not present in small fragments. The small fragments, however, favoured regeneration of those species, which were absent in the large fragments. Thus, both small and large fragments together enhanced total plant diversity at mild disturbance. Therefore, to conserve tree diversity a protective buffer of edge species around newly fragmented forest patches is required to protect the diverse core species from altered micro-climate as well as other anthropogenic activities. Future conservation efforts should address the broad socio-ecological processes that are most likely to occur across the northeastern region. The network of protected areas should be functionally integrated in a conservation strategy. In this context, study on impact of forest area on different community parameters will provide significant support to conservation planning by producing accurate information regarding local threats.

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