植物生态学报 2008，32(1)73～79
Journal of Plant Ecology (*Chinese Version*)

EFFECTS OF HUMAN ACTIVITIES ON STRUCTURE AND COMPOSITION OF WOODY SPECIES OF THE NOKREK BIOSPHERE RESERVE OF MEGHALAYA, NORTHEAST INDIA

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Abstract ***Aims*** Our study was conducted in the Nokrek Biosphere Reserve (NBR) in the Garo hills districts of Meghalaya, Northeast India. Our aim was to assess the effects of human activities on plant diversity, population structure and regeneration.

Methods We selected a representative 1.2 hm^2 stand in both the core and buffer zones of NBR. Structure and composition were determined by randomly sampling square quadrats, population structure was assessed by determining age structure, and regeneration was assessed by measuring densities of seedling, sapling and adult trees.

Important findings More woody species were recorded from the core zone than the buffer zone (87 vs. 81 species), and there were a large number of tropical, temperate, and Sino-Himalayan, Burma-Malaysian and Malayan elements, primitive families and primitive genera. The trees were distributed in three distinct strata, canopy, subcanopy and sapling. Subcanopy and sapling layers had the highest species richness (81% – 88%). Lauraceae and Euphorbiaceae were the dominant families in terms of the number of species, and a large number of families were represented by single species. Most woody species (57% – 79%) were contagiously distributed and had low frequency (< 20%). Although stand density was high in the buffer zone, its basal area was low compared to the stand in the core zone. Low similarity and high β-diversity indicate marked differences in species composition of the stands. Shannon diversity index was high in both the stands, while Simpson dominance index was low. The diameter-class distribution for dominant species revealed that the most had a large number of young individuals in their populations. Preponderance of tree seedlings, followed by a steep decline in population density of saplings and adult trees, indicated that the seedling to sapling stage was the most critical in the life cycle of the tree populations. Most species (42% – 48%) had no regeneration, 25% – 35% had good/fair regeneration, and the rest had poor regeneration or reoccurred as immigrants.

Key words Nokrek Biosphere Reserve, dispersion pattern, population structure, regeneration, species richness and stratification

The tropical and subtropical forests have attracted the attention of a large number of researcher all over the world, who have carried out comprehensive studies on their community organization and dynamics, and have estimated species richness, biomass, productivity and their role as a major carbon sink in the global carbon cycle (Valencia *et al*., 1994; Aiba & Kitayama, 1999; Evans, 2001). In Asia, these forests occupy much forested area of India and dry areas of Southeast Asia, which have pronounced periodicity of temperature, dry and wet seasons. These forests are best developed in monsoon areas of India, Burma, Thailand and Malaya (Puri, 1960). The subtropical forests found in India have been termed as montane subtropical forests by Champion & Seth (1968). The subtropical forests found in the state of Meghalaya, Northeast India are highly fragmented and disturbed by various human activities. The undisturbed forest patches are mainly confined to inaccessible hill slopes and valleys along the banks of rivers and streams or in the form of protected forest (Tripathi, 2002). Understanding the consequences of human disturbances on forest dynamics is fundamental to wise management of forest ecosystems.

The existence of a species in the community largely depends on its successful regeneration under varied environmental conditions. To assess the establishment of tree seedling, their survival and growth in different habitats

Received: 2006-03-09 Accepted: 2007-04-23
The authors are thankful to Indian Institute of Remote Sensing, Dehradun for financial assistance in the form of a research project
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provide basic guidelines for forest management and restoration practices in disturbed landscapes (Quintann-Ascencio *et al*., 2003). The potential regeneration of a species in a community can be assessed from the population dynamics of seedlings and saplings in the forest community. Differences in seedling and sapling survival in response to natural or human disturbance are critical for the recruitment of the canopy species. Most attention has been given to the survival of natural or planted saplings in relatively undisturbed forests (Ashton, 1995; Turner, 1996). A few studies exist on tree recruitment in human disturbed habitats (Clarke *et al*., 1999, Mesquita *et al*., 2001).

The local community residing within the reserve is Garo tribes which are basically '*Jhumias*'. There are 132 villages within the reserve with total human population of forty thousands and the population of grazing animals exceeds twenty-two thousands. Local tribes within the reserve maintain their terrestrial jurisdiction among the Clans (Akhing). There are about 26 such clans around the national park (core zone). Before its declaration as national park, the area was known as *Citrus* gene sanctuary and under the administrative control of district council where as the actual land belongs to *Nokamas* (village chief). They have affected about 16.4% of total reserve area. The primary reason of forest destruction is habitat destruction due to cattle grazing, overexploitation for medicinal and ornamental purposes and encroachment in forest area for cultivation. Since the illegal tree felling, extraction of fuel wood, cattle grazing and Jhuming was taking place in the buffer zone of the reserve, therefore, it experiences moderate level (20%) of disturbances (Tripathi, 2002). Therefore, understanding the regeneration status of some important trees is prerequisite for their conservation. The paper presents data on the effects of human disturbance on tree diversity, community structure and population structure in two forest stands located between 1 100 m and 1 400 m asl in Nokrek Biosphere Reserve (NBR), East Garo hills districts of Meghalaya, Northeast India.

1 Study Site and Methodology

The present study was conducted in the NBR (25°18′–25°36′ N, 90°13′–91°37′ E) in Garo hills district of Meghalaya during 2000–2002. The total area of the NBR is 820 km^2 and covering parts of all the three districts of Garo hills. The core zone of the NBR is spread over an area of 47.48 km^2 in west Garo hills district. The topography of the reserve is variable with an average altitude of about 600 m asl. and the highest peak is the Nokrek peak (1 412 m). Two forest stands were selected in the buffer (25°27′ N, 90°18′ E, 1 125 m asl.) and core (25°27′ N, 90°19′ E, 1 425 m asl.) zone to assess the tree diversity, community structure and population behaviour of important tree species.

The climate of the study area was monsoonic. The climatic variables, like temperature, rainfall and humidity, vary widely from place to place due to the wide variation in topography. Based on the atmospheric conditions, a year may be divided into summer (March to mid May), rainy (mid May to September), autumn (October to November) and winter season (December to February). The average annual rainfall was about 430 cm, minimum and maximum temperature was 11 and 34 ℃, respectively, and relative humidity ranges from 56% (March) to 77% (August) during the study period (Fig. 1).

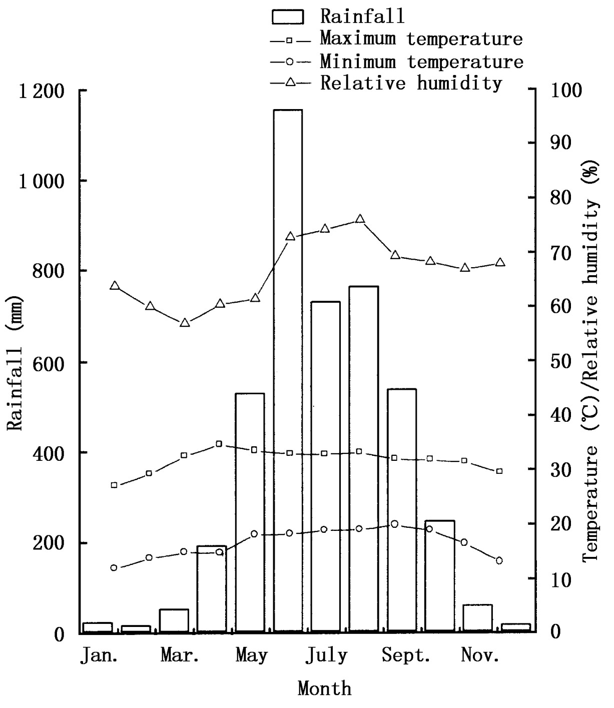

Fig. 1 Climatic diagram of the study site

Soil moisture in the studied stands varied between 31% and 42%. The soil temperature was relatively low (11.8 ℃) in the core than the buffer zone. In both the stands soil was acidic (pH value ranging between 5.41 and 5.80) in nature. Soil organic carbon and organic matter ranged from 1.84% to 2.62% and from 3.17% to 4.52%, respectively. Total nitrogen ranged between 0.35% and 0.42%, and 0.32% and 0.44% in buffer and core zone of the reserve, respectively. Available phosphorus ($\mu g \cdot g^{-1}$) ranged between 25 and 29 in buffer 32 and 36.7 in the core zone. The soil of core zone seems to be rich in nutrient composition than the buffer zone and its concentration in the upper soil layer (0 – 10 cm) was more than the lower layer (Tripathi, 2002).

Each of the selected forest stands was sampled using square quadrats. A total of thirty quadrats of 20 m × 20 m for woody (≥5 cm *dbh*) species and 5 m × 5 m for tree saplings and 100 quadrats of 1 m × 1 m for tree seedlings were placed randomly. Plant species were collected, brought to the laboratory and identified with the help of regional floras (Balakrishnan, 1981 – 1983; Haridasan & Rao, 1985 – 1987). Herbaria of Botany Department, North-Eastern Hill University, Shillong and Botanical Survey of India, Shillong were also consulted for identification. Vertical profile, frequency, density, basal cover and importance value index were calculated according to Misra (1968) and Mueller-Dombois & Ellengberg (1974). Various diversity indices were calculated according to Magurran (1988).

The population structure was studied based on the density and basal cover of species in three girth classes, namely young (≤55 cm), mature (55 – 95 cm) and old (≥95 cm) based on one year data. The state of regeneration of species was based on seedling, sapling and adult trees density, and categorized: 1) good, if seedlings > saplings > adult, 2) fair, if seedling > sapling ≤ adult, 3) poor, if species survives only in saplings stage but not as seedlings (though saplings may be less or equal to adult), 4) none, if a species is absent both in seedling and sapling stage but present as adult, and 5) new, if a species present only in seedling/sapling stage but not as adult trees (Shankar, 2001).

2 Results

2.1 Tree diversity and stratification

A total of 81 and 87 woody species representing 63 and 65 genera, and 36 and 38 families were recorded from the sampled area of buffer and core zone of the NBR, respectively (Table 1). There were tropical, temperate, and Sino-Himalayan, Burma-Malaysian and Malayan elements in the forest. Besides that taxa belonging to primitive families, like Annonaceae, Ranunculaceae, Piperaceae, Menispermaceae, Lauraceae and Myricaceae, and primitive genera, like Myrica, were also present in the forest.

The trees were distributed in three distinct strata, viz. canopy (> 20 m height), sub-canopy (10 – 20 m) and tree-let (2 – 10 m) layer. Canopy layer was composed of 11 and 15 species in the buffer and core zone of the NBR. Sub-canopy and tree-let layers together had the maximum tree species (83% – 86%) in both stands. *Elaeocarpus rugosus*, *Dysoxylum gobara* and *Engelhardtia spicata* in the buffer zone, and *Castanopsis tribuloides*, *D. gobara* and *Syzygium cuminii* in the core zone were among the dominant canopy tree species of the reserve. Lauraceae (11 species) and Euphorbiaceae (12 species) were the dominant family in the buffer and core zone of the reserve, respectively. A large number of families (16) were monospecious in the forest stands.

In terms of importance value index *Vitex vestita*, *Callicarpa arborea*, *Citrus hystrix* and *Macaranga indica* in the buffer zone and *Castanopsis kurzii*, *C. tribuloides*, *Elaeocarpus lancifolius* and *Dysoxylum gobara* in the core zone were among the dominant tree species (Tripathi, 2002). Dominance-distribution pattern among the tree species was similar in both the stands, i.e. it showed log normal distribution pattern, signifying high equitability and low dominance in the community (Fig. 2). Majority of trees (57% – 79%) was contagiously distributed and only 5 – 11 species showed regular distribution (Table 2).

Table 1 Community characteristics of woody species of the buffer and core zones of the Nokrek Biosphere Reserve

Variables	Buffer zone	Core zone
Density (ind.·hm^{-2})	1 023	834
Basal cover (m^2·hm^{-2})	33.3	38.8
Species richness	81	87
Number of genera	63	65
Number of families	36	38
Shannon diversity index	4.20	4.20
Simpson dominance index	0.02	0.02

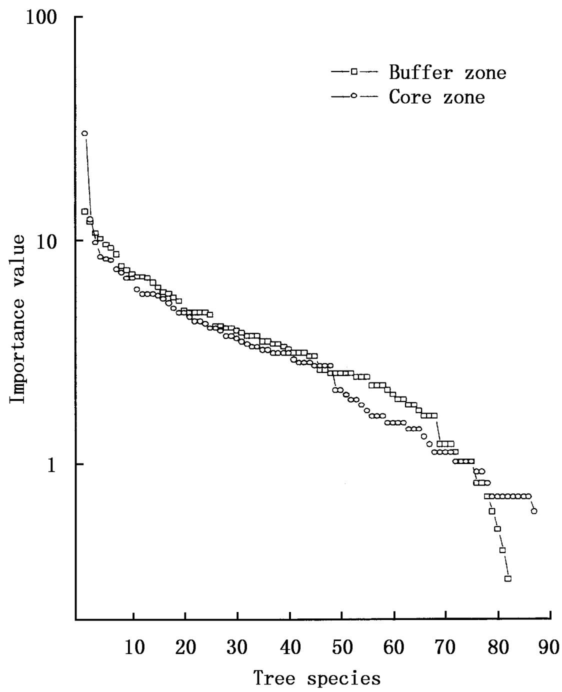

Fig.2 Dominance-distribution curves of the trees in buffer and core zone of the Nokrek Biosphere Reserve

Table 2 Stratification and distribution pattern of woody species of the buffer and core zone forest stands of the Nokrek Biosphere Reserve

Forest stands	Stratification			Distribution pattern		
	Canopy	Sub-canopy	Tree-let	Regular	Random	Clumped
Buffer zone	11 (13.6)	37 (45.7)	33 (40.7)	11 (13.6)	24 (29.6)	46 (56.8)
Core zone	15 (17.2)	41 (47.1)	31 (35.7)	5 (5.8)	13 (14.9)	69 (79.3)

Values in parentheses are the percentage of the total number of species in a given stand

2.2 Stand density, basal cover and diversity indices

The density of woody species was comparatively more in the buffer zone than the core zone; however, basal cover of the former forest stand was less than the later stand (Table 1). In terms of density, *Callicarpa vestita*, *Citrus hyxtrix* and *Castanopsis indica* in the buffer zone, and *Castanopsis kurzii*, *C. tribuloides*, *Elaeocarpus lancifolius* and *Derris robusta* in the core zone were the dominant woody species. They together constitute 15% and 18% of the total stand density.

Distribution of stand density in different girth classes revealed that trees of young individuals accounted for 81% and 60% of the total stand density in the buffer and core zone of the reserve, respectively. Trees beyond 95 cm girth class accounted for only 5% and 20% of the total stand density (Fig. 3a). Distribution of basal cover in different girth classes showed a reverse trend, that is, old trees though less in number, contributed maximum basal cover (45%) in the core zone followed by young individuals. In the buffer zone, young individuals contributed maximum to the basal cover and showed a declining trend (Fig. 3b). Sorensen's index of similarity for trees between the two stands was low Whittaker's β-diversity was high, suggesting marked difference in the species composition of the stands (Tripathi, 2002). Values of Shannon diversity index were high in both the stands, while Simpson dominance index showed a reverse trend (Table 1).

2.3 Density of seedling, sapling and adult trees

Mean seedling density (plants·100 m^{-2}) was 969 in the buffer zone and 512 in the core zone. Seedlings of *Castanopsis kurzii*, *Macaranga denticulata*, *Citrus hystrix*, *Persea duthiei* and *Skimmia laureola* were common in the buffer zone while those of *Ostodes paniculata*, *P. duthiei*, *M. denticulata*, *Diospyros undulata* and *Engelhardtia spicata* were common in the core zone. The mean sapling density was higher in the core zone (7 659 ind.·hm^{-2}) than the buffer zone (3 627 ind.·hm^{-2}). The saplings of *Cinnamomum pauciflorum*, *Helicia excelsa*, *Castanopsis indica* and *Bielshmiedia roxburghiana* were common in the buffer zone, while those of *Glochidion assamicum*, *Ficus oligodon*, *Citrus hystrix*, *Lindera caudate*, *Albizia chinensis* and *Camellia caudata* were common in the core zone. The density (ind.·hm^{-2}) of adult species was high in the buffer zone than the core zone of the NBR.

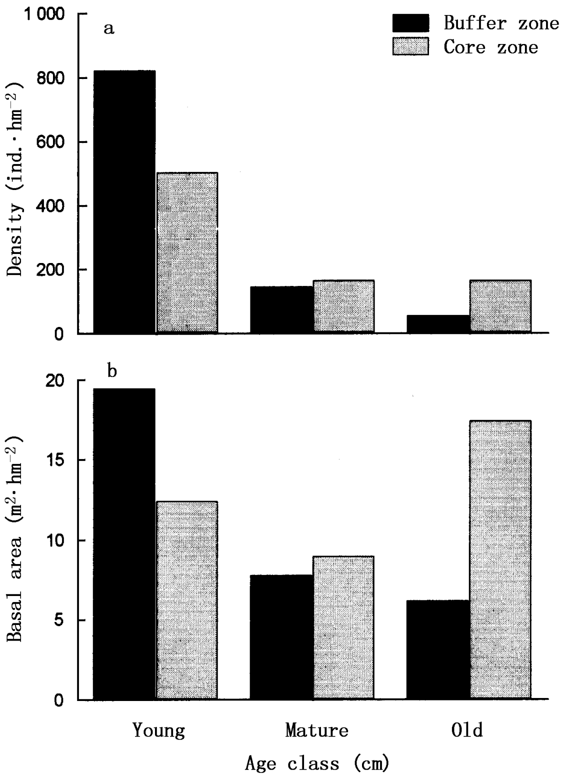

Fig.3 Population structure of species based on density (a) and basal area (b) in buffer and core zone of the Nokrek Biosphere Reserve

2.4 Population structure of dominant species

In both forest stands, individuals of all the girth classes were present in almost all selected species (Fig. 4). The girth-class distribution pattern in the dominant species revealed that the population structure in most of the species was upright pyramidal, with large number of young individuals in their populations. Preponderance of tree seedlings, followed by a steep decline in population density of saplings and adult trees, indicated that the period between seedlings to sapling stage was the most critical stage in the life cycle of the tree population, as maximum mortality occured during this period. Majority of species (42% – 48%) lack the regeneration and only 5% – 9% showed good and 20% – 26% fair regeneration. About 6% – 7% species showed poor and the remaining 14% – 25% seemed to be either reappearing or immigrants (Table 3).

Table 3 Regeneration of woody species in the buffer and core zone of the Nokrek Biosphere Reserve

Forest stands	Regeneration status (number of species)				
	Good	Fair	Poor	None	New
Buffer zone	9 (8.5)	20 (19.8)	6 (5.6)	45 (42.3)	26 (24.4)
Core zone	5 (5)	26 (25.7)	7 (6.9)	48 (47.5)	14 (13.9)

Values in parentheses are the percentage of the total number of species in a given stand

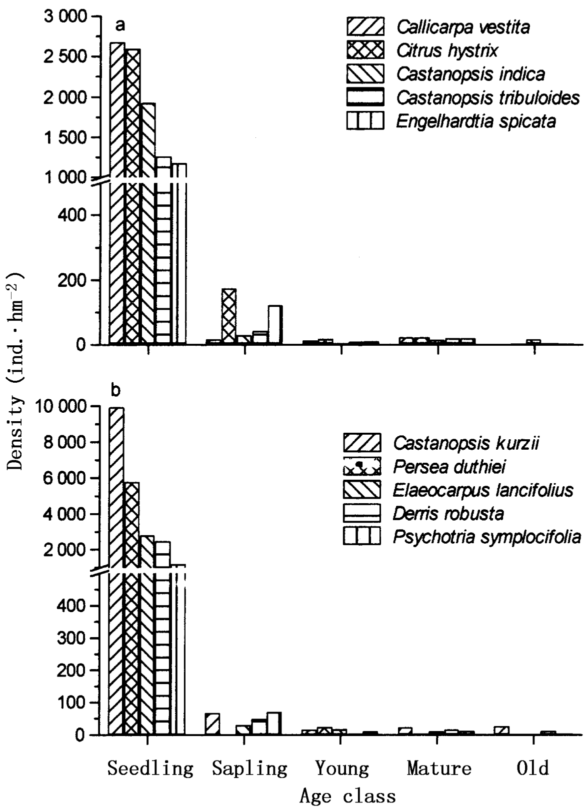

Fig.4 Population structure of five dominant species in buffer (a) and core (b) zone of the Nokrek Biosphere Reserve

3 Discussion

The buffer zone of the Nokrek Biosphere Reserve is disturbed due to the various human activities while the core zone was comparatively undisturbed. Therefore, the differences in the floristic composition and community characteristics observed in both forest stands could be attributed mainly due to disturbance. On the basis of families' dominance, present forest stands can be compared to the tropical forest of Sierra de Manantlam (Vazquez & Givnish, 1998) and tropical evergreen forest of Western Ghats (Ayyappan, 2002), where Lauraceae, Moraceae, Euphorbiaceae and Rubiaceae are reported to be the dominant families. This similarity might be due to edapho-climatic condition of the forest. Tree growth was better in both forest stands as large number of old trees (> 95 cm *cbh*) were present in these stands. Tree species richness (81 – 87 species) of present study are comparable with those of Felfili & Maria (1995) from Gamma gallery forest (87 species from 1 hm^2), Bunyavejchewin (1999) from seasonal dry evergreen forest of Thailand (76 – 100 species from 1 hm^2) and Parthasarathy (1999) from tropical wet evergreen forest in southern Western Ghats of India (80 – 85 species from 1 hm^2).

The majority of species in both forest stands had low frequency and showed contagious/clumped distribution, therefore, making the community highly heterogeneous and patchy. Several factors contribute to the clumped distribution of species; the notable among them are insufficient mode of seed dispersal (Richards, 1996) and formation of gaps due to the natural disturbance (Armesto *et al*., 1986). The lognormal dominance-distribution curves, as found in three stands of present study, signify equitability and stability of the community (Magurran, 1988). It also indicates the maturity and complexity of natural community.

The stand density of tree species in the buffer zone was comparatively higher than the core zone primarily due to the presence of a large number of young individuals. The tree density at the present study sites is comparable to the values reported by Pelissier & Riera (1993) of humid forest from French Guyana (1 168 stem · hm^{-2}), Parthasarathy & Karthikeyan (1997) from Thirumanikkuzhi tropical evergreen forest, Western Ghats (974 stem·hm^{-2}) and Upadhaya *et al*. (2003) from undisturbed subtropical evergreen forest, Jaintia hills (938 – 1 476 stem · hm^{-2}). The undisturbed core stand had higher basal cover than the buffer stand primarily due to the presence of large old trees in the stand. The tree basal cover is comparable with the results of Pascal & Pelissier (1996) from tropical evergreen forest, Uppangala (39.7 m^2·hm^{-2}), and Bunyavejchewin (1999) from seasonal dry evergreen forest of Thailand (29.1 m^2·hm^{-2}).

A number of studies have predicted the regeneration status of tree species based on the age and diameter structure of their population (Khan *et al*., 1987; Bhuyan *et al*., 2003; Mishra *et al*., 2004; Duchok *et al*., 2005). Population structure characterized by the presence of sufficient number of seedlings, saplings and young trees depicts the satisfactory regeneration behaviour, while inadequate number of seedlings and saplings of tree species in a forest indicates the poor regeneration. A large number of factors such as interaction of biotic and abiotic factors of the environment, magnitude and frequency of disturbances determine the population size of seedlings, saplings and adult trees in the community (Armesto & Pickett, 1985; Khan *et al*., 1987; Mishra *et al*., 2004).

The poor regeneration in the forest stands could be due to greater loss of individuals during the period of conversion of seedlings to saplings which is a more vulnerable stage in the life cycle or life history of the species as compared to the period during which the saplings developed into the adult trees. High mortality and low growth rate are typical for juvenile of rainforest trees due to the low understorey light level, exposure to physical and biotic disturbances and short-term water deficits. Movement of people inside the core zone is strictly prohibited, whereas there is free movement of the local people and their cattle in the buffer zone, which may be the reason for low seedling density. The expanding population structure of trees for the dominant species in the present study indicates that the stand harbours a growing population. Similar findings were also reported by Campbell *et al*. (1982) from Brazilian Amazon and Kadavul & Parthasarathy (1999) in tropical semi-evergreen forest of Kalrayan hills, Eastern Ghats, India.

The study revealed that subtropical broad-leaved forest of the NBR is rich in tree species diversity and can be compared to the other forests in species richness. The buffer zone is subjected to deforestation and forest fragmentation due to the large scale forest land clearing by slash and burn agriculture, extraction of forest resources such as timber, fuel-wood and collection of medicinal plants. These human activities resulted in the shrinkage in the forest cover of the reserve and also altered the micro-environmental condition and structure of the forest ecosystem which ultimately resulted in change in species composition between the forests (Tripathi, 2002).

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