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RESEARCH ARTICLE

SPECIES DIVERSITY, COMMUNITY CHARACTERISTIC AND POPULATION STRUCTURE IN DISTURBED AND UNDISTURBED FOREST OF SEPAHIJALA WILDLIFE SANCTUARY, TRIPURA

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ABSTRACT

This study was conducted in Sepahijala Wildlife Sanctuary, West Tripura, India to assess the plant diversity, community characteristics and population structure in buffer and core areas using random sampling procedures. Altogether 74 woody species were recorded from selected forests and revealed that species diversity and density increases with decrease in disturbance. Other community parameters such as basal cover and indices did not showed much variation among the stands. Forest canopy was composed mainly of *Shorea robusta, Schima wallichii, Aporosa dioica*. Majority (84% to 88%) of species showed low frequency making community heterogeneous. Basal cover was slightly higher (39.82 m^2 ha^{-1}) in disturbed forest than the undisturbed forest (37.54 m^2 ha^{-1}) in spite of low stand density. Greater proportion of contagiously distributed species made the community highly patchy in nature. Similarity between the stands was high mainly due to being part of same land cover. Diversity indices for woody species was higher in undisturbed forest than the disturbed forest areas, however, dominance index reveals the reverse trend to that of woody species. The overall population density of seedlings, saplings and adult trees formed a pyramidal structure indicated that the period between saplings to adult stage was critical stage in the life cycle, as the maximum mortality occurred during this period. Based on the results of the above study it can be concluded that forest degradation leads to reduction of forest areas, isolation of smaller patches, habitat loss and increased ground growth. Grazing and other anthropogenic activities in the forest areas should be restricted by the authority to check further degradation in the wildlife sanctuary.

INTRODUCTION

Tripura is situated in the Indian sub-region of Oriental Zoo-geographic region, local flora and fauna bear a very close affinity and resemblance with floral and faunal components of Indo-Malayan and Indo-Chinese sub-regions (http://tripuraforest.nic.in). The structure and function of forest ecosystem is determined by the plant component more than any other living component of the system (Richards, 1996). The most important characteristics of the tropical moist deciduous forests are their species richness, heterogeneity and complex community organization. Population structure, in terms of relative proportion of seedlings, saplings and young trees, provides adequate information of the regeneration status of the forest. Little attention has been given to tropical deciduous forests, whereas degradation and conversion of these forests are far more advanced (Bullock *et al*., 1995; Rundel and Boonpragob, 1995). As primary forests have been increasingly kept as protected areas for environment and biodiversity conservation, the importance of the estimated 850 million ha of degraded and secondary forests has grown considerably in relation to their potential for wood production, environmental functions and support for the livelihood of local people (ITTO, 2002). Forest degradation is generally accompanied by species extinction, reduction in diversity and decrease in primary productivity. This necessitates quantification of habitat characteristics of forests for proper conservation and sustainable management of natural resources. Tropical forests of developing countries are more vulnerable following the fact that the majority of forest adjacent communities are poor and depend directly on the forest resources to sustain their livelihood (Shackleton and Shackleton, 2004). Habitat loss, fragmentation and degradation are currently the most important threats to biodiversity conservation worldwide. Human activities have been widely reported to contribute more to this problem compared to natural factors. The distribution and abundance of different tree species over a landscape is what constitutes diversity in respect of tree species. Trees are the major structural component of forest ecosystems, while forests are disappearing at alarming rates owing to deforestation for extraction of timber and other forest produce (Raghubanshi and Tripathi, 2009). Unsustainable use of forest resources like logging and shifting cultivation has potential impact on its ecological functioning due to sudden changes on their structure and composition. Comparison of the species diversity of

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different vegetation types is often difficult because of the dissimilarity of the available data. Quantitative plant diversity inventories of forests are available from various forests (Roy *et al*., 2002, Jha *et al*., 2005; Tripathi *et al*., 2010). Species diversity is one of the analytical tools applied in determining the degree of variability of species within community or a landscape. Floristic and structural composition changes from one community to another there are concomitant changes in the competitive abilities of seedlings that depend on shifting opportunities for regeneration. Recruitment, growth and survival are influenced by a range of microclimatic and edaphic factors, which vary among different tropical forest formations (Augspurger, 1984). Population behaviour of component species in a community can be evaluated by density-diameter. The ratio of various diameter groups in a population determines the reproductive status of the population and it indicates the future course of stability of forest communities (Odum, 1971). Understanding the factors related to human disturbance that affect the tree biodiversity and forest vegetation structure can help conservation managers to suggest best forest management practices in ways that can best protect these values. The objectives of this study were to describe the tree diversity, community composition and population structure and compare these parameters of undisturbed forest with that of disturbed forest in Sepahijala Wildlife Sanctuary.

MATERIALS AND METHODS

Tripura is situated between 22°57′N and 24°32′ N and 91°10′E and 92°20′E. It is almost completely surrounded by Bangladesh on three sides i.e. North, South and West and Assam and Mizoram on the East side, having a tenuous link with the rest of the country through the Cachar district of Assam (Map 1). The study was conducted in the Tropical moist deciduous forests of Sepahijala Wildlife Sanctuary, West Tripura. It lies between 23°37′ to 23°42′N and 91°17′ to 91°21′E at an altitude of 50 msl. The sanctuary covers an area of 18.53 km^2 of which about 0.9 km^2 consists of water bodies. The climate is characterized by warm and humid summer and cold winter. It has a tropical climate and receives rainfall during the monsoons. The temperature ranges between 25.2°C to 35.5°C during summer and falls between 10.8°C to 26.8°C during winter. The average annual rainfall received is 212.2 cm. The soil is sandy loam to loamy sand, clay loam to pure clay or lateritic. It is grey to brown in colour. A large tract of soil is alluvium consisting of sand, silt and clay, pure sands being confined to the river beds. Except the sandy loam, all other varieties of soil become very sticky even after shower, but they dry up quickly. Soil samples were collected randomly in replicates and analyzed by following standard methods and methodologies were presented in report of Kikhi (2011). 40 quadrats of 10m x 10m were placed randomly for woody species, 5m x 5m for Shrub/Saplings and 2m x 2m for ground vegetation. All individuals encountered were recorded and scientific names were determined from flora compiled by Tripura University. Their distribution pattern was studied using Whitford index (Whitford, 1948). The dominance-distribution pattern of species was determined on the basis of IVI values, respectively. Species richness index (Margalef, 1958), Shannon diversity index (Shannon and Weaver, 1949), Menhinic diversity index, Morista-Horn Measure and Simpson dominance index (Simpson, 1949) were also calculated. Density-distribution was studied by determining the number of individuals in different girth classes viz., 15–45, 46–75, 76–105, 106–135, 136-170 cm. Field data for computing frequency density, abundance and IVI of plant species were calculated following Misra (1968) and Mueller-Dombois and Ellenberg (1974). Margalef's diversity index D_{Mg} (Clifford and Stephenson, 1975) and Menhinick's index D_{Mn} (Whittaker, 1977) are being used to estimate the species diversity. Whittaker β-diversity (Whittaker, 1975) was used to compare the species diversity between the different forests. Shannon and Wiener (1963) index of diversity ($\bar{H}$) and Simpson dominance index (Simpson, 1949) were calculated Sorensen's similarity index is being used to find the similarity (or dissimilarity) between different sites. Morista – Horn measure is also used to calculate the similarity of different sites. It is not influenced by the species richness and sample size. Disturbance index was calculated based on the number of cut stumps present in the forest.

Disturbance index (%) =

$$\frac{\text{Number of cut stumps}}{\text{Total number of individuals including cut stumps}} X\ 100$$

RESULTS

Land use-cover (LULC), forest disturbance and soil properties

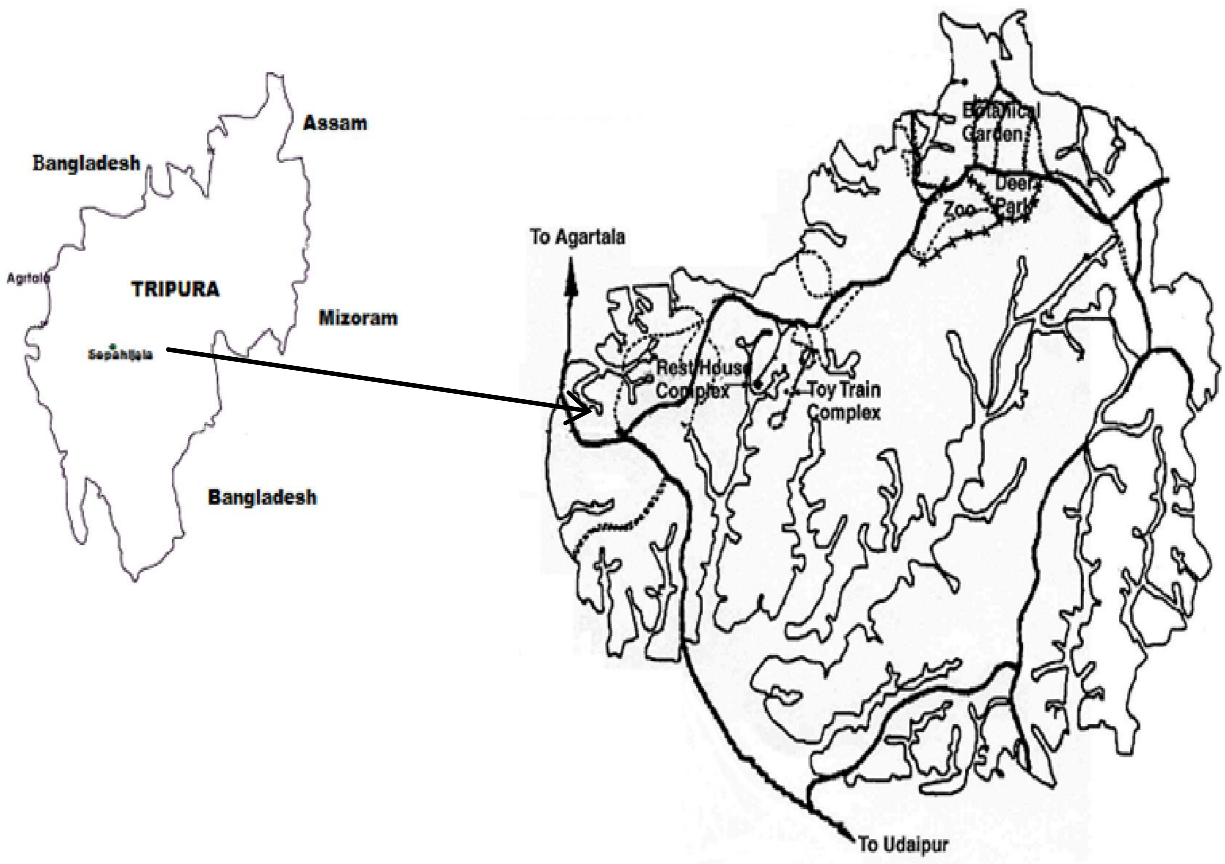
LULC map was prepared and classified into five broader categories i.e., forest area (13.63 km^2), agricultural area (1.67 km^2), open scrub land (1 km^2), built-up areas (2 km^2) and water bodies (0.3 km^2). Area covered under different LULC reveals that the maximum area of wildlife sanctuary is under forest cover (73%) followed by built-up and agricultural cover. Out of the total forest cover, 32% area was undisturbed, 50% was moderately disturbed and 18% area was highly disturbed due agricultural activities and settlements (Kikhi, 2011). Around the settlement areas in the LULC map two buffer zones were created at 500m and 1000m. It was observed that around 500m from the settlement the forest area was highly disturbed. Between 500m to 1000m zone the disturbances were moderate with some patches of good forest and those areas beyond the 1000m buffer were the undisturbed forest patch. Based on ground thruthing it was confirmed that the disturbance level around the settlement area in sanctuary were very high (Kikhi, 2011). This is because of the anthropogenic activities carried out by the villagers in the surrounding areas. The activities include agriculture, fuel-wood collection, grazing cattle and forest fire. From the analysis of the map, it can be concluded that the sanctuary is facing a greater potential threat from the surrounding villages. A forest boundary map was also prepared and was classified into undisturbed and disturbed forest areas. These two categories were further classified as highly disturbed and moderately disturbed areas. The NDVI was calculated for all these classes and the values ranged from 0 to 0.33 (Table 1). Soil of upper depth (0-15cm) was loamy sand to sandy loam in nature while silty clay to silty clay loam

Table 1. Forest cover under undisturbed, moderately disturbed and highly disturbed areas in Sepahijala Wildlife Sanctuary

Forest	NDVI Range	Area (Sq Km)	% Area
Undisturbed	0.24 – 0.34	4.30	31.55
Moderately Disturbed	0.195 - 0.241	6.85	50.26
Highly Disturbed	0.085 – 0.196	2.48	18.20
TOTAL		**13.63**	**100**

Table 2. Community characteristics of vegetation in disturbed (D) and undisturbed (UD) forest of Sepahijala Wildlife Sanctuary, Tripura

	Woody species		Shrub/Saplings		Ground vegetation	
	D	**UD**	**D**	**UD**	**D**	**UD**
Number of species	50	43	36	24	20	30
Number of genus	42	39	36	24	20	30
Number of families	28	28	25	21	17	24
Stand density (individuals ha^{-1})	1402	1113	4500	7480	59750	86000
Basal cover (m^2 ha^{-1})	37.54	39.82	-	-	-	-
Shannons diversity index	3.40	3.32	3.19	2.84	2.81	3.21
Simpson dominance index	0.059	0.06	0.06	0.07	0.07	0.05
Beta diversity index	5.05	6.36	2.56	1.14	1.98	3.28
Menhinic diversity index	2.09	1.98	1.70	0.88	1.08	1.94
Margalaef diversity index	7.71	6.82	5.73	3.48	3.25	5.30
Disturbance index (%)		31.56		7.60		
Sorensens similarity index	73.10		25.06		31.80	
Morista-Horn Measure	0.95		0.89		0.84	



Map 1. Location map of Sepahijala Wildlife Sanctuary, Tripura

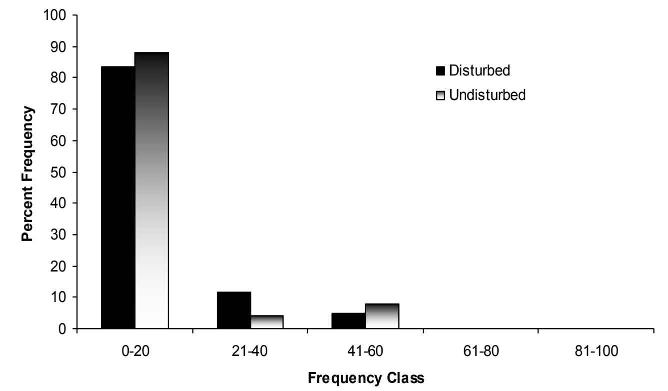
at lower depth (15-30cm). Soil moisture was low at both the soil depth and was acidic nature and acidity ranges from 4.7 to 4.9. Soil organic carbon, total nitrogen, available phosphorus and available potassium were higher at upper depth than the lower soil depth (Kikhi, 2011).

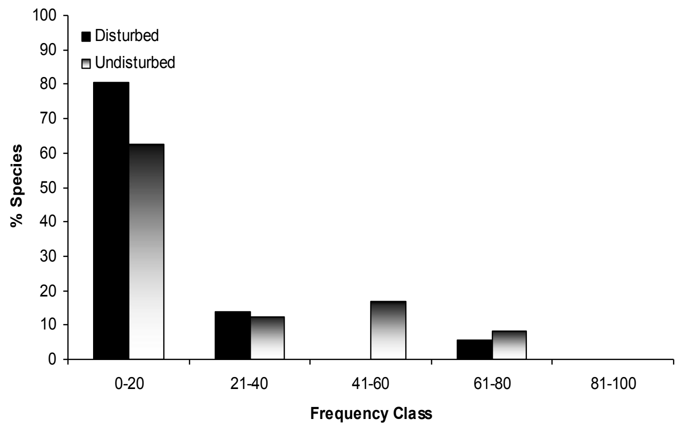
Plant diversity

The forest canopy was almost exclusively composed of species like *Shorea robusta, Schima wallichii, Aporosa dioica, Grewia microcosm* and *Bambusa polymorpha*. Forest floor was almost devoid of annual and perennial flowering plants, tree seedlings, saplings and herbs except in monsoon season. *Psychotria callicarpa, Shorea robusta* and *Syzygium cuminii* in disturbed forest and *Grewia microcosm, Dalbergia thomsonii* and *Garcinia cowa* in undisturbed forest areas were among the most frequently found seedling species in the wildlife sanctuary. Altogether (including tree seedlings and saplings) 74 species belonging to 62 genera and 36 families were recorded from the forest areas. The proportion of woody species was higher as compared to shrubs/saplings and ground vegetation. 43 woody species belonging to 39 genera and 28 families and 50 species from 42 genera and 28 families were recorded from disturbed and undisturbed forest areas, respectively. Shrubs/saplings were represented by 36 species belonging 36 genera and 25 families and 24 species from 24 genera and 21 families from disturbed and undisturbed forest areas, respectively. Ground layer was composed of 20 species from 20 genera and 17 families in the disturbed and 20 species belonging to 20 genera and 17 families in the undisturbed forest areas (Table 2).

Community Characteristics

Majority of woody species (84% to 88%) showed low frequency in both the forest areas and frequency class C and D were absent (Fig.1A). *Shorea robusta, Schima wallichii* and *Bambusa polymorpha* in disturbed forest and *Aporosa dioica, Grewia microcosm* and *Schima wallichii* in undisturbed forest areas were among the most frequently found woody species in the wildlife sanctuary (Table 3). Among the shrubs/saplings, 66-80% species had low (<20%) frequency and a few Raunkiaer's classes were absent (Fig. 1B).





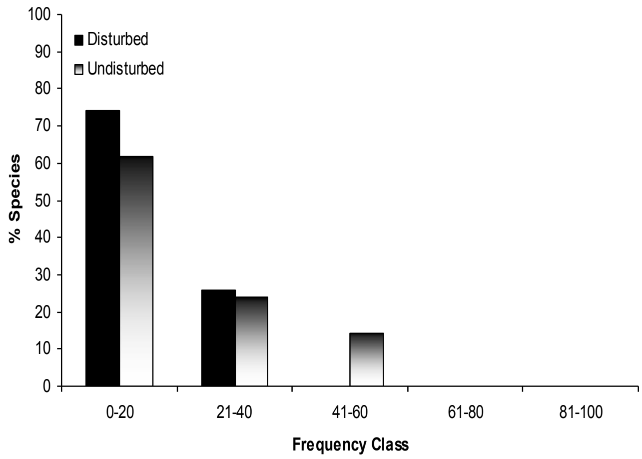


Figure 1. Frequency distribution curves of woody (A) shrubs/saplings (B) and Ground vegetation (C) in selected forest of Sepahijala Wildlife Sanctuary

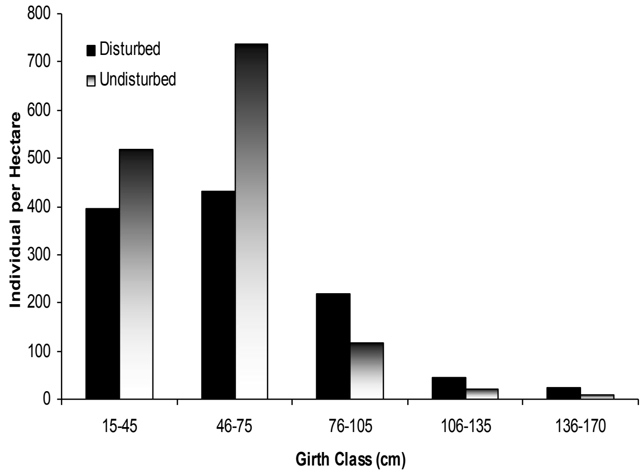


Figure 2a. Density-girth (cm) distribution pattern of woody species in selected forests of Sepahijala Wildlife Sanctuary, Tripura

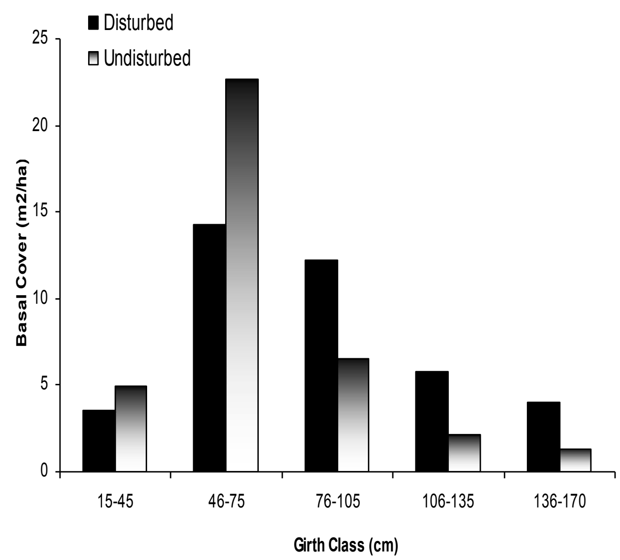


Figure 2b. Density-basal cover (m^2 ha^{-1}) distribution pattern of woody species in disturbed and undisturbed forests of Sepahijala Wildlife Sanctuary, Tripura

Ground vegetation (including seedlings) frequency distribution pattern reveals almost similar to that of shrubs/sapling layer (Fig. 1C). Contribution of higher frequency classes was comparatively higher in undisturbed forest areas than the disturbed forest areas. Woody species density was 1113 and 1402 stems ha^{-1} in disturbed and undisturbed forests, respectively. Disturbed forest had lower stand density but basal cover was slightly higher (39.82 m^2 ha^{-1}) than that of undisturbed forest (37.54 m^2 ha^{-1}) (Table 3).

in case of similarity index except saplings layer of disturbed forest. This reveals that there is heterogeneity in species composition in undisturbed areas as compared to disturbed forest areas. The diversity indices for woody species was higher in undisturbed forest than the disturbed forest, however, other indices reveals the reverse trend to that of woody species (Table 2). In case of sapling layer all the diversity indices were higher in undisturbed forest than the undisturbed forest areas.

Table 3. Density (D), frequency (F) and importance value index (IVI) of ten dominant woody species, saplings/shrubs and seedlings/herbs of Sepahijala Wildlife Sanctuary.

Species	Family	Undisturbed			Disturbed		
		D	F	IVI	D	F	IVI
Woody species							
Shorea robusta	Dipterocarpaceae	191	50.00	53.74	152	52.50	53.08
Schima wallichii	Theaceae	54	52.50	21.53	36	45.00	19.44
Aporosa dioica	Euphorbiaceae	76	57.50	27.13	40	22.50	19.39
Ficus hispida	Moraceae	5	10.00	4.14	35	27.50	17.48
Bambusa polymorpha	Poaceae	10	17.50	6.51	27	37.50	15.76
Tectona grandis	Verbenaceae	-	-	-	25	22.50	13.79
Grewia microcosm	Tiliaceae	37	57.50	18.21	18	32.50	12.26
Flacourtia jangomas	Salicaceae	16	25.00	9.04	13	20.00	9.08
Kleinhovia hospita	Malvaceae	7	15.00	5.23	13	17.50	8.92
Anthocephalus chinensis	Rubiaceae	-	-	-	5	2.50	8.84
Shrubs/saplings							
Lagerstroemia speciosa	Lythraceae	-	-	-	4	5	37.08
Slerispermos semisiotum	Sterculiaceae	40	37.50	20.76	70	65.00	37.08
Flacourtia jangomas	Salicaceae	44	40.00	22.29	7	12.50	27.56
Aquilaria agallocha	Thymeleaceae	1	2.50	2.28	35	5.00	26.25
Grewia microcosm	Verbenaceae	73	65.00	34.01	102	52.50	26.25
Erythrina fusca	Papilionaceae	1	2.50	2.28	15	17.50	22.17
Dalbergia thomsonii	Papilionaceae	33	40.00	18.79	56	47.50	18.66
Bambusa polymorpha	Poacaea	3	5.00	4.01	4	5.00	18.66
Klienhovia hospita	Malvaceae	23	22.50	13.70	87	47.50	18.38
Caesalpinia bonduc	Ceasalpiniaceae	3	2.50	5.79	4	10.00	9.39
Ground vegetation							
Shorea robusta	Dipterocarpaceae	36	27.50	23.77	29	32.50	25.53
Psychotria calocarpa	Rubiaceae	14	17.50	12.38	22	37.50	22.40
Syzygium cuminii	Mrytaceae	13	10.00	12.47	20	32.50	20.35
Garcinia cowa	Clusiaceae	54	42.50	32.75	21	17.50	19.67
Kleinhovia hospita	Malvaceae	43	40.00	27.98	19	27.50	18.96
Schima wallichii	Theaceae	10	17.50	10.15	16	22.50	16.45
Grewia microcos	Verbenaceae	29	47.50	23.70	13	27.50	15.33
Dalbergia thomsonii	Papillionaceae	30	42.50	23.13	12	25.00	14.27
Aporusa dioica	Euphorbiaceae	23	35.00	18.91	11	22.50	13.22
Clerodendron viscosum	Verbenaceae	21	37.50	18.53	11	17.50	12.57

For both the ground as well as under-storey vegetation, the density was higher for the disturbed areas as compared to undisturbed forest areas (Table 3). In both the forest areas, individuals having <75 cm cbh constituted 74.35% and 89.6% of the tree population, while the proportion of intermediate girth class (75-135 cm cbh) trees ranged between 9.8 % (undisturbed) and 23.6% and there was only a few individuals in higher girth class (Fig. 2a). Although the stand density of intermediate girth class was low while its contribution towards basal cover was more. In the undisturbed, individuals having lower girth class has contributed more (73.4%) towards the basal cover followed by intermediate and higher girth class (Fig. 2b). Based on importance value, *Shorea robusta* was the dominant species followed by *Aporosa dioica* and *Schima wallichii* in the forest while large number of species of least importance. Sorensen's index of similarity between the stands was high in case of woody species (73%) followed by seedlings (31.8%) and sapling species (25.6%). Morista-Horn index ranges between 0.84-0.95 (Table 2). Whittaker 's β-diversity was high and followed the similar pattern as observed

However, ground layer results the reverse trend to that of sapling layer. Simpson dominance index was low (0.05 to 0.07) for the all layers and type of forests (Table 2). Majority (80% to 96%) of woody species exhibited clumped or contagious distribution; 4% to 20% species were randomly distributed and none of the species resulted regular distribution (Kikhi, 2011). Distribution of random species was higher in case of seedling layer followed by sapling and woody species. There was not much variation in spatial distribution of species among the forest areas.

Density of seedling, sapling and woody species

Mean seedling density (plants per 100 m^2) of woody species was 660 individuals and 598 individuals in disturbed and undisturbed forest areas of wildlife sanctuary, respectively. Seedlings of *Garcinia cowa, Kleinhovia hospital* and *Shorea robusta* in disturbed areas and *Shorea robusta*, *Psychotria calocarpa* and *Garcinia cowa* in undisturbed forest areas were the common (Table 3). The mean sapling density (ha^{-1}) was

3800 individuals and 6480 individuals in undisturbed and disturbed forest areas, respectively. Saplings of *Aporosa dioica, Grewia microcosm* and *Clerodendron viscosum* in disturbed and *Aporusa dioica, Grewia microcosm* and *Klienhovia hospita* in undisturbed forest areas were the common (Table 3). The overall population density of seedlings, saplings and woody species in forest areas revealed that there was preponderance of seedlings and substantially low population density of saplings and woody species. Based on this observation, the population of seedlings may be considered as the most vulnerable in the life cycle of these trees. In both the forest areas status of regeneration was assessed based on the relative size of the populations of seedlings, saplings and adult species. Regeneration status was better in disturbed areas than the undisturbed forest area, where individuals of all ages from seedling to mature tree were present. In the other case the regeneration was impeded as was indicated by the absence of either enough seedlings or saplings (Tripura, 2011).

DISCUSSION

The forest type of Sepahijala wildlife sanctuary is tropical moist forests found at lower altitudes, represent the climax plant communities in the state. Shifting agriculture, logging, grazing and other human activities have been responsible for destruction and degradation of forest giving rise to large number of secondary successional communities, which are found on the degraded sites. High rainfall and topography have further accentuated the human impact on the forest. The state of Tripura, like other parts of northeast India, is undergoing rapid transformation due to urbanization, commissioning of developmental activities and extraction of forest products, besides continuance of age-old practice of shifting agriculture or 'Jhum'. All these activities are destroying natural forests. As a result, the forests are getting degraded. It is clearly evident from the high frequency of small-size forest patches. Forest degradation may have serious consequences on species composition, community structure and regeneration of trees in the forest communities of the state. Tree felling during the past few decades has degraded the forests as results of which a number of species have become rare are endemic or may be eliminated due to inundation of large forest areas. The trees are generally medium to short statured not exceeding >25 m height. The shrubby and herbaceous layers are devoid except during the monsoon season. This has led to the clear ground in most part of the year. The forest floor is spongy due to presence of thick litter and duff layers and a dense network of fine roots. Degradation of natural forests in the form of tree cutting for fire-wood, grazing and fire during dry winter due to anthropogenic pressure is a common phenomenon. The intensity of disturbance as assessed by disturbance index and number of cut stumps indicates that though both the forest were mildly disturbed, the buffer areas were relatively more disturbed than the inner zones. Being the part of the same forest, they were similar to each other in species composition. However, a close examination of community parameters such as density, basal cover and importance value of species revealed changes in these parameters, which seem to be the result of forest degradation and associated micro-environmental changes. Woody species richness and diversity showed an increasing tendency with level of disturbance. Though the dominance among the constituent's species of the community was similar in both areas, but the dominance of few species showed a progressive decrease with decrease in disturbance. Conversely, some species showed a distinct increase in their dominance with increase in disturbance. Despite general similarity in the soil and climatic condition, forests differed markedly in species richness. This could be related to the level of disturbance to which they were exposed. The disturbed forest areas were low density in lower girth classes, however, disturbed forest areas are evident by the presence of larger number of trees having >135 cm circumference. Contagious/clumped distribution pattern and low frequency of most species in both the stands was responsible for making the community highly heterogeneous and patchy due to gap phase dynamics. The log-normal dominance-distribution curves, which signify equitability and stability of the community, signifies abundance of species having intermediate dominance values in the community and indicates maturity and complexity of natural community. Comparatively higher density of woody species in undisturbed forest areas than the disturbed forest areas was primarily due to disturbance which was responsible for removal of young plants for fuel-wood purposes from the latter stand leading to creation of large number of favorable micro-sites for better tree regeneration. Similar results were obtained for the basal cover, primarily due to the presence of large old trees in the former stand.

The species richness, tree density and basal cover obtained in the present study is comparable with the results of Upadhaya *et al.,* 2008; Tripathi and Khongjii, 2010; Mishra and Tripathi, 2005; Mishra *et al*., 2004 and Tripathi *et al*., 2008 from different forests areas. Population density was comparatively higher in the undisturbed forest areas than the disturbed forest areas due to presence of large number of young individuals. Higher basal cover in later forest areas was primarily due to the presence of many individuals having higher girth than the individuals present in the former forest areas. Poor under-canopy and ground growth in undisturbed forest area could be due to microenvironment. However, more population of these groups of plants in disturbed area could be due to the condition prevailing in area which has favored the growth of many species (both light as well as shade loving). The poor seedling and sapling density of some species in the forests are attributed to the 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 Lichstein *et al.,* 2004. Reduced abundance of shade-tolerant under-storey seedlings in forest fragments could result from both limited seedling recruitment and increased mortality of established seedlings (Bruna, 2002; Tripathi and Tripathi, 2010). Seedlings have a limited tolerance range of light, temperature and humidity which are strongly altered in the disturbed forests (Gehlhausen *et al.,* 2000). However, the effects of disturbance on tropical plants are not uniformly detrimental, some taxa show enhanced reproduction and growth in the degraded forests (Dick, 2002). Based on the results of the above study it can be concluded that forest degradation leads to reduction of forest areas, isolation of smaller patches, habitat loss and increased ground growth (Kikhi, 2011). All these were responsible for decrease in woody species diversity. Undisturbed forest areas harboured such species which were not present in disturbed areas and disturbed areas favored regeneration of those species, which were absent in the undisturbed areas. Thus, both forest areas need to be conserved through protective buffer of edge species. Grazing and other anthropogenic activities in the forest areas should be restricted by the authority to check further degradation in the wildlife sanctuary.

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