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Patterns of plant species diversity in the forest corridor of Rajaji–Corbett National Parks, Uttaranchal, India

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Patterns of vegetation diversity in the various strata (trees, shrubs and herbs) were analysed in the Rajaji–Corbett corridor forest. Mean species numbers of all the vegetation strata were correlated with each other. The seedlings and saplings showed weak correlation with herbs and shrubs, proving that some species of

herbs and shrubs are detrimental for regeneration of trees. The α -diversity is highest for trees, while shrubs showed the highest β -diversity. Mosaic diversity values were low indicating that the study area had a relatively simple landscape with few dominating environmental gradients.

Keywords: Corridor forest, mosaic diversity, Shannon–Wiener index, similarity, species richness.

THE broad stratification of vegetation of any area into the following strata, viz. trees, shrubs and herbs is the first and foremost feature that one notices while attempting to characterize the vegetation. Forest and woodland ecosystems extend over *ca.* 37% of the earth's terrestrial surface¹, where the distinction of canopy strata has long been used for the description of vegetation^{2,3}. While diversity indices have been computed for various forest types by various workers, less effort has been devoted to the description of patterns of diversity in these conspicuous strata of vegetation. This issue is important because it may reveal ecological processes responsible for plant community structure. The present communication focuses on the vertical distribution of various measures of diversity in the corridor forest of northwestern India based on the study of the various patterns of plant species diversity such as the α , β , γ and compositional pattern diversity. These parameters were analysed and their distribution was studied across the different strata.

A variety of factors contribute to the diversity of plants in a region. Plant species diversity is affected by several topographic gradients and climatic variations. It is generally observed that areas with high species diversity are found in the middle latitudes, particularly in the tropics because of the congenial climatic, edaphic and other factors prevailing therein.

The most widely used indices for measurement of diversity are the 'information theory indices'. Among the various such indices, the Shannon–Wiener index is most commonly used. This index has been used for the present study, since sampling was done randomly and also because it is the most widely used measure of diversity and thus the findings of the present work could be easily compared with other studies done in the surrounding areas. Species richness is essentially a measure of the number of species in a defined sampling unit. This is the basic component of diversity of any community and is relatively simple to measure. Species richness measures also provide an easily comprehensible expression of diversity. The β -diversity can be defined as the 'extent of species replacement or biotic change along environmental gradients'⁴. Studies by Whittaker have established the importance of identifying β - and α -diversity as components of overall plant diversity. Accurate measurement of β -diversity is important because: (i) it indicates the degree to which habitats have been partitioned by species; (ii) values of β -diversity can

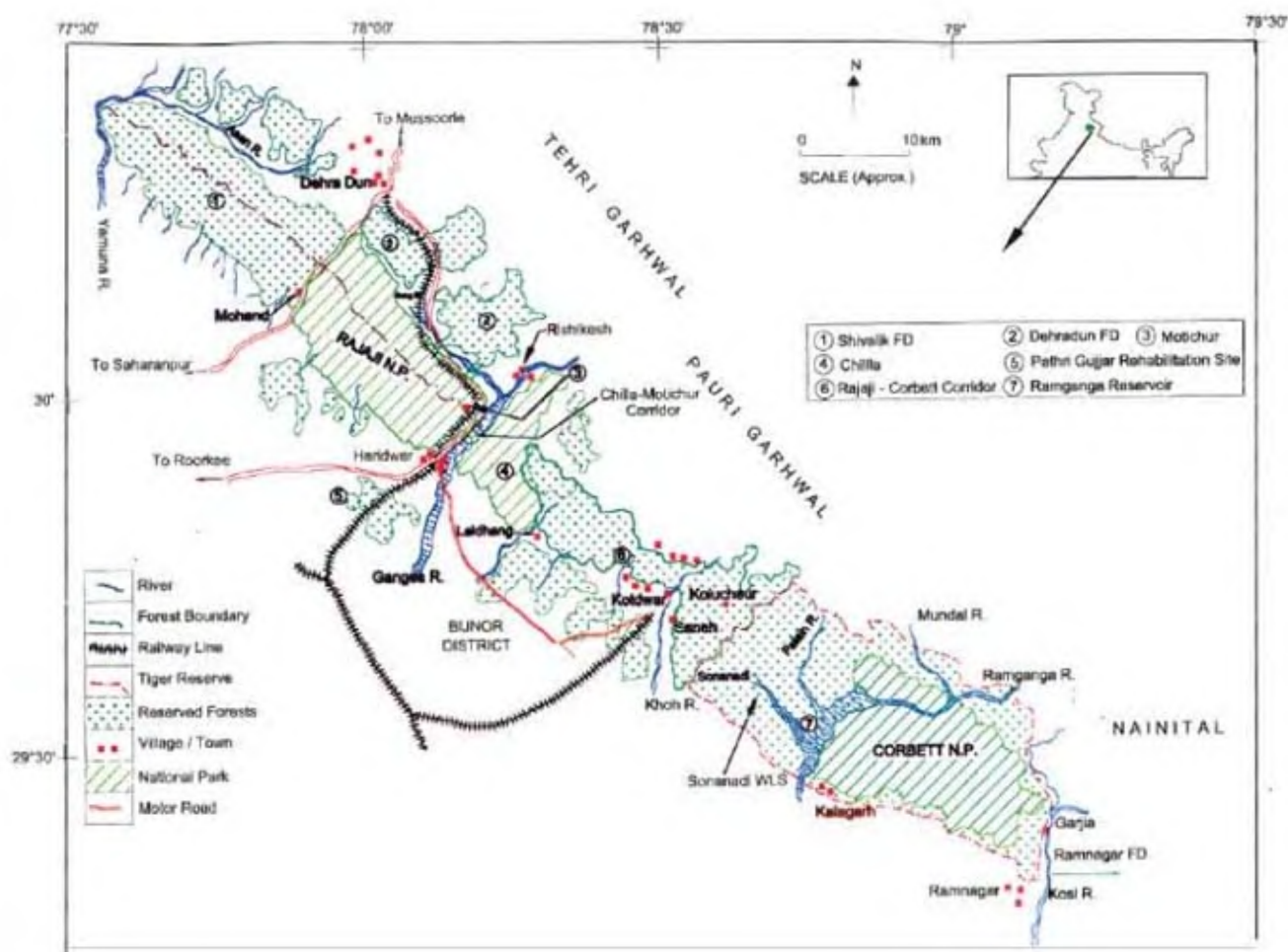


Figure 1. Study area.

be used to compare the habitat diversity of different study systems, and (iii) β - and α -diversity together measure the overall diversity or biotic heterogeneity of an area⁵. The β -diversity of a native species pool generally increases with an increase in the diversity of habitats and hence the environmental heterogeneity increases⁴. Diversity can also be measured by grouping species into several subunits in an ecological unit. This is known as differentiation diversity⁶. This analyses the relative arrangement of these subunits within an ecological unit, and is known as pattern diversity⁷. Mosaic diversity measures compositional pattern diversity, which is the arrangement of subunits in the mathematical space defined by the site-species composition matrix and hence measures landscape complexity. It measures variation in species richness, as also variation in evenness among species and the interaction of these two properties to create floristic gradients. In this context, a simple landscape is one dominated by a few species and controlled by one or few environmental gradients. Contrastingly, a complex landscape supports no ubiquitous species and is controlled by many environmental gradients.

The study area is located in the foothills of the Himalayas, and falls under the districts of Haridwar and Pauri Garhwal, Uttarakhand and Bijnor district, Uttar Pradesh (Figure 1). To the west lies the Rajaji National Park, while the Kalagarh forest division of Corbett National Park lies in the eastern boundary of the area. Administratively, this area partly falls under the Lansdowne forest division and partly under the Bijnor plantation forest division and lies between 29°37'–29°54'N lat. and 78°16'–78°41'E long. The altitude varies from 240 m asl in the south to 1150 m asl in the north.

The study area was stratified into various vegetation classes and plots of 10 m radius were randomly laid within each vegetation class. A total of 35 sites were selected based on the various vegetation classes and 10 plots were laid in each site. Data for tree, shrub and herb species were recorded. Recruitment parameters were also recorded.

Three types of diversity were calculated from the site-species matrix, viz. (1) Inventory diversity (both community species richness or α -diversity and total species richness or γ -diversity were measured). (2) Differentiation or

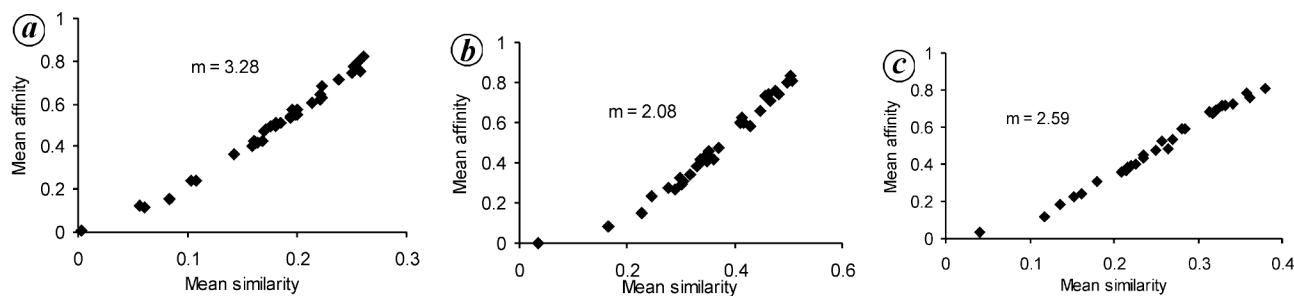


Figure 2. Affinity analysis graphs: *a*, Tree layer; *b*, Shrub layer; and *c*, Herb layer.

Table 1. Mean species number (\pm SD) of vegetation strata

Vegetation stratum	No. of species
Tree	23.56 \pm 16.51
Shrub	10 \pm 4.79
Herb	18.22 \pm 7.85
Seedling	21.11 \pm 11.76
Sapling	10.87 \pm 9.23

β -diversity (mean similarity among communities based upon Jaccard's similarity index). (3) Compositional pattern diversity or mosaic diversity.

Community-level diversity was computed using Shannon–Wiener index⁸. Richness was calculated using Margaleff's index⁹. Compositional pattern diversity was calculated using a software package Affinity Analysis⁷. Site-level data were utilized for affinity analysis. Qualitative data, i.e. presence–absence data were used for analysis. Differences in mean species richness among strata were determined using one-way ANOVA. The mean number of species in each strata, viz. trees, shrubs, herbs, seedlings and saplings were significantly correlated with each other using Pearson's correlation coefficient.

The number of tree species was highest followed by the number of seedling species. The number of shrub species was least amongst all (Table 1). The numbers of species in each stratum were also correlated with each other and the result has been displayed in a matrix in Table 2. It shows a highly significant positive correlation in most cases. The highest correlation value was obtained in the case of tree and seedling numbers, while the correlation between saplings and trees was relatively lower than the former. This reveals that although seedling formation is satisfactory in this region, growth of seedlings into saplings is not adequate. This has also been observed in another study conducted in this area¹⁰. The correlation of seedling numbers with both herb and shrub numbers is relatively weak. This was also observed in the field that the numbers of seedlings were less in places that had extensive herb and shrub cover. Thus one of the major reasons for inadequate development of tree species in this area is the

extensive growth of invasive (exotic) herbs and shrubs like *Parthenium hysterophorus* and *Lantana camara*. It is also evident that the sapling numbers are relatively less correlated with shrub numbers (the level of significance is lower in this case, i.e. $P < 0.05$ as against $P < 0.01$ in other cases).

The difference in the mean diversity values was determined by ANOVA and was found to be statistically significant at $P < 0.05$. The diversity values (H' and γ) show an initial decrease and then an increase as we move from the herbs to the trees. The β -diversity value however shows a different trend. It is highest for shrubs followed by herbs and the trees have the least diversity (Table 3). The β -diversity value indicates changes in species composition from one location to another⁵. It is therefore indicative of habitat heterogeneity. Therefore, in this area shrubs showed maximum change in species composition. This phenomenon was evident in the field, where some areas with lower elevation had intensive growth of *L. camara*, whereas areas with higher elevation had no *L. camara*. Similarly, the other dominating shrub species, i.e. *Clerodendrum viscosum* was only found associated with patches of *Shorea robusta* and was almost absent in other areas.

The mosaic diversity values were quite low for all the three strata (tree = 3.58, shrub = 2.08, herb = 2.59), which indicates that the landscape of the area is relatively simple and is governed by a few environmental gradients. The results have been graphically depicted in Figure 2.

One of the measures of the well-being and stability of any ecosystem is the estimation of its species diversity and richness. These values also indicate the nature of the forests in a region. Along with the composition of the forest, information on the diversity of the communities and of the landscape as a whole, provides better insight into the state of the forests of an area.

It has also been observed that a change in the habitat variables such as nature of substrate can affect species diversity especially within the habitat species diversity, i.e. γ -diversity of a region. Natural or anthropogenic disturbances can reduce low-population densities of plant species even further and isolate populations of commonly found species by habitat destruction. Therefore, fragmen-

Table 2. Correlation of mean species number among different vegetation strata

	Tree	Shrub	Herb	Seedling	Sapling
Tree	×	0.88 ($P < 0.01$)	0.89 ($P < 0.01$)	0.92 ($P < 0.01$)	0.89 ($P < 0.01$)
Shrub	0.8 ($P < 0.01$)	×	0.9 ($P < 0.01$)	0.69 ($P < 0.05$)	0.74 ($P < 0.05$)
Herb	0.89 ($P < 0.01$)	0.9 ($P < 0.01$)	×	0.79 ($P < 0.05$)	0.9 ($P < 0.01$)
Seedling	0.92 ($P < 0.01$)	0.69 ($P < 0.05$)	0.79 ($P < 0.05$)	×	0.91 ($P < 0.01$)
Sapling	0.89 ($P < 0.01$)	0.74 ($P < 0.05$)	0.9 ($P < 0.01$)	0.91 ($P < 0.01$)	×

Table 3. Diversity values of tree, shrub and herb layer

Vegetation stratum	H'	β	γ	m
Tree	2.57 ± 0.96	0.23 ± 0.08	10 ± 3.21	3.58
Shrub	1.99 ± 0.74	0.37 ± 0.11	2.38 ± 1.01	2.08
Herb	2.36 ± 0.59	0.26 ± 0.08	5.19 ± 2.33	2.59

H' = Shannon–Wiener diversity index; β = Jaccard's similarity index; γ = Margaleff's species richness index; m = Mosaic diversity.

tation of large forest tracts into small isolated patches is a major factor leading to loss in species diversity and subsequently, loss of biological diversity as a whole. Plant species diversity is also dependent on the regeneration potential of various species and the presence of competitors that may either inhibit or promote regeneration.

The diversity values calculated from the corridor area (0.87–3.89) were comparable to those reported from studies done elsewhere in the Siwalik foothills. Shannon–Wiener index for tree species was 1.84–2.46, 1.39 and 0.53 for Shiwaliks, Doon Valley and outer Himalaya respectively¹¹. The diversity values obtained in the present study were also comparable to studies done in the Corbett National Park¹², where the values ranged from 1.79 to 3.64. Thus it was evident that the corridor forest bears similarity to the surrounding forests, both in terms of vegetation composition as well as parameters such as species diversity, richness and evenness. This area is therefore fit to function as a connecting corridor between the two national parks, as one of the prerequisites of a corridor is that it should have a similar habitat as found in the forest patches that it connects¹³.

The corridor forest serves as an essential connecting link between the two national parks, viz. Rajaji and Corbett national parks. Its species diversity patterns show that the forest is still at par with the adjacent national parks. However, this forest is not being protected stringently and is facing anthropogenic disturbances. If proper conservation measures are not implemented immediately, the forest may undergo severe fragmentation and the connectivity between the two national parks may be lost forever. This will result in serious problems for species such as the large herbivores to move from one national park to the other.

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