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Western Ghats : A lifescape

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Abstract

The patterns of distribution of biological diversity over the hill chain of Western Ghats are moulded by manifold natural factors as well as human interventions. There are many surprises in store when one looks at them in detail—for instance, the inverse correlation between bird and woody plant species diversity in the Uttara Kannada district. Humans have not only extensively transformed natural communities into plantations and put to other uses, but also have greatly depleted biomass and diversity levels in areas remaining under forest cover. The extent of such depletion of biomass may be about 50% over the last half century for Uttara Kannada. This has also led to loss of species, especially the more delicate evergreen species incapable of coppicing.

Keywords: Western Ghats, biodiversity, diversity gradients.

1. Introduction

Mountains are the treasure troves of biological diversity in the world today for a variety of reasons. Their topography promotes environmental heterogeneity. The annual rainfall, for instance, ranges from as much as 8000 mm in the southwestern corner of upper Nilgiris to a mere 500 mm in the Moyar gorge just 30 km to its east. In contrast, the annual rainfall spans a range of no more than 800 to 1000 mm over hundreds of kilometers across the Deccan plateau. Mountains also create isolated habitats far away from other similar habitats, promoting local speciation. Thus distinct species of *Rhododendrons* occur on the higher reaches of Western Ghats and Himalayas, with a large gap in the distribution of the genus in between. Finally mountains are less hospitable to human occupation and therefore retain much larger areas under natural or semi-natural biological communities. This is why the Western Ghats and the Eastern Himalayas are today the most significant repositories of India's biodiversity[1].

The Western Ghats and Eastern Himalayas are regarded not only as biological treasure troves, but are also considered as two of the world's 18 biodiversity hot spots[2]. The hot spots are defined as biodiversity-rich areas that are under a high degree of threat. Indeed the landscape of Western Ghats and Eastern Himalayas is today being rapidly transformed in many ways leading to an erosion of their biodiversity. Given the current imperative of conserving world's biodiversity, it is important to understand the lifescape, *i.e.*, patterns of distribution of biodiversity—over these mountains, and the processes underlying ongoing changes in these patterns. Along with several collaborators and

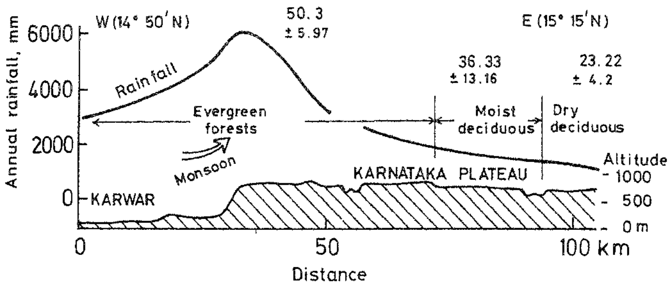

FIG. 1. An east-west cross section through the Uttara Kannada district indicating topography, annual rainfall and natural vegetation types. Also indicated are mean and standard deviation of numbers of woody plant species in 2400 m^2 belt transects.

students, I have been investigating the lifescape of the Western Ghats over the last two decades. This article reviews some of the recent results, based in particular on the work carried out jointly with R.J. Ranjit Daniels, M.D. Subash Chandran, Shri Niwas Singh and N.V. Joshi.

2. Diversity gradients

Levels of biological diversity vary along many gradients; for instance, as one passes from temperate regions towards tropics, or from islands to continents. Three kinds of gradients are well known for levels of diversity of flowering plants along the hill chain of Western Ghats[1,3]. The diversity of plant species increases as one travels south across the 1600 km length of the Ghats from river Tapi to Kanyakumari. This has been related to the southward increase in the number of rainy days. Diversity of plant species also increases as one crosses the Western Ghats from the east to the west, in conjunction with an increase in the total rainfall. Figure 1 depicts the results of a study of 38 belt transects of 600 × 4 m, in the district of Uttara Kannada (13°55'N–15°32'N lat and 74°5'E to 75°5' E long) near the centre of the Western Ghats. These transects sample dry deciduous, moist deciduous and evergreen forest types along gradient of increasing rainfall. The number of woody plant species in the 2400 m^2 sample increases from 23.22 ± 4.2 to 36.33 ± 13.16 to 50.3 ± 5.97[4]. The third known gradient is the increase in the number of plant species with an increase in the mean temperature from higher elevations to the coastal plains.

But our studies have revealed further complexities. Daniels[5] censussed birds by walking along the centre of the 600 m long transect strip at a pace of ~10 m every 2 min during the morning hours of 0800–1000. A limit of 100 m on either side was set to record birds sighted and/or heard on the transect. Birds thus recorded on these systematic transects represented about 30–40% of the total bird species in a locality. As mentioned above, all woody plants were also surveyed along a strip of 4 m width. All individual

Table I

The correlation matrix of attributes of 38 samples of natural vegetation in Uttara Kannada district. Simple correlations are to the left of and below the diagonal, partial correlations to the right of and above the diagonal

⟶ Partial correlations

	Woody pl species richness	*Woody pl species diversity*	*Vertical stratification*	*Canopy density*	*CV of canopy density*	*Tree density*	*Bird species richness*
Woody plant sp. richness	–	0.73*	0.28	0.53	0.57*	0.06	0.17
Woody plant sp. diversity	0.85*	–	–0.09	–0.14	–0.29	–0.06	–0.35⁺
Vertical stratification	0.52*	0.44*	–	0.00	–0.27	–0.06	–0.24
Canopy density	0.70*	0.62*	0.56*	–	–0.64*	0.46*	0.15
CV canopy density	–0.31	–0.37⁺	–0.49*	–0.77*	–	–0.14	0.07
Tree density	0.56*	0.49*	0.45*	0.83*	–0.69*	–	–0.28
Bird species richness	–0.31	–0.44*	–0.39⁺	–0.36⁺	0.37⁺	–0.43*	–

Simple correlations ⟵

* and ⁺ indicate that values of simple/partial correlation coefficients are significantly different from 0 at $p < 0.01$ and 0.05 level, respectively.

plants were identified and assigned to one of the following seven height classes: 0–1 m (seedlings), 1–2 m (shrubs), 2–4 m (understory) and several canopy layers at 4–8, 8–16, 16–32 and > 32 m. These height categories were used to assign vertical stratification to the vegetation. Canopy density was recorded every 5 m at 120 points as follows : 0 when there was none overhead, 1 when canopies from adjacent trees barely met, 2 when the canopies overlapped with the sky still showing through and 3 when the sky was no longer visible through the overhead foliage. Density of trees above 30 cm girth at 130 cm above ground was estimated in 10 quadrats of 10 × 10 m at 50 m intervals.

Woody plant species diversity was computed as e^H, where H is the Shannon–Weaver index—$\Sigma\, p_i.\ln p_i$, p_i being the proportion of plants belonging to ith species. Vertical stratification is computed as $1/\Sigma\, p_i^2$, where p_i is the proportion of plants in the ith height class. Canopy cover is the average of canopy density scores. Tree density is expressed as the number of trees with a girth > 30 cm at breast height per 1000 m^2. As Table I brings out, bird species richness is negatively correlated with woody plant species diversity as well as with vertical stratification, canopy density and tree density. Bird species richness is however significantly correlated positively with the coefficient of variation of canopy density. Since the various attributes of vegetation strongly correlate with each other, we performed a partial correlation analysis to determine the relative significance of different vegetational attributes with path analysis technique. This analysis reveals that the predominant influence is that of woody plant species diversity. The more diverse natural vegetation supports a lower number of bird species, while the bird species richness increases with patchiness of the tree cover.

The explanation for the lower level of bird species richness in the structurally more complex and diverse vegetation may lie in the fact that the less complex and diverse, drier, more deciduous vegetation has been more effectively colonised from a pool of bird species of the adjacent tracts of peninsular India. The evergreen forests of Western Ghats, on the other hand, constitute a relatively restricted habitat island (64750 km^2) at a considerable distance (1500 km) from the large tracts of the evergreen vegetation of Eastern Himalayas and Southeast Asia. In consequence, the evergreen forest bird fauna of the Western Ghats is rather impoverished, especially with respect to large-sized birds, fruit eaters and above all sedentary insectivores such as babblers and laughing thrushes.

3. Impact of man

These natural gradients of biological diversity are today greatly affected by a whole range of human interventions. These include overharvest of natural vegetation leading to a reduction in standing biomass or regression to lower successional stages, as well as conversion of natural vegetation to man-made plantations, cultivation or aquaculture. Shri Niwas Singh has attempted to systematically sample the ongoing transformations in Kumta and Sirsi taluks of Uttara Kannada district along a series of transects. Figure 2 summarizes his conclusions. Along the coast there is a tendency to convert sand dunes to

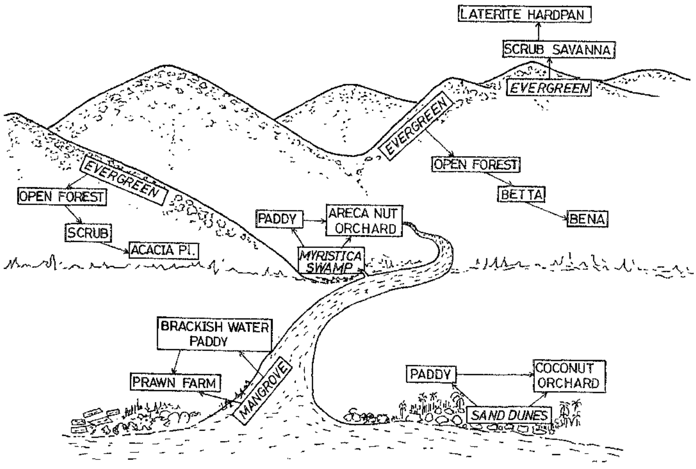

FIG 2. Ongoing patterns of landscape transformation in Uttara Kannada district.

coconut orchards either directly or *via* paddy cultivation. At the same time mangrove forests have been giving way to brackish water paddy cultivation, and more recently prawn farms. In the hills the characteristic *Myristica* swamps, a special vegetation association of narrow wet valleys is giving way to arecanut orchards, either directly or *via* paddy fields. The natural evergreen forest is being opened up and reduced to scrub and then converted to *Acacia auriculiformis* plantations by the forest department. In more exposed localities it may end up as a laterite hardpan with scanty shrub and grass growth. Where land is under private control the evergreen forest may be converted to so-called betta or bena lands. Betta lands are maintained under more open, deciduous tree growth to supply leaf manure to arecanut orchards; bena lands are maintained as grasslands for grazing livestock through annual fires.

But human impact on bird communities is less drastic. Daniels undertook 20 transects in man-made plantations along with 38 transects in the more natural vegetation (Table II). His studies showed that the plantations were poorer in number and diversity of plant species, in vertical stratification as well as in canopy density. However, planta-

Table II
Attributes of natural vegetation ($n = 38$) and man-made plantations ($n = 20$) of Uttara Kannada district

Attribute	*Vegetation type*	*Mean*	*SD*	*Minimum*	*Maximum*	*Statistical significance*
No. of woody plant species*	Plantations	11.89	5.99	1.00	23.00	S
	Natural vegetation	40.58	13.76	17.00	64.00	
Woody plant* species diversity	Plantations	3.70	2.08	1.00	7.90	S
	Natural vegetation	15.52	7.57	2.50	32.70	
Vertical stratification	Plantations	3.26	1.24	1.50	5.69	S
	Natural vegetation	4.34	0.85	2.25	5.59	
Canopy density	Plantations	1.23	0.57	0.26	2.21	S
	Natural vegetation	1.74	0.62	0.62	2.85	
C. V. of canopy density	Plantations	0.66	0.38	0.26	1.69	NS
	Natural vegetation	0.57	0.27	0.16	1.69	
Tree density	Plantations	114.44	94.37	21.00	305.00	S
	Natural vegetation	56.87	23.99	23.00	119.00	
Bird species richness	Plantations	17.33	4.84	10.00	31.00	NS
	Natural vegetation	18.66	7.10	4.00	31.00	

S: Plantations and natural vegetation differ significantly at $p < 0.01$

NS: Not significant by t test

* per 2400 m^2

+ $e^{H'}$, H' = Shannon–Weaver diversity index

$1/Ep_i^2$, where p is the proportion of individual plants in the ith height class

Mean of 120 points scored as 0, 1, 2 and 3

Coefficient of variation for the 120 scores

per 1000 m^2; plants ≥ 30 cm GBH

per transect 600 × 200 m.

Plantations and natural vegetation are significantly different at $p < 0.01$ (t-test) not significant tions had higher tree densities and mere patchy canopy. But notably enough there was no significant difference amongst the plantations and natural vegetation in the richness of the bird species. This may be related to the fact that the bird communities of the plantations are very similar to those of drier, more deciduous forests which harbour a richer species pool[6].

4. Response to disturbance

One of the least understood aspects of ecological change in India is the slow attrition of biomass in biological communities retaining forest physiognomy. In the district of Uttara Kannada, for example, the forest cover has declined from around 70 to 60% of land over the last 50 years. There is however no assessment of the change in levels of biomass or diversity in the 60% of the remaining land that continues under forest cover. We have examined from this perspective 30 of the 600 × 4 m transects located in natural evergreen forest sites[7].

When plotted in the phase space of number of plants per transect and the proportion of deciduous plants, these 30 transects segregate into two clusters of 20 and 10 (Fig. 3). It turns out that the cluster of 20 points includes sites significantly further from the nearest villages, with fewer foot paths, and lower incidences of grazing and fire. The

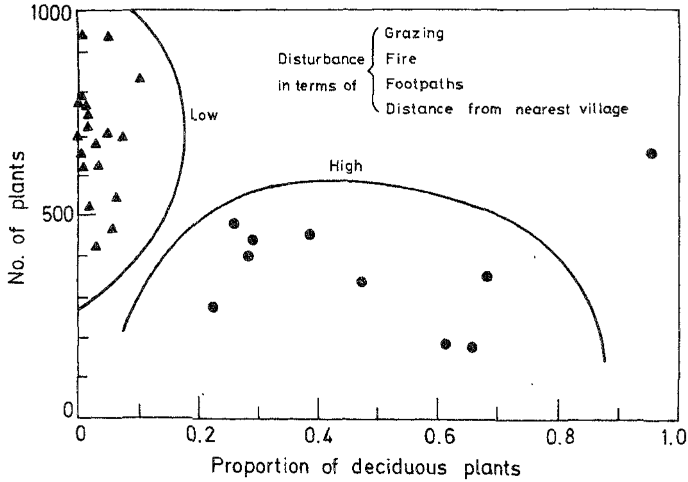

FIG. 3. Distribution of low (▲) and high disturbance (●) transects according to the fraction of individuals of deciduous species (x-axis) and the total number of individual plants (y-axis) in each transect.

Table III
Levels of disturbance

Height (m)	*Low*	*High*
0–1	0.213	0.328*
1–2	0.2*	0.171
2–4	0.242**	0.148
4–8	0.131	0.11
8–16	0.153	0.184
16–32	0.058	0.059
> 32	~0	0

* Statistically significant at 5%.
** Statistically significant at 1%.

Table IV
Disturbance level

	Low	*High*
Species richness	48.8 ± 5.6	35.7 ± 11.9
Species turnover	0.65 ± 0.1	0.73 ± 0.07
Number of plants/2400 M^2	694 ± 136	379 ± 135

All differences are statistically significant at 1% level

species composition of the two clusters of sites is also significantly more distinctive than would be expected on the basis of chance alone. These two clusters may therefore be compared to assess the differences between sites with low and high level of disturbance. The density of plants in sites with high levels of disturbance is roughly half that in sites with low levels of disturbance. There is no consistent difference in the distribution of individuals amongst different height classes, presumably because local villagers selectively remove smaller trees while commercial harvests tend to remove larger ones from the more disturbed sites (Table III). This suggests that the plant biomass loss from the more disturbed sites may be around 50%, probably over the last 50 years when the pace of forest exploitation has picked up with eradication of malaria, establishment of plywood and paper industries and a spurt in population growth. We may then estimate the rate of attrition of forest biomass at around 1.7% per year.

We have also looked at the differences in two indices of diversity, species richness, or number of species at a given site and species turnover, or the proportion of unshared species amongst any pair of sites with low or high levels of disturbance (Table IV). The sites with low disturbance level are significantly richer in species, but have lower levels of unshared species. However, both these differences are no more than what would be expected on the basis of the fact that sites with higher levels of disturbance have much lower plant densities.

But a more careful look at the species composition of the two sets of sites reveals many differences (Table V). Expectedly, there is preponderence of evergreen species on sites with low levels of disturbance, and deciduous species on sites with high levels of disturbance. Most interestingly sites with high levels of disturbance are significantly deficient in species with poor coppicing power in demand by plywood industry. Table VI provides a list of sets of species which are characteristic of the two types of sites.

5. Management regimes

Given the significance of human impact, an important applied question pertains to how these relate to various management regimes. We have attempted to look at this issue

Table V
Number of species

Attribute	*All sites*	*LD sites*	*HD sites*	*Only LD sites*	*Only HD sites*	*LD and HD sites*
Deciduous	33	23	31	2	10	21
Evergreen	121	107	65	56	14	51
Human demand	54	44	35	19	10	25
Coppicing possible	136	110	95	41	26	69
Used for plywood	36	30	23	13	6	17
Used for plywood and coppicing possible	27	21	21	6	6	15
Used for plywood but non-coppicing	9	9	2	7	0	2
Coppicing possible but no plywood use	109	89	74	35	20	54
Total	525	433	346	179	92	254

LD: low disturbance; HD: high disturbance.

through a study of 29 one ha plots located in Kumta and Siddapur taluks of Uttara Kannada district under a variety of situations[8]. Figure 4 depicts these in the phase space of number of trees of more than 30 cm girth at breast height *versus* number of species. The best sites lie in reserve forests on steep, inaccessible slopes of river Sharavathy. One of the most depleted sites is a so-called minor forest, an accessible reserve forest site which is left open to harvest by villagers without any authority to regulate. In contrast, two of the three village forest sites where local communities have a measure of regula tory authority are in better condition. Most notable are some of the sacred groves. In spite of being highly accessible some of these support diverse tree communities harbour-ing the few remaining stands of *Dipterocarpus* and *Myristica* swamp associates. This suggests that active participation by local communities could be a very significant step towards long-term conservation of the biological diversity of the Western Ghats.

Table VIa
Characteristically exclusively on sites with low levels of disturbances (in ≥ 7 out of 20 transects)

Syzigium gardneri *Myristica malabarica* *Holigarna grahamii* *Calophyllum elatum* *Dysoxylon malabaricum* *Polyalthia fragrans*	Industrial
Gnetum ula *Dicapetalum gelinoides* *Elaeocarpus sp.* *Neolitsea zeylanica*	Village use

Table VIb
Characteristically exclusively on highly disturbed sites (in ≥ 4 out of 10 transects)

Albizzia odoratissima
Cassia fistula
Dalbergia latifolia
Odina odier
Schleichera oleosa
Tectona grandis
Xeromphis spinosa

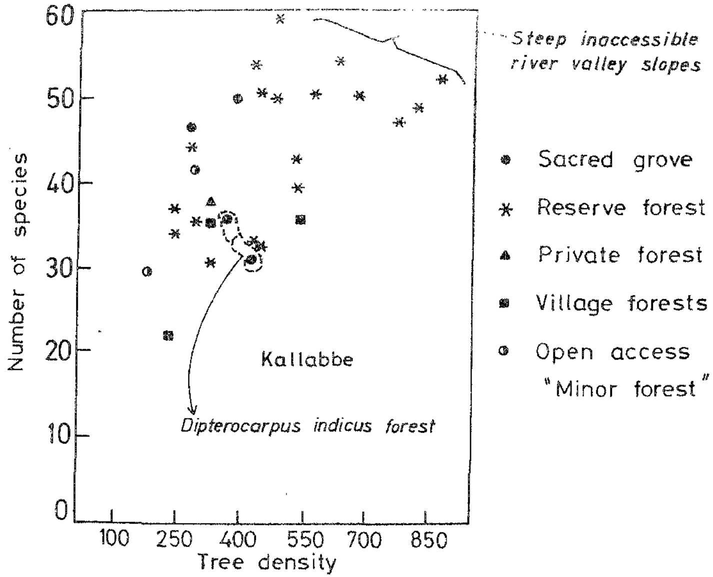

FIG. 4. Density of trees more than 30 cm in girth at breast height and number of species in one ha. sample plots.

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