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Vertical stratification and its relation to foliage in tropical forest birds in Western Ghats (India)

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Abstract. The study was carried out from May 1988 to April 1993 in two types of tropical forests: the tropical evergreen and moist deciduous. The vertical distribution of birds and foliage abundance was recorded by visual observation in seven height classes, using the line transect method. The vertical distribution of 94 bird species was recorded in evergreen forest, and of 90 in moist deciduous forest. Bird species richness and the numbers of birds were highest in the stratum from 1 to 5 m in both the evergreen forests (57 species) and the moist deciduous forests (68 species). The species richness indices of birds in the two types of forest did not display such a clear relationship. Foliage abundance was high up to a height of 30 m in the evergreen forests, whereas in moist deciduous forests, foliage was abundant only up to 20 m. A significant positive correlation was obtained between foliage abundance and species richness and also between the numbers of birds in both types of forests. Significant correlation was also obtained between foliage abundance and the species diversity indices in the two types of vegetation.

Key words: vertical stratification of birds, tropical forest, Western Ghats, Kerala, India

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INTRODUCTION

Foliage diversity of a forest stand has an important role in providing food for birds. This feature adds to the ability of tropical forests to harbor high bird diversity and density. The pioneering, studies of MacArthur & MacArthur (1961) established the relationship between bird diversity and foliage density. MacArthur et al. (1962, 1966) supported the above hypothesis. Some studies have documented negative relationship also (Wiens 1983). Other vegetation characters, which have significant effect on bird diversity, are foliage volume, percentage vegetation cover, percentage canopy cover (Karr & Roth 1971, James & Wamer 1982). Species composition and population density of canopy and understory birds were described by Munn (1985).

Even though many studies have been reported on the forest bird communities from South India (Johnsingh & Joshua 1994, Daniels 1996, Gokula & Vijayan 1996) relation between foliage abundance and bird diversity has not been dealt in detail. The aim of this paper was to describe the correlation between the abundance of birds in different height classes of tropical forest canopy with foliage abundance. The study forms part of a major investigation (Jayson 1994), which determined many ecological aspects of two bird communities. Seasonal changes in these bird communities were reported earlier (Jayson & Mathew 2000a). Similarly, diversity and species abundance distribution were also published (Jayson & Mathew 2000b).

STUDY AREA, MATERIAL AND METHODS

The study areas are located in Palghat District of Kerala State, (11°3'–11°13'N, 76°25'–76°35'E) in the SW Ghats, southern India. Two study sites were selected: a tropical evergreen forest, Silent

Valley, and a moist deciduous forest at Mukkali. The elevation of the sites varied from 500 m to 1500 m a.s.l. The topography is undulating. These two study sites are at a distance of about 20 km with a difference in elevation of 400 m between them.

In the classification of Udvardy (1975) Silent Valley and Mukkali falls under the Malabar Rain Forest Realm. According to the Biogeographic classification of Rodgers & Panwar (1989) the area falls under the Biogeographic Zone 5 Western Ghats, Biogeographic Province 5B Western Ghats Mountains and Biogeographic Sub-division Nilgiri. There are two distinct seasons in the study area. The monsoon season starting from end of May up to middle of November and the dry summer season from December to the first half of May. Compared to Silent Valley (5096 mm/year), mean annual rainfall was less at Mukkali (4227 mm/year). Temperature was high at Mukkali and it varied from 21°C in January to 27°C during April. A total of 966 species of angiosperm plants were recorded from Silent Valley and adjacent areas (Manilal 1988). Pascal (1988) described the vegetation of the Silent Valley as *Cullenia exarillata*, *Mesua ferrea-Palaquium ellipticum* type. It is characterized by the abundance of the three species and these may constitute about 80% of the large trees. Degraded areas and other vegetation types like grasslands are also found here. Vegetation of the Mukkali area is Southern Secondary Moist Mixed Deciduous Forest.

Analysis of vegetation

Three transects at one m interval between each one were laid 3 m away on both sides of the main transect line. Measurements were taken at one m interval on each transect line and thus 45 points (15 per transect) were covered on each side, providing 90 points from both sides. Foliage abundance in seven height classes was measured using the method described by Schemske & Brokaw (1981). Measurement was made at five-m height interval on each point. Height classes were 0–5 m, 5–10 m, 10–15 m, 15–20 m, 20–25 m, 25–30 m and > 30 m. Foliage abundance at each height category was assessed by recording the number of touches by vegetation to a imaginary vertical pole at each strata. Data from 90 points were pooled and depicted for each sampling station. Each such sites, 500 m apart, distributed in the main transect line were enumerated two times in two area in each season (summer and monsoon) for making foliage height profiles.

Census of birds

Variable width line transects was adopted for the census of birds (Burnham et al. 1981). In this method the observer walks through a fixed path counting the birds seen or heard on both sides of the path. Whenever a bird was spotted it was identified up to species (Ali & Ripley 1983a, 1983b) and details like the number of birds and perpendicular distance from the transect, height at which it is located in the canopy and habitat features were noted. Data from both the areas were pooled separately and classified into seven groups: 0 m, 1–5 m, 6–10 m, 11–15 m, 16–20 m, 21–30 m, and > 30 m. Species richness, abundance and diversity indices of birds in the each of the height classes were calculated, using the program SPDIVERS.BAS (Ludwig & Reynolds 1988). Spearman Rank Correlation was used to find out the correlation between foliage abundance and diversity parameters.

Two line transects were selected, each was 4 km in length. The first transect covered evergreen forests (EV) at Silent Valley and the second one covered habitats like moist deciduous forests (MD), rocky patches and fire burned moist deciduous forests at Mukkali. Census was started 30 minutes after sunrise in all the months. Transects were covered at a uniform speed. No census was done on days with very heavy rain and fog. Two samples were collected from each area in a month. The second sample was started from the end of the first sample. A total of 150 samples were collected between 1988 and 1993. No systematic data was collected on nocturnal birds. All calls were considered as single individuals.

Distribution pattern of rarely sighted birds were omitted from the analysis. To demonstrate the relationship between foliage abundance and bird community parameters coefficient of correlation was used. For this mean of foliage abundance at each stratum was calculated from the eight localities in each area.

RESULTS

Species richness of birds in height strata

Tropical evergreen forest (EV). Vertical distribution of 94 species of birds was recorded from Silent Valley. Only six species of birds used all the seven classes of height categories in the evergreen forests. These species can be termed as generalists and prominent among them were *Hypsipetes leucocephalus* and *Dicrurus adsimilis*. Important ground feeders were *Perdicula erythrorhyncha*, *Gallus sonneratii*, *Turdoides affinis*, and *Motacilla flava*. *Iole indica*, *Saxicola caprata*, *Nectarinia minima*, *Turdoides striatus* and *Megalaima viridis* were the common species recorded from the height category of 1–5 m. These species were common in the next height category also (6–10 m). *Hypsipetes leucocephalus* was another species recorded in abundance from this height. The 11–15 m height class was mainly occupied by species such as *Psittacula krameri*, *Gracula religiosa*, *Iole indica*, *Hypsipetes leucocephalus* and others. Height category between 16–20 m was also occupied by the same species. The vertical section up to 20 m was extensively utilised by a larger number of species than those above 20 m. Birds of prey like the *Spilornis cheela* and the *Elanus caeruleus* were seen in the top canopy. The highest number of bird species was recorded from the second height stratum 1 to 5 m, followed by third and fourth strata (Table 1). The lowest number of species was seen in the top stratum (Table 1). Species richness indices like Margalef Index confirmed the same trend. Highest value was recorded for the second height stratum followed by third and fourth strata. But highest value for Menhinick Index was obtained for the third and fourth strata (Table 1). The highest number of individuals (1492) was observed in the second height stratum of 1–5 m (Fig. 1).

Tropical moist deciduous forests (MD). Vertical height preference of 90 species was recorded from the moist deciduous forests and in this vegetation type also highest number of species was recorded from the second height stratum, followed by third and fourth strata (Table 1). Lowest species richness was obtained at the top most stratums. Highest value of Margalef Index was obtained again at the second stratum followed by third and fourth. Lowest value for both indices was recorded from the top most stratums (Table 1). Menhinick Index also established a similar trend. In this vegetation, the maximum numbers of birds were also found at the second stratum (991) followed by others in decreasing order (Fig. 1). However, one difference here was the occurrence of only few individuals at the top stratum, starting from 31 m and above. One disparity between the evergreen forest and moist deciduous forest was the paucity of birds above 30 m. In the moist deciduous forest the section up to 20 m was used extensively. A few parakeets, which were utilising the upper canopy, were the only occupants of the portion above 30 m. Only eight species were found to use all the first six height categories in the moist deciduous forests.

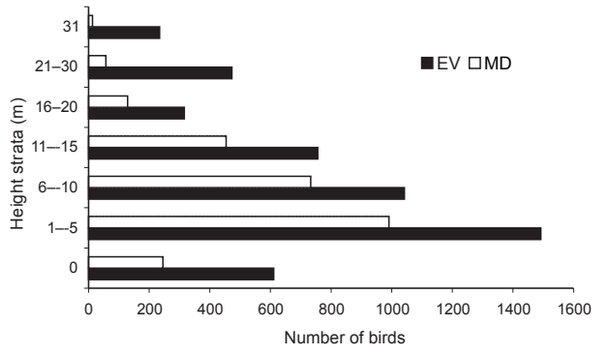

Fig. 1. Abundance of birds in height strata in both forest types studied. EV — evergreen forest, MD — moist deciduous forest.

Diversity of birds in different height strata

At tropical evergreen forests, the highest diversity index (H') was obtained in the second stratum followed by third and fourth. A slight reduction of diversity was observed from the fifth stratum onwards. Lowest diversity was recorded at the fifth stratum. The two indices demonstrated the same pattern of decrease (Table 1). Another pattern of difference in diversity index was obtained from tropical moist deciduous forests. The highest value of Shannon-Wiener index was obtained in

Table 1. Species richness (SRI) and diversity indices (SDI) of birds in different height strata in two study plots: evergreen forest (EV) and moist deciduous forest (MD).

Height (m)	Number of species		SRI				SDI			
			Margalef's		Menhinick's		Shannon-Wiener's (H')		Simpson's	
	EV	MD	EV	MD	EV	MD	EV	MD	EV	MD
0	35	30	5.30	5.27	1.42	1.92	2.79	2.83	0.09	0.08
1–5	57	68	7.67	9.71	1.48	2.16	2.89	2.81	0.11	0.17
6–10	53	54	7.48	8.03	1.64	1.99	2.71	3.28	0.16	0.05
11–15	45	44	6.64	7.03	1.64	2.07	2.80	3.25	0.09	0.05
16–20	22	27	3.65	5.35	1.24	2.38	2.23	2.91	0.16	0.06
21–30	32	21	5.03	4.95	1.47	2.78	2.35	2.73	0.17	0.06
> 30	21	3	3.66	0.77	1.36	0.83	2.35	0.54	0.14	0.71

the middle canopy starting from 6–10 m of height and the lowest at the top most stratums above 31 m (Table 1). The two indices followed the same pattern and Simpson's index also revealed the same trend (Table 1).

Foliage abundance in different height strata

In the evergreen forest and moist deciduous forest the foliage abundance was highest at 0–5 m then it reduced gradually as the height increased (Fig. 2) in both the seasons. No significant difference was obtained in foliage abundance between vegetation and between seasons.

Relation between foliage and abundance of birds

The results illustrated that as the height increased the foliage density decreased (Fig. 2) in both the forest types. The highest number of birds was also found in the strata of the highest foliage abundance. As the foliage abundance increased the diversity of birds and species richness were also increased in the evergreen forest. Similar patterns were found in the moist deciduous forest also. Total number of birds decreased as the foliage abundance reduced. High diversity and species richness were also found in the strata of higher foliage density. One difference found in the moist deciduous forest was that the decrease in diversity and species richness of birds and foliage abundances, in the two upper most levels was higher than in the evergreen forest. In the evergreen forest, significant negative correlation was obtained between foliage abundance and height ($r = -0.84$, $p < 0.05$, $n = 7$). Foliage abundance and number of individuals ($r = 0.93$, $p < 0.01$, $n = 7$) and foliage abundance and species richness ($r = 0.85$, $p < 0.01$, $n = 7$) also showed significant positive relationship. Significant positive correlation obtained between bird diversity indices at each height stratum with foliage abundance ($r = 0.79$, $p < 0.01$, $n = 7$).

In the moist deciduous forest also significant negative correlation was obtained between height and foliage abundance ($r = -0.96$, $p < 0.01$, $n = 7$). Here also the number of individuals and foliage abundance showed significant positive correlation ($r = 0.84$, $p < 0.01$, $n = 7$). Significant correlation was obtained between number of species and foliage abundance ($r = 0.93$, $p < 0.01$, $n = 7$). Significant positive correlation was obtained between foliage abundance and species diversity indices ($r = 0.79$, $p < 0.01$, $n = 7$).

DISCUSSION

Information on the vertical stratification of tropical forest birds is important for practical aspects of forest management and nature conservation. For long, it has been recognized that forest canopy has a complex structure that is significant for environmental interactions, regeneration, growth and biotic habitat (Parker & Brown 2000). Authors above reported that as there is difference in the transmittance of photo synthetically active radiation (PAR) along the different layers of canopy ecological conditions crucial for the birds are also varied. Some of the parameters, which are bound to change, are microclimate, food availability for frugivores and insectivores, food substrate and nesting sites.

Out of the 94 species of birds only six species has been using all the height categories in the evergreen forest. Species richness and diversity indices values revealed that middle canopy are highly utilised by the birds than the bottom or top

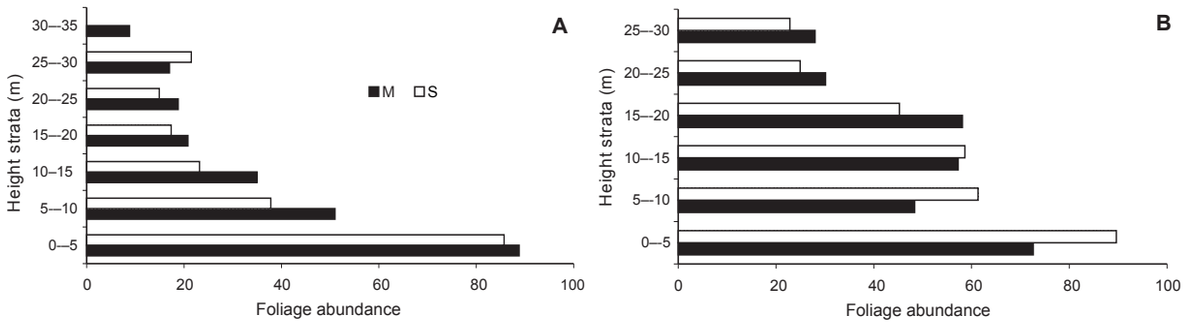

Fig. 2. Foliage height profile. A – at evergreen forest (EV), B – at moist deciduous forest (MD) in monsoon season (M) and summer (S).

canopy in evergreen forest and the moist deciduous forest. The study clearly established the positive correlation between foliage abundance and species richness and number of individuals.

Relationship between vertical foliage diversity and bird diversity had been established in 1960s. But until MacArthur & MacArthur (1961) devised a quantitative measurement of vertical foliage diversity it was not possible to depict this phenomenon quantitatively. Authors above obtained foliage diversity by visually estimating the proportion of total foliage in chosen horizontal layers and obtained best relationships in three horizontal layers in 0–0.7 m, 0.7 to 7.6 m and > 7.6 m in temperate Central America. For Australia Recher (1969) and for Europe Moss (1978) proved this relationship. Other workers also demonstrated the relationship between bird diversity and vegetation structure (Cody 1981, Verner & Larson 1989), but Pearson (1971) could not find such relationship. Vertical distribution of bird species in the canopy is related to microhabitat use and resource availability (Wiens 1989). Other vegetation features, which have significant effect on bird diversity, are foliage volume, density of vegetation cover (Karr & Roth 1971) percentage canopy cover (James & Wamer 1982). Ground feeders like *Gallus sonneratii*, *Turdoides* sp. and ground thrushes contributed to the higher number of omnivorous species at ground level. Insectivorous birds that depended on foliage were relatively higher in the middle canopy. Occurrence of nectar feeding birds in the lower canopy is explainable to the abundance of flowers in that level produced by the herbs and shrubs.

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STRESZCZENIE

[Rozmieszczenie pionowe ptaków lasu tropikalnego w zależności od warstwowości listowia]

Badania prowadzono w latach 1988–1993 w stanie Kerala (południowe Indie), w dwóch typach lasu tropikalnego: zawsze zielonym (EV) i wilgotnym liściastym (MD). Rozmieszczenie pionowe liczebności ptaków i obfitości listowia określano metodą transektową w 7 klasach wysokości (Tab. 1). Zebrano dane o 94 gatunkach w lesie EV i 90 gatunkach — w MD. W obu typach lasu bogactwo gatunkowe i liczebność ptaków były najwyższe w klasie wysokości 1–5 m (Fig. 1, Tab. 1), natomiast najniższe w warstwie najwyższej. Wskaźniki różnorodności wykazywały tę regularność w mniejszym stopniu (Tab. 1). W obu sezonach wegetacji (pora monsunowa i lato) obfitość ulistnienia zmniejszała się ze wzrostem wysokości (Fig. 2). Bogactwo gatunkowe i liczebność ptaków w obu lasach wykazały istotną pozytywną zależność od obfitości listowia, natomiast zależność ta nie uwidoczniła się we wskaźnikach różnorodności (Tab. 1). Wysoką różnorodność składu gatunkowego miała raczej średnia warstwa wysokości koron drzew.

T. Cofta