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A STUDY ON BIRD COMMUNITIES - HABITAT STRUCTURE RELATIONSHIPS IN PENCH NATIONAL PARK, M.P.

DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT,
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By
R. JAYAPAL

UNDER THE SUPERVISION OF
QAMAR QURESHI

WILDLIFE INSTITUTE OF INDIA
DEHRADUN

All mathematics would suggest
a steady straight line as the best
But left and right alternately
is consonant with History.

- W.H.Auden
(*The Labyrinth*)

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

This is to certify that Mr. R. Jayapal of the Wildlife Institute of India has carried out an original research work titled "A Study on Bird Communities - Habitat Structure Relationships in Pench National Park, Madhya Pradesh" in partial fulfillment of the M.Sc. (Wildlife Science) degree of Saurashtra University. These investigations were carried out under my supervision from November 1996 to June 1997. I also certify that this research work has not been submitted for any other degree to any University.

Qamar Qureshi

Date: 30th June 1997
Place: Dehra Dun

(SH. QAMAR QURESHI)
Faculty of Wildlife Biology

Post Box No. 18, Chandrabani, Dehradun - 248 001. India
EPABX : 640112 to 640115; Fax : 0135-640117; Gram : WILDLIFE
E-Mail:wii.isnet@axcess.net.in

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SUMMARY

There has been a number of studies on bird communities and their relationships with habitat features of floristics and physiognomy. In particular, the spatial distribution of bird communities along the axis of structural variables of a habitat has received a wider attention in the light of recent findings on landscape behaviour.

Most of these works relate to either temperate or neotropical forests and our knowledge of community dynamics of tropical deciduous forests is very limited, for there has been hardly any comprehensive study in the tropics. The present study was done in the deciduous forests of the Pench National Park, Central India (M.P) between November, 1996 and April, 1997 covering winter (November,1996-January,1997) and summer (March,1997-April,1997).

Seven distinct habitat types were identified for the study based on floristic and structural diversity. Seasonal data on 27 habitat structural variables were collected from bird-centred sampling plots. Point-count census technique was employed to study the bird population.

Principal Components Analysis (PCA) was used to determine the patterns of inter-relationships among the habitat structural variables. Canonical Correspondence Analysis (CCA) was done to understand the relationships of habitat components to the distribution of bird communities.

For guild analysis, two different sets of criteria were used to identify the guilds among the bird populations *viz.*, food type and foraging behaviour. Twelve guilds were recognized based on the food type and, six among the insectivores with respect to foraging behaviour.

The results of the PCA showed that habitat structural variables of tropical deciduous forests have a marked pattern of inter-relationships on two axes of landscape behaviour, *viz.*, heterogeneity and complexity. But they failed to reveal any such segregation *vis-a-vis* bird community structure, as the scale of measurement did not address all the members of the community. The spatial distribution pattern of bird communities in relation to habitat architecture was shown by CCA to be not very tenacious; the interactions of other extraneous factors like floristics, habitat dynamics, phenophases of vegetation, disturbance, or interactions within the community may influence the habitat selection process.

There was no linear correlation observed between Foliage Height Diversity and Bird Species Diversity; possible explanations and alternative views have been discussed briefly.

The response of bird communities to floristics was found to be inconsistent across habitat types as positive linear relationship was detected only for Teak-dominant forests in winter, and for *Anogeissus-Boswellia* forests and *Cleistanthus collinus* woodland in summer.

Guild compositions of various habitat types were not found to be significantly different from each other though the seasonal change was consistent across all the habitats.

1. INTRODUCTION

1.1 BIRD COMMUNITIES : PATTERN & PROCESS

The term 'community' has been defined in ecology by various authors in several ways with same fundamental connotations. MacArthur (1971), viewed community as any set of organisms currently living near each other and about which it is interesting to talk. Fauth *et al.* (1996), have recently proposed functional definitions for all the key terms like communities, guilds, assemblages, ensembles, etc. in an effort to simplify the jargon of community ecology.

Studies of bird communities have been a major area of research in community ecology, from both theoretical and empirical perspectives. A study on bird community, broadly speaking, works at two levels : pattern and process (MacArthur, 1971; Cody, 1974; Rice *et al.*, 1983; Emlen, 1986; Wiens, 1989). The recognition of pattern involves studies that search for and describe the structure and organization of communities, patterns in species diversity, distribution along environmental gradients (in terms of climatic parameters, topographic features, or disturbance.), correlation to habitat (vegetation) structure and dynamics, and their adaptive disposition *vis-a-vis* the cycling and availability of food resources. Community processes refer essentially to the functional component that includes interactions within communities such as competition, resource division, or niche-shift and, factors operating in habitat selection by particular taxa. In brief, process stands for the cause while pattern is the effect.

The focus of most of the bird community studies in the past has been on pattern, for a study on process, on the one hand calls for a great deal of knowledge of pattern, and hypotheses about processes on the other hand, are considerably more difficult to frame and test (Wiens, 1989). Further, the distinction between a pattern and a process is not always clear-cut (*Ibid.*).

1.2 HABITAT STRUCTURE & BIRD COMMUNITIES

The role of habitat architecture in structuring the community organization of birds has repeatedly been shown to be important (Erdelen, 1984). Habitat structure with respect to avian communities refers essentially to the configuration of vegetation; the structure can thus act in habitat selection as an ultimate factor by its association with critical resources like food, nesting sites, or cover from predators

(Rotenberry & Wiens, 1980). The structural components of habitat operate over a functional gradient of time and space, a phenomenon often referred to as landscape behaviour. And the response of bird communities to such landscape behaviour is an important correlate in habitat selection and spatial distribution of birds.

1.3 LITERATURE REVIEW

Robert H.MacArthur whose impacts were perceptibly dramatic on the ideas and approaches of his contemporary community ecologists (Fretwell, 1975), was probably the first biologist to look into the pattern of avian communities. Ever since MacArthur and MacArthur (1961) proposed, based on their seminal study on breeding birds of Florida, a linear correlation between bird species diversity (BSD) and foliage height diversity (FHD), there has been quite a number of studies most of which sought either to substantiate the correlation or to repudiate it. The criticism revolves basically around two issues :

i. Can the FHD alone (which itself is largely arbitrary), be taken to measure the structural complexity of vegetation? (Willson, 1974; Roth, 1976; James & Wamer, 1982; Rice *et al.*, 1984; Morrison *et al.*, 1992)

ii. Can such an empirical correlation, based on one study, be theoretically assigned a predictive value? (Fretwell, 1975; Wiens, 1989; Morrison *et al.*, 1992).

Taking cognizance of shortcomings in the methods used by MacArthur and reservations expressed about his inductive conclusions, subsequent studies embarked upon a multivariate approach that took into consideration a combination of FHD and other vegetation parameters, on both vertical and horizontal variability axes, as a measure of structural complexity (e.g. Karr & Roth, 1971; Willson, 1974; Roth, 1976; Holmes *et al.*,1979; Rotenberry & Wiens, 1980; Anderson, 1981; James & Wamer, 1982; Rice *et al.*, 1983a; Cody, 1985; Sherry & Holmes, 1985; Terborgh, 1985; Morrison *et al.*, 1992; Moskat & Waliczky, 1992; Brown & Stillman, 1993).

Another aspect of avian community ecology that has received a wide attention is whether it is the floristics or physiognomy of vegetation that chiefly determines the habitat selection in insectivores. Studies have indicated that insectivores respond more to structural characteristics of vegetation than to floristics (MacArthur & MacArthur, 1961; James & Wamer, 1982; Sherry & Holmes, 1985; Terborgh, 1985; Morrison *et al.*, 1992).

Interestingly, similar studies in sub-tropical forests of India indicate the opposite trend (Katti, 1989; Rai, 1991).

A majority of these ecological works look into the habitat association of bird communities in the light of their spatial distribution and very few studies have actually considered the implications of temoporal variations for the community structure (Morris, 1990; Vila *et al.*, 1996).

Though the Indian subcontinent is gifted with a rich diversity of birdlife and an equally diverse set of habitat types, our knowledge of general avian ecology (not to mention community ecology of birds), is still elementary (Ali & Ripley, 1983). But there is an imperative need for uncovering the complexity of community patterns of tropical avifauna (MacArthur, 1972), as what we know today of bird community structure and dynamics are largely based on works in temperate areas and a comparative study may be needed for a better understanding.

Given the current scenario of Indian ornithology in which even the fundamental information like geographical distribution, breeding biology, seasonal movements, foraging ecology, etc. of a majority of species are still poorly-understood (Ali & Ripley, 1983), it is not surprising to note that there are very few studies with an emphasis on community relationships.

Daniels *et al.* (1992), studied the bird communities of humid tropical evergreen forests in the Western Ghats, probably the only extensive study of this kind in India. It was found that bird species richness (BSR), was inversely related to woody plant species diversity and (plant species richness along) vertical stratification of vegetation, a pattern attributed to the impoverished understorey bird fauna like timaliids in the Western Ghats. They also pointed out that avian communities of drier vegetation (represented in plantations), showed the commoner trend of a positive correlation between BSR and vertical stratification of vegetation.

Katti (1989), studied the bird communities of Lower Dachigam valley in Kashmir. He concluded that unlike the majority of temperate examples where the pattern of avian communities is greatly influenced by structural complexity of vegetation, the Lower Dachigam avifauna seem to respond to a number of factors like food resource diversity and distribution, apart from structural diversity.

Rai (1991) found in his study on non-breeding bird communities of Rajaji NP, an inverse linear correlation between FHD and BSD. He observes that the vastly diverse habitats of tropical areas have a significant assortment of floristic as well as structural attributes that tend to reveal gradients but no well-defined patterns.

In a study on bird communities of riparian forests in Bori Wild Life Sanctuary, Pai (1993) infers that the bird species richness (BSR) is correlated to canopy cover in winter but is very highly correlated to FHD in summer.

1.4 OBJECTIVES OF THE STUDY

With this background, the present study was conceived, drawing ideas and methods freely from a host of past studies. But in view of short duration of study and other associated limitations, this study attempted, on a simple but operative scale, to look into the pattern of avian communities of dry- and moist-deciduous forests of the Pench National Park, with two broad approaches :

1. Within-Habitat Pattern :
    - How is bird species diversity correlated to structural complexity of vegetation, both vertically and horizontally?
2. Between-Habitats Pattern :
    - How do bird communities differ across various habitat types?

The main objectives of the study are :

1. To understand the inter-relationships of habitat structural components.
2. To investigate the spatial distribution and organization of bird communities in response to structural diversity of vegetation.
3. To study bird communities in relation to floristic diversity and richness.
4. To look into seasonal changes in guild structure both within and across various habitat types.

2. STUDY AREA

2.1 GEOGRAPHIC LOCATION & PHYSICAL FEATURES

The Pench National Park (Fig.1) lies in southern Madhya Pradesh, covering Seoni and Chindwara districts (79°07' to 79°22'E and 21°37' to 21°50'N). The total area of the Park which was notified in 1983 is 292.85 Km². The National Park forms the core zone of the Pench Tiger Reserve, which was commissioned under the Project Tiger in 1992.

The Pench river that cuts through the area in a north-south direction, bifurcates the Park into two parts, the 147.61 Km² of the Western Block which falls in the Chindwara forest division and the 145.24 Km² of the Eastern Block that forms the Seoni division.

The average altitude of the area is around 612 m. The Park is located in the southern reaches of the Satpura Hills and the terrain is highly undulating, criss-crossed by a number of seasonal streams and *nullahs*. The average rainfall is around
1400 mm, 80% of which is received during south-west monsoon between June and September.

2.2 VEGETATION

According to Champion and Seth (1968), the forests of the Pench NP are classified as follows :-

I. <u>Tropical Moist Deciduous Forests</u> ;

  i. TYPE 3B/C_{1b} Slightly moist teak forests

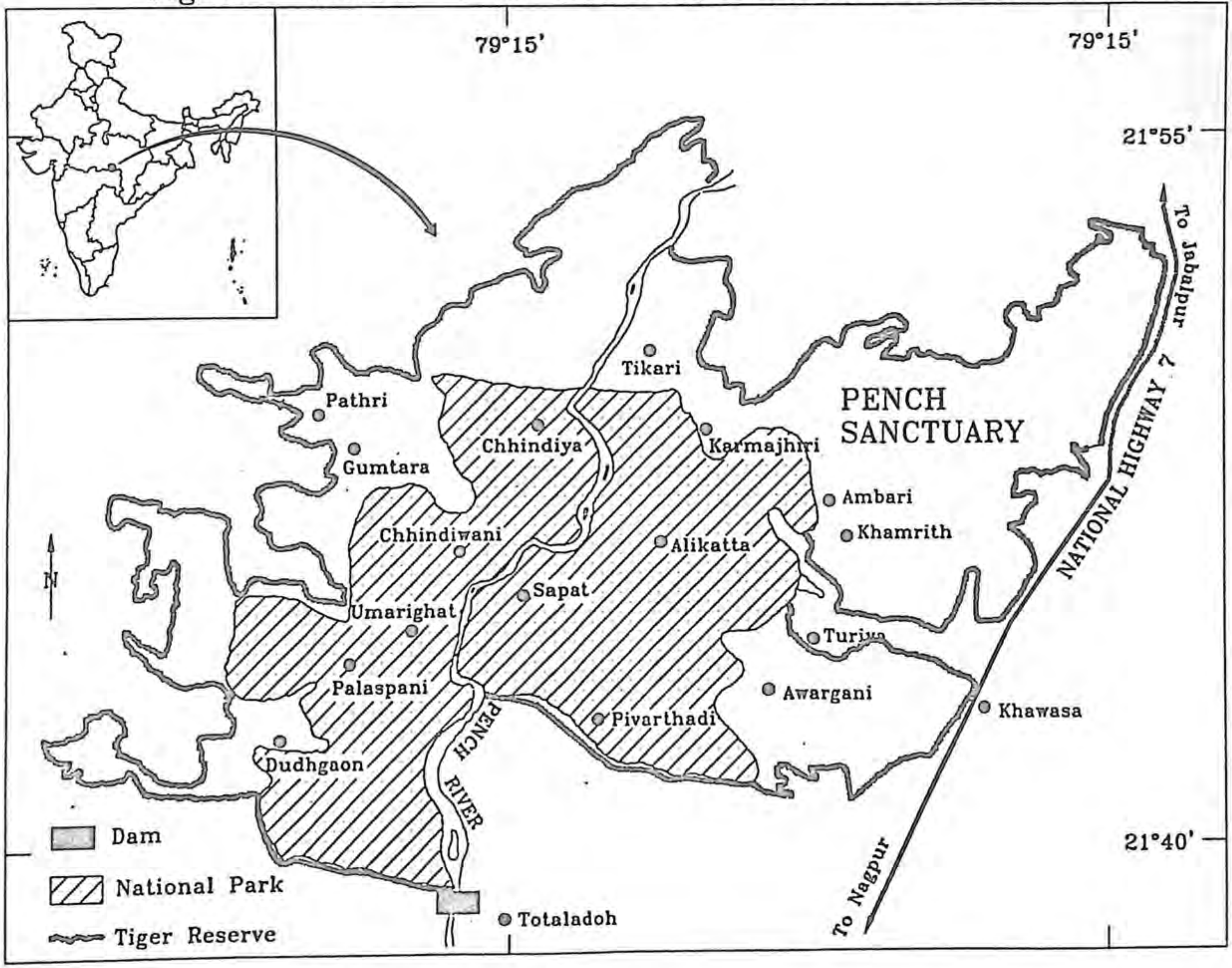
II. <u>Tropical Dry Deciduous Forests</u> :

  i. TYPE 5A/C_{1b} Dry teak forests

  ii. TYPE 5A/C_3 Southern dry mixed deciduous forests

Seven distinct habitat types were identified for the present study, based on floristic and structural diversity of vegetation :

Fig 1. PENCH TIGER RESERVE, MADHYA PRADESH



i. TEAK DOMINANT FORESTS :

This forms the major vegetation type in the Park and is characterized by the dominant population of teak (*Tectona grandis*), and *Lagerstroemia parviflora*. The other associated tree species that occur in relatively small numbers include *Miliusa velutina, Diospyros melanoxylon, Grewia tiliaefolia,* and *Bauhinia racemosa. Acacia pinnata,* a woody climber is quite common. *Grewia hirsuta* is the chief shrub species that occurs here.

ii. MISCELLANEOUS FOREST WITH TEAK :

The dominant trees are teak, *Lagerstroemia parviflora, Grewia tiliaefolia, Diospyros melanoxylon, Zizyphus xylopyra, Lannea coromandelica, Pterocarpus marsupium,* and *Kydia calycina. Butea superba* is the common woody climber found here.

iii. MISCELLANEOUS FOREST OF HIGHLANDS :

These forests are characteristic of the uphill slopes and teak is conspicuous by its absence. Major woody vegetation includes *Diospyros melanoxylon, Emblica officinalis, Zizyphus xylopyra, Buchanania lanzan, Terminalia tomentosa,* and *Ougeinia dalbergioides. Phoenix humilis,* is an important shrub forming the ground vegetation.

iv. *ANOGEISSUS + BOSWELLIA* DOMINANT FOREST :

Anogeissus latifolia and *Boswellia serrata* are the predominant trees and the terrain is marked with a good number of deep, narrow ravines and valleys. Other associated trees are mainly, *Ougeinia dalbergioides, Terminalia tomentosa, Semecarpus anacardium, Lagerstroemia parviflora,* and *Bridelia retusa.*

v. BAMBOO FOREST :

It is dominated by the bamboo species (*Dendrocalamus strictus*). Other trees found are *Ougeinia dalbergioides, Kydia calycina, Chloroxylon swietenia,* and *Albizzia odorotissima.*

vi. *CLEISTANTHUS COLLINUS* WOODLAND :

This forms one of the major unique vegetation types of the Park. It comprises of a small pocket of woodland and is almost exclusively formed of the tree species *Cleistanthus collinus* with no ground vegetation. Other trees found occasionally along with *C.collinus* include *Emblica officinalis, Diospyros melanoxylon,* and *Madhuca indica.*

vii. RIVERINE VEGETATION :

Though true riverine forests are absent in the Pench National Park, vegetation along the Pench river and streambanks contain several riparian species characterised by a structural diversity distinct from others. Major trees are *Terminalia arjuna, Madhuca indica, Mitragyna parvifolia, Ficus infectoria, Schleichera trijuga, Ixora parviflora, Diospyros melanoxylon,* and *Syzygium cumini.* The shrub *Helicteres isora* is commonly found in several clumps.

2.3 AVIFAUNA

No systematic study, has earlier been conducted on the bird diversity of Pench NP. However, a preliminary checklist of the Park, prepared by the Forest Department, puts the total number of species at 171 and 66 more species have recently been added. Of the 237 species of birds recorded so far in the park, waterfowl constitute 44 species and the remaining 193 are essentially woodland birds, the group which this study seeks to deal with.

Of them, raptors form 22 species, owls 7, woodpeckers 7, babblers 5, flycatchers 11 and warblers 14 (including 6 species of *Phylloscopus* sp.). For a detailed account of the birds of the Pench NP, refer to Appendix I.

3. METHODS

3.1 SAMPLING METHODS

Through a reconnaissance survey prior to the study, seven habitat types were identified and chosen based on floristic and structural diversities. These habitat types have been described in the previous chapter. The field work was done from mid November 1996 to April 1997, covering two seasons, i.e., winter (Nov.'96 - Jan.'97) and summer (Mar.'97 - Apr.'97). The seasons were defined in such a way that they amply reflected the phenological change in the local vegetation and were characterized by the movement of migrant birds.

Most of the past studies that aimed to correlate habitat variables and birds have employed a multitude of field methods to quantify the component variables and such methodological divergencies may even, very often preclude any comparison (Erdelen, 1984). For this study, bird-centered vegetation sampling (James, 1971; Whitmore, 1975; Larson and Bock, ----) was opted for, owing to the following reasons:

1. Consistency and repeatability of bird and vegetation sampling
2. Generation of larger sample size
3. Sensitivity to microhabitat correlates or the finer level of scale, at which bird communities are correlated to the habitat structure.

Sampling of study plots was done by stratified random technique (Snedecor and Cochran, 1967; Krebs, 1989) in which 12 points were sampled in each habitat type with the minimum point-to-point distance being 150-200 m. All the points (7 X 12 units) were marked and used as permanent study plots for monitoring bird populations and quantifying vegetation parameters. The sample size of 12 points was arrived at by plotting cumulative frequency curve of bird species richness against number of plots.

3.2 BIRD CENSUS METHODS

Bird population data were collected using variable-width circular plot technique (point count with unlimited distance), which was preferred to the widely-used line-transect method as point counts are ideal in fine-grained habitats if identification of habitat determinants of bird communities is an objective of the study (Bibby *et al.*, 1992; see also MacArthur, 1964; Blondel *et al.*, 1981; Edwards *et al.*, 1981; Verner, 1985).

Moreover, point counts facilitate our efforts to elicit correspondence of structural variables of vegetation to bird communities at finer scale as the same points are used to lay vegetation plots. But, violation of certain assumptions leads to much larger errors in density figures with point counts, because the area sampled with point counts increases geometrically with distance from the observer (Verner, 1985); nevertheless, point count technique was employed as the study did not involve any density estimation.

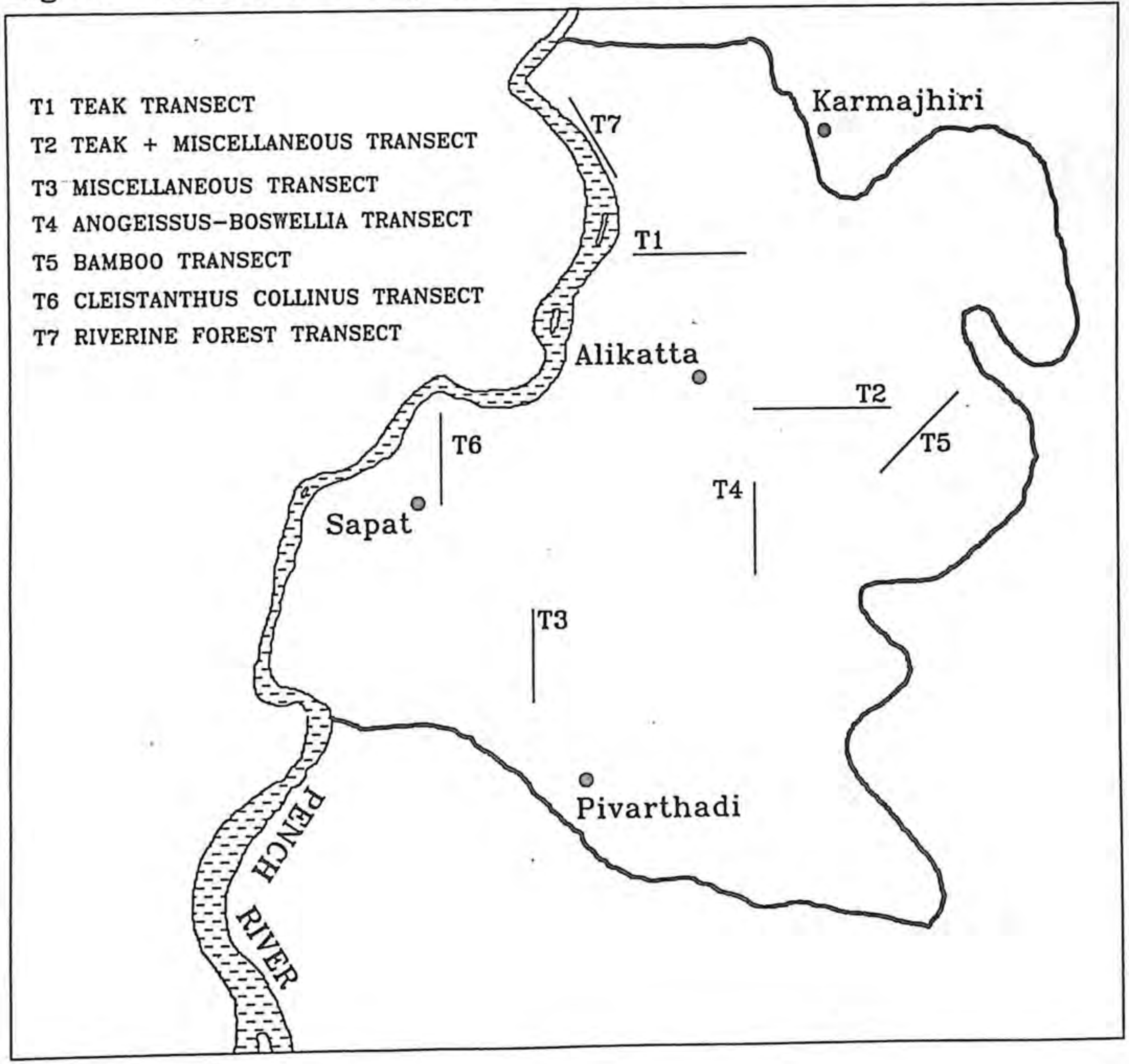
Line transects were also laid in all the habitat types (Fig.2) and data were collected to assess the bird population trends, though these data were not used for correlational and guild analyses.

The timing of the census operations was kept consistent throughout the season, in accordance with the time of maximum activity of bird life. Bird counts were done between 0730 hrs and 1000 hrs in winter and between 0645 hrs and 0915 hrs in summer. The duration of point count at each point was kept at 10 minutes allowing the first two minutes for the birds to settle (Verner, 1988). Evening operations were not undertaken as the sample counts showed a drastic decline in the number of detected bird species owing probably to minimal bird activity in evenings. Two replicates of point counts and two replicates of line transects were undertaken per habitat per season.

3.3 VEGETATION PARAMETERS

Circular plots of 10 m radius were sampled for vegetation quantification at the same points where point counts for birds were done in all the seven habitats. As mentioned elsewhere, the vegetation parameters of both vertical and horizontal variables were measured. Though some of the variables are correlated to some extent, they are nevertheless taken into account to see if there is any differential response from avian communities. Vegetation parameters were measured for both winter and summer separately.

Fig 2. Intensive study area showing locations of transects



3.3.1 Vegatation parameters of vertical variability:

TREE SIZE :

All the woody plants including lianas having a GBH (girth at breast height) of >15 cm and a height of >3 m were considered as trees. Tree size was measured and expressed as GBH.

HEIGHT OF CANOPY TOP (CT) :

The heights of the trees were measured approximately by using a protactor and referring to a standarized conversion table of degrees to heights. Occasional protrusions of the overstorey canopy were excluded.

HEIGHT OF CANOPY BOTTOM (CB) :

Height of the lowest branch which is functionally a dividing line of upper dense canopy and lower, sparse sub-canopy layers was recorded for each individual tree in the plot (Emlen, 1956).

SNAG VARIABLES :

The number and height of dead trees (snags) were measured.

BLOCK GEOMETRY OF CANOPY (BG) :

The geometrical shape of the canopy if considered as a block, is likely to influence the structure and composition of bird communities of the canopy layer. Accordingly, four classes of block geometry were conceived as below, and the number of individuals under each class were recorded:

i. Homogeneously dense canopy, e.g. *Buchanania lanzan*

ii. Homogeneously sparse canopy, e.g. *Tectona grandis*

iii. Dense interior and sparse periphery, e.g. *Terminalia tomentosa*

iv. Sparse interior and dense periphery, e.g. *Lagerstroemia parviflora* (Fig.3)

However, it is to be noted here that within a species, individual variations were quite high and hence all the individual trees were separately assessed and grouped.

SCREENING EFFICIENCY OF CANOPY (SE) :

It is best defined and measured in terms of the percentage of background obscured by a layer of foliage of given thickness; though in reality, it is the product of screening efficiency and canopy depth rather than the screening efficiency *per se* (Emlen, 1956). Three classes were made as below, and number of individuals under each class were noted:

1. SE >75%
2. SE 30-75%
3. SE <30%.

TWIG TYPE FOR PERCH QUALITY (TT) :

Though Emlen (1956) has identified six classes of twigs based on the inclination of branches, only two groups were identified in the study area :

1. Horizontal: A majority of branches are lying perpendicular to the trunk, i.e. angle between branch and trunk is 60-90°.
2. Steep: A majority of branches are sloping upwards steeply. i.e. the angle between the branch and trunk is < 60°.

The number of individuals in each category was recorded.

CANOPY VOLUME (CV) :

The volume of the canopy was calculated for trees of Block Geometry classes 1,2, and 3 using the formula (Morrison *et al.*, 1992):

CV = crown cover x canopy height.

Crown cover has been dealt with later in this section, while the difference between canopy top and canopy bottom gives the canopy height. This method was used for trees belonging to BG classes 1, 2 and 3.

For the trees of BG class 4 (sparse interior and dense periphery), canopy volume was calculated using the formula (Sturman, 1968):

$$CV = 2\pi/3\ (h_o r_o^2 - h_i r_i^2)$$

where, h_o = height of the canopy

$h_i = h_o$ - thickness of the peripheral foliage layer
(height of the sparse core of the canopy)

r_o = radius of the canopy

$r_i = r_o$ - thickness of the peripheral foliage layer
(radius of the sparse core of the canopy).

FOLIAGE HEIGHT DIVERSITY (FHD) :

Foliage height diversity which is an estimate of foliage cover at various height bands taken vertically through woodland (MacArthur and MacArthur, 1961; MacArthur & Horn, 1969), was measured using a standard ocular tube (Bibby *et al.*, 1992). The number of leaves was counted and noted for 16 height-bands of 1 m interval from 0 to >15 m. I walked a parallel line, 10 m away from the central axis of the circular plot and the number of leaves was noted at every 1 m point, with a corresponding 1 m increase in the vertical height-band. FDH thus calculated actually reflects the dimensional nature of foliage profile.

3.3.2 Vegetation parameters of horizontal variability:

DISPERSION INDEX :

All the individuals of woody plants in a circular plot were mapped using a magnetic compass and the point-to-plant distances were measured from the vegetation map to calculate the dispersion index.

Apart from this, a simple measure of dispersion index using tree-abundance data was also made (Krebs, 1989) which is given by the variance-mean ratio.

CROWN COVER (CC) :

The lengths of the two axes of the crown perpendicular to each other were measured (D_1 and D_2), and crown cover was expressed as (Mueller-Dombois and Ellenberg, 1974):

$$CC = [(D_1 + D_2) / 4]^2 \times \pi$$

OVERSTOREY CANOPY DENSITY (OCD) :

Ten spherical densiometer readings were taken at random points in a circular plot and overstorey canopy density was calculated and expressed as percentage canopy density on the horizontal axis.

SAPLING MEASURES :

In a dry deciduous forest, the ground cover is mainly formed of saplings. Barring shrubs, all the plants of GBH <10 cm and height <3 m were considered as saplings, and the number and heights were noted.

SHRUB MEASURES :

The following parameters were measured for all the shrubs (shrub was defined floristically rather than functionally):

1. Shrub abundance (SHRAB)
2. Shrub volume (SHRV)

GROUND COVER :

The ground cover was expressed as percentage occupancy of the following 5 components:

1. Grass (GRA)
2. Rock (RCK)
3. Gravel (GRV)

4. Bare soil (BS)
5. Leaf litter (LL).

Five 0.5 m X 0.5 m random quadrats were used for the estimation. In addition, data on mean grass height (GRHT) and leaf litter depth (LLD) were collected. LLD was measured by piercing a sharp quill into the litter layer and counting the number of leaves stuck on the quill. Average slope of the terrain was estimated as percentage.

FALLEN LOG VARIABLES :

Fallen wood pieces of > 7.5 cm in diameter (i.e. > 24 cm girth) were considered as fallen logs (Dueser and Shugart, 1978). The following variables were measured in each 10 m vegetation plot.

1. Fallen log abundance (FLA)
2. Fallen log girth (FLG)
3. Fallen log length (FLLN).

TERMITARIES :

The termitaries in each plot were counted in two terms:

1. Number of termitaries on ground (TERMG)
2. Number of termitaries on tree-trunk (i.e, the number of trees infested with termite colonies) (TERMT).

3.4 ANALYSIS

3.4.1 Species Diversity

The species diversity index for birds, trees and shrubs were calculated using the Shannon-Wiener Index (H') as follows:

$$H' = - \Sigma P_i \log_e P_i$$

where P_i is the proportion of the community that belongs to the i^{th} species.

Species diversity itself is an ecological concept that defies any satisfactory mathematical definition as it is the function of two separate components: species richness and the equitability or evenness of species abundances (Lloyd and Ghelardi, 1964; Tramer, 1969; Pielou, 1978; Magurran, 1988; Krebs, 1989). Shmida and Wilson (1985) have shown that species diversity is actually influenced by four biological determinants: niche relations, habitat diversity, mass effects, and ecological equivalency. However, Shannon-Weaver Index is probably the only mathematical function of the P_i values that reflect, if not fully, the two diversity components, i.e. species richness and evenness of abundance (Tramer, 1969; Pielou, 1978).

3.4.2 Species Richness

Communities of birds and trees are simple enough to permit a complete count of the number of species present, and hence the species richness is taken simply as the total number of species present (Krebs, 1989).

3.4.3 Other Diversity Indices

Other diversity indices, *viz.* Block Geometry Diversity (BGD), Screening Efficiency Diversity (SED), and Twig Type Diversity (TTD) were calculated using Shannon-Wiener's index (refer to Section 3.4.1).

3.4.4 Foliage Height Diversity

Foliage height diversity was calculated using Shannon-Wiener's formula (refer to Section 3.4.1) (MacArthur and MacArthur, 1961; Karr and Roth, 1971; Pearson, 1971; Willson, 1974; Roth, 1976; James and Wamer, 1982; Erdelen, 1984; Rice *et al.*, 1984; Morrison *et al.*, 1992), where P_i refers to the total area of the leaves of the i^{th} plant species, expressed as a proportion of the total leaf area of all the species on the census plot.

3.4.5 Multivariate Analysis of Influence of Structural Variables on Bird Communities:

Subsequent to MacArthur's seminal study on the relationships between FHD and BSD, several avian community ecologists have emphasized the need for multivariate approach as it has been shown that a number of habitat variables rather than a single parameter plays a role in structuring bird communities (Karr and Roth, 1971; Holmes *et al.*, 1979; Rotenberry and Wiens, 1980; Anderson, 1981; James and Warner, 1982; Rice *et al.*, 1983b; Morrison *et al.*, 1992; Moskat and Waliczky, 1992; Brown and Stillman, 1993).

Principal Components Analysis (PCA), (Norusis, 1990), was employed to extract axes (sets of linear combinations of the observed structural variables), where the first principal component is the combination that accounts for the largest amount of variance in the sample. (In other words, PCs are sets of correlated variables transformed to uncorrelated, independent variables). These 'Factors' were then put to Factor Analysis, to obtain unrotated factor matrix and rotated factor matrix of axes (sets of variables), that brings forth maximum variation in the observed distribution.

Canonical Correspondence Analysis (CCA) ordination was done using CANOCO package (Ter Braak, 1986), to relate bird species composition to the structural variables of the habitat. This programme identifies an environmental basis for community ordination by detecting the patterns of variation in community composition that can be explained best by the environmental variables (Ter Braak, 1986). In the resultant ordination plot (Fig.4 & 7), species and sites were represented along the correlation arrows of structural components. In other words, CCA is the technique that selects the linear combination of environmental variables that maximizes the dispersion of the species scores (Ter Braak, 1987).

Standard, multivariate statistical techniques assume linear relationships among variables, but have found only limited application in ecology because of the generally non-linear, non-monotone response of species to environmental variables, and many of these techniques are essentially heuristic and have a less secure theoretical basis (Ter Braak and Prentice, 1988). CCA on the other hand, is based on a theory of statistics, *viz.* regression, calibration, ordination and constrained ordination are treated as distinct, well-defined statistical problems. Moskat and Waliczky (1992), have shown that CCA demonstrated the dynamical aspects of changes in bird community structure with respect to structural changes of vegetation along ecological gradients.

3.4.6 Other Statistical Tests

The following tests were also employed using SPSS.WIN95 package for the purposes mentioned below:

i. Kolmogorov - Smirnov Goodness of Fit Test for the normal distribution of relevant variates prior to the application of all parametric tests.

ii. T-test for Paired Samples for comparing Bird Abundance (BA), Bird Species Richness (BSR), and Bird Species Diversity (BSD), obtained from two replicates of a season.

iii. Wilcoxon Matched Pair-Signed Rank Test for deducing the significance level of seasonal change in BSD and BSR in a habitat.

iv. Multiple Regression of Bird Species Richness (BSR) with Bird Species Diversity (BSD), and of woody Plant Species Richness (PSR) with woody Plant Species Diversity (PSD), across habitats to find out regression coefficient.

v. Spearman Correlation Coefficient for comparing BSD with PSD, and BSR with PSR.

vi. T-test for Paired Samples to detect seasonal change in FHD in all habitats.

vii. Pearson's Correlation Coefficient for determining the nature of relationship between FHD and BSD, and between FHD and log-transformed BSR across all habitats.

3.4.7 Analysis of Guild Structure

Root (1967), defined guild as a group of species that exploit the same class of environmental resources in a similar way and that overlap significantly in their niche requirements irrespective of their taxonomic relationships. Many studies in avian community ecology have looked into community structure in terms of guilds (Cody, 1974; Holmes *et al.*, 1979; Landres & MacMohan, 1980; Wagner, 1981), but most of them failed to distinguish between criteria and considerations of guild assignment (Simberloff & Dayan, 1991). A most common fault involves clumping of two different sets of guilds viz., trophic and foraging-behavioural guilds into a single and untenable analytical criterion.

Based on the available literature (Ali & Ripley, 1983 in particular) and *ad libitum* observations, 12 trophic guilds based on the type of food resources were identified in the study area:

1. Granivores : Exclusive grain-feeders
2. Insectivores : Exclusive insect-feeders
3. Frugivores : Predominantly fruit-eating birds
4. Insect + Grain feeders

5. Insect + Fruit eaters
6. Insect + Nectar foragers
7. Insect + Nectar + Fruit feeders
8. Insect + Small Vertebrate feeders
9. Fruit + Grain feeders
10. Fruit + Nectar feeders
11. Aquatic Fauna feeders
12. Omnivores

All the insectivorous birds (irrespective of diversification of their other food resource choices), were classified into six foraging-behavioural guilds as follows:

1. Foliage gleaners : That probe into canopy layer of both overstorey and understorey woody plant species.
2. Bark feeders : That feed on the tree trunks like woodpeckers.
3. Air-sallyers : That resort to air-sallying from a perch.
4. Ground-sallyers : That frequently alight to ground usually from a low perch for picking up an insect and settle again on perches.
5. Undergrowth foragers : That move almost entirely within the undergrowth (grasses & shrubs) probing for insects.
6. Ground foragers : That forage on ground mostly rummaging through leaf litter cover.

These two sets of guilds were analysed separately and independent interpretations were done.

4. RESULTS

4.1 PCA AND FACTOR ANALYSIS

Totally, 29 habitat structural variables were treated with Principal Component Analysis to extract the factors of significant contribution to variation, and PCA identified 8 factors. The Kaiser-Meyer-Olkin test of sampling adequacy for factor analysis computed a value of 0.6 which is ranked as mediocre (Norusis, 1990). For eigenvalues and percentage of variance of each factor, refer to Table.1.

After rotation of factor matrix, it was found that factors 1,2, and 3 consisted of structural variables that showed a higher amount of inter-relationship. Significant habitat components of factor 1 include snag abundance, height of canopy top, sapling abundance, snag height, and sapling height.

Factor 2 comprised of grass percentage, leaf litter percentage, leaf litter depth, grass height and GBH of woody plant species.

Canopy cover, canopy volume, and tree abundance forms the core of factor 3.

4.2 CANONICAL CORRESPONDENCE ANALYSIS

4.2.1 Ordination of Winter Data

Of four ordination axes obtained by CCA for the correlational analysis of habitat structure (environmental variables), and bird communities (species variables) for winter (Fig.4), the species-environment correlation coefficient was high for all axes (Table.2), while the eigenvalue which is a measure of separation of the species distributions along the ordination axes (Jongman *et al.*, 1987) was high only for first two axes. In other words, the accuracy of correspondence between related pair of species and environment was found to be good only for first two axes though the correlation coefficient was very significant for all axes. Tests for regression coefficient (expressed as t-value) identified six structural variables viz., canopy volume, sapling height, grass %, leaf litter, tree abundance, and tree termitaries operating on the first axis while the species co-ordination for t-value biplot gave rise to the species Jerdon's Chloropsis (*Chloropsis cochinchinensis*).

Leaf litter depth forms the only major structural variable of Axis 2 along which bird species like Rufous Turtle-Dove (*Streptopelia orientalis*) , Ashy Drongo (*Dicrurus leucophaeus*) , Grey-headed Flycatcher (*Culicicapa ceylonensis*) , and Common Iora (*Aegithina tiphia*) are distributed.

TABLE 1. **Results of Factor Analysis by PCA after rotation of Factor Matrix.**

KMO value for sampling adequacy=0.6

FACTOR	EIGENVALUE	% of VAR	STRUCTURAL VARIABLES
1	5.664	19.5	Snag Abundance, Canopy Top, Sapling Abundance, Snag Height, Sapling Height.
2	3.739	12.9	Grass %, Leaf Litter%, LL depth, Grass Height, GBH.
3	3.286	11.3	Canopy Cover, Canopy Volume, Tree Abundance.
4	2.488	8.6	Plant Species Diversity, Tree Dispersion Index, Block Geometry Diversity, Screening Efficiency Diversity.
5	2.169	7.5	Fallen Log Girth, Fallen Log Abundance, Fallen Log Length.
6	1.589	5.5	Terrain Slope, Canopy Bottom, Tree Termitaries.
7	1.257	4.3	Shrub Volume, Ground Termitaries.
8	1.149	4.0	Shrub Aabundance.

TABLE 2. Results of Ordination by CCA: Eigenvalues and Species-Environment Correlation Coefficients for the first four axes in Winter (Nov'96-Jan'97) and Summer (Mar'97-Apr'97).

SEASON	CORRELATE	Axis1	Axis2	Axis3	Axis4	F-STATISTIC
Winter	Eigenvalue	0.749	0.507	0.364	0.364	Trace=4.51 F-ratio=1.32 p value=0.02
	Cor. Coeff.	0.985	0.835	0.789	0.867	
Summer	Eigenvalue	0.356	0.320	0.280	0.216	Trace=2.97 F-ratio=1.12 p value=0.04
	Cor. Coeff.	0.873	0.895	0.853	0.838	

Monte-Carlo Test

Number of Permutations : 99

Upon the third axis, canopy cover and shrub abundance are likely to influence the distribution of Tickell's Blue Flycatcher (*Muscicapa tickelliae*), Shama (*Copsychus malabaricus*), Crimson-breasted Barbet (*Megalaima haemacephala*), and Large Green Barbet (*Megalaima zeylanica*).

No significant bird species was identified on Axis 4 which is governed by tree dispersion ratio, ground termitaries, and leaf litter percentage (see Fig.4).

The overall results of Monte Carlo test for winter (no. of random permutations : 99), showed a trace value of 4.51 with significant F-statistic ($F=1.32$, $p \leq 0.02$).

4.2.2 Ordination for Summer Data

CCA done for summer data yielded some interesting correlations between structural variables and bird species though the ordination plot (Fig.7) contained a good amount of *noise*. The eigenvalues for all four axes were relatively low despite the consistency of high correlation coefficients across all axes (Table 2).

Regression coefficient tests (expressed as t-value) spotted five structural variables viz., tree species diversity, snag height, sapling height, ground termitaries, and tree dispersion ratio operating along the first axis. Jungle Babbler (*Turtoides striatus*) and Large Cuckoo-shrike (*Coracina novaehollandiae*) were correlated to ground termitaries, while snag height plays a role in the distribution of Little Green Bee-eater (*Merops orientalis*) and Jungle Crow (*Corvus macrorhynchus*).

On Axis 2, a combination of three structural components viz., overstorey canopy density, tree species richness, and block geometry diversity influence the abundance of Malabar Pied Hornbill (*Anthracoceros coronatus*), Grey-headed Myna (*Sturnus malabaricus*), White-eye (*Zosterops palpebrosa*), Yellow-fronted Pied Woodpecker (*Picoides mahrattensis*), Red Turtle-Dove (*Streptopelia tranquebarica*), and Blossom-headed Parakeet (*Psittacula cyanocephala*).

Though Axis 3 has five variables, namely tree termitaries, sapling height, screening efficiency diversity, and height of canopy bottom, Black-naped Monarch Flycatcher (*Hypothymis azurea*) which is the sole species detected, has closer eigenvector values to the the distribution arrows of only the last two components (see Fig.7).

TABLE 2. **Results of Ordination by CCA: Eigenvalues and Species-Environment Correlation Coefficients for the first four axes in Winter (Nov'96-Jan'97) and Summer (Mar'97-Apr'97).**

SEASON	CORRELATE	Axis1	Axis2	Axis3	Axis4	F-STATISTIC
Winter	Eigenvalue	0.749	0.507	0.364	0.364	Trace=4.51 F-ratio=1.32 p value=0.02
	Cor. Coeff.	0.985	0.835	0.789	0.867	
Summer	Eigenvalue	0.356	0.320	0.280	0.216	Trace=2.97 F-ratio=1.12 p value=0.04
	Cor. Coeff.	0.873	0.895	0.853	0.838	

Monte-Carlo Test

Number of Permutations : 99

Along Axis 4, tree termitaries besides snag abundance and shrub volume correspond to the distribution of Lesser Golden-backed Woodpecker (*Dinopium benghalense*) and Paradise Flycatcher (*Terpsiphone paradisi*) .

The overall results of Monte-Carlo test (number of random permutations : 99), for summer showed a trace value of 2.97 with significant F-statistic (F ratio : 1.12, $p \leq 0.04$).

4.3 BIRD SPECIES DIVERSITY & BIRD SPECIES RICHNESS

T-test for Paired Samples was done separately for winter and summer to find out the significance of difference in BSD and BSR between two replicates within a season. No difference was detected for all habitats in winter (df=11, $p \leq 0.05$; Table.3); the two replicates were shown to have recorded two populations of equal mean and variance. Similar trends were detected for summer replicates in all habitats except Teak-dominant forest where the differences in BSD and BSR of two replicates were quite significant (df=11, $p \leq 0.05$; Table.4).

In Wilcoxon Matched Pairs - Signed Ranks Test, employed to find the significance level of seasonal change in BSD and BSR between winter and summer in all habitats, the differences were found to be significant in all habitat types barring Teak-dominant forest and Miscellaneous + Teak forest (df=11, $p \leq 0.05$; Table.5).

The results of the Multiple Regression, done to ascertain the nature of correlation between BSR and BSD across all habitats (Sec. 3.4.6) have established a linear correlation in both winter and summer ($R^2 = 0.687$ & 0.801 respectively, (df=82, $p \leq 0.05$; Table.6). Yet, the regression coefficient (slope of regression curve) was perceptibly higher in summer.

4.4 PLANT SPECIES DIVERSITY & PLANT SPECIES RICHNESS

The results of the Multiple Regression (Sec. 3.4.6) showed a significant linear correlation between woody plant species diversity (PSD), and woody plant species richness (PSR) across all habitats ($R^2 = 0.805$, df=82, $p \leq 0.05$; Table.7).

TABLE 3. Comparison of Bird Species Richness(BSR) & Bird Species Diversity (BSD) between two Replicates in Winter (Nov'96-Jan'97) in Pench NP, M.P.

HABITAT	INDEX	T-STATISTIC
1. Teak	BSR	t=1.43 2-tail sig. 0.180 SE=0.466 CI (-0.359, 1.693)
	BSD	t=1.09 2-tail sig. 0.299 SE=0.115 CI (-0.128, 0.379)
2. Misc+Teak	BSR	t=1.34 2-tail sig. 0.206 SE=0.434 CI (-0.379, 1.840)
	BSD	t=1.25 2-tail sig. 0.236 SE=0.122 CI (0.155, 420)
3. Misc.	BSR	t=1.38 2-tail sig. 0.194 SE=0.482 CI (-0.394, 1.728)
	BSD	t=1.07 2-tail sig. 0.308 SE=0.127 CI (-0.144, 0.417)
4. Ano.+ Bos.	BSR	t=-0.30 2-tail sig. 0.770 SE=0.836 CI (-2.000, 1.800)
	BSD	t=-0.10 2-tail sig.0.921 SE=0.174 CI (-0.401, 0.366)
5. Bamboo	BSR	t=-0.12 2-tail sig.0.908 SE=0.701 CI(-0.1.627, 1.461)
	BSD	t=-0.39 2-tail sig. 0.706 SE=0.179 CI (-0.464, 0.325)
6 *Cleistanthus collinus*	BSR	t=1.82 2-tail sig. 0.096 SE=0.459 CI (-0.175, 0.841)
	BSD	t=0.54 2-tail sig.0.602 SE=0.145 CI (-0.242, 0.398)
7. Riverine Forest	BSR	t=-0.68 2-tail sig. 0.508 SE=0.609 CI (-1.757, 0.924)
	BSD	t=-1.02 2-tail sig. 0.331 SE=0.129 CI (-0.415, 0.152)

T-test for paired samples

* : Signi. at $p \leq 0.05$, df=11

TABLE 4. Comparison of Bird Species Richness(BSR) & Bird Species Diversity (BSD) between two Replicates in Summer (Mar'97-Apr'97) in Pench NP, M.P.

HABITAT	INDEX	T-STATISTIC
1. Teak	BSR	t=-3.55 2=tail sig. 0.005* SE=0.376 CI (-2.161, -0.505)
	BSD	t=-3.16 2=tail sig. 0.009* SE=0.092 CI (-0.493, -0.088)
2. Misc+Teak	BSR	t=-1.39 2=tail sig. 0.193 SE=0.601 CI (-2.156, 0.490)
	BSD	t=-1.40 2=tail sig. 0.189 SE=0.124 CI (-0.446, 0.099)
3. Misc.	BSR	t=-1.51 2=tail sig. 0.160 SE=0.663 CI (--2.459, 0.459)
	BSD	t=-1.65 2=tail sig. 0.127 SE=0.155 CI (-0.599, 0.085)
4. Ano.+Bos.	BSR	t=-0.44 2=tail sig. 0.666 SE=0.752 CI (-1.989, 1.322)
	BSD	t=-0.23 2=tail sig. 0.823 SE=0.131 CI (-0.318, 0.258)
5. Bamboo	BSR	t=-1.00 2=tail sig. 0.339 SE=0.333 CI (-1.067, 0.401)
	BSD	t=-1.67 2=tail sig. 0.123 SE=0.084 CI (-0.327, 0.045)
6. C.collinus	BSR	t=-1.20 2=tail sig. 0.225 SE=0.555 CI (-1.889, 0.555)
	BSD	t=-1.86 2=tail sig. 0.089 SE=0.143 CI (-0.580, 0.048)
7. Riverine Forest	BSR	t=-0.86 2=tail sig. 0.410 SE=0.584 CI (-1.785, 0.785)
	BSD	t=-1.79 2=tail sig. 0.101 SE=0.126 CI (-0.502, 0.0502)

T-test for paired samples

* : Signi. at $p \leq 0.05$, df=11

TABLE 5. Seasonal Change in Bird Species Richness(BSR) & Bird Species Diversity (BSD) between Winter (Nov'96-Jan'97) and Summer (Mar'97-Apr'97) in Pench NP, M.P.

HABITAT	INDEX	Z - STATISTIC	
		Z-VALUE	2-TAIL SIGNI.
1. Teak	BSR	-1.0225	0.306
	BSD	-1.4120	0.158
2. Misc+Teak	BSR	0.0000	1.000
	BSD	-0.6668	0.505
3. Misc.	BSR	-1.9876	0.047*
	BSD	-2.0396	0.041*
4. Ano.+Bos.	BSR	-2.3953	0.016*
	BSD	-2.5887	0.009*
5. Bamboo	BSR	-2.0140	0.044*
	BSD	-2.5784	0.009*
6. C.collinus	BSR	-1.9367	0.053*
	BSD	-2.8241	0.004*
7. Riverine Forest	BSR	-2.1915	0.028*
	BSD	-2.7562	0.005*

Wilcoxon Matched Pairs - Signed Ranks Test

* : Signi. at $p \leq 0.05$, df=11

TABLE 6. **Linear Correlation between Bird Species Richness (BSR) & Bird Species Diversity (BSD) across all Habitats in Pench NP, M.P.**

SEASON	CORRELATION SIGNIFICANCE	F-STATISTIC
Winter	Multiple R=0.82910 R^2=0.68741	DF=82 F=180.322 Sig. F=0.0000
Summer	Multiple R=0.89503 R^2=0.80108	DF=82 F=330.223 Sig. F=0.0000

Multiple Regression

df=82, $p \leq 0.05$

TABLE 7. **Linear Correlation between Plant Species Richness (PSR) and Plant Species Diversity (PSD) across all Habitats in Pench NP, M.P.**

REGRESSION VALUES	F-STATISTIC
Multiple R=0.89707 R^2=0.80474 SE=0.25805	DF=82 F=337.949 Sig. F=0.0000

Multiple Regression

df=82, $p \leq 0.05$

4.5 BSD *vs* PSD and BSR *vs* PSR

In winter, only in Teak-dominant forest both BSD and BSR showed significant correlation to PSD and PSR respectively; in summer, similar correlations were detected in *Anogeissus* + *Boswellia* dominant forest and *Cleistanthus collinus* woodland (Spearman Rank Correlation, df=22, $p \leq 0.05$; Table.8).

4.6 FHD *vs* BSD

T-test for Paired Samples was done for all habitat types to find out whether FHD responded to seasonal changes from winter to summer. The results show that FHD had a marked decline in summer in all the habitats except in Miscellaneous + Teak forests where the drop was not significant (df=11, $p \leq 0.05$; Table.9). Significant seasonal change in FHD was also observed across all habitat types (Wilcoxon Matched Pairs - Signed Ranks Test, $z = -7.537$, 2-tail $p = 0.000$; df=83, $p \leq 0.05$).

Pearson's Correlation Coefficient for Paired Samples indicated no significant correlation between FHD and BSD in both winter and summer across all the habitat types. Similarly, no correlation was detected between FHD and BSR (log-transformed), in both the seasons across all habitats (df=84, $p \leq 0.05$; Table.10).

4.7 GUILD ANALYSIS

4.7.1 Trophic Guilds

As mentioned in Sec.3.4.7, 12 classes of trophic guilds based on major food resource were identified in the study area. The insectivorous birds constitute the largest guild (54.83 %), followed by insect + nectar + fruit feeders (8.6 %). The species composition of all trophic guilds is given in Table.11.

The trophic guild structure showed a marked similarity across all habitats within a season, with an equally corresponding reorganization with the seasonal change. Three guilds viz., insect+grain feeders, insect+small vertebrate feeders, and fruit+nectar feeders were absent in winter in any habitat; the composition of omnivorous guild had a two-fold increase in summer across all habitats (Table.12).

TABLE 8. Correlation between PSD & BSD and PSR & BSR in Winter (Nov'96-Jan'97) and Summer (Mar'97-Apr'97) in all Habitat Types in Pench NP, M.P.

HABITAT	SEASON	CORRELATE	τ_s-STATISTIC
1. Teak	Winter	PSD-BSD	0.7250 sig. 0.008
		PSR-BSR	0.7273 sig. 0.007
	Summer	PSD-BSD	-0.4685 sig. 0.124
		PSR-BSR	-0.4188 sig. 0.175
2. Misc+Teak	Winter	PSD-BSD	0.5455 sig. 0.067
		PSR-BSR	-0.0824 sig. 0.797
	Summer	PSD-BSD	0.3099 sig. 0.327
		PSR-BSR	0.0168 sig. 0.959
3. Misc.	Winter	PSD-BSD	0.2448 sig. 0.443
		PSR-BSR	0.1304 sig. 0.686
	Summer	PSD-BSD	-0.2102 sig. 0.512
		PSR-BSR	-0.3566 sig. 0.255
4.Ano.+ Bos.	Winter	PSD-BSD	0.0909 sig. 0.799
		PSR-BSR	0.3072 sig. 0.331
	Summer	PSD-BSD	-0.6503 sig. 0.022
		PSR-BSR	-0.5320 sig. 0.075
5. Bamboo	Winter	PSD-BSD	-0.3573 sig. 0.254
		PSR-BSR	-0.3975 sig. 0.201
	Summer	PSD-BSD	-0.3853 sig. 0.216
		PSR-BSR	-0.4462 sig. 0.146
6.*C.collinus*	Winter	PSD-BSD	0.2727 sig. 0.391
		PSR-BSR	-0.1079 sig. 0.739
	Summer	PSD-BSD	0.5849 sig. 0.046
		PSR-BSR	0.6349 sig. 0.027
7. Riverine Forest	Winter	PSD-BSD	0.0070 sig. 0.983
		PSR-BSR	0.1189 sig. 0.071
	Summer	PSD-BSD	0.0385 sig. 0.905
		PSR-BSR	0.0162 sig. 0.960

Spearman Rank Correlation [df= 22, $p \leq 0.05$]

TABLE 9. Seasonal Change in Foliage Height Diversity (FHD) between Winter (Nov'96-Jan'97) & Summer (Mar'97-Apr'97) in all Habitats in Pench NP, M.P.

HABITAT	T-STATISTIC
1. Teak	t= -7.64 2-tail sig. 0.000* SE=0.075 CI (-0.736, -0.407)
2. Misc.+ Teak	t= -2.03 2-tail sig. 0.068* SE=0.089 CI (-0.378, 0.016)
3. Misc.	t= -6.26 2-tail sig. 0.000* SE=0.970 CI (-0.820, -0.393)
4. Ano. + Bos.	t= -5.92 2-tail sig. 0.000* SE=0.119 CI (-0.963, -0.441)
5. Bamboo	t= -3.28 2-tail sig. 0.007* SE=0.114 CI (-0.623, -0.123)
6. *C.collinus*	t=-12.66 2-tail sig. 0.000* SE=0.080 CI (-1.186, -0.835)
7. Riverine Forest	t= -4.01 2-tail sig. 0.002* SE=0.072 CI (-0.445, -0.129)

T-test for Paired Samples

* : Signi. at $p \leq 0.05$, df=11

TABLE 10. Correlation between FHD & BSD, and FHD & BSR in Winter (Nov'96-Jan'97) and Summer (Mar'97-Apr'97) across all Habitats in Pench NP, M.P.

SEASON	CORRELATES	τ_s-STATISTIC
Winter	FHD-BSD	τ_s= 0.0438 p= 0.692
	EHD-BSR	τ_s= 0.0389 p= 0.726
Summer	FHD-BSD	τ_s=-0.0264 p= 0.812
	FHD-BSR	τ_s= 0.0256 p= 0.817

Pearson's Correlation Coefficient

df=84, $p \leq 0.05$

TABLE 11. Bird Species Composition of Trophic Guilds encountered during Counts in Pench NP, M.P.

NO.	GUILDS	No. OF SPECIES	%
1	Granivores	6	6.45
2	Frugivores	5	5.38
3	Insectivores	51	54.83
4	Insect + Grain feeders	3	3.23
5	Insect + Fruit feeders	2	2.15
6	Insect + Nectar feeders	5	5.38
7	Insect + Nectar + Fruit feeders	8	8.60
8	Insect + Small vertebrate feeders	2	2.15
9	Fruit + Grain feeders	3	3.23
10	Fruit + Nectar feeders	2	2.15
11	Aquatic Fauna feeders	2	2.15
12	Omnivores	4	4.30
	TOTAL	93	100.00

TABLE 12. A Matrix of the Species Composition of Trophic Guilds in Winter (Nov'96-Jan'97) and Summer (Mar'97-Apr'97) in all Habitats in Pench NP, M.P.

H	SEASON	1	2	3	4	5	6	7	8	9	10	11	12
1	Win.	2	10	2	0	0	2	2	0	3	0	0	0
	Sum.	1	12	3	1	1	2	4	1	3	1	0	2
2	Win.		16	0	0	0	1	3	0	3	0	0	1
	Sum.	1	10	3	1	1	2	4	1	3	1	0	2
3	Win.	1	13	0	1	0	5	3	0	3	0	0	1
	Sum.	3	7	1	1	0	3	6	1	3	1	0	2
4	Win.	0	8	0	1	0	4	3	0	2	0	0	2
	Sum.	4	13	0	1	1	4	5	0	3	0	0	2
5	Win.	3	9	0	1	0	2	3	0	3	0	0	1
	Sum.	1	12	3	1	0	2	4	1	3	0	0	2
6	Win.	0	11	0	0	0	4	3	0	2	0	0	1
	Sum.	0	10	1	1	0	3	4	1	1	1	0	3
7	Win.	1	11	3	1	0	3	2	1	3	0	0	2
	Sum.	1	9	2	1	0	3	3	1	1	1	1	4

HABITAT CODES (H):
1. Teak
2. Misc.+ Teak
3. Misc.
4. *Anogeissus* + *Boswellia*
5. Bamboo
6. *Cleistanthus collinus*
7. Riverine forest

GUILD CODES :
1. Granivores
2. Insectivores
3. Frugivores
4. Insect + Grain feeders
5. Insect + Fruit feeders
6. Insect + Nectar feeders
7. Insect + Nectar + Fruit feeders
8. Insect + Small Vertebrate feeders
9. Fruit + Grain feeders
10. Fruit + Nectar feeders
11. Aquatic Fauna feeders
12. Omnivores

4.7.2 Foraging-behavioural Guilds

Six guilds based on foraging behaviour were identified among the insectivorous birds as explained in Sec.3.4.7. Foliage gleaners form the largest guild (33.80 %) followed by Air-sallyers and Ground-foragers (19.72 % each). Table.13 provides the total number of species composition of each foraging-behavioural guild.

As in trophic guilds, similar trends were observed with the seasonal change in the composition of foraging-behavioural guilds across all habitats. But unlike the former, there was no differential response by the guilds to habitat types with respect to the season (refer to Table.14).

TABLE 13. Bird Species Composition of Insectivorous birds encountered during counts (Foraging-behavioural Guilds) in Pench NP, M.P.

No.	GUILDS	No.OF SPECIES	%
1	Foliage Gleaners	24	33.80
2	Bark Feeders	5	7.04
3	Air-Sallyers	14	19.72
4	Ground-Sallyers	7	9.86
5	Undergrowth Foragers	7	9.86
6	Ground Foragers	14	19.72
	TOTAL	71	100.00

FIG. 4

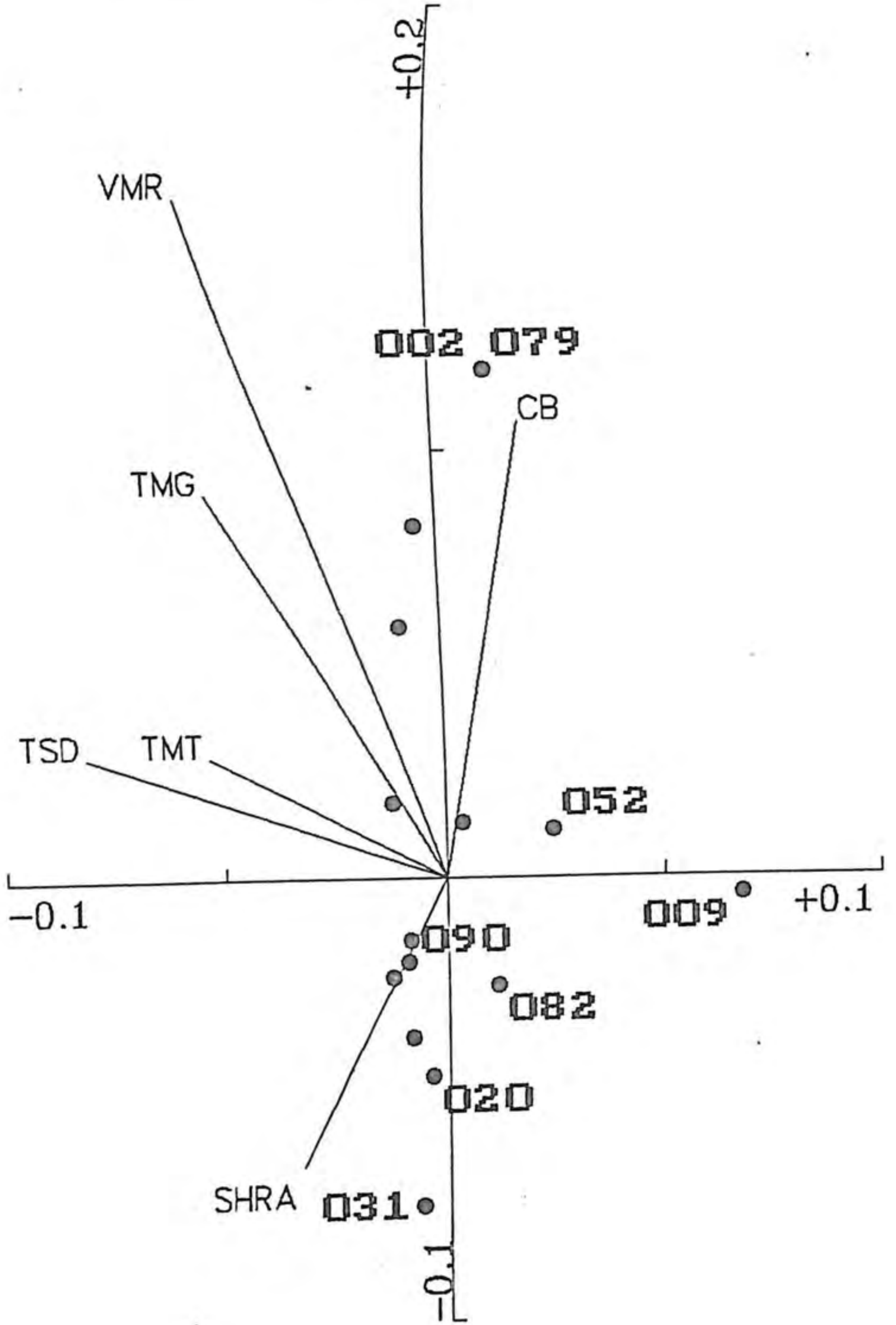

+0.2
VMR
002
079
CB
TMG
TSD
TMT
052
−0.1
009
+0.1
090
082
020
SHRA
031
−0.1

FIG. 4 CANOCO SPECIES-ENVIRONMENT PLOT FOR WINTER

HABITAT STRUCTURAL VARIABLES :

CB : Height of Canopy Bottom
VMR : Variance mean Ratio (Tree Dispersion Index)
TMG : Number of Ground Termitaries
TMT : Number of Tree Termitaries
TSD : Tree Species Diversity
SHRA: Shrub Abundance

BIRD SPECIES :

52 : Jerdon's Chloropsis
79 : Orange-headed Ground Thrush
02 : Red Spurfowl
90 : White-eye
20 : Little Green Bee-eater
09 : Alexandrine Parakeet

FIG. 5

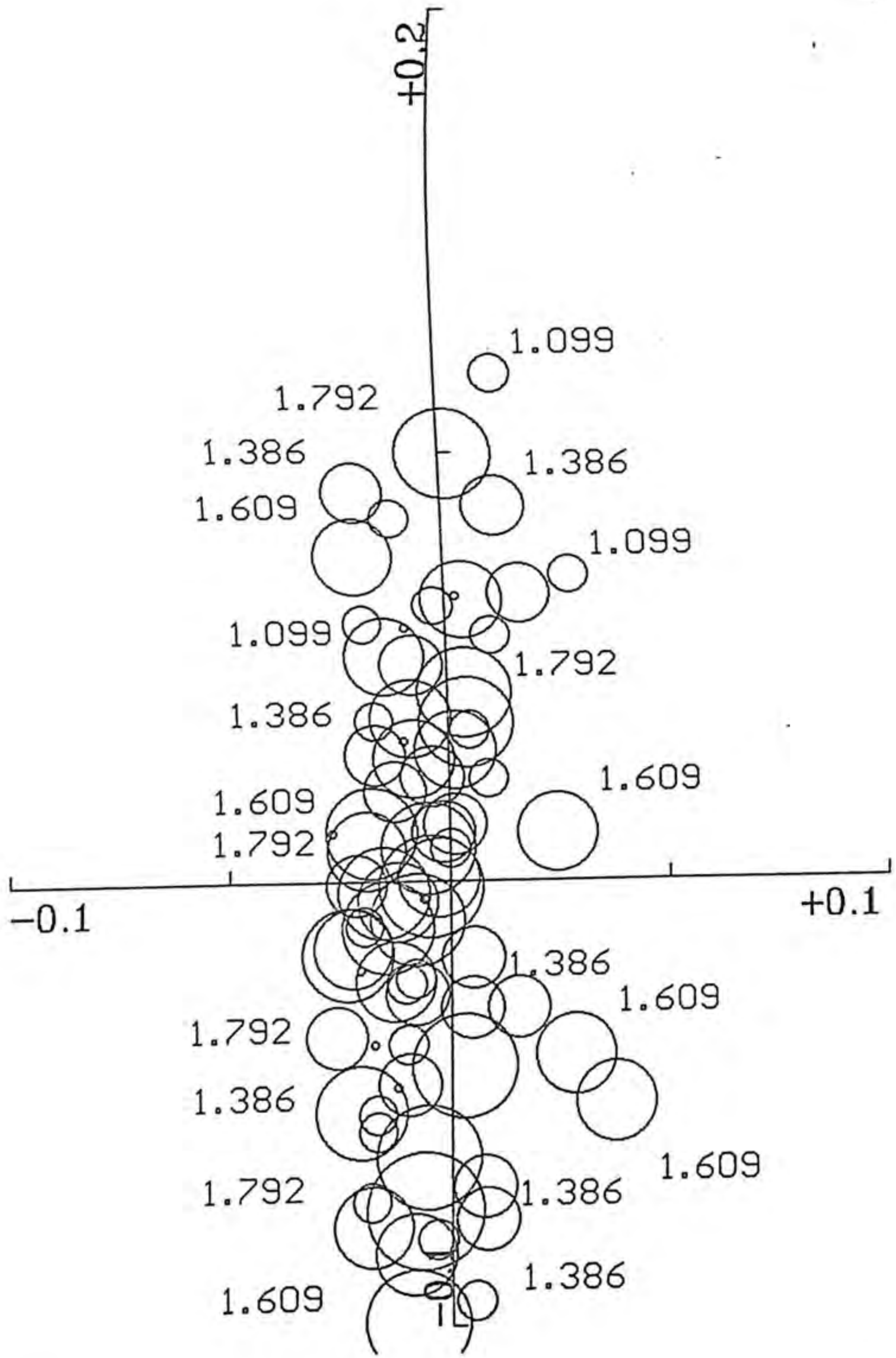

+0.2
1.099
1.792
1.386
1.386
1.609
1.099
1.099
1.792
1.386
1.609
1.609
1.792
-0.1
+0.1
1.386
1.609
1.792
1.386
1.609
1.792
1.386
1.386
1.609

FIG. 7

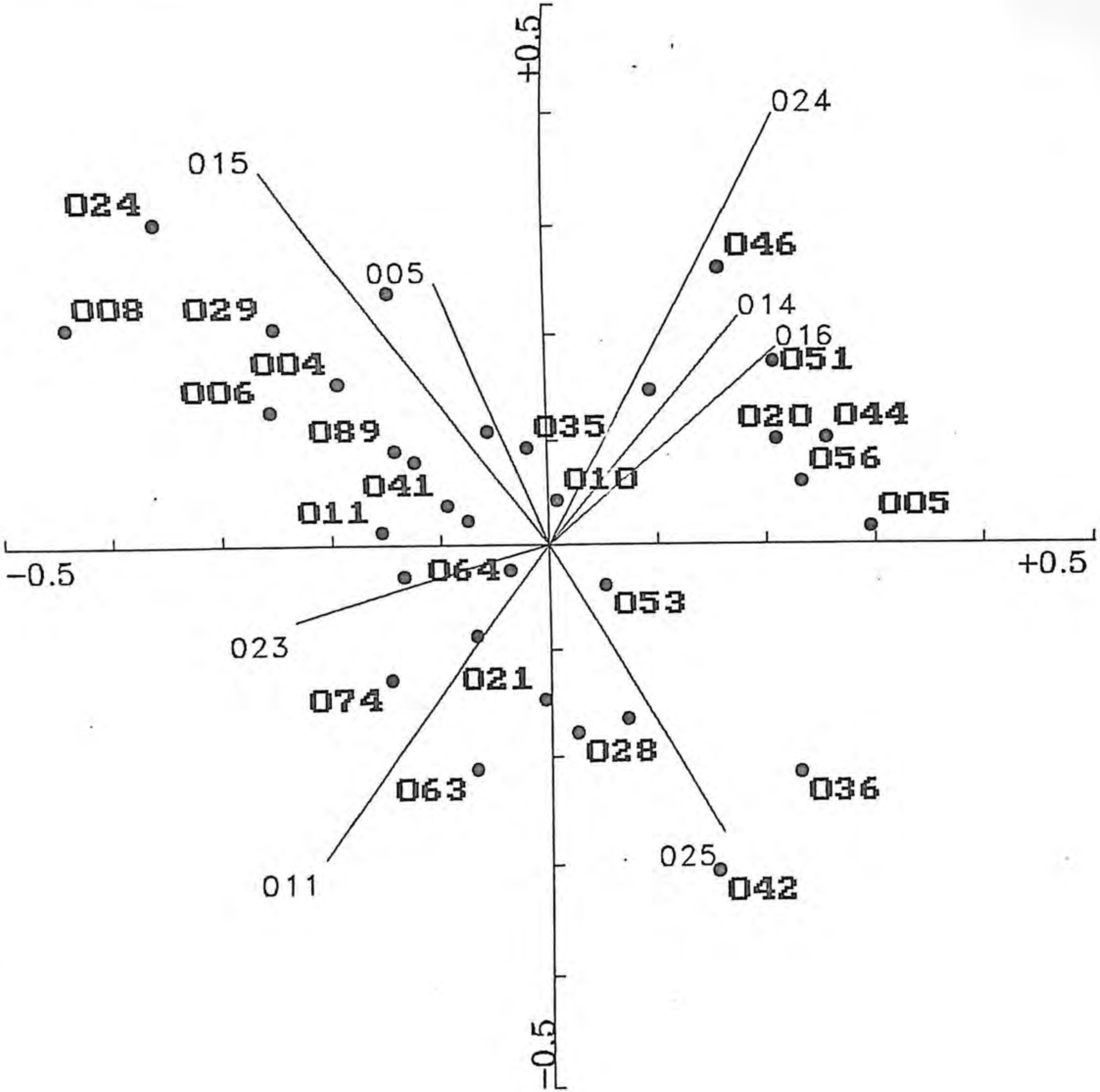

+0.5
-0.5
-0.5
+0.5
024
015
005
014
016
023
011
025
024
008
029
004
006
089
041
011
035
010
046
051
020
044
056
005
064
053
021
074
028
063
036
042

FIG. 7 CANOCO SPECIES-ENVIRONMENT PLOT FOR SUMMER

HABITAT VARIABLES :

16 : Sapling Height
14 : Snag Height
24 : Number of Ground Termitaries
05 : GBH
15 : Sapling Abundance
23 : Fallen Log Abundance
11 : Twig Type Diversity
25 : Number of Tree Termitaries

BIRD SPECIES :

56 : Jungle Babbler
46 : Large Cuckoo-shrike
24 : Malabar Pied Hornbill
41 : Grey-headed Myna
90 : White-eye
29 : Yellow-fronted Pied Woodpecker
08 : Red Turtle Dove
11 : Blossom-headed Parakeet
64 : Black-naped Monarch Flycatcher
25 : Lesser Golden-backed Woodpecker

FIG. 8

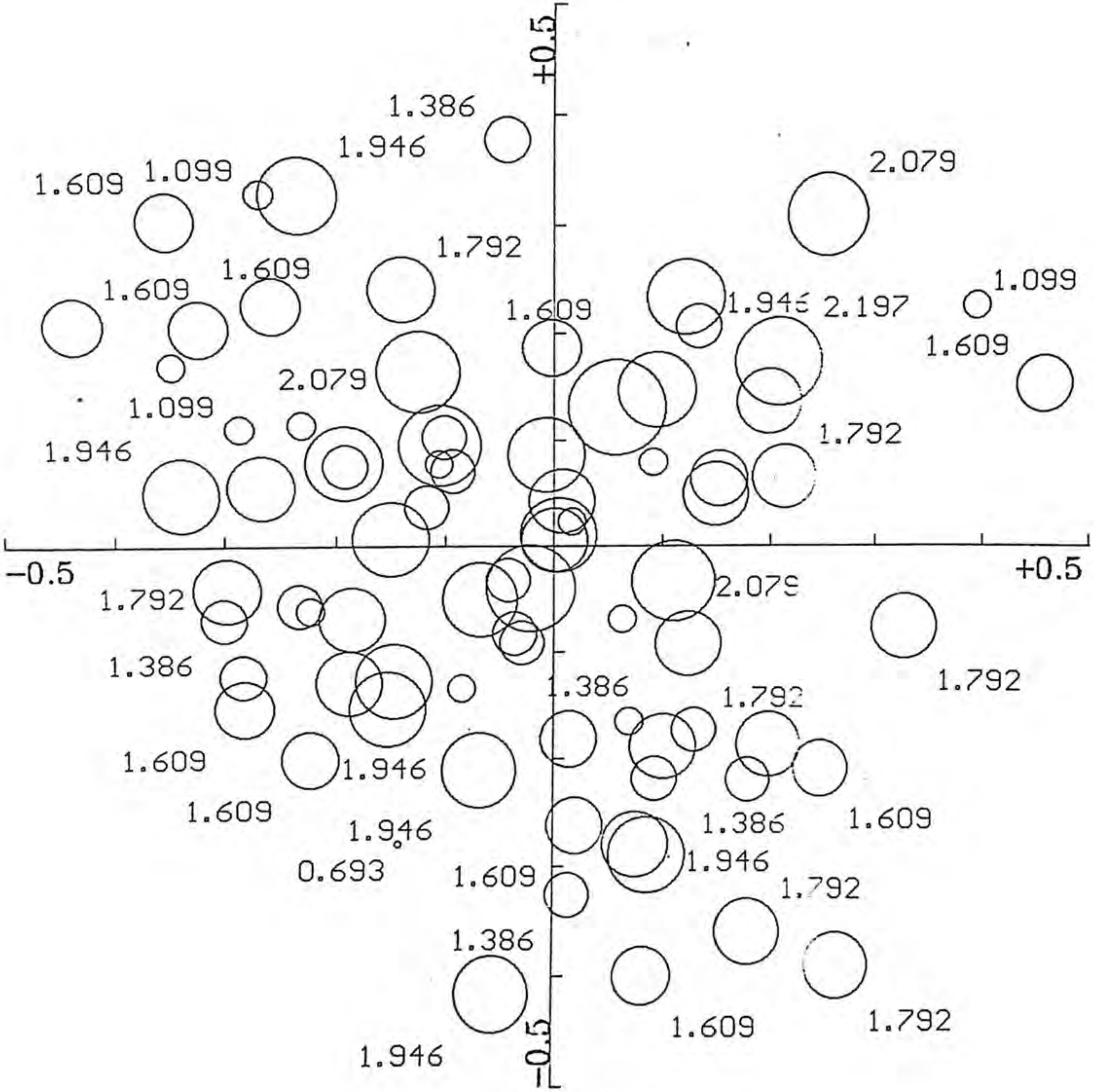
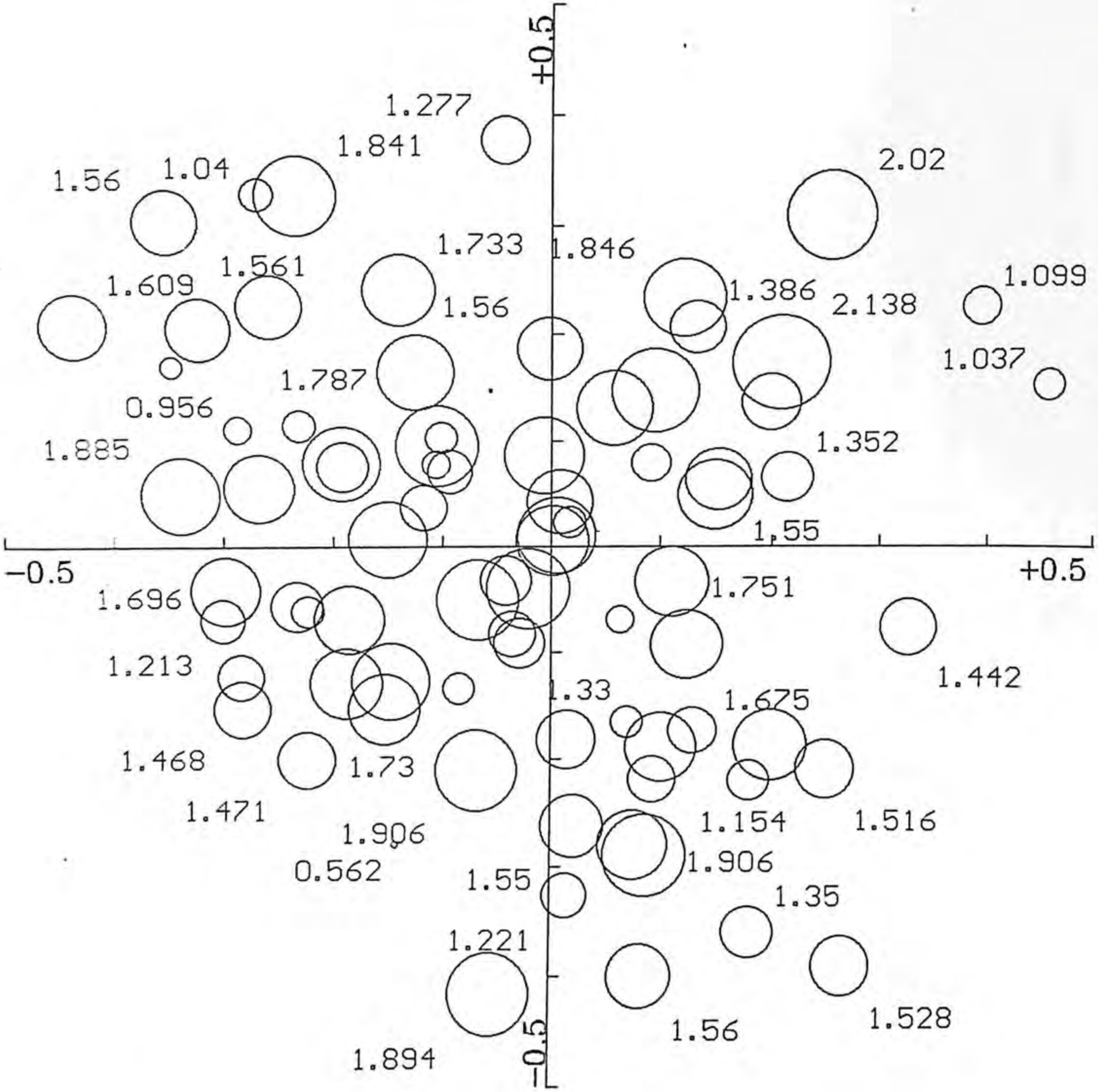

+0.5
1.386
1.946
1.609
1.099
2.079
1.792
1.609
1.609
1.946
2.197
1.099
1.609
1.609
2.079
1.099
1.792
1.946
-0.5
+0.5
1.792
2.079
1.386
1.386
1.792
1.792
1.609
1.946
1.609
1.609
1.386
1.946
0.693
1.609
1.946
1.792
1.386
1.946
1.609
1.792
-0.5

FIG. 9


+0.5
-0.5
+0.5
-0.5
1.277
1.841
1.56
1.04
1.733
1.846
2.02
1.609
1.561
1.56
1.386
2.138
1.099
1.787
1.037
0.956
1.885
1.352
1.55
1.696
1.751
1.213
1.442
1.33
1.675
1.468
1.73
1.471
1.154
1.516
1.906
0.562
1.906
1.55
1.35
1.221
1.56
1.528
1.894

5. DISCUSSION

5.1 RELATIONSHIP BETWEEN BIRD COMMUNITIES AND HABITAT STRUCTURE

Community data matrix, when applied to any multivariate analysis is prone to two kinds of bottlenecks : *noise* and *redundancy* (Gauch, 1982; Moskat & Waliczky, 1992; Morrison *et al.*, 1992). Such inherent problems underscore the need for a biologically sensible and cautious approach while interpreting the results of multivariate statistical analyses, for

i. the results are entirely based upon the data collected in the field and there is every possibility of cumulative effects of observer bias and sampling error reflecting on the final output of such sophisticated analyses, and

ii. the shorter duration of study in the present context, has contributed to significant increase in the probability of 'chance encounters' in the species data through low sample size, thus amplifying the noise in the pattern.

With a fair deal of familiarity with both the habitat and the species under study through *ad libitum* observations, it is possible to eliminate such noise to a certain extent. Peters (1991) points out to two more problems associated with PCA and CCA *viz.* opacity of results and uncertainty of multivariate statistics. Keeping all these reservations and cautions in mind, certain interesting deductions can be made from the results.

5.1.1 LANDSCAPE BEHAVIOUR OF HABITAT STRUCTURAL VARIABLES

Before passing over to the correlation of bird species distribution to habitat structure, it is necessary to look into the relationship *per se* of structural variables i.e. the principal components. McCoy and Bell (1991), have designated three axes of habitat structure *viz.* heterogeneity (variations attributable to the relative abundance of different structural components), complexity (variations attributable to the absolute abundance of individual structural variables) and the scale of measurement. In other words, while heterogeneity refers to kinds of structure, complexity involves amounts of structure. Very few studies have actually looked into the landscape behaviour of the structural components of a habitat, though occasional attempts to quantify heterogeneity have been made (Roth, 1976; Palmer & Dixon, 1990; Li & Reynolds,

1995) In the light of such demonstrations, the set of structural variables forming the factors (obtained through rotated factor matrix. see Sec. 4.1.) can be looked into.

It is interesting to note from Table 15. that habitat structural variables combine themselves into two sets of components based on heterogeneity and complexity. Though there is an overlap in factor 3, the factor score for TTD, the sole component of habitat heterogeneity in the factor is appreciably different from others. This is not to say that both sets of components influence the dependent bird communities independent of each other, but to emphasise the presumption that both heterogeneity and complexity variables are likely to have a higher scale of self-regulatory, functional intra-relationships among themselves. Now if we extend this postulate to habitat selection process in bird communities, a couple of questions arise :

i. To what degree both the axes of structural variables interact with each other in time and space in their functional role as a habitat ?

ii. Do the bird communities show any trade-off between heterogeneity and complexity in their habitat selection ?

Even a speculative if not definitive answer is highly improbable, as almost all the habitat-selection studies have over-emphasised the importance of either competition or of predation/disturbance (Paine 1977, Gilbert 1980, McCoy and Bell 1991, Peters, 1991).

Interestingly, attempts made to plot these segregated structural components (expressed in PCA as eigenvalue factors), against the distribution of birds (expressed as diversity and richness indices), showed no definite pattern of such landscape behaviour. It was likely due to the third axis along which the habitat components function viz., the *scale of measurement.* This axis can pose a severe problem especially for the study of avian communities where a particular structural component of the habitat operates on different scales for a host of species each having a diverse range of ecological requirements that are often in accordance with body-size gradients; but habitat variables are usually measured in the field at the same scale of dimensions for practical reasons. For example, twig type for perch quality was determined for all individual trees using same criteria (Sec.3.3.1), and the quantification did not take into account the scale of difference between, say White-eye and Large Cuckoo-shrike in their use of twigs as perches.

5.1.2 CANONICAL CORRELATION IN WINTER

It is already seen in Sec 4.2.1, that canopy volume, tree abundance and tree termitaries form a major axis along which Jerdon's Chloropsis has a significant level of distribution. The species being exclusively arboreal and a foliage gleaner, the correlation is quite understandable. The occurrence of other factors of the axis like sapling height, grass percentage, and leaf litter may not be construed as immediate ecological correlates of the chloropsis but as an outcome of inter-relationships of the structural variables (multi-collinearity) as explained in Sec. 5.1.2. The association of tree termitaries has little to do with the bird

TABLE 15. **Segregation of Habitat Structural Components along two Axes of Landscape Behaviour**

FAC	N.CO	HABITAT COMPONENTS	HETER.	COMP.
1	5	Snag Abundance, Canopy Top, Sapling Abundance, Snag Height, Sapling Height	0	5
2	5	Grass %, Leaf Litter %, Leaf Litter Depth, Grass Height, GBH of Trees	0	5
3	4	Canopy Cover, Canopy Volume, Tree Abundance, Overstorey Canopy Density	0	4
	1	Twig Type Diversity	1	0
4	4	Tree Species Diversity, Block Geometry Diversity, Screening Efficiency Diversity, Tree Dispersion Ratio	4	0
5	3	Fallen Log Abundance, Fallen Log Girth, Fallen Log Length	0	3
6	3	Slope, Ht. of Canopy Bottom, Tree Termitaries	0	3

Principal Components Analysis - Rotated Factor Matrix

ABBREVIATIONS :

FAC : Factor
N.CO : Number of Habitat Components
HETER : No. of components under Heterogeneity Axis
COMP : No. of components under Complexity Axis

species itself, as chloropsis is not an avid termite-feeder. But in dry deciduous forests of Central India, almost all the individuals of the tree species *Miliusa velutina*, owing to the deeply grooved nature of their bark-structure, are prone to tree-termite infestation (though such colonies are not found to be fatal), and the widespread dispersion of *Miliusa velutina* has subsequently been addressed to in the analysis.

The next axis is influenced by a single structural component, *viz.* leaf litter depth, and the distributed bird species are Rufous Turtle Dove, Ashy Drongo, Grey-headed Flycatcher, and Common Iora. Interestingly, all these species are strictly arboreal (though the dove forages on ground, it is confined to dense canopy when not foraging). Here the correlation is actually not very explicit; higher leaf litter depth implies the dense-canopied, close forest structure that would permit all these species to inhabit. It is to be noted here that leaf litter percentage was not accounted for, as it is a function of other extrinsic factors like leaf-shedding of deciduous tree species, wind velocity, slope of the terrain, etc.

On axis 3, two variables act on the species: canopy cover and shrub abundance. The species associated were Tickell's Blue Flycatcher, Shama, Crimson-breasted Barbet and Large Green Barbet. Both Tickell's Blue Flycatcher and Shama inhabit woodland shrubbery; while the flycatcher frequents shrubs in open-canopied forests, Shama is found only in shrubs of close forests. Hence the variable, canopy cover assumes importance. Both the barbet species are entirely arboreal, their distribution governed more by the phenology of fruit-yielding trees than by the habitat structure. But a point worthy of note here is that common dense-foliaged tree species found in Pench National Park like *Buchanania lanzan*, *Ficus infectoria*, *Diospyros melanoxylon* and *Ficus benghalensis* are all fruit-bearing, suggestive of a possible link.

5.1.3 CANONICAL CORRELATION IN SUMMER

Canonical correlation analysis done for summer data also showed some interesting pieces of information (Sec 4.2.2.). On the axis 1, Jungle Babblers were found to be influenced by structural variables like sapling height, and ground termitaties. The distribution of Jungle Babblers, being woodland species unlike other congeneric babblers of *Turdoides* sp., is also dictated by tree structural variables like tree species diversity, tree dispersion ratio, and snag height. The correlation of Large Cuckoo-shrike, another species plotted on Axis 1, to these variables may partly hold true, but can better be explained by the fact that the Cuckoo-shrike is an invariable member of the mixed hunting flocks that rove about in deciduous forests of Central India and Jungle Babbler forms one of the core component species of such flocks.

On axis 2, all the woodland species like Malabar Pied Hornbill, Grey-headed Myna, White-eye, Yellow-fronted Pied Woodpecker, Red Turtle-Dove, and Blossom-headed Parakeet were distributed along a combination of three variables of tree structure: overstorey canopy density, tree species richness and canopy block geometry diversity. Of these species, both Malabar Pied Hornbill and Grey-headed Myna are local migrants, the local movements probably governed by their breeding season and availability of food resources.

Along axis 3, the distribution of Black-naped Monarch Flycatcher, a canopy feeder, is shown to be controlled by two components: screening efficiency diversity, and height of canopy bottom. The flycatcher was found to prefer bamboo patches where the screening efficiency diversity is quite high and the perches are available right from the ground level to ten metre height.

On axis 4, the distribution of Lesser Golden-backed Woodpecker was related to the structural variables: tree termitaries, snag abundance and shrub volume. Another species, Paradise Flycatcher's response towards these variables as shown by the CCA may just be a case of noise as the actual sighting of the species as such is less than three, on my census walks.

Out of 93 species of birds and 27 habitat structural variables fed into CANOCO, the final results took into account less than one-third of them. To put it briefly, the habitat selection in bird communities in dry-deciduous forests is not a phenomenon of landscape behaviour alone but a function of a combination of other determinants as well like floristics, habitat dynamics, phenophase of vegetation, disturbance, and intra- and inter-specific interactions within the community.

Further thoughts over the results of CCA may raise another question. Can we extend the obtained pattern of species-habitat structure association to other species of known kinship using the plotted ones as 'ecological surrogates' ?

The answer is quite elusive as it entails two inherent problems:

i) The scale of measurement (Palmer and Dixon 1990, Morrison *et al.*, 1992).

ii) Taxonomic and ecological relationships are often overlapping and sometimes too ambiguous to distinguish. Hence no attempts of surrogation may be satisfactory and ecologically meaningful.

5.1.4 FOLIAGE HEIGHT DIVERSITY VS BIRD SPECIES DIVERSITY

The FHD - BSD construct of MacArthur and MacArthur (1961) is one of the most widely criticized concepts of community ecology (see also Introduction for more information). Several studies in temperate habitats showed a similar positive linear relationship (Recher 1969, Karr and Roth 1971, Willson 1974, Terborgh 1977, Erdelen 1984 and Verner and Larson 1989), while some others refuted such correlation (Roth 1976, Terborgh 1985, Wiens and Rotenberry 1981).

However, in the deciduous forests of central India, my studies revealed no linear correlation of BSD to FHD in both winter and summer. The relatively low structural diversity of homogeneous deciduous forests may be a factor for such outcome. It is not very clear whether homogeneity of a habitat is in correspondence with the structural diversity; but MacArthur (1964) concluded that within homogenous habitats, the number of layers of vegetation is sufficient to account for the diversity of breeding bird species and with increasing heterogeneity, the correlation becomes weaker. Meanwhile, Willson (1974) has cited many studies which show such linear correlations both within series of similar habitats and in gradients of dissimilar vegetation types.

Many authors have in the past, pointed out the possibility that FHD-BSD correlation may just be a case of sampling artefact rather than an actual phenomenon, (see Morrison *et al* 1992). The observer can increase the FHD by simply changing the number of categories included in the calculations, as the FHD is a statistical function of evenness of foliage layers and numbers of categories (see Sec 3.4.1 for the determinants of diversity index). M. Erdelen (1984), concluded that comparative studies of FHD-BSD relationships should not be attempted at as the methodology and habitat architecture are too dissimilar in many cases to warrant any such comparison. (For example, Willson (1974), used binomial variates of presence or absence of foliage at each height interval to arrive at FHD.). Further, the BSD indices in MacArthur's construct were based on breeding birds while several of the subsequent studies involved non-breeding birds; incidentally, it is not known whether the FHD is linearly correlated to both the breeding and non-breeding birds of a locality.

Is FHD actually an arbitrary parameter? Is the contention of many community ecologists that foliage height-bands should be decided *a priori*, valid ? In this study, FHD of each habitat type showed a marked change with the corresponding change in season though the changes defied any regression as the variations were either positive or negative (Table 9). This may indicate to the point that FHD may not be as arbitrary as widely thought of.

'*A priori*' determination of foliage height bands is actually unwarranted as the hypothesis is to find out any correlation between FHD and BSD, rather than to elicit any structural patterns of vegetation in terms of FHD. In other words, FHD should be reckoned as a measure of the optimal height bands of vegetation of a locality or habitat type that correspond to (or that account for) the observed vertical distribution of bird species. Such an approach understandably does not yield any answer that can be transformed into a predictive model of bird species diversity based on FHD, as attempted by MacArthur and MacArthur (1961). But it may serve as an ecological tool to explore the patterns of avian communities further. Hence, determination of foliage height bands based on the vertical distribution of bird species of a habitat type (expressed as a function of perch heights in the case of non-breeding birds and nesting-heights in breeding birds) does make a lot of ecological sense as such an approach is non-arbitrary and is devoid of any logical circularity.

5.2 RELATIONSHIP BETWEEN BSD, BSR, PSD AND PSR

As mentioned in chapter 3, two replicates of bird counts (point-counts), per habitat type were undertaken in each season and as expected, the BSD and BSR showed no significant difference between two winter replicates. Similar trends were obtained for the replicates of summer season, except for the Teak-dominant forest, probably due to the fact that my summer bird census was started off with the teak-dominant forest when some of the individuals of the overwintering migrant bird populations like Green Leaf Warbler (*Phylloscopus trochilioides*), Black Redstart (*Phoenicurus phoenicurus*), and Red-breasted Flycatcher (*Muscicapa parva*) were still detected and also as the seasonal change in the composition of bird communities [with the entry of localized migrants like Grey-headed Myna (*Sturnus malabaricus*), Indian Roller (*Coracina benghalensis*), White-bellied Drongo (*Dicrurus caerulescens*), and Golden Oriole (*Oriolus oriolus*)] was not yet complete. Such seasonal changes in BSD and BSR in all habitats were found to be significant (Table 3). The seasonal change in the bird species composition seems to be more a function of ultimate factors like breeding cycles of birds and phenology of vegetation, than a function of proximate causes such as disturbance, structural transparency of forests.

Similar to BSD-BSR constructs, all the habitats showed a positive linear correlation between woody Plant Species Diversity (PSD) and woody Plant Species Richness (PSR).

The linear relationships between BSD and PSD, and between BSR and PSR were detected only for Teak-dominant forests in winter and for *Anogeissus-Boswellia* forests and *Cleistanthus collinus* woodland in summer.

Any explanations for such observed anomalies would become rather untenable as there seems to be very little ecological understanding of the nature of response of bird communities to floristics of the vegetation. It is to be noted here that both floristics and physiognomy of vegetation are actually not independent components and often are inter-correlated; it is therefore very difficult to mask the effects of one component while taking the other into analysis for any meaningful interpretations.

5.3 GUILD STRUCTURE

It would be of much interest to see the correlation between guild components of bird communities and the habitat structure, but for want of time, such analysis was not attempted. In fact, there are very few studies that have tried to fit guild components into the structural matrix of habitat. Though trophic guilds are more a function of habitat dynamics, foraging-behavioural guilds of insectivores are positively a correlate of structural diversity of habitats (McCoy and Bell 1991).

Terborgh (1977), showed that diversity of nectarivores was nearly independent of vegetation structure whereas frugivores responded weakly and insectivores strongly to some habitat factors.

An interesting phenomenon of the guild composition of bird communities in central Indian forests is the consistency of change along seasonal gradient, across all habitat types. It is not surprising since BSD itself showed similar trends (Table 5). The observed two-fold increase in the number of omnivores can be attributed to the vegetation structure becoming more open in summer in predominantly deciduous forests. This increased the visibility and thus facilitated detection of carcasses of wild and domestic animals by the omnivores to scavenge upon.

CONCLUSIONS

- Habitat structural variables of deciduous forests of Central India showed a marked pattern of inter-relationships on two axes: heterogeneity and complexity. But they failed to reveal any such segregation *vis-a-vis* bird community structure as the scale of measurement did not address to all the members of the community.

- The distribution of bird communities in relation to the axis of structural components of habitats in Central Indian deciduous forests is probably influenced by other extraneous factors like floristics, habitat dynamics, phenophase of vegetation, disturbance and intra- and inter-specific interactions within the community.

- There was no linear correlation observed between Foliage Height Diversity and Bird Species Diversity and it is likely due to the arbitrariness of the construct rather to the low structural diversity of the habitat.

- There was a positive linear correlation between BSD and BSR in both winter and summer, and between PSD and PSR across all habitat types.

- Positive linear relationships were detected between BSD and PSD, and between BSR and PSR only for Teak-dominant forests in winter, and only for *Anogeissus-Boswellia* forests and *Cleistanthus collinus* woodland in summer.

- There was no significant difference in guild composition of different habitat types though the seasonal change in guild composition is consistent across all habitat types.

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APPENDIX I. A CHECKLIST OF THE BIRDS OF PENCH NATIONAL PARK, M.P.

S.NO.	COMMON NAME	SCIENTIFIC NAME	HABITAT					ST
			O	D	M	R	W	
	PODICIPEDIDAE							
001	Little Grebe	*Podiceps ruficollis*	0	0	0	0	3	R
	PHALACROCORACIDAE							
002	Large Cormorant	*Phalacrocorax carbo*	0	0	0	0	3	LM
003	Indian Shag	*P. fuscicollis*	0	0	0	0	3	R
004	Little Cormorant	*P. niger*	0	0	0	0	4	R
005	Oriental Darter	*Anhinga rufa*	0	0	0	0	2	R
	ARDEIDAE							
006	Grey Heron	*Ardea cinerea*	0	0	0	0	3	R
007	Little Green Heron	*Ardeola striatus*	0	0	0	0	3	R
008	Cattle Egret	*Bubulcus ibis*	0	0	0	0	4	R
009	Large Egret	*Ardea alba*	0	0	0	0	4	R
010	Intermediate Egret	*Egretta intermedia*	0	0	0	0	4	R
011	Little Egret	*E. garzetta*	0	0	0	0	4	R
012	Black-crowned Night Heron	*Nycticorax nycticorax*	0	0	0	0	4	R
	CICONIIDAE							
013	Painted Stork	*Mycteria leucocephala*	0	0	0	0	3	R
014	Openbill Stork	*Anastomus oscitans*	0	0	0	0	3	R
015	White-necked Stork	*Ciconia episcopus*	0	0	0	0	3	R
016	Black Stork	*C. nigra*	0	0	0	0	3	R
017	Black-necked Stork	*Ephippiorhynchus asiaticus*	0	0	0	0	2	LM
	THRESKIORNITHIDAE							
018	White Ibis	*Threskiornis aethiopica*	0	0	0	0	4	R
019	Spoonbill	*Platalea leucorodia*	0	0	0	0	3	LM
	ANATIDAE							
020	Lesser Whistling Teal	*Dendrocygna javanica*	0	0	0	0	4	LM
021	Ruddy Shelduck	*Tadorna ferruginea*	0	0	0	0	4	W
022	Pintail	*Anas acuta*	0	0	0	0	4	W
023	Common Teal	*Anas crecca*	0	0	0	0	3	W
024	Spotbill Duck	*Anas poecilorhyncha*	0	0	0	0	2	W
025	Mallard	*Anas platyrhynchos*	0	0	0	0	2	W

S.NO.	COMMON NAME	SCIENTIFIC NAME	HABITAT					ST
			O	D	M	R	W	
026	Gadwall	*Anas strepera*	0	0	0	0	3	W
027	Wigeon	*Anas penelope*	0	0	0	0	3	W
028	Garganey	*Anas querquedula*	0	0	0	0	3	W
029	Cotton Teal	*Nettapus coromandelianus*	0	0	0	0	2	W
	ACCIPITRIDAE							
030	Black-winged Kite	*Elanus caeruleus*	3	0	0	0	0	R
031	Honey Buzzard	*Pernis ptilorhyncus*	4	3	3	4	0	R
032	Pariah Kite	*Milvus migrans*	1	0	0	0	0	R
033	Brahminy Kite	*Haliastur indus*	0	0	0	0	2	R
034	Shikra	*Accipiter badius*	4	4	1	0	0	R
035	Crested Goshawk	*Accipiter trivirgatus*	0	0	0	2	0	R
036	Common Buzzard	*Buteo buteo*	0	0	2	0	0	W
037	White-eyed Buzzard-Eagle	*Butastur teesa*	2	4	4	4	0	R
038	Crested Hawk-Eagle	*Spizaetus cirrhatus*	0	3	4	3	0	R
039	Pallas's Fishing Eagle	*Haliaeetus leucoryphus*	0	0	0	0	3	R
040	King Vulture	*Sarcogyps calvus*	0	3	0	0	0	R
041	Cinereous Vulture	*Aegypius monachus*	0	1	0	0	0	W
042	Long-billed Vulture	*Gyps indicus*	4	4	2	4	0	R
043	White-backed Vulture	*Gyps bengalensis*	4	4	2	4	0	R
044	Egyptian Vulture	*Neophron percnopterus*	3	3	0	2	0	R
045	Pied Harrier	*Circus melanoleucos*	0	0	0	0	2	W
046	Marsh Harrier	*Circus aeruginosus*	0	0	0	0	3	W
047	Crested Serpent Eagle	*Spilornis cheela*	3	4	3	3	0	R
048	Osprey	*Pandion haliaetus*	0	0	0	0	3	W
	FALCONIDAE							
049	Laggar Falcon	*Falco jugger*	3	3	0	0	0	R
050	Shaheen Falcon	*Falco peregrinus*	3	3	3	0	0	R
051	Kestrel	*Falco tinnunculus*	4	3	0	0	3	R
	PHASIANIDAE							
052	Painted Partridge	*Francolinus pictus*	0	3	4	0	0	R
053	Grey Partridge	*F. pondicerianus*	3	3	0	0	0	R
054	Jungle Bush Quail	*Perdicula asiatica*	2	4	4	0	0	R
055	Red Spurfowl	*Galloperdix spadicea*	0	3	4	0	0	R
056	Painted Spurfowl	*Galloperdix lunulata*	1	1	0	0	0	R
057	Red Junglefowl	*Gallus gallus*	2	4	4	3	0	R
058	Common Peafowl	*Pavo cristatus*	3	4	2	4	0	R

S.NO.	COMMON NAME	SCIENTIFIC NAME	HABITAT					ST
			O	D	M	R	W	
	TURNICIDAE							
059	Yellow-legged Button Quail	*Turnix tanki*	0	2	0	0	0	R
060	Common Bustard-Quail	*Turnix suscitator*	0	3	3	0	0	R
	RALLIDAE							
061	White-breasted Waterhen	*Amaurornis phoenicurus*	0	0	0	0	4	R
062	Purple Moorhen	*Porphyrio porphyrio*	0	0	0	0	3	LM
	JACANIDAE							
063	Bronze-winged Jacana	*Metopidius indicus*	0	0	0	0	3	R
	ROSTRATULIDAE							
064	Painted Snipe	*Rostratula benghalensis*	0	0	0	0	4	R
	RECURVIROSTRIDAE							
065	Black-winged Stilt	*Himantopus himantopus*	0	0	0	0	4	LM
	BURHINIDAE							
066	Stone Curlew	*Burhinus oedicnemus*	3	4	2	0	0	R
	GLAREOLIDAE							
067	Indian Courser	*Cursorius coromandelicus*	3	0	0	0	0	R
	CHARADRIIDAE							
068	Red-wattled Lapwing	*Vanellus indicus*	0	0	0	0	4	R
069	River Lapwing	*Vanellus duvaucelii*	0	0	0	0	3	R
070	Yellow-wattled Lapwing	*Vanellus malabaricus*	3	3	0	0	0	R
071	Little Ringed Plover	*Charadrius dubius*	0	0	0	0	2	W
072	Green Sandpiper	*Tringa ochropus*	0	0	0	0	4	W
074	Wood Sandpiper	*Tringa glareola*	0	0	0	0	3	W
075	Common Sandpiper	*Tringa hypoleucos*	0	0	0	0	3	W
076	Little Stint	*Calidris minuta*	0	0	0	0	1	W
	LARIDAE							
077	River Tern	*Sterna aurantia*	0	0	0	0	3	R
	PTEROCLIDIDAE							
078	Painted Sandgrouse	*Pterocles indicus*	3	2	0	0	0	R
	COLUMBIDAE							

S.NO.	COMMON NAME	SCIENTIFIC NAME	HABITAT					ST
			O	D	M	R	W	
079	Yellow-legged Green Pigeon	*Treron phoenicoptera*	3	4	4	4	0	R
080	Blue Rock Pigeon	*Columba livia*	2	0	0	0	0	R
081	Rufous Turtle Dove	*Streptopelia orientalis*	0	1	3	0	0	R
082	Ring Dove	*Streptopelia decaocto*	4	3	0	0	0	R
083	Red Turtle Dove	*S. tranquebarica*	0	0	2	0	0	R
084	Spotted Dove	*S.chinensis*	3	4	4	4	0	R
085	Little Brown Dove	*S.senegalensis*	2	3	0	0	0	R
087	Emerald Dove	*Chalcophaps indica*	1	0	0	2	0	R
	PSITTACIDAE							
088	Alexandrine Parakeet	*Psittacula eupatria*	3	4	4	4	0	R
089	Rose-ringed Parakeet	*Psittacula krameri*	4	4	3	4	0	R
090	Blossom-headed Parakeet	*Psittacula cyanocephala*	3	4	4	4	0	R
	CUCULIDAE							
091	Pied Crested Cuckoo	*Clamator jacobinus*	4	3	0	2	0	LM
092	Common Hawk-Cuckoo	*Cuculus varius*	4	4	2	3	0	R
093	Indian Cuckoo	*Cuculus micropterus*	3	3	0	0	0	LM
094	Koel	*Eudynamys scolopacea*	4	3	0	0	0	R
095	Sirkeer Cuckoo	*Taccocua leschenaultii*	0	3	3	0	0	R
096	Coucal	*Centropus sinensis*	4	3	2	3	0	R
	STRIGIDAE							
097	Barn Owl	*Tyto alba*	2	0	0	0	0	R
098	Collared Scops Owl	*Otus bakkamoena*	3	4	4	4	0	R
099	Great Horned Owl	*Bubo bubo*	0	0	2	3	0	R
100	Brown Fish Owl	*Bubo zeylonensis*	0	0	0	3	0	R
101	Jungle Owlet	*Glaucidium radiatum*	4	4	4	4	0	R
102	Spotted Owlet	*Athene brama*	1	0	0	0	0	R
103	Brown Wood Owl	*Strix leptogrammica*	0	0	2	2	0	R
	CAPRIMULGIDAE							
104	Jungle Nightjar	*Caprimulgus indicus*	4	4	2	4	0	R
105	Common Indian Nightjar	*Caprimulgus asiaticus*	4	4	0	3	0	R
106	Franklin's Nightjar	*Caprimulgus affinis*	3	4	3	4	0	R
	APODIDAE							
107	White-rumped Spinetail Swift	*Chaetura sylvatica*	0	0	3	2	0	LM
108	House Swift	*Apus affinis*	3	3	0	0	3	R

S.NO.	COMMON NAME	SCIENTIFIC NAME	HABITAT					ST
			O	D	M	R	W	
109	Crested Tree Swift	*Hemiprocne longipennis*	2	3	4	2	0	R
	ALCEDINIDAE							
110	Lesser Pied Kingfisher	*Ceryle rudis*	0	0	0	0	4	R
111	Common Kingfisher	*Alcedo atthis*	0	0	0	3	4	R
112	Stork-billed Kingfisher	*Pelargopsis capensis*	0	0	0	3	3	R
113	White-breasted Kingfisher	*Halcyon smyrnensis*	4	4	2	2	3	R
	MEROPIDAE							
114	Blue-tailed Bee-eater	*Merops philippinus*	0	0	0	0	2	W
115	Little Green Bee-eater	*Merops orientalis*	4	3	3	4	4	R
	CORACIIDAE							
116	Indian Roller	*Coracias benghalensis*	4	4	3	3	0	R
	UPUPIDAE							
117	Hoopoe	*Upupa epops*	3	3	3	3	0	R
	BUCEROTIDAE							
118	Common Grey Hornbill	*Tockus birostris*	3	4	4	4	0	R
119	Malabar Pied Hornbill	*Anthracoceros coronatus*	0	2	3	3	0	R
	CAPITONIAE							
120	Large Green Barbet	*Megalaima zeylanica*	3	4	4	4	0	R
121	Crimson-breasted Barbet	*Megalaima haemacepahala*	4	4	3	4	0	R
	PICIDAE							
122	Rufous Woodpecker	*Micropternus brachyurus*	0	2	3	0	0	R
123	Little Scaly-bellied Woodpecker	*Picus myrmecophoneus*	0	2	2	2	0	R
124	Small Yellow-naped Woodpecker	*Picus chlorolophus*	0	3	3	2	0	R
125	Lesser Golden-backed Woodpecker	*Dinopium benghalense*	4	4	4	4	0	R
126	Yellow-fronted Pied Woodpecker	*Picoides mahrattensis*	4	4	4	4	0	R
127	Brown-crowned Pygmy Woodpecker	*Picoides nanus*	0	3	4	3	0	LM
128	Black-backed Woodpecker	*Chrysocolaptes festivus*	0	1	3	2	0	R

S.NO.	COMMON NAME	SCIENTIFIC NAME	HABITAT					ST
			O	D	M	R	W	
	PITTIDAE							
129	Indian Pitta	*Pitta brachyura*	2	2	3	3	0	LM
	ALAUDIDAE							
130	Rufous-winged Bush Lark	*Mirafra assamica*	2	0	0	0	0	R
131	Red-winged Bush Lark	*Mirafra erythroptera*	2	0	0	0	0	R
132	Ashy-crowned Finch-Lark	*Eremopterix grisea*	4	0	0	0	0	R
133	Crested Lark	*Galerida cristata*	3	0	0	0	0	R
	HIRUNDINIDAE							
134	Collared Sand Martin	*Riparia riparia*	0	0	0	3	0	R
135	Common Swallow	*Hirundo rustica*	3	3	4	4	4	W
136	Wire-tailed Swallow	*Hirundo smithii*	0	0	0	3	4	R
137	Cliff Swallow	*Hirundo fluvicola*	0	0	0	0	3	R
138	Red-rumped Swallow	*Hirundo daurica*	4	4	0	3	4	R
	LANIIDAE							
139	Grey Shrike	*Lanius excubitor*	2	0	0	0	0	W
140	Bay-backed Shrike	*Lanius vittatus*	3	0	0	0	0	R
141	Rufous-backed Shrike	*Lanius schach*	4	3	3	2	0	R
142	Brown Shrike	*Lanius cristatus*	3	3	0	0	0	W
	ORIOLIDAE							
143	Golden Oriole	*Oriolus oriolus*	2	3	4	4	0	LM
144	Black-headed Oriole	*Oriolus xanthornus*	4	4	4	4	0	R
	DICRURIDAE							
145	Black Drongo	*Dicrurus adsimilis*	4	3	2	3	0	R
146	Ashy Drongo	*Dicrurus leucophaeus*	3	3	4	4	0	W
147	White-bellied Drongo	*Dicrurus caerulescens*	4	3	3	4	0	R
148	Greater Racket-tailed Drongo	*Dicrurus paradiseus*	3	4	4	4	0	R

	STURNIDAE							
149	Grey-headed Myna	*Sturnus malabaricus*	3	4	4	3	0	LM
150	Black-headed Myna	*Sturnus pagodarum*	4	3	3	3	0	R
151	Starling	*Sturnus vulgaris*	2	0	0	0	0	W
152	Pied Myna	*Sturnus contra*	0	1	0	0	0	R
153	Common Myna	*Acridotheres tristis*	4	4	3	4	0	R
154	Jungle Myna	*Acridotheres fuscus*	0	1	0	1	0	LM
	CORVIDAE							
155	Indian Treepie	*Dendrocitta vagabunda*	4	4	4	4	0	R
156	House Crow	*Corvus splendens*	1	0	0	0	0	R
157	Jungle Crow	*Corvus macrorhynchos*	4	3	2	4	0	R
	CAMPEPHAGIDAE							
158	Common Wood Shrike	*Tephrodornis pondicerianus*	2	4	4	3	0	R
159	Large Cuckoo-shrike	*Coracina novaehollandiae*	3	4	4	4	0	R
160	Scarlet Minivet	*Pericrocotus flammeus*	0	2	3	3	0	R
161	Long-tailed Minivet	*Pericrocotus ethologus*	0	0	3	0	0	W
162	Small Minivet	*P. cinnamomeus*	3	4	4	4	0	R
163	White-bellied Minivet	*P.erythropygius*	1	0	0	0	0	R
	IRENIDAE							
164	Common Iora	*Aegithina tiphia*	4	4	4	4	0	R
165	Golden-fronted Chloropsis	*Chloropsis aurifrons*	0	3	3	3	0	R
166	Jerdon's Chloropsis	*C. cochinchinensis*	3	4	4	3	0	R
	PYCNONOTIDAE							
167	Red-vented Bulbul	*Pycnonotus cafer*	4	3	2	4	0	R
168	White-browed Bulbul	*Pycnonotus luteolus*	2	0	0	0	0	R
	MUSCICAPIDAE							
	Timaliinae							
169	Rufous-bellied Babbler	*Dumetia hyperythra*	3	0	2	3	0	R
170	Yellow-eyed Babbler	*Chrysomma sinense*	3	0	0	0	0	R
171	Common Babbler	*Turdoides caudatus*	3	0	0	0	0	R
172	Large Grey Babbler	*Turdoides malcolmii*	2	0	0	0	0	R
173	Jungle Babbler	*Turdoides striatus*	4	4	4	4	0	R
	Muscicapinae							
174	Brown Flycatcher	*Muscicapa latirostris*	0	0	2	1	0	W
175	Brown-breasted Flycatcher	*Muscicapa muttuii*	0	0	1	0	0	W
176	Red-breasted Flycatcher	*M. parva parva*	0	3	4	4	0	W

		M. parva albicilla	4	2	2	0	0	W
177	White-browed Blue Flycatcher	*Muscicapa superciliaris*	0	3	4	3	0	W
178	Tickell's Blue Flycatcher	*Muscicapa tickelliae*	3	4	4	4	0	R
179	Verditer Flycatcher	*Muscicapa thalassina*	3	3	3	0	0	W
180	Grey-headed Flycatcher	*Culicicapa ceylonensis*	0	2	3	0	0	R
181	White-browed Fantail Flycatcher	*Rhipidura aureola*	1	3	4	4	0	R
182	White-throated Fantail Flycatcher	*Rhipidura albicollis*	4	2	1	2	0	R
183	Paradise Flycatcher	*Terpsiphone paradisi*	3	0	3	3	0	LM
184	Black-naped Flycatcher	*Hypothymis azurea*	3	3	4	3	0	R
	Sylviinae							
185	Franklin's Wren-Warbler	*Prinia hodgsonii*	4	4	3	4	0	R
186	Rufous-fronted Wren-Warbler	*Prinia buchanani*	3	0	0	0	0	R
187	Plain Wren-Warbler	*Prinia subflava*	1	0	0	0	0	R
188	Ashy Wren-Warbler	*Prinia socialis*	2	0	0	0	0	R
189	Jungle Wren-Warbler	*Prinia sylvatica*	3	3	3	2	0	R
190	Common Tailorbird	*Orthotomus sutorius*	4	4	4	4	0	R
191	Blyth's Reed-Warbler	*Acrocephalus dumetorum*	4	3	2	3	0	W
192	Lesser Whitethroat	*Sylvia curruca*	3	3	0	0	0	W
193	Brown Chiffchaff	*Phylloscopus collybita*	0	0	3	2	0	W
194	Olivaceous Leaf Warbler	*Phylloscopus griseolus*	3	4	4	3	0	W
195	Yellow-browed Leaf Warbler	*Phylloscopus inornatus*	2	2	2	2	0	W
196	Large-billed Leaf Warbler	*P. magnirostris*	0	1	1	1	0	W
197	Greenish Leaf warbler	*P. trochiloides*	4	4	4	4	0	W
198	Large-crowned Leaf Warbler	*P. occipitalis*	2	3	4	3	0	W
	Turdinae							
199	Magpie-Robin	*Copsychus saularis*	4	4	3	4	0	R
200	Shama	*Copsychus malabaricus*	0	0	2	0	0	LM
201	Black Redstart	*Phoenicurus ochruros phoenicuroides*	4	3	3	3	0	W
		P. o rufiventris	0	0	0	2	0	W
202	Collared Bush Chat	*Saxicola torquata*	4	0	0	0	0	W
203	Pied Bush Chat	*Saxicola caprata*	4	0	0	0	0	R
204	Dark-Grey Bush Chat	*Saxicola ferrea*						S
205	Red-tailed Chat	*Oenanthe xanthoprymna*						S
206	Indian Robin	*Saxicoloides fulicata*	4	3	0	0	0	R
207	Blue Rock Thrush	*Monticola solitarius*	4	0	0	3	0	W
208	Orange-headed Ground Thrush	*Zoothera citrina cyanotus*	2	3	4	3	0	R
209	Tickell's Thrush	*Turdus unicolor*	3	3	0	2	0	W
210	Blackbird	*Turdus merula*	2	3	3	3	0	LM

211	Blackthroated Thrush	*Turdus ruficollis atrogularis*	3	3	0	2	0	W
	PARIDAE							
212	Grey Tit	*Parus major*	4	4	4	4	0	R
213	Yellow-cheeked Tit	*Parus xanthogenys*	3	3	3	3	0	R
214	Fire-capped Tit	*Cephalopyrus flammiceps*	0	2	2	0	0	W
	MOTACILLIDAE							
215	Indian Tree Pipit	*Anthus hodgsoni*	2	3	4	4	0	W
216	Paddyfield Pipit	*Anthus novaeseelandiae*	3	0	0	3	0	R
217	Water Pipit	*Anthus spinolata*	0	0	0	2	0	W
218	Forest Wagtail	*Motacilla indica*	0	0	0	1	0	W
219	Yellow Wagtail	*Motacilla flava*	0	0	0	3	0	W
220	Yellow-headed Wagtail	*Motacilla citreola*	0	0	0	3	0	W
221	Grey Wagtail	*Motacilla cinerea*	3	0	0	4	0	W
222	White Wagtail	*Motacilla alba*	0	0	0	3	0	W
223	Large Pied Wagtail	*M. maderaspatensis*	3	0	0	4	0	R
	DICAEIDAE							
224	Thick-billed Flowerpecker	*Dicaeum agile*	2	3	4	4	0	R
225	Tickell's Flowerpecker	*Dicaeum erythrorhynchos*	0	2	3	0	0	R
	NECTARINIIDAE							
226	Purple Sunbird	*Nectarinia asiatica*	4	4	4	4	0	R
	ZOSTEROPIDAE							
227	White-eye	*Zosterops palpebrosa*	4	4	4	4	0	R
	PLOCEIDAE							
	Passerinae							
228	House Sparrow	*Passer domesticus*	3	0	0	0	0	R
229	Yellow-throated Sparrow	*Petronia xanthocollis*	3	4	3	3	0	LM
	Ploceinae							
230	Baya Weaver	*Ploceus philippinus*	3	0	0	0	0	R
	Estrildinae							
231	Red Munia	*Estrilda amandava*	3	2	0	2	0	R
232	White-throated Munia	*Lonchura malabarica*	3	3	0	0	0	R
233	White-backed Munia	*Lonchura striata*	3	0	0	0	0	R
234	Black-headed Munia	*Lonchura malacca*	2	0	0	0	0	R
	FRINGILLIDAE							
235	Common Rosefinch	*Carpodacus erythrinus*	3	0	0	2	0	W

	EMBERIZIDAE							
236	Black-headed Bunting	*Emberiza melanocephala*	0	0	0	2	0	W
237	Crested Bunting	*Melophus lathami*	0	0	0	2	0	W

HABITAT CODES :

O : Open Scrub Jungle
D : Dry Deciduous Forests
M : Moist Deciduous Forests
R : Riverine Forests
W : Wetlands

ABUNDANCE CODES :

0	Absent
1	Rare
2	Uncommon
3	Occasional
4	Common

STATUS CODES :

R : Resident
W : Winter Visitor
LM : Local Migrant
S : Staggler