# Patterns in Plant Species Richness and Diversity in the Forest Fragments of Western Ghats, Karnataka.

*Dissertation Submitted to*
**Saurashtra University, Rajkot.**

**in Partial Fulfillment of the Master's Degree in Wildlife Science**

*By*

NAVENDU V. PAGE

*Under the supervision of*

SH. QAMAR QURESHI
&
DR. G.S. RAWAT

Wildlife Institute of India

JUNE 2007

TM/WII/2007
581.5
PAG

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

## Certificate

This is to certify that **Mr. Navendu Page**, student of Wildlife Institute of India has carried out original research titled **"Patterns in Plant Species Richness and Diversity in Forest Fragments of Western Ghats, Karnataka"** for the partial fulfillment of the M.Sc. Degree in Wildlife Science from the Saurashtra University, Rajkot, India. These investigations were carried out under our supervision from November 2006 to June 2007. We also certify that this research has not been submitted for any other degree to any University.

Quamar Qureshi, Sr. Reader,
Landscape Ecology.

Dr. G.S. Rawat, Professor, 22/06
Habitat Ecology.

Dated: June 22, 2007
Place : Dehradun.

# Table of Contents

## Acknowledgements

First of all I thank Shonil Bhagwat and MS Chaitra for inspiring to take up a study in sacred groves of Kodagu.

**Starting from my filed study area, I thank...**

Dr, Kushallapa for all his help and encouragement during my sampling days. Looking back at my sampling days, I feel that there was no way that I could have completed my field work without his guidance.

College of Forestry- hostel inmates for making my field stay pleasant and enjoyable. I wish to thank Sujay, Muddasir. Manu, Mohan, Mahesh, Anil, Parshu, Abhishek ,Shrinath, Kartik, Kiran, Shrinivas, Ratnavarma for accompanying me and helping me out in the field.

Chandru, Raghavendra, Satish, Yetish, Balu for giving me a fantastic exposure to the sacred landscapes of kodagu and helping me with plant identification. Learning dentification of trees from these people made my life much easier.

G T and Raghunath for helping me with choosing my study sites.

Dr Ravi Kumar at KFRLHT, Bangalore for identifying all my tricky and specimens.

**Back at the Institute, I thank**

I thank Director and Dean WII for all their and support through out our master's course.

Dr. B.K. Mishra and Dr. Kartik for their help and guidance through the entire course duration.

I would like to thank Nilanjana, Babita and Dr. Manoj Agarwal for their help in the GIS cell.

Mr Saklani and Mr. Babu in the herbarium section and all the staff of the library for their cooperation throughout the course.

My supervisors Dr. Rawat and Qamar Sir for making the dissertation a wonderful learning experience. I consider myself very lucky to have their guidance for my dissertation.

Pankaj, Padma and Jeevan for providing me with all the right stuff related to epiphytes .

Pankaj again for making my colour plates and for having those long arguments on epiphyte host preference.

Ramesh and Jaypal, Meena for being such great seniors.

Chandan for formatting my data.

**and**

Rashid for guiding me through the toughest period of my dissertation.

## Summary

Patterns of species richness diversity and distribution, and the factors affecting these patterns have always attracted the attention of many ecologists. Degree of fragmentation is one such factor affecting the species richness and composition also of great importance to conservation biology in light of rapid loss of biodiversity. The study examined the patterns of distribution and species richness and its correlates in a fragmented landscape in Kodagu district, Western Ghats, Karnataka. The study also examined some of the factors affecting distribution of epiphytes such as distribution along the tree height gradient and host specificity.

A total of 129 species of trees, 29 species of lianas and 68 species of vascular epiphytes were recorded in 56, 25m x 25m square plots. 60 species of shrubs were recorded in 90, 5m x 5m square plots. Patch area was found to be significantly correlated with tree species richness, but area was not correlated with shrub, liana and epiphyte species richness. However plant density used as measure of site specific productivity along with area were significantly correlated with lianas and epiphyte richness. Neither of these could explain the variation in shrub species richness. Lianas and shrubs did not show any such trend but epiphyte richness showed a negative trend in rarefied species richness with increase in area. Rank abundance curves indicated that Reserve forest had the most equitable distribution of abundance classes and also more number of rare species. Species composition was found to differ significantly across different size classes. All the plant communities showed moderate levels of nestedness. Distribution of an epiphyte along the tree was not influenced by the mode of dispersal alone. There was no strong evidence in support of host specificity however some selective host species were found to be favoured by epiphytes.

# 1. INTRODUCTION

## 1.1 Habitat Fragmentation and Species Composition

Distribution patterns of individual species and communities have received a lot of attention in ecological literature (MacArthur and Wilson, 1967; Rickleft and Schutler, 1993). Generally it can be expected that species replace one another along predefined gradients such as rainfall, altitude, distance or among different habitats, suggesting that spatial variation in species composition reflect spatial distribution of suitable environmental conditions. Abrupt changes in habitat conditions into unsuitable types may affect distribution of species and cause fragmentation of habitat for several species.

One of the most commonly found relationships in the context of habitat fragmentation is the decrease in species number with decrease in patch area (Piessens et al, 2004). Theory of Island Biogeography predicts that smaller fragments contain less species because they are more sensitive to area dependant extinction processes (Schafer, 1981; Primm et al, 1988). The decrease in species richness can theoretically be counteracted by the colonization of individuals of the species, the so called rescue effect (Brown and Codric-Brown, 1977). Species composition is another important aspect of fragmented communities.

### Species Area Relationship

The analysis and interpretation of 'z' values, the slope estimates resulting from log-log species-area regression (logs=log k + z log A, where S is species richness, A is area and k and z represent the intercept and slope of the species area regression) has been a debated issue in fragmentation and island biogeography research, with some authors interpreting 'z' value biologically and others suggesting no biological meaning can be attributed to z (Preston, 1962; Connors and McCoy, 1979; Gilbert, 1980). Fragments generally have higher z values than island archipelagos (Lomolino, 1984; Patterson and Atmar, 2000) while a review done by Watling and Donelly (2006) found z values significantly higher on true islands than in terrestrial patches.

One important feature of species–area curves is that the slope '*z*' depends on the overlap in the species composition of the localities used to draw the curve. When localities share many species, there is a 'slow' increase in the number of species with area, and *z* will be relatively small. Alternatively, when localities share just a few species, there is a 'faster' increase in the number of species with area, and *z* will be relatively high.

**Nested Subset Patterns**

Communities of fragmented habitat often exhibit nonrandom pattern of species composition. A frequently observed example of such a nonrandom example of species composition is the nested subset pattern (Piessens et al, 2004). A highly structured pattern of distribution on islands termed as nested subsets was identified by Patterson and Atmar in mammal fauna on three archipelagos (Patterson and Atmar, 1986). The nested subset hypothesis states that the species comprising a depauperate insular biota are a proper subset of those in richer biota, and that an archipelago of such biotas, ranked by species richness, presents a nested series (Patterson, 1987).

The pattern of species composition is based on the underlying non random pattern of species distribution in which individual species tend to be present in all richer biotas within an archipelago than the most depauperate one in which they are found (Patterson, 1987). A similar pattern .was demonstrated by Patterson and Atmar for South Western mountain top mammals. These patterns were subsequently also observed in several other biotas like isolated mountain tops, forest fragments, refugias etc.

**Effect of Matrix**

Brown and Kodric-Brown in 1977, found out that conspecific immigrants tend to reduce extinction rates of insular populations. The decrease in species richness can theoretically be counteracted by the colonization of individuals of the species, the so called rescue effect (Brown and Codric-Brown, 1977) This finding was supported by Piessens et al in a study on heathland fragments where the extinction of species as a result of area dependant extinction processes was found to be prevented through isolation dependant colonization processes in less isolated patches (Piessens et al, 2004). A similar study conducted by Bhagwat et al (2005) on forest fragments of Karnataka in Western, Ghats found evidence in support of the rescue effect. Sacred groves in Kodagu are patches of forest in a landscape that probably once had continuous tree cover. The biogeographic processes related to species loss from forest remnants have had an obvious effect on sacred groves but the tree-covered nature of the matrix (coffee plantations which maintain native tree cover) has contributed in reducing the intensity of the species loss and maintained the similarity in species composition of sacred groves and the forest reserve despite the distance (Bhagwat et al, 2005).

**Epiphytes**

One of the characteristic features of tropical vegetation is the abundance of epiphytes covering the limbs and trunks of the forest trees and hanging in masses from the outer branches. True epiphytes may be considered those species, which normally germinate on the surface of another living plant and pass the entire life cycle without becoming connected to the ground (Madison, 1977). In addition to species in which all the species are epiphytes for part of the life cycle there are a number of species where a portion of the population consist of true epiphytes and the remaining individuals are terrestrial. This is seen in members of Ericaceae and Myrtaceae where growth habit is plastic and a single species may occur as a lithophyte, epiphyte, liana, or tree depending on where it happens to germinate. Certain epiphytic plants may have a direct vascular connection to their host. They represent a highly specialized group called parasitic epiphytes systematically and physiologically distinct from the true epiphytes.

Epiphytes are found in 65 families of vascular plants, of which 9 are Pteridophytes, two Gymnosperms, 16 families of monocots and 38 of dicots. Epiphytic communities are generally characterized by a great abundance and richness in species, accounting for about 10 percent of vascular plants (Kress, 1986). Several hypothesis have been put forth to explain the high diversity in ecological communities, the niche diversification is perhaps most widely accepted. For epiphytic communities in particular this hypothesis is supported by the observation that, at least in some forests, vascular epiphytes exhibit host tee specificity or marked preference for particular host species (ter Steege and Cornelissen, 1989), and that various characteristics of host tree species may correlate with the presence and abundance of epiphytes (Frei and Dodson, 1972). These include variation in canopy effects of light, allelopathic and fertilization effect of throughfall, substrate moisture conditions, bark stability and factors such as bark surface rugosity (Kernan and Fowler, 1995; Tally et al, 1996; Rietz and Briones, 1998). Moreover, phorophyte architecture such as canopy structure, branching pattern, leaf size etc. may also have strong influences on the germination and establishment of epiphytes (Benzing, 1978).

Among other factors spatial distribution of epiphytes generally depend on the phorophyte species, its age and microclimatic conditions (Schimper, 1888; Went, 1940; Sanford, 1968; Johansson, 1974, 1975; Catling et al 1986). Different trunk diameter of the same tree species usually represent different ages and are correlated with degree of epiphyte diversity (Bennett, 1986) and species associations (Catling and Lefkovitch, 1989). Within a tree distinct epiphytic floras are found on twigs (Chase 1987) or on accumulations of humus in branch forks (Schimper, 1888). Canopy trees can be divided into five life zones (Johansson, 1974), three of those dividing the crown into equal thirds. The inner structure of these zones can be further divided and in some cases it has already been shown that branch diameters are correlated with epiphyte abundance (Valdivia, 1977; Catling et al, 1986). Johansson (1974) discussed the theoretical distribution patterns along large branches and found two groups of environmental changes: decreasing factors (roughness of substrate, humus deposits, nutrients, humidity) and increasing factors (temperature, light, wind velocity). Quantity and quality of microclimatic gradients have been verified within an emergent tree in Costa Rica (Freiberg, 1994). The interaction of these gradients leads to different distribution patterns in epiphytic communities.

**Relation between Tree Size and Epiphyte Richness**

As epiphytic species richness is linked to tree size, the same reasoning that is applied to species area relationship could be applied to explain this system. Unlike real islands however trees change in size over -time (size, age, and environmental diversity), generating new microhabitats for epiphytes.

Daniel Kelly (1985), in his study on the wet tropical forest of Jamaica found a marked correlation between tree height and number of compact epiphytic species and between tree height and total number of dependant species. He also found the threshold level for the trees, below which the height supported only a depauperate dependant flora. The result was in contrast with that of Valdivia (1977), who worked in south Mexico, found no relationship between tree height and number of epiphytes.

Catling and Lefkovitch (1989) in their study on cloud forests of Gautemalan, considered relationship of species associations with the trunk diameter. Conditional clustering and constellation analysis revealed associations of small closely related species on smaller and consequently younger trunks, and associations of large, less closely related species on larger and hence older trunks.

Bums and Dawson (2005) studied patterns in distribution and among epiphytes and wines. Based on the ground based surveys they showed that species diversity of epiphytes and vines increased with diameter of the host tree, however the relation differed between epiphytes and vines.

Annaselvam and Parthasarathy (2001), in tropical evergreen forests of Western Ghats also detected a significant positive relationship between trunk size and epiphytic associations. Large epiphyte species occurred mostly on middle and larger stems and smaller epiphytic species occurred on smaller stems. The occurrence of such pattern was explained by the large area offered with a greater variety of branch diameters, crotches and knot holes, with different microhabitat for epiphytes.

**Effect of Mode of Dispersal on Epiphyte Distribution**

Daniel Kelly (1985) found a correlation between vertical zonation and mode of dispersals. Epiphytes of upper strata have small, wind dispersed. diaspores. The proportion of epiphytic species with succulent diaspores increases on going down wards. Nearly all species regenerating above 16m were found to be adapted for wind dispersal, while a great majority of those growing below 8 m are adapted for animal dispersal reflecting very limited air movement at these levels.

Neider et al (2000) studied family wise vertical distribution; however vertical separation was not significant between most families. Range of vertical distribution within families was generally wide, with exception of families represented by very few members. Differences were found to be more finely tuned on generic levels. Due to relatively low number of individuals, vertical distribution differences of species in most cases were not significant, however vertical distribution was clearly structured because of different light conditions of different species. They also studied spatial distribution of vascular epiphytes in southern Venezuela. They compared single occurrence of epiphytic plants with those occurring in epiphytic stands. Of all epiphytic individuals 63.4% occurred in stands with other epiphytes. This was particularly frequent in ant garden epiphytes, while orchids usually grew as solitary plants.

Todzia (1986), in Panama studied preferential growth of hemiepiphytes on different parts of the host tree. He found that different hemiepiphytic species have distinctive locations within host trees. He inferred that differences in establishment requirements like, host tree microhabitat, behaviour of dispersal agents might be responsible for interspecific variation in distribution of hemiepiphytes. His results also suggest that spatial patterns of hemiepiphytes are in part due to differential loss of individuals. Bessey (1908) showed that humus pockets of host might be important for germination of certain species.

**Host Specificity and Preference**

Very little evidence has been found for host specificity in spite of good number of studies supporting dependency of vascular epiphytes on canopy trees for their habit (Zimmerman and Olmstead, 1992). In the study carried out by Todzia (1986) in Panama, found uneven distribution of epiphytes on host trees of similar density. Guy (1977) proposed major factors influencing establishment of hemiepiphytes on host tree species including bark texture, trunk physiognomy and the food preference of there animal dispersers.

Munoz et al (2003) assessed whether epiphytic and vine species exhibit preference among host tree species and tested whether species richness on tree hosts differs from that expected by chance, by comparing observed frequencies of occurrence and species richness with randomly simulated frequency distributions generated under the assumption of no epiphyte preferences. Most epiphytes and vines (65%) showed preference for one or two tree species, while species richness was significantly lower than expected by chance on one of the host species.

Large scale ecological studies on herbaceous vascular epiphytic species are lacking in Indian tropics. Annaselvam and Parthasarathi (2001) studied diversity and distribution of vascular epiphytes in evergreen forests of Western Ghats with respect to the trunk size and epiphytic associations while Padmawathe (2001) studied species composition and distribution of epiphytes and the effect of logging on them. Due to technical advancements in canopy sampling techniques in western countries, comparatively, there have been a higher number of studies, which have addressed the ecological requirement of epiphytes. Apart from general distribution, microclimatic factors and sensitivity to change in these microclimatic factors have also been documented (Ingram and Nadkarni, 1984; ter Steege and Cornelissen et al, 1989; van Leerdan et al, 1990). Some researchers have used trees and branch size to establish cronosequences for studying the succession dynamics of epiphytes, and studies have shown that epiphytes species assemblages change in accordance with the tree size (Catling & Letkovitch, 1989; Rudolph et al., 1998; Lyons et al., 2000; Ruchty et al., 2001; Zotz & Vollrath, 2003). The relationship between tree size and epiphyte species richness (TS-ER hereafter) has been well documented with positive, neutral and negative relationships identified (Yeaton & Gladstone, 1982; Kikuchi et al., 1992; Rietz & Rietz-Seifert, 1995a,b; Cordoba & Del Castillo, 2001; Zotz &Vollrath, 2003).

## 1.2 Objectives

The present study seeks to investigate the aspects of the epiphyte-phorophyte relationship to explain the patterns of epiphytic species richness and abundance.

**Objective-1: To study the effect of degree of fragmentation on species richness, abundance, species area relationship in plant communities and to determine the factors responsible for the observed species richness.**

1. To study the effect of area and isolation on species richness.
2. To compare the observed slopes of species area curve for forest fragment with the standard range of slope values of island archipelagos.
3. To investigate if the plant species are distributed non randomly across the different habitat patches.
4. To investigate if different life forms or plant groups exhibit differential response with respect to fragmentation.

**Objective-2: To study the patterns in spatial distribution and diversity of vascular epiphytes in tropical evergreen forest of central Western Ghats.**

1. To investigate whether mode of dispersal influences distribution of epiphytes along the tree stature.
2. To investigate whether epiphytic species exhibit certain degree of host specificity and host preference.

## 2. Study Area

### 2.1Western Ghats

The Western Ghats (Sahyadris) form a continuous chain of mountains running parallel to the western coast of Indian Peninsula. The mountain range is 1600 km long and 5 to 150 km wide extending from 8° -20° N latitudes and 73°-77° E longitudes. It is practically unbroken except at Palghat where it is interrupted by a 30 km wide gap (Pascal, 1988). Western Ghats has been described as one of 25 global biodiversity hotspots on account of its high levels of species richness, endemism and loss of primary vegetation (Myers et al, *2000*).

**Kodagu:** The district Kodagu (Coorg) is situated on the eastern slopes of Western Ghats extending from 75°25'- 76°14' E and 12°15'- 12°45' N. The altitude of the district ranges between 300m (FRLHT) to 1734m above the sea level. Tadiandamol is the highest peak in the district, situated on the extreme west boundary of the district which forms the natural barrier between Kodagu and the low lying, neighboring, coastal districts (Pascal, 1988).

The district contains a large number of forest types in a comparatively smaller area (4106 sq km). This is because of a sharp gradient in bioclimatic factors like the amount of annual precipitation, duration of the monsoon and other topographical features such as the aspect and altitude. Based on these factors (Pascal, 1986) broadly classified the forest types in to the following vegetation types

i. Wet Evergreen forests: These are found mainly along the western boundary of the district and on the western aspect of the Western Ghats. This forest type receives very high rainfall and has a short dry season. These forests are characterized by high species richness and is further classified in three vegetation types depending on the elevation and species composition

a) Low elevation (up to 800-900m) *Dipterocarpus indicus - Kingiodendron pinnatum - Humboldtia brunonis* type.

b) Medium elevation (650m- 1400m) *Mesua ferrea - Palaquium ellipticum* type.

c) High elevation (1400m-1800m) *Schefflera spp. - Gordonia obtuse - Meliosma arnottiana* type.

ii. Moist Deciduous forests: These are situated along the central-eastern plains of Kodagu district. These receive relatively lower rainfall (1500-2000m) and a longer duration of dry season. These forests are dominated by *Alstonia scholaris, Vitex altissima, Dillenia pentagyna, Stereospermum personatum.*

iii. Dry Deciduous: This forest type is found mainly on the eastern side of the district with an annual rainfall of 750-1500mm and a dry season of 5-8 months. These forests are characterized by species like *Tectona grandis, Terminalia spp, Anoegissus latifolia.*

**Virajpet taluka:** The intensive study sites are located in reserve forest, sacred groves and coffee plantations in the Virajpet taluka of the Kodagu district. This is the largest and the southernmost among the three talukas (Madikeri and Somvarpet being the other two) with an area of about 150,000 ha. Virajpet taluka is recognized a 'global hotspot' because of the highest density of sacred groves in the world (more than 500 sacred groves) (Kushalappa and Bhagwat, 2001).

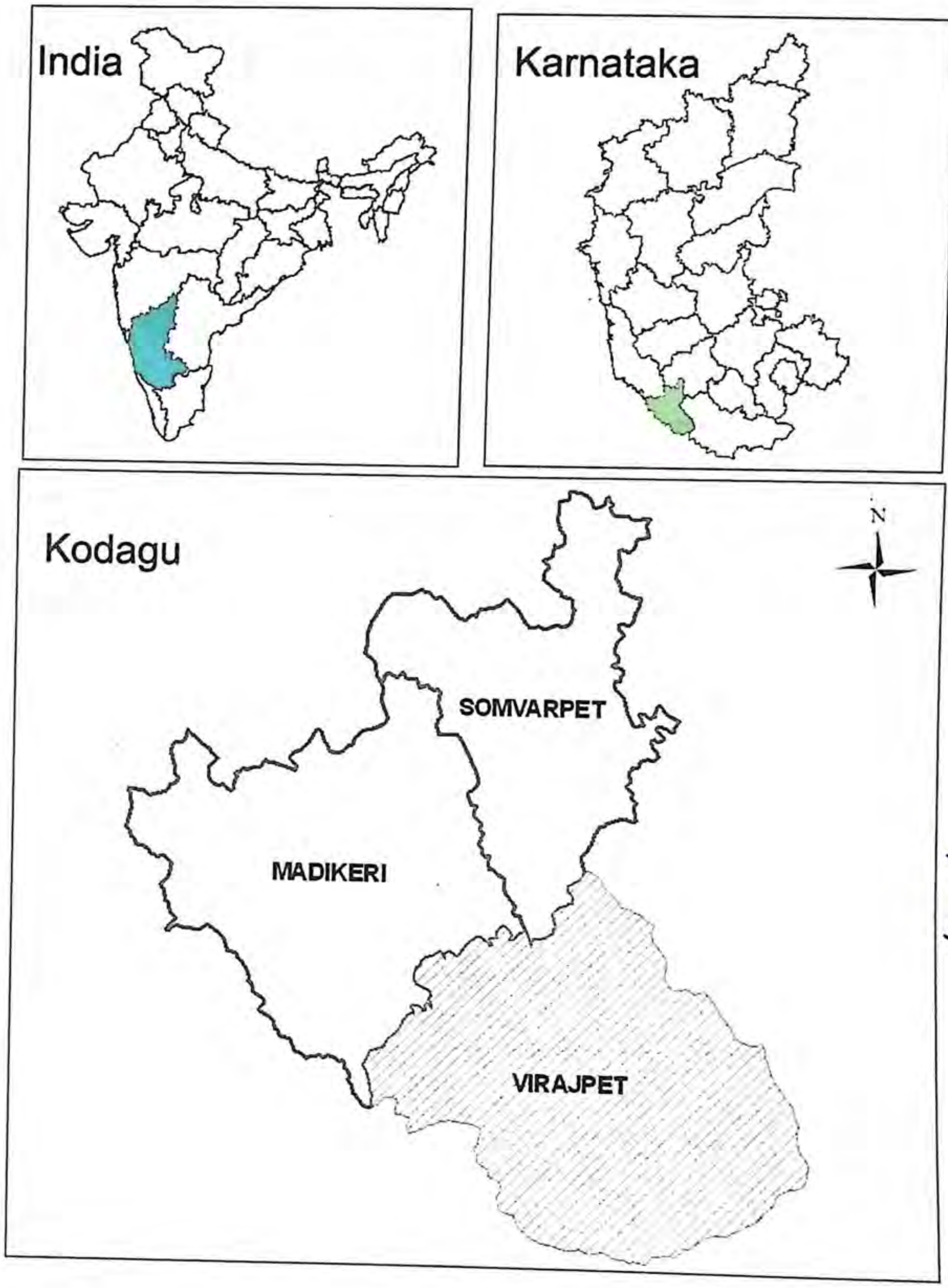



**Figure 2.2.1** Map of the study area showing the three tehesils (taluks). Most of the study areas are located within the Virajpet tehsil.

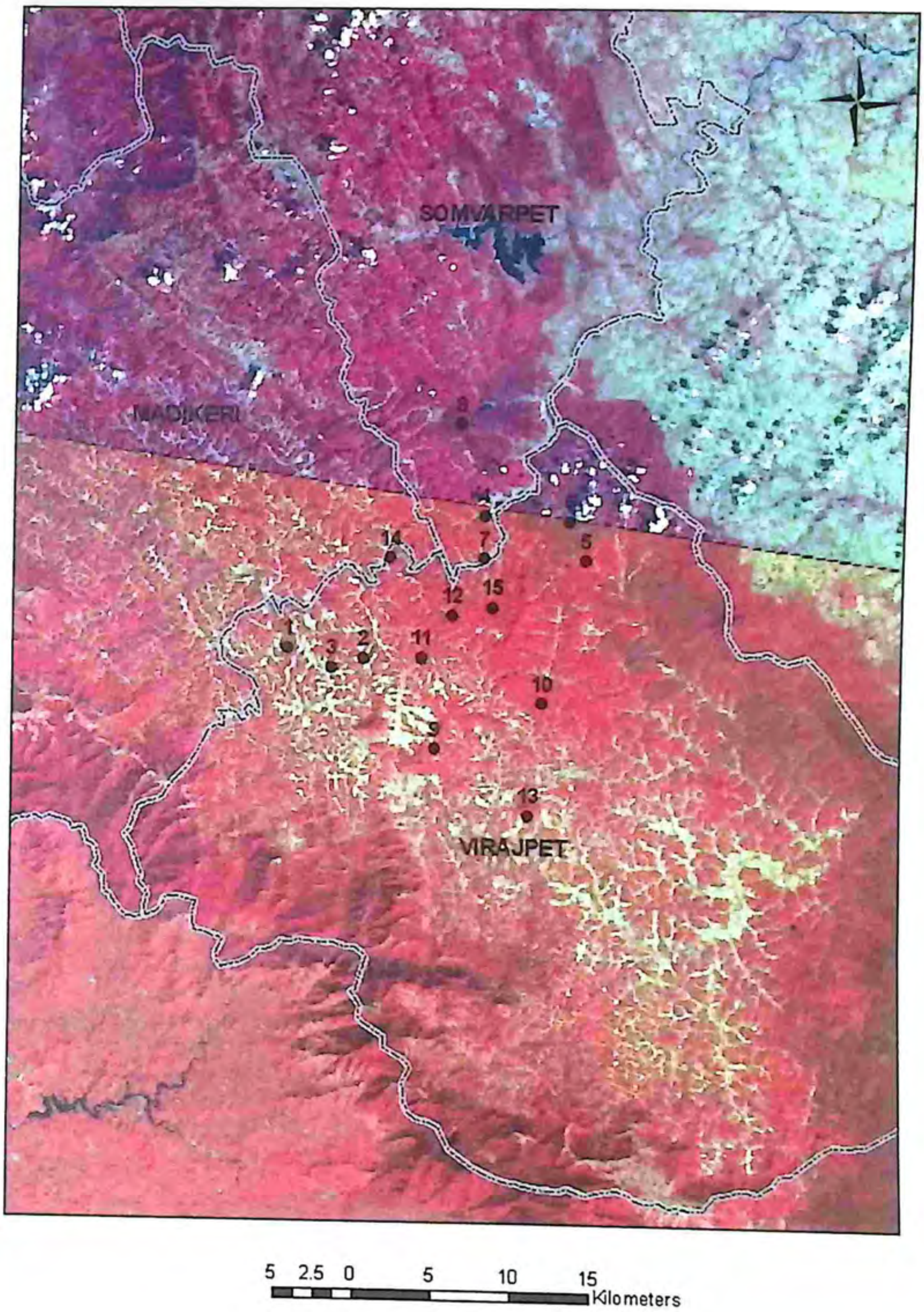



**Figure 2.2.2** False color composite image showing the study area with sampling localities.

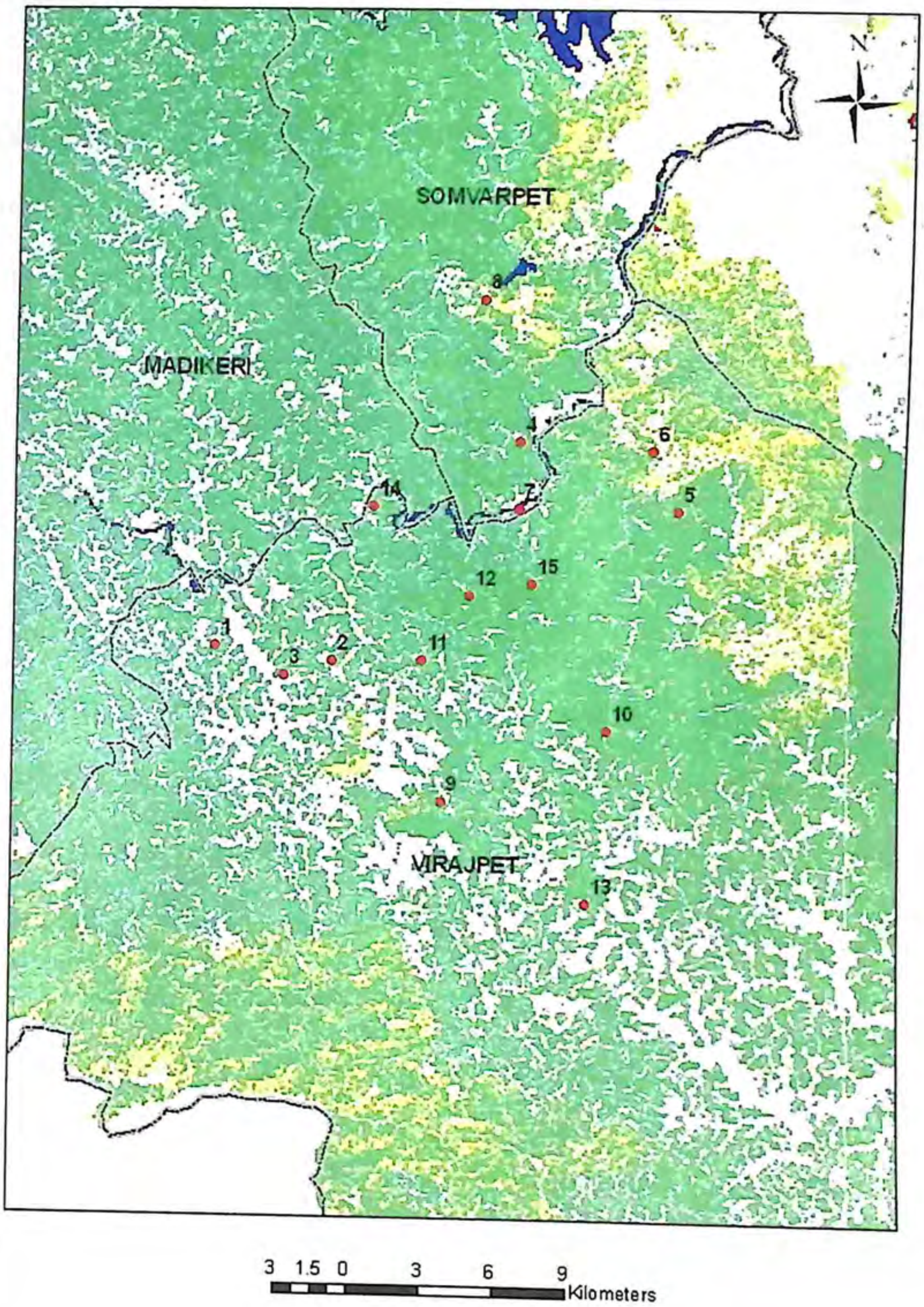



**Figure 2.2.3** Forest Cover Map of the study area with sampling localities.(Point identities correspond to Sr. No. in Table

## 2.2 Vegetation Type

The study sites were restricted to Mid-elevation *Mesua ferea - Palaquium ellipticum* type.

Bioclimatic Limits-

This forest type is found at an altitudinal range between 750-1250m. Climax forests of this vegetation types exists only at the edge of the Ghats in the Kodagu district while the one on the plateau have been severely fragmented due to transformation into Coffee and Cardamom plantations. The study area receives heavy rains during the summer monsoon exceeding 2000m. The dry season varies between 4 to 5 months (Pascal, 1988).

Floristic Composition-

The floristic composition exhibits subtle variations with respect to aspect, altitude and edaphic conditions. The common species representing the different structural assemblages or stratas are describes below (Adopted from Pascal, 1988).

The species common in the uppermost strata (the emergent strata) are *Democarpus longana, Calophyllum polyanthum, Syzigium densiflorum, Canarium strictum, Aphanathe cuspidata, Michelia champaka* and *Holigarna grahmii.* Less common species include *Crysophyllum lanceolatum, Aglaia elaeagnoides, Dysoxylum malabaricum, Persea micrantha and Plaquium ellipticum.*

The second stratum is represented by *Cinnamomum malbathrum, Nothopegia racemosa, Hydnocarpus pentadra, Knema attenuata, Elaeocarpus serratus, Garcinia gummi-gutta and Evodia lunu-ankenda* etc. Species which are associated with canopy openings (Heliophytes) are *Macaranga peltata, Mallotus tetracocus, Vernonia monosis* and *Caryota urens.*

Species comprising the lowermost structural assemblages include shrubs and small trees such as *Agrostisstachys indica, Syzigium laetum, Xanthophyllum flavescens, Euonymus indicus, Psychotria dalzelli, Goniothalamus cardiopetalus, Atalantia wightii,* and *Memecylon spp.*

Lianas abound where there is availability of sufficient light. These include *Acacia concinna, Strychnos wallichiana, Toddalia asiatica, Mesoneurum cuculatum, Grewia heterotricha, Ventilago maderaspatana, Gnetum ula, Derris sp. and Alangium salvifolium.*

Variations in latitude are not very pronounced in the study area. The changes are however more abrupt with change in altitude. Members of family Lauraceae become more frequent with increase in altitude (Pascal, 1988).

### 2.3 Land Use Types

**Coffee plantations**: Coffee plantation is one of the most prominent land use occupying about 29% of the land area in Kodagu district (Elauord, 2000a; Bhagwat, 2002). Pepper, cardamom, ginger and paddy are other important crops (Bhagwat, 2002). Initially restricted only to the moist deciduous areas of the district, the plantations have extended to the medium elevation wet evergreen forest area because of the lucrative business of the coffee and the need to bring more area under coffee cultivation (Elouard et al, 2000). This resulted in major alterations in the landscapes of Kodagu leading to severe fragmentation of the wet evergreen forest and thus affecting the ecosystem and their biological diversity (Elouard et al, 2000).

Coffee is a shade demanding plant. Therefore the planters maintain canopy cover over the coffee plants to keep the humidity and temperature requirements of the crop. In most of the plantations canopy cover constitutes native forest species with varying percentage of exotics like Silver Oak (*Grevillea robusta*) and *Erythrina sp*, depending upon the plantation management and the land tenure system.

Studies on the tree diversity in the coffee plantations (Muthappa et al 2001; Sathish, 2004) have shown that tree diversity and density in the coffee plantations differ with respect to vegetation type, land tenure system, age and size of the plantation, variety of coffee, and also to a certain extent with respect to the altitude. Overall results indicate a positive correlation of native tree species richness with the size of the coffee plantation. Species richness was found to be highest under unredeemed tenure of the semi evergreen vegetation type.

The coffee based agroforestry has been viewed as better landuse practice as compared to agriculture as it has a high potential for biodiversity conservation because they can act as a reservoir for local, endemic and endangered tree species and also as an important source of genetic diversity (Elouard et al, 2000).

**Sacred groves**: Traditional conservation practices have played a major role in protection and conservation of biodiversity, especially in countries like India where nature worship has played a key role in making the people believe that all creations of nature have to be protected. One of such conservation practices is dedicating the forest patches to the local deity (Khambongmayum et al, 2004). Such forests reserved in the name of God (local deity) are called sacred groves. Until recently, local beliefs and religious taboos and fear of the God had prevented people from extracting and using any kind of resources from these sacred forests.

In Kodagu the number of scared groves or *Devarakadus,* as they are locally called, exceeds 1200 (Kalam, 1996), making it the district with perhaps the highest density of scared groves in the world (Bhagwat and Kushalappa, 2000). In 1887 sacred groves in Kodagu were declared protected forests and separate set of rules were laid down for protection of sacred groves which legally prohibited people from felling, lopping, burning trees within the limits of the sacred grove and also preventing removal of any other produce from the sacred groves except on special permits. In 1985 Govt. of Karnataka declared them as Reserve Forests, however, sacred groves have never been formally handed over to the forest department but remain to be managed by the local communities (Kalam, 2000).

The size of the sacred groves in Kodagu district ranges from a very large number of sacred groves falling within an area of less than 2 ha to very few sacred groves larger than 10 ha. Some of the largest sacred groves are as large as 50 ha.

Following table gives the size class distribution of scared groves in three talukas of Kodagu district (After Kushalappa and Kushalappa, 1996).

**Table 2.2.1.** Size class distribution of Sacred groves in Kodagu district.

| **Extent (ha)** | **Virajpet** | **Madikeri** | **Somwarpet** | **Kodagu** |
|---|---|---|---|---|
| | **(*N*=508 ;%)** | **(*N*=284 ;%)** | **(*N*=422 ;%)** | **(*N*=1214 ;%)** |
| < 2.0 | 80.29 | 71.46 | 87.18 | 80.87 |
| 2.0 - 6.0 | 11.21 | 17.25 | 8.28 | 11.6 |
| 6.0 - 10 | 4.91 | 4.92 | 1.88 | 3.86 |
| > 10 | 3.54 | 6.33 | 2.6 | 3.87 |

**Reserve forests**: Of the 46% of the total area of Kodagu which is under forest cover, 30% is under Reserve Forest (R F). About 70% of the RF is represented by wet evergreen forests which lie along the western boundary of the district. Most of the dense and undisturbed forests are now found only in the Reserve Forests. This RF is contiguous with Bramhagiri, Talakaveri and Pushpagiri Wildlife Sanctuaries (Elouard et al, 2000).

Table 2.2.2. Description of the Study Sites

| Sr. No. | Site | Status | Area* (ha) | Altitude (m) | Latitude | | | Longitude | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | degree | min | sec | degree | min | sec |
| 1 | Arapattu | Sacred grove | 19.27 | 935 | 12 | 14 | 7.3 | 75 | 44 | 9.3 |
| 2 | Heggala-Ayappa | Sacred grove | 42.05 | 929 | 12 | 8 | 41 | 75 | 46 | 13.4 |
| 3 | Kadanoor | Sacred grove | 9.07 | 864 | 12 | 13 | 9.3 | 75 | 47 | 0.8 |
| 4 | Devangere- Ayappa | Sacred grove | 8.26 | 927.9 | 12 | 15 | 30 | 75 | 48 | 26.9 |
| 5 | Devangere- Tatappa | Sacred grove | 0.95 | 942.6 | 12 | 15 | 20 | 75 | 47 | 54.4 |
| 6 | Arji- Bhagvati | Sacred grove | 8.51 | 900 | 12 | 10 | 58 | 75 | 47 | 50.8 |
| 7 | Mytadi- Koovale | Sacred grove | 4 | 856 | 12 | 17 | 8.4 | 75 | 46 | 38.8 |
| 8 | Mytadi- Thomadu | Sacred grove | 4 | 910 | 12 | 15 | 49 | 75 | 47 | 27.7 |
| 9 | Palangala | Sacred grove | 46.43 | 920 | 12 | 11 | 4.4 | 75 | 42 | 52.5 |
| 10 | Rudraguppe | Sacred grove | 13 | 835 | 12 | 9 | 26 | 75 | 51 | 21 |
| 11 | Bettoli | Sacred grove | 9.72 | 896 | 12 | 11 | 24 | 75 | 47 | 19.8 |
| 12 | Heggala | Reserve forest | >1000 | 978 | 12 | 7 | 56 | 75 | 45 | 38.2 |
| 13 | Kokka | Reserve forest | >1000 | 778 | 12 | 5 | 27 | 75 | 50 | 24.3 |
| 14 | Mytadi | Coffee plantation | 12 | 910 | 12 | 15 | 21 | 75 | 47 | 12.9 |
| 15 | Chikpet | Coffee plantation | 15 | 896 | 12 | 12 | 28 | 75 | 47 | 34.7 |

* Source for Area - Details of Devarakadus of Virajpet Forest Division of Kodagu circle, Karnataka, Survey of India.

### 2.4 Description of the Study Sites

**1. Devengere- Tatappa devarakadu**

Area- 0.94 ha. Altitude- 942 m. Deity- Tatappa

This sacred grove is one of the smallest in the study area. The deity is situated outside the grove. The grove remains protected because of private coffee land surrounding the plantation. In spite of its small size it has still retained many old trees with girth exceeding 2m and height exceeding 30m.

**2. Mythadi- Batamakki/ Thommadu devarakadu**

Area- 4 ha Altitude- 910m Deity- Batamakki/ Thommadu

The deity is small and situated very near to the entrance of the grove, without clearing any major vegetation or large trees. Its is protected by a barb fence from all sides. The grove has a few large canopy openings in the intermediate and interior zone. These typically have a dense growth of *Acacia concinna*. There is also a small ephemeral pond not very far from the edge of the grove. The interior zone of the grove is very moist as compared to the outer zones, which has species like *Syzigium montana* and *Syzigium spicata* which are typical of moist places.

**3. Mythadi- Koovale Ayappa/ Ishwara devarkadu**

Area- 4 ha Altitude- 856 m Deity- Koovale Ayappa/ Ishwara

The deity is situated at the very edge of the grove. River Cauvery runs along one of the edges of the grove. Surrounding landscape includes coffee plantation, paddy fields and a small teak plantation. The species composition, especially of the under storey is very different from the other groves in the study area. This may be because of the close proximity to the river. These include species like *Agrostistachys indica*, *Reinwardtiodendron anamallayense, Calophyllum polyanthum and Drypetes oblongifolia.*

**4. Arji- Bhagvati devarakadu**

Area- 8.51 ha Altitude- 900m Deity- Bhagvati

A tar road is built through the sacred grove dividing it into two. Both the halves are fenced. A small temple is built for the deity by clearing a considerable amount of area around the temple and new construction is still in progress. The path leading to the temple from the entrance has undergone widening.

**5. Bettoli- Bhadrakali devarakadu**

Area- 9.72 ha Altitude- 896m Deity- Bhadrakali

The grove is like an isolated island surrounded by paddy fields from all the sides. The deity is housed in an elaborate temple constructed in the centre by clearing a large area around the temple premises. A wide and lengthy path connects the entrance to the temple creating an artificial edge in the sacred grove. There is abundant regeneration of coffee in some places where it has completely replaced the native vegetation.

**6. Kadanoor- Ayappa devarakadu**

Area- 9.07 ha Altitude- 864m Deity- Ayappa

This is a fairly large grove situated on Virajpet- Madikeri road. The grove has more than one entrance to get to the deity. Large canopy openings present along the entrance from the main road side has lead to dense growth of invasive and light demanding species like *Lantana, Cromolina* and *Clerodendrum*. There are several interconnected trodden paths in the grove. The interior area where canopy is intact are relatively moist where one gets to see pure stands of *Shumanianthus virgatus*, a tall rhizomatic herb which is otherwise seen growing in the marshy areas. The deity exists in the form of a small platform built at the base of large tree without any construction, surrounded by piles of statues of 'dog'an animal supposed to be the companion of Lord Ayappa who is believed to be a hunter god.

**7. Devengere- Ayappa devarakadu**

Area- 8.26 ha Altitude- 927m Deity- Ayappa

The grove is protected by a barbed fence. Most of the grove is surrounded by a coffee plantation. The deity is situated a little inside from the entrance of the grove, by cutting a few large trees around it. This grove has a good number of old trees belonging to species like *Spondias, Michelia, Bombax* and *Antiaris toxicaria* with giant buttresses and height exceeding 40m. Only grove among the study sites which has a population of Bombax *ceiba*, a species seen much more frequently in deciduous forests.

**8. Arapattu- Mahadevarakadu**

Area- 19.27 ha Altitude- 935m Deity- Mahadev

This sacred grove is one of the few remaining largest sacred grove, which are not connected to the reserve forest. The deity is placed in a stone temple near the centre of the grove. The grove is surrounded by coffee plantation from all sides. There exist some marshy areas along the stream that cuts across through the grove. This sacred grove has a few large trees of *Aglaia jainii* and *Dysoxylum malabaricum*, the later endemic to Western Ghats and also a population of *Adenia hondala*, one of Karnatakas red listed medicinal plants.

**9. Rudraguppe**

Area- 13 ha Altitude- 835 m

Giant lianas belonging to species like *Gnetum ula*, *Ventilago*, Derris and *Strychnos wallichiana*, characterize this scared grove. There exists one large canopy opening in the intermediate zone, where there is abundant growth of weeds and light demanding ferns. The deity temple has a road approach from two sides. Surrounding landscape use includes paddy and coffee plantation.

**10. Palangala- Ayappa devarakadu**

Area- 46.43 ha Altitude- 920m Deity- Ayappa

The location of the sacred grove is fairly remote and is one of the farthest locations among the study sites, from Virajpet town. It's located on the eastern aspect of the hill slope and continues to join the reserve forest on the upper reaches of the hill. It's the largest sacred grove in the study area. Deity is located just near to the entrance of the grove. A perennial stream flows along one of the edges of the grove. The canopy is intact and dense. The interior part has giant buttressed trees of *Syzigium densiflorum*, *Palaquium ellipticum* and *Turpinia malabarica.*

**11. Heggala-Ayappa Devarakadu**

Area- 42.05 ha Altitude- 929m Deity- Ayappa

This grove is connected to the reserve forest, the boundary demarcated by putting up a series of piles of stones. One or two canopy openings have been created by cutting down a few large trees. The grove is situated on the eastern slope and a stream flowing down from the hill cuts through the centre of the sacred grove. There are monodominant patches of *Bambusa arundinacea* and *Pandanus sp.* near the stream. This sacred grove along with the adjoining reserve forest has some species which are found exclusively in these sites, eg. *Dillenia bracteata, Syzigium munronii* and *Bischofia javanica.*

**12. Heggala Reserve Forest**

Altitude- 978m

Heggala RF is one of the least disturbed sites in the study area. It is an unfragmented, continuous stretch of forest connected to the Bramhagiri Wildlife Sanctuary. The forest canopy is higher and denser than the sacred groves because of which the epiphytic flora is extremely dapauperate. Heggala reserve forest also differs from the sacred groves in terms of its species composition. It has a few species both from low elevation and high elevation evergreen forest.

**13. Kokka Reserve Forest**

Altitude- 778m

This RF is located just above the upper altitudinal limit of the Low Elevation Evergreen forest. The forest lies at the transitional zone between Low-elevation and Mid-elevation evergreen forest. Consequently this reserve forest has some species which are abundantly seen in Low-elevation forests like *Vateria indica*. This species is not seen any of the other study sites. The under storey is dominated by *Stobilanthus sp.* wherever there is little light penetration. The reserve forest is bordered by coffee plantation. A road goes right from the Kokka village to a few km deep inside the reserve forest.

**Figure 2.2.4** Deity place in Palangala- Ayappa sacred forest.

## 3. Method

### 3.1 Selection of the Study Sites

The sampling was carried out for duration of 5 months from December 2006 to April 2007. A total of eleven forest fragments, two coffee plantations and two sites within reserve forest, ranging from a size of 0.94 ha to 43 ha (Table 2) were samples. Fragments were selected to represent a gradient in size, and such that they were also similar in topography, altitude and surrounding landscape type. Selection was also done based on the degree of disturbance, and sites with large canopy openings and weed invasion by *Lantana camara* and *Cromolina odorata* were excluded. The study sites are located within a radius of 15 km from Virajpet town and were primarily composed of Mid-elevation Evergreen forest (Pascal and Meher-Homji, 1986). All the fragments exist in the form of sacred groves (*Devarkadus*) and are managed by the local community.

These eleven fragments were grouped into five size classes based on their area.

**Table 4.1 a** Five size classes based on the fragment area.

| Size Class | Area (ha) | Sacred Forests |
|---|---|---|
| Size class1 | 0 to 5 ha | devengere-tatappa,batamakki, koovale |
| Size class2 | 5 to 10 ha | devangere- ayappa ,arji, kadanoor, bettoli |
| Size class3 | 10 to 25 ha | rudraguppe, arapattu |
| Size class4 | 25 to 50 ha | heggala, palangala |
| Size class5 | Reserve forest | heggala RF, kokka RF |

In addition to the eleven fragments, two coffee plantations were also selected to get an idea of epiphytic diversity supported by shade grown coffee plantations. Two coffee plantations with differing degree of exotics and native tree cover were selected. One plantation consisted of a mixture of native and exotic shade tree species. The exotics were predominantly Silver Oak (*Grewillea robusta*) and *Erythrina sp.* The second coffee plantation selected for the study is perhaps one of the oldest coffee plantations in the study area. It is also one of the very few remaining coffee plantations that maintain 100% native tree cover. Both of these are privately owned coffee plantations.

Two sites were selected within the reserve forest adjoining the Bramhagiri Wildlife Sanctuary as controls, such that they were similar to the sampling areas with respect to vegetation type, aspect, altitude and other topographic features.

### 3.2 Sampling of Plants

**Woody Plants:** Stratified random sampling (Mueller-Dombois & Heinz Ellenberg, 1974) was carried out for woody species in each of the fragments and reserve forest. Quadrats of 25m x 25m were used as a primary sampling unit for trees and lianas. Each fragment was divided into edge, intermediate and interior strata and plots were laid in each of the strata so as to cover vegetation heterogeneity. A minimum of one plot was laid in each of the above three zones and then more number of plots were laid subsequently based on the rate of species accumulation. Each time a plot resulted in accumulation of new species more than 5% of the total species recorded so far in that fragment, a new plot was laid. This was repeated until the number of new species recorded in new plot was less than 5%. Plots were laid using a magnetic compass (SUNTO, Finland) and the boundaries were demarcated using a rope, which was marked at every 25m. All the trees within the plot with girth exceeding 30cm and lianas with girth exceeding 10cm were recorded.

For each tree girth was recorded at breast height (1.35m; GBH) and for lianas girth was recorded at the base (height; any abbreviation?). Height for trees was estimated using a combination of a clinometer and a lazar rangefinder (Bushnell, Germany), or by visual estimation. Smaller plots of 5m x 5m were laid within the larger quadrat in diagonally opposite corners for sampling shrubs and regeneration.

All the species (shrub and regenerating trees excluding herbs) with height more than 30 cm were recorded along with their height. Measurements for height were taken with the help of a measuring tape. Species were identified using regional floras and field keys. The unidentified specimens were taken to the Herbarium of FRLHT (Foundation for Revitalization of Local Health Traditions), Bangalore for identification.

**Epiphyte Sampling:** Epiphytes sampling was carried out in the above 25m x 25m tree plots. Observations were made with a pair of binoculars and a spotting scope. All trees with GBH >30cm were sampled for vascular epiphytes, which includes Pteridophytes and Angiosperms. All epiphytes (including hemiepiphytes and hemiparasites) occurring on the host tree were enumerated. The host tree was stratified into four zones viz. lower trunk, upper trunk, inner canopy and outer canopy (Figure 1a). Each epiphyte individual was put into one of the above four zones based upon its place of occurrence along the tree stature

Height of the epiphyte from the ground was estimated using clinometer and rangefinder. Epiphytes were put into class intervals of $60^{\circ}$ based upon its position around the branch (Fig1b). Secondary branches harboring epiphytes were put into class intervals of $30^{\circ}$ depending upon its angle with the trunk axis (Fig. 1a). Using GBH as reference, girth of the branch at the point where the epiphyte occurred, was put into size classes of 5cm interval by ocular estimation. All the epiphytes were classified into different life forms based upon their habit, form and structure (Table 3) and size classes for each species with respect to these life forms were also recorded. For quantifying the size of an epiphytic individual, a different set of characters was used for each species belonging to different life forms; like the number of leaves, number of pseudo bulbs, length of the pseudo stem and length or height of the entire epiphytic plant. A number of other parameters on the host tree like bark texture, tree architecture and other host species specific characters such as secondary growth, presence of ant nests and moss, lichen cover on the bark surface, were also recorded.

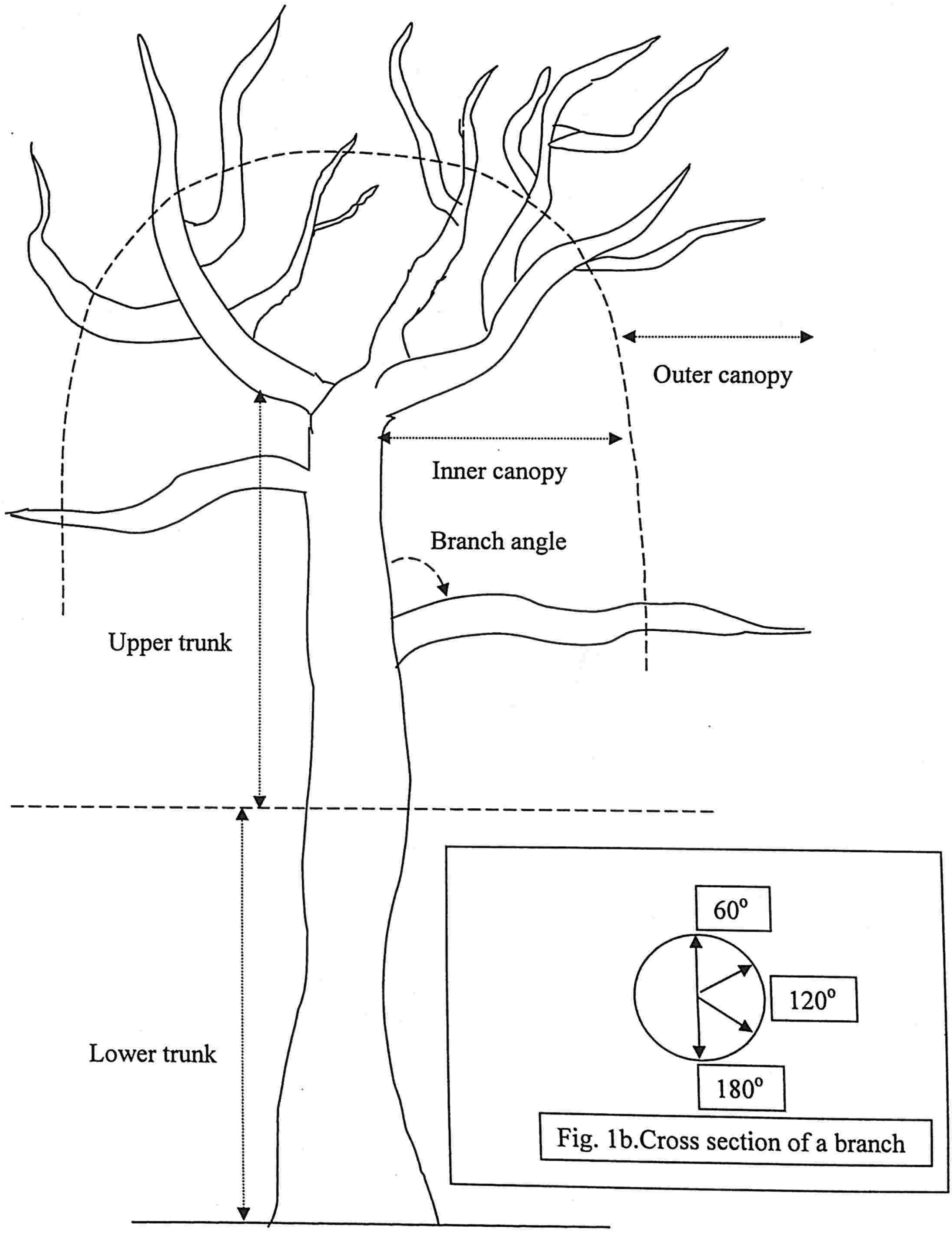



**Figure1a.** Diagrammatic representation of a tree showing different zones, modified from Johansson (1974) and Longaman and Jenik (1987).

Apart from the above quadrat based sampling, Point Centered Quarter technique. (Mueller-Dombois & Heinz Ellenberg, 1974) was also used for sampling epiphytes. This technique involves measurement of four distances at each sampling point. Then four quarters are established at each sampling points. This is achieved through a cross formed by two cross lines. The first line is the compass direction and the second laid perpendicular to the first. The compass bearing for laying the first line was randomized. The distance from the sampling point to the midpoint of the nearest tree in each quarter is measured. A host tree was considered as a sampling point in this case. Each of the nearest trees in all four quarters along with the sampling point tree was sampled for epiphytes. This was primarily done to increase the number of epiphytes sampled.

**Table 3.** Life Form Classification of Epiphytes (Modified from Hosokawa, 1943)

| Sr. No. | Life Form | Examples |
|---|---|---|
| 1 | Compact (densely tufted) | *Asplenium nidus, Cymbidium sp.* |
| 2 | Bulbous creeping | *Pholidota pallida, Coelogyne breviscapa, Liparis viridiflora, Bulbophyllum spp.* |
| 3 | Monocauline woody | *Aeridis spp., Rhyncostylis sp.* |
| 4 | Monocauline succulent | *Oberonia spp, Peppromia tetraphylla* |
| 5 | Multicauline (woody & terate) | *Dendrobium spp., Luisia spp.* |
| 6 | Succulent twining | *Hoya spp., Aeschinanthus sp., Medinella sp.* |
| 7 | Arobrescent hemiepiphyte | *Schefflera spp, Fagrea sp., Premna sp., Ficus spp.* |
| 8 | Root (or rhizome) climbing | *Pothos sp., Piper sp., Raphidophora sp., Drynaria quercifolia* |
| 9 | Hemi parasitic | *Loranthus spp., Viscum spp.* |

## 4. Analysis

### 4.1 Species Richness Estimation

**Species Rarefaction Curves**

Species rarefaction curves gives an estimate of what the species richness of the assemblage would be if the at a particular level of sampling effort. Species rarefaction curves thus can be used to make a direct comparison among assemblages differing in their sampling effort. The comparison can thus be directly made on the basis of number of individual in the smallest sample (Magurran, 2004). This is done by taking a mean of repeated resampling of all pooled individuals or samples (Gotelli and Colwell, 2001). Thus sample based rarefaction curves can be used to account for natural levels of sample heterogeneity (patchiness) in the data (Gotelli and Colwell, 2001).

Randomisations of both pooled sample and individuals were done using program EcoSim700 (Gotelli & Entsminger, 2001).

**Nonparametric Estimators.**

Chao1 and Jackknife 1 estimators are one of the most popularly used estimators. These are based on mark-recapture analysis. Chao1 gives an estimate of absolute number of species in an assemblage. The species richness estimates produced by Chao1 is based on number of rare species (singletons and doubletons) in a sample and thus requires abundance data. The Jackknife1 estimator on the other hand employs the number of species that occur only in one sample (Magurran, 2003). Program EstimateS (Colwell, 2001) was used to estimate the number of unsampled species in a fragment.

**Dominance Diversity Curves (Rank Abundance Plots)**

A dominance diversity curve is a methods of graphically representing relative species abundance data. The curves are a graph of logarithm of relative species abundance of species plotted on y axis and rank in abundance of the species on x axis. The commonest species occur towards the left (low ranks) and the rarest on the right (high ranks). The percentage relative abundances facilitate comparison between different assemblages. Program BioDiversity ProVer.2 (McAleece, 1997) was used to generate Rank abundance curves

## 4.2 Correlates of diversity and Composition.

### Linear Regression & Correlation

Simple Linear Regression and correlations were used to find the strength in relationship between Species richness estimates and its correlates. (SPSS 14, 2005). Data was log10 transformed where appropriate.

### Mantels Test

Mantels test is used to test the correlation between similarity or dissimilarity distance matrices. It tests the null hypothesis of no relation between two square symmetrical matrices (McCune and Grace, 2002). It was used to test the correlation between geographical dissimilarity distance and ecological dissimilarity distance.

## 4.3 Multivariate Analysis for community composition

### Cluster Analysis

The purpose of cluster analysis is to define groups of items based on their similarities.

The result can be interpreted with the help of a dendrogram which shows a hierarchy of relationships among the rows in the main matrix. The dendrogram is scaled by the objective function converted into a scale of percentage of information remaining.

This grouping technique was used to form clusters of sample plots and sites and to see how close or apart they are depending upon the level at which branching occurs.

### Multi-Response Permutation Procedures (MRPP)

This is a multivariate non-parametric technique is used for testing the differences between two to more groups of entities.

MRPP was used to test if the sites and size classes differ significantly with respect to species composition and abundance. In MRPP the test statistic T is a measure of separation between the groups. The more negative the T stronger the separation.

### Nonmetric Multidimensional Scaling (NMS)

Non-metric MultiDimensional Scaling is a distance-based technique (as against others which are Eigenvector techniques). The data matrix is converted into a dissimilarity matrix which is what is actually incorporated into the ordination. Information about individual species is not actually included in the determination of where sample units are located in ordination space.

Preliminary NMS was carried out to get get three dimensions which were used for testing pair wise differences between groups. This analysis for plot based data.

### Hotelling's Two-Sample Test

This test is a multivariate extension of two sample Students t-test. This test is used when response variable are two or more although it can be used for one variable also. It was used to test for pairwise differences in species compositional differences among size classes. Axis obtained from NMS analysis were used. Software NCSS was used to carry out this test (Hintze, 2006).

### Indicator Species Analysis

Indicator species analysis is a technique used for comparing across groups by combining information by accounting for relative species abundance and relative frequency. It thus identified a species or asset of species which are perfect indicators of that group or in other words exclusive to that group. The indicator values ranges from 0 to 100 signifying no indication to perfect indication (McCune and Grace, 2002). This technique was used to identify indicator species for groups defined by NMS analysis and Hotelling's tests.

### Nestedness Temperature

Program Nestedness (Ulrich, 2006) was used to quantify nestedness of species by site matrix. The program provides with nestedness scores in form of 'temperature-T' the values of which range between 0 to 100. Low scores (cool temperature" indicate nested matrices. The program has six models for randomisation. The lognormal model is a passive sampling model, but the fixed row equiprobable column constraint accounts best for passive sampling (McAbendroth et al, 2004).

The program Nestedness gives eight different measures to measure the degree of nestedness, such as N0, which counts how often a species is absent from a site more species rich than the most impoverished site it occurs. N1 is exactly complimentary to prior. NC counts number of pair wise co-occurrences summed over all combinations of sites. UA and UP counts unexpected absences from most species rich site and presences from most depauperate sites respectively. UT is the sum of the earlier two and thus gives the total number of deviations from perfect nestedness. BR (like UT) uses the number of discrepancies that must be filled or erased to produce a perfectly nested matrix (Ulrich, 2006). Along with these the program also calculates matrix temperature T, a concept introduced Atmar and Pattterson (1993).

## 4.4 Host-Epiphyte Relationship

### Chi Square Test

Chi Square tests the null hypothesis of no differences between observed and expected frequencies values within a category or across different categories.

This was used to test if the frequency of occurrence of epiphytic species is significantly different across different zones of the tree

### Host Use and Preference

Ivlev's index was used as measure of host availability and use.

Ivlev's Index = (Use% - Availability%) / (Use% + Availability%), (Ivlev, 1961).

## 5. Results

### 5.1.1 Patterns in Plant Richness Across Fragments

#### Trees

Species richness across fragments of different sizes was estimated using Chao1 and Jack-knife1 estimators were used to estimate the number of unsampled species in a fragment. Both observed and estimated species were found to increase consistently with area. The smallest fragment, (*Tatappa devarakadu*) was found to have lowest species richness, while the *Heggala devarakadu*, the second largest fragment (42 ha) had highest observed and estimated species richness. Species richness estimates for the two sites in the reserve forest were same as that of the largest fragments. (Tble 5.1.1 a)

**Table 5.1.1** a Diversity of tree species across fragments and Reserve Forest.

| Sacred Grove | Area (ha) | Obs. Richness | Jackknife 1 | Shanon's Heterogeniety | Shanon's evenness | Density /ha |
|---|---|---|---|---|---|---|
| devengere-tatappa | 0.95 | 17 | 23 | 1.188 | 0.839 | 170.67 |
| batamakki | 4 | 19 | 25.67 | 1.208 | 0.853 | 341.33 |
| koovale | 4 | 22 | 30.67 | 1.026 | 0.802 | 272.00 |
| devangere-ayappa | 8.26 | 24 | 36.67 | 1.242 | 0.925 | 245.33 |
| arji | 8.51 | 26 | 33.75 | 1.294 | 0.938 | 280.00 |
| kadanoor | 9.07 | 30 | 43.5 | 1.151 | 0.936 | 400.00 |
| bettoli | 9.72 | 22 | 30.25 | 1.555 | 0.911 | 216.00 |
| rudraguppe | 13 | 37 | 52.2 | 1.252 | 0.847 | 326.40 |
| arapattu | 19.27 | 26 | 35 | 1.219 | 0.908 | 492.00 |
| heggala | 42.05 | 51 | 80.17 | 1.412 | 0.859 | 314.67 |
| palangala | 46.43 | 45 | 60.83 | 1.384 | 0.882 | 426.67 |
| s heggala RF | 1000 | 50 | 51.89 | 1.488 | 0.876 | 522.67 |
| t kokka RF | 1000 | 46 | 61.83 | 1.407 | 0.846 | 453.33 |

#### Lianas

Estimated values for Liana species richness were found to be highest in the Heggala R.F. followed by Rudraguppe fragment which ranks 4th in terms of the patch area. There is no clear trend in the liana species richness with respect to area. The smallest fragments had higher levels of species richness than some of the medium sized fragments.

**Table 5.1.1 b** Diversity and density of liana species across fragments and Reserve Forest.

| Sacred Grove | Area (ha) | Obs. Richness | Jackknife 1 | Shanon's Heterogeniety | Shanon's evenness | density |
|---|---|---|---|---|---|---|
| devengere-tatappa | 0.95 | 10 | 7 | 0.636 | 0.91 | 3.33 |
| batamakki | 4 | 14 | 6.33 | 0.785 | 0.87 | 4.67 |
| koovale | 4 | 10 | 6.2 | 0.638 | 0.913 | 3.33 |
| devangere-ayappa | 8.26 | 9 | 7 | 0.301 | 1 | 3.00 |
| arji | 8.51 | 28 | 11.75 | 0.636 | 0.91 | 7.00 |
| kadanoor | 9.07 | 17 | 4 | 0.616 | 0.881 | 4.25 |
| bettoli | 9.72 | 2 | 3.5 | 0.79 | 0.935 | 0.50 |
| rudraguppe | 13 | 34 | 16.8 | 0.487 | 0.809 | 6.80 |
| arapattu | 19.27 | 9 | 7.25 | 0.759 | 0.976 | 2.25 |
| heggala | 42.05 | 13 | 12 | 0.947 | 0.947 | 2.17 |
| palangala | 46.43 | 20 | 14.17 | 0.969 | 0.898 | 3.33 |
| s heggala RF | 1000 | 17 | 21.17 | 1.018 | 0.943 | 2.83 |
| t kokka RF | 1000 | 18 | 13 | 0.962 | 0.962 | 3.00 |

### Shrubs

Observed and estimated species richness estimate was found to be highest in the in the second largest fragment (Heggala sacred forest), but interestingly the largest fragment (Palangala sacred forest) had lowest number of estimated species (after Tatappa fragment). With the exceptions of Palangala fragment and Rudraguppe fragment, rest of the sites showed an increasing trend in the species richness with increase in area.

**Table 5.1.1 c** Diversity of shrubs across fragments and Reserve Forest

| Sacred Grove | Area (ha) | Obs. Richness | Jackknife 1 | Shanon's Heterogeniety | Shanon's evenness | Density |
|---|---|---|---|---|---|---|
| devengere-tatappa | 0.95 | 14 | 18.17 | 0.844 | 0.66 | 15600 |
| batamakki | 4 | 22 | 25.14 | 0.802 | 0.666 | 30133 |
| koovale | 4 | 21 | 29.33 | 0.953 | 0.71 | 16000 |
| devangere- ayappa | 8.26 | 16 | 20.17 | 0.967 | 0.732 | 17533 |
| arji | 8.51 | 16 | 22.13 | 0.882 | 0.732 | 12900 |
| kadanoor | 9.07 | 19 | 27.75 | 0.902 | 0.787 | 12950 |
| bettoli | 9.72 | 21 | 30.25 | 0.976 | 0.682 | 14200 |
| rudraguppe | 13 | 14 | 17.2 | 0.944 | 0.738 | 10640 |
| arapattu | 19.27 | 19 | 26.13 | 1.08 | 0.817 | 24950 |
| heggala | 42.05 | 27 | 37.8 | 0.723 | 0.6 | 17720 |
| palangala | 46.43 | 16 | 19.33 | 0.93 | 0.811 | 19467 |
| s heggala RF | 1000 | 25 | 35.29 | 1.017 | 0.728 | 18571 |
| t kokka RF | 1000 | 14 | 19.83 | 0.755 | 0.659 | 10333 |

**Epiphytes**

With the exception of Heggala fragment, richness estimates of epiphytes were higher in larger fragments. The medium sized and the large fragments had similar species richness estimates. Contradictory to the results of the other plant groups, the two reserve forest sites were found to exhibit least levels of species richness.

The possible correlates of the species richness will be discussed in the section (5.1.2).

**Table 5.1.1 d** Diversity of Epiphytes across fragments and reserve forest.

| Sacred Grove | Area (ha) | Obs. Richness | Jackknife 1 | Shanon's Heterogeniety | Shanon's evenness |
|---|---|---|---|---|---|
| devengere-tatappa | 0.95 | 77 | 8.67 | 1.237 | 0.909 |
| batamakki | 4 | 58 | 23.67 | 0.966 | 0.743 |
| koovale | 4 | 119 | 18.17 | 1.119 | 0.909 |
| devangere-ayappa | 8.26 | 135 | 31.33 | 1.088 | 0.81 |
| arji | 8.51 | 14 | 28.25 | 0.681 | 0.876 |
| kadanoor | 9.07 | 76 | 43 | 1.182 | 0.881 |
| bettoli | 9.72 | 98 | 31 | 0.805 | 0.843 |
| rudraguppe | 13 | 105 | 41.2 | 1.266 | 0.849 |
| arapattu | 19.27 | 53 | 30.25 | 0.988 | 0.862 |
| heggala | 42.05 | 115 | 13.17 | 1.301 | 0.881 |
| palangala | 46.43 | 22 | 45 | 1.247 | 0.844 |
| s heggala RF | 1000 | 10 | 6.4 | 0.408 | 0.678 |
| t kokka RF | 1000 | 46 | 15.83 | 0.487 | 0.487 |

### 5.1.2 Species Area Relationship

Species-area curves were generated for all four plant groups (across the eleven fragments) and slope and intercept values were obtained. These constants were obtained by using the log form of the power function

$$S = kA^{z}$$

where, $S$ is the number of species

A is the area and

z and k are the constants (slope and intercept respectively).

The log form of the above equation is

$$\log S = \log C + z \operatorname{Log} A$$

**Table 5.1.2 a** Summary of the values for slope and intercept and the strength of the fitted equation ($R^2$) for the four plant groups.

| | R Square | F | Sig. | Parameter Estimates Constant | b1 |
|---|---|---|---|---|---|
| Trees | 0.744024 | 26.1596 | 0.000633 | 1.297 | 0.295099 |
| Lianas | 0.186765 | 2.066911 | 0.184371 | 0.701 | 0.196434 |
| Shrubs | 0.076546 | 0.746023 | 0.410166 | 1.324 | 0.061569 |
| Epiphytes | 0.272725 | 3.374967 | 0.099367 | 1.173 | 0.244553 |

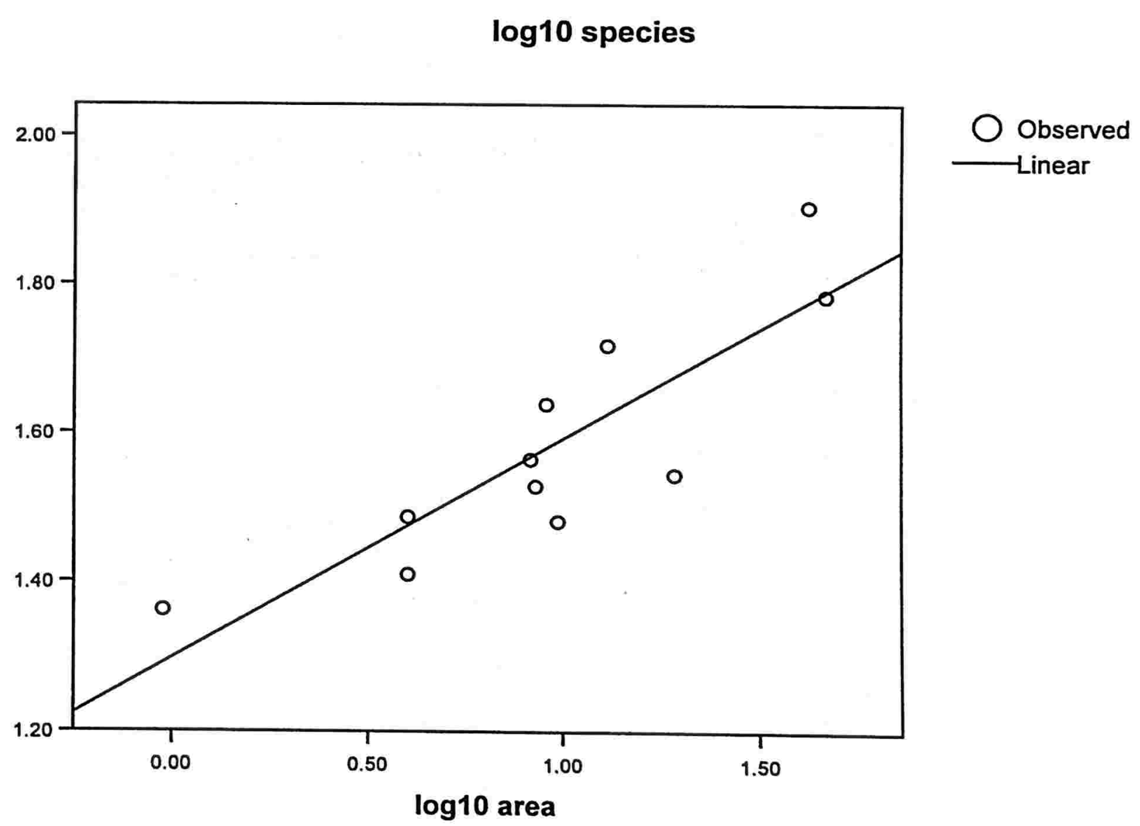



**Fig. 5.1.1.a** Tree species richness vs. area

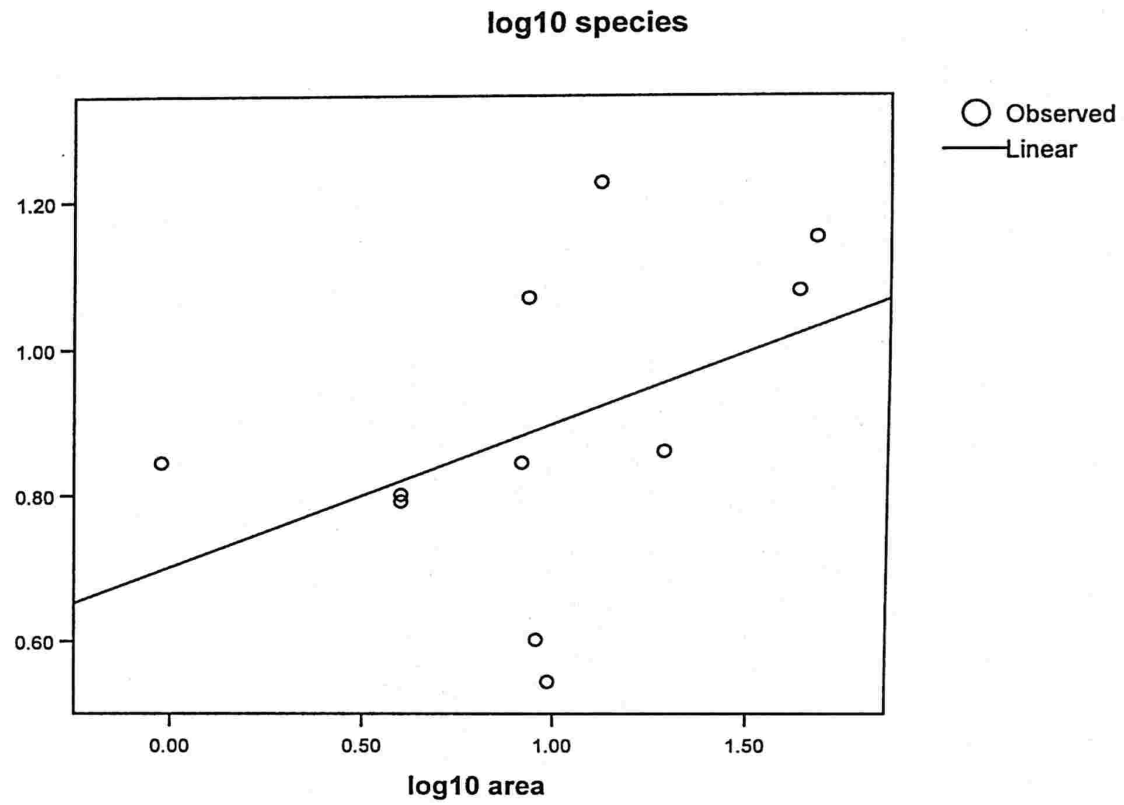



**Fig. 5.1.1.b** Liana species richness vs. area

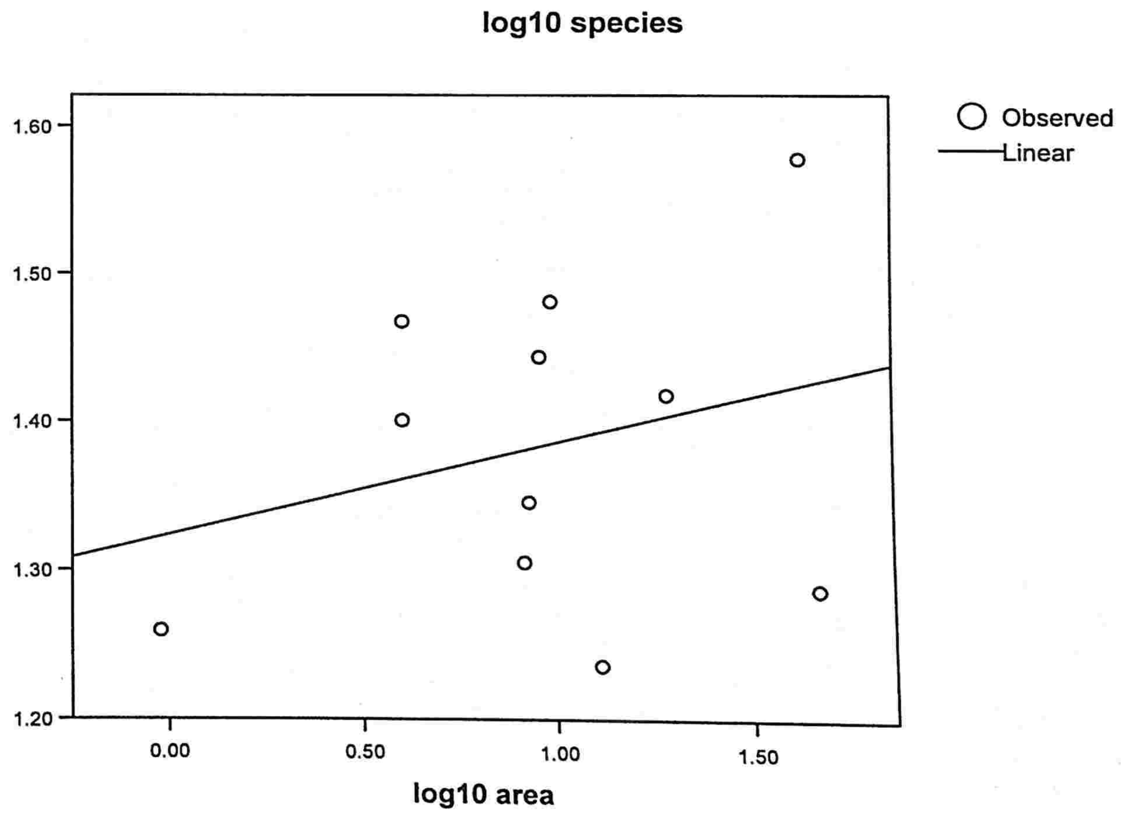



**Fig. 5.1.1.c** Shrub species richness vs. area

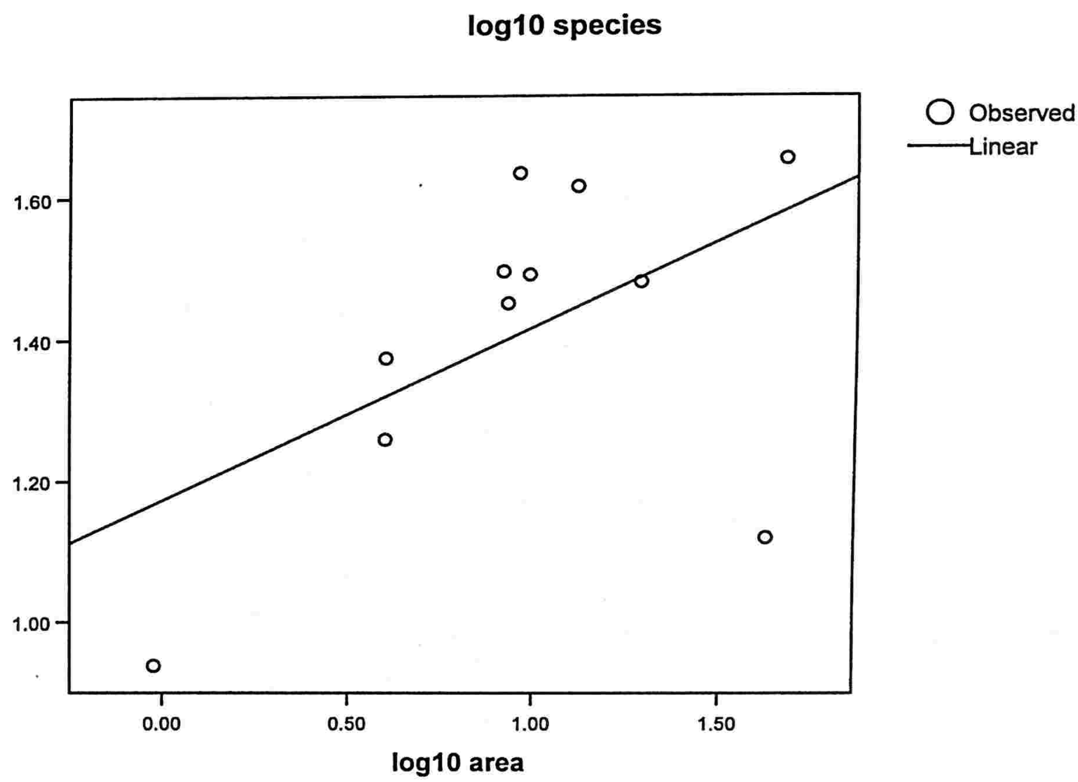



**Fig. 5.1.1.d** Epiphytes species richness vs. area

Estimated species richness was significantly correlated with area explaining 745 variations in species composition. However area couldn't explain the variation in species richness for the other three groups.

Since area was found to be correlated with only tree density significantly, density was used as an additional predictor for explaining the variation in lianas, shrubs and epiphytes. Since habitat productivity has an influence on species diversity, it was used as an additional correlate along with area as a predictor for observed patterns in species richness. Density was used as a surrogate for species diversity.

**Trees**

Tree density as a predictor with area, only marginally increased the strength of the relation with species richness.

**Table 5.1.2 b** Model summary for multiple linear regression with area and density both as predictors of species richness.

| R square | Std. Error | F | Significance |
|---|---|---|---|
| 0.75 | 0.08 | 12.65 | 0 |

**Constant**

| | Slope | Std. Error | Significance |
|---|---|---|---|
| Area (ha) | 0.33 | 0.08 | 0.027 |
| Density | -0.2 | 0.28 | 0.48 |

**Lianas**

**Table 5.1.2 c** Model summary for multiple linear regression with area and density both as predictors of species richness.

| R square | Std. Error | F | Significance |
|---|---|---|---|
| 0.57 | 0.158 | 5.1.42 | 0.03 |

**Constants**

| | Slope | Std. Error | Significance |
|---|---|---|---|
| Area (ha) | 0.23 | 0.1 | 0.055 |
| Density | 0.44 | 0.16 | 0.02 |

Area and density together proved to be much better predictors than area alone. Together they explained 57% variation in liana species richness. Slope values for density are higher than the slope value of area indicating that species accumulate at faster rate along a density gradient as compared to the area.

**Shrubs**

**Table 5.1.2 d** Model summary for multiple linear regression with area and density both as predictors of species richness

| R square | Std. Error | F | Significance |
|---|---|---|---|
| 0.11 | 0.11 | 0.51 | 0.61 |

**Constants**

| | Slope | Std. Error | Significance |
|---|---|---|---|
| Area (ha) | 0.59 | 0.07 | 0.44 |
| Density | 0.15 | 0.27 | 0.57 |

Density and area were not found to be correlated with shrub species richness. Together they could account for only 11 % variation, with a highly insignificant P value.

**Epiphytes**

**Table 5.1.2 e Model summary for multiple linear regression with area and density both as predictors of species richness**

| R square | Std. Error | F | Significance |
|---|---|---|---|
| 0.53 | 0.17 | 4.69 | 0.044 |

**Constants**

| | Slope | Std. Error | Significance |
|---|---|---|---|
| Area (ha) | 0.28 | 0.11 | 0.03 |
| Density | 0.37 | 0.17 | 0.06 |

Area alone could explain only 27% variation in species richness, but together with density it could significantly account for 53% variation in plant species richness.

**Table 5.1.2 f** Model summary for multiple linear regression with area, tree density and epiphyte density as predictors of species richness

| R square | Std. Error | F | Significance |
|---|---|---|---|
| 0.66 | 0.51 | 4.59 | 0.044 |

**Constants**

| | Slope | Std. Error | Significance |
|---|---|---|---|
| Area (ha) | 0.13 | 0.13 | 0.37 |
| Tree density | 0.79 | 0.49 | 0.15 |
| Epiphyte density | 0.37 | 0.15 | 0.047 |

Since the species richness of epiphytes is influenced by the density of its host, tree density was added to the above two predictors. All the three variables together had stronger relationship with epiphyte species richness. The strength of the relationship increased from 53% to 66% by adding tree density an additional predictor.

### 5.1.3 Comparison of Species Richness across Fragments.

To make a valid comparison for species richness counts across different size classes, sampling curves were generated by pooling all the samples within each size class. Then the number of samples and individuals were randomised to generate sample based and individual based rarefaction curves.

Sample based rarefaction curves give a better estimate for patchy habitats, as against individual based rarefaction curves which often overestimates the number of species in such cases.

**Trees**

Table 5.1.2a summarises mean slope values for the rarefied sample based accumulation curves. For the first three size classes show decrease in the steepness of the slope with increase in size. The slope value shows a increases in size class4 and a drop again in size class 5. . Size class1 and Size class5 (R.F.) have identical slope values but the species richness is much higher in the reserve forest than in the smallest size class. Though the strength of rise of each curve is different, species richness values show a consistent increase across the five size classes at comparable number of samples (Fig. 5.1.3a). This could very well be because of higher stem densities in the consecutively larger size classes.

Table 5.1.3b summarises mean slope values for individual based species accumulation curves. The slope represents rate of accumulation of species per unit individuals. After controlling for density, the slope values show a reverse trend in species accumulation across the size classes.

Though size class4 shows a stronger rise per individual, the species richness estimates are exactly identical with the Size class5 (Fig. 5.1.3b). This shows that Size class4 and Size class5 (R.F.) are the ones with maximum richness at comparable number of individuals. Interestingly, size class2 has higher species richness than size class3 after controlling for stem density

**Table 5.1.3a** Slope values of sample based rarefaction curves for trees across five size classes.

| Size Class | Slope | S.E. | Significance |
|---|---|---|---|
| 1 ( 0 to 5 ha) | 0.59 | 0.03 | P << 0.05 |
| 2 ( 5 to 10 ha ) | 0.57 | 0.02 | P << 0.05 |
| 3 ( 10 to 25 ha) | 0.56 | 0.03 | P << 0.05 |
| 4 ( 25 to 50 ha) | 0.61 | 0.02 | P << 0.05 |
| 5 (R.F.) | 0.59 | 0.02 | P << 0.09 |

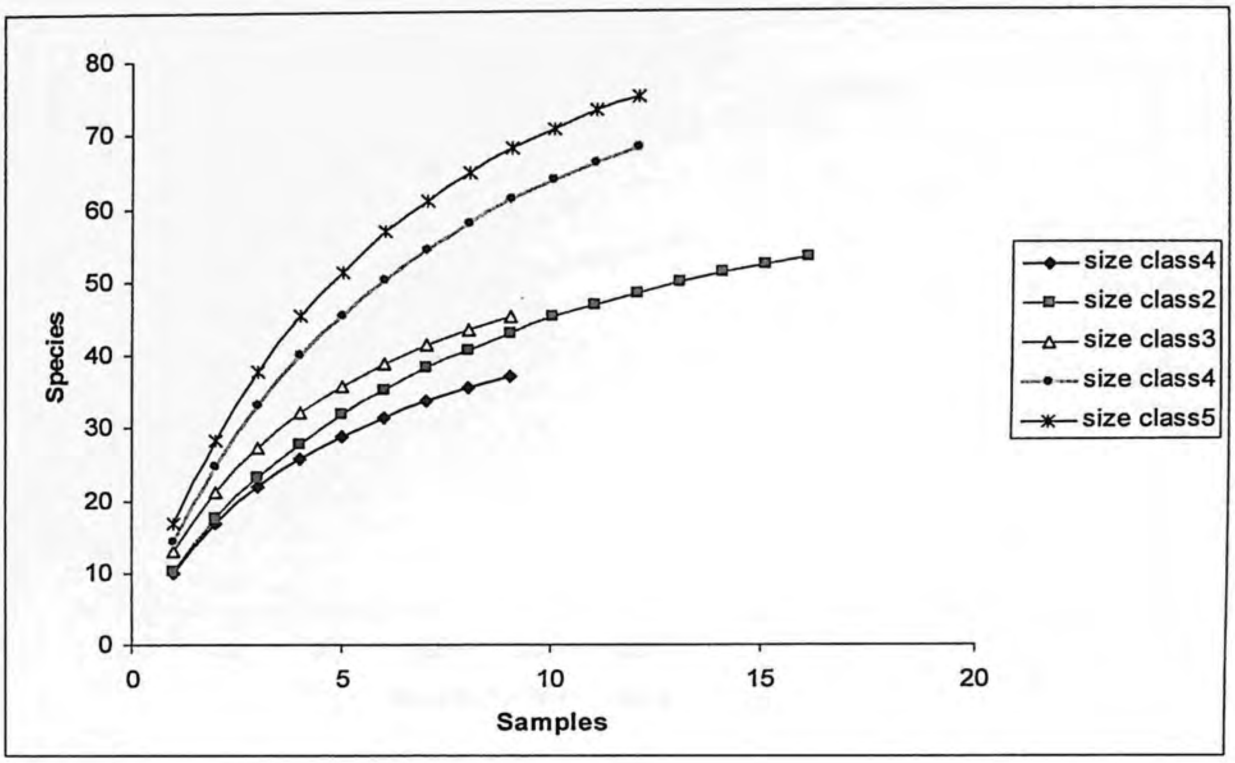



**Fig. 5.1.3a** Sample based rarefaction curves for trees across five size classes

| Size class 1 | Slope | S.E. | Significance |
|---|---|---|---|
| 1 | 1.415415 | 0 | |
| 2 | 0.475806 | 0.022606 | P<< 0.05 |
| 3 | 0.479826 | 0.020215 | P<< 0.05 |
| 4 | 0.535436 | 0.02275 | P<< 0.05 |
| 5 | 0.512921 | 0.020652 | P<< 0.05 |

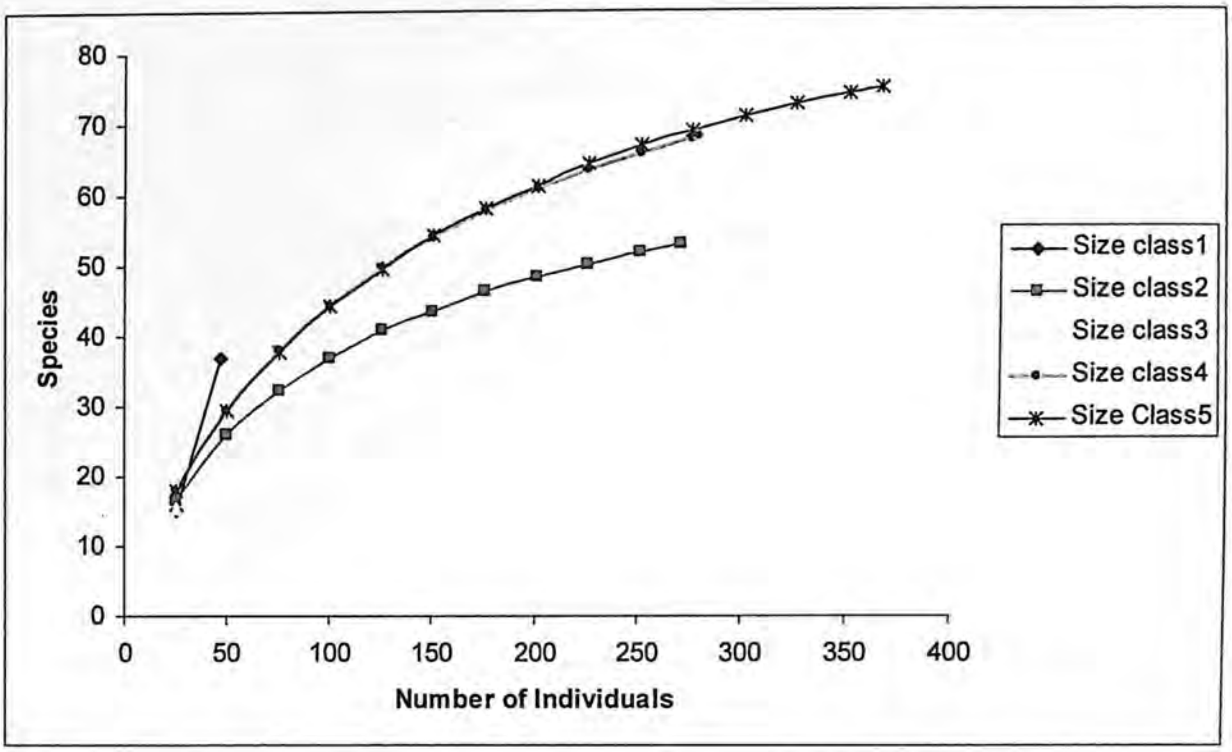



**Fig. 5.1.3b** Individual based rarefaction curves for trees across five size classes

**Lianas**

The slope values for lianas, based on sample rarefaction curves (Table 5.1.3c) don't show any particular trend. This could be because lianas might be patchily distributes across different fragments. Higher richness (and perhaps density) of lianas in size class one could be because lower tree stem density in smaller patches. Contrary to this size class5 (R.F.) has highest species richness (even after controlling for density of lianas) even though the tree stem density in the R.F. was found to be highest among all classes.

**Table 5.1.3c** Slope values of sample based rarefaction curves for lianas across five size classes.

| Size Class | Slope | Std. Error | Significance |
|---|---|---|---|
| 1 | 0.661496 | 0.019555 | P << 0.05 |
| 2 | 0.554354 | 0.013884 | P << 0.05 |
| 3 | 0.595163 | 0.020889 | P << 0.05 |
| 4 | 0.670723 | 0.021474 | P << 0.05 |
| 5 | 0.738048 | 0.024833 | P << 0.05 |

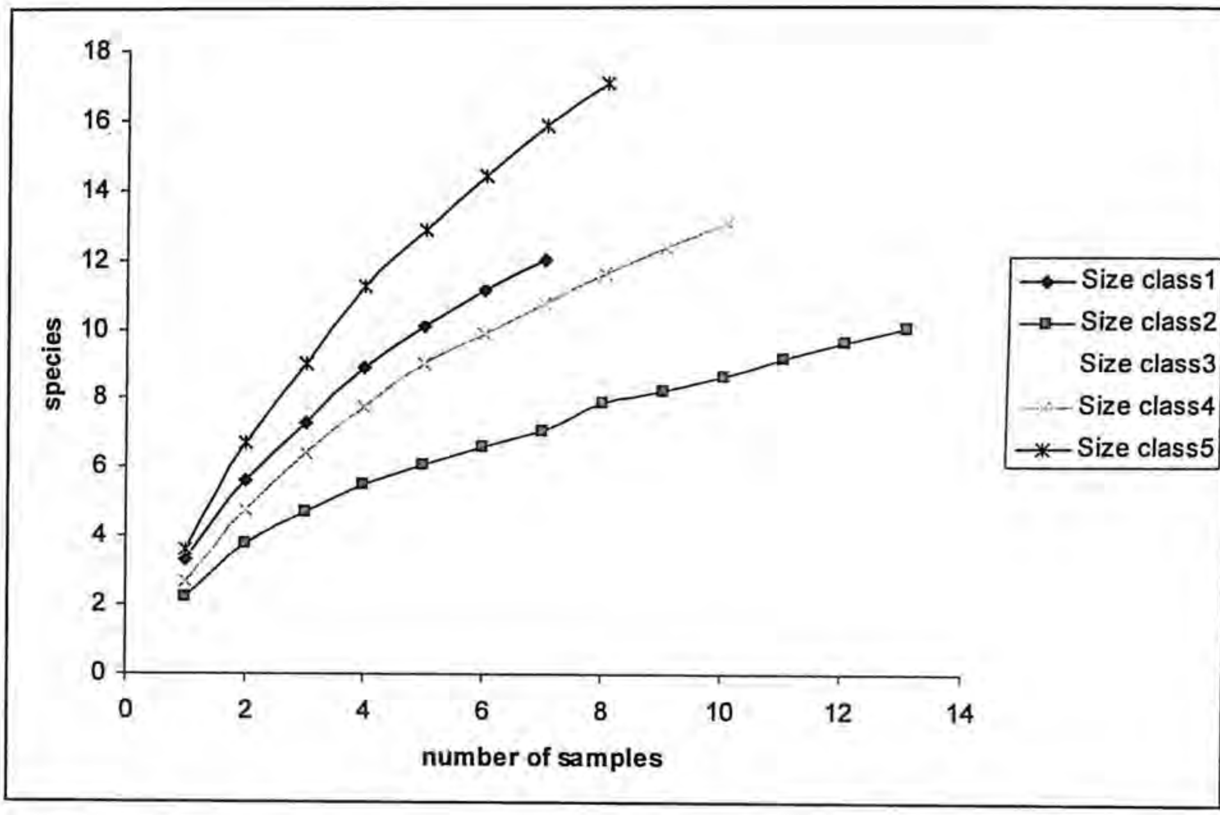



**Fig. 5.1.3c** Sample based rarefaction curves for lianas across five size classes

The slope values for individual based rarefaction curves (Table5.1.3d) shows stronger rise in accumulation of new liana species, across the size classes, except for the size class2 which has lower liana species richness than size class1. Size class5 shows to have the steepest slope for lianas and also higher species richness (Fig. 5.1.3d).

**Table 5.1.3d** Slope values of individual based rarefaction curves for lianas across five size classes.

| Size Class | Slope | Std. Error | Significance |
|---|---|---|---|
| 1 | 0.567759 | 0.027581 | P << 0.05 |
| 2 | 0.437139 | 0.005011 | P << 0.06 |
| 3 | 0.566725 | 0.01762 | P << 0.07 |
| 4 | 0.595139 | 0.026139 | P << 0.08 |
| 5 | 0.690209 | 0.022122 | P << 0.09 |

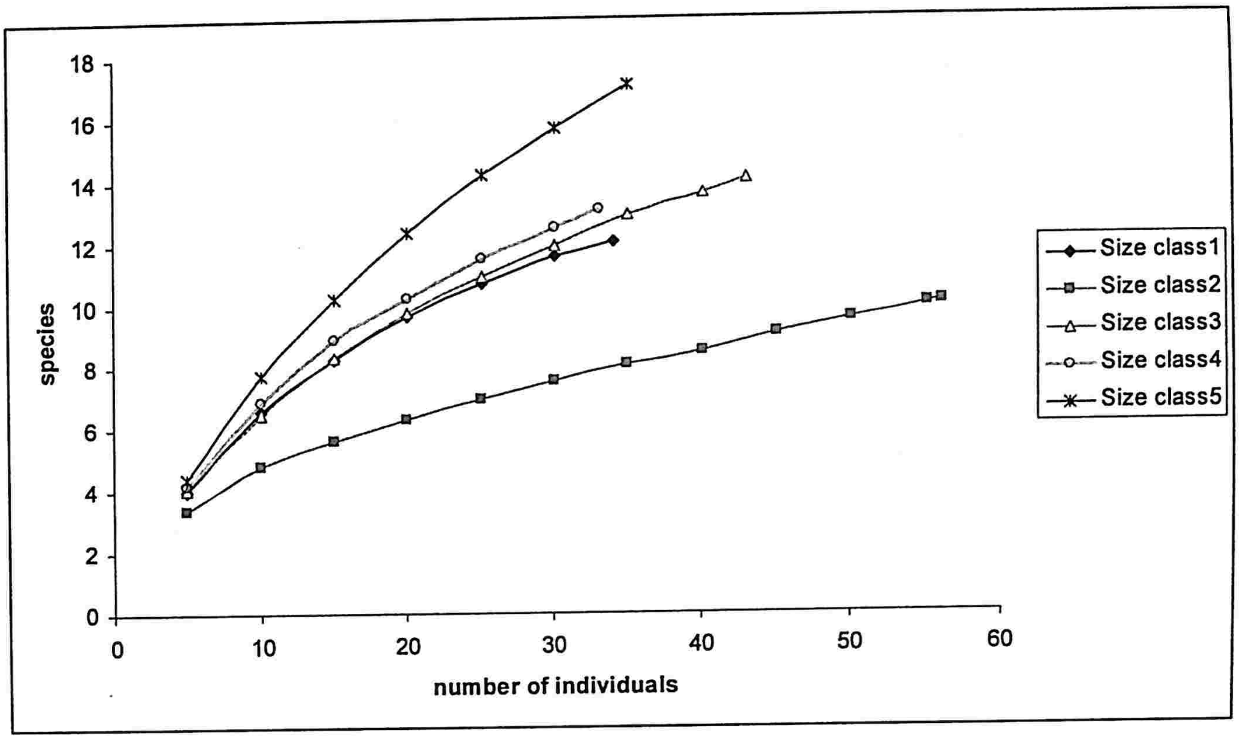



**Fig. 5.1.3d** Individual based rarefaction curves for lianas across five size classes

**Shrubs**

**Table 5.1.3e** Slope values of sample based rarefaction curves for shrubs across five size classes.

| Size Class | Slope | Std. Error | Significance |
|---|---|---|---|
| 1 | 0.422105 | 0.013864 | P << 0.05 |
| 2 | 0.378989 | 0.012941 | P << 0.06 |
| 3 | 0.351318 | 0.012989 | P << 0.07 |
| 4 | 0.48797 | 0.012799 | P << 0.08 |
| 5 | 0.576105 | 0.02162 | P << 0.09 |

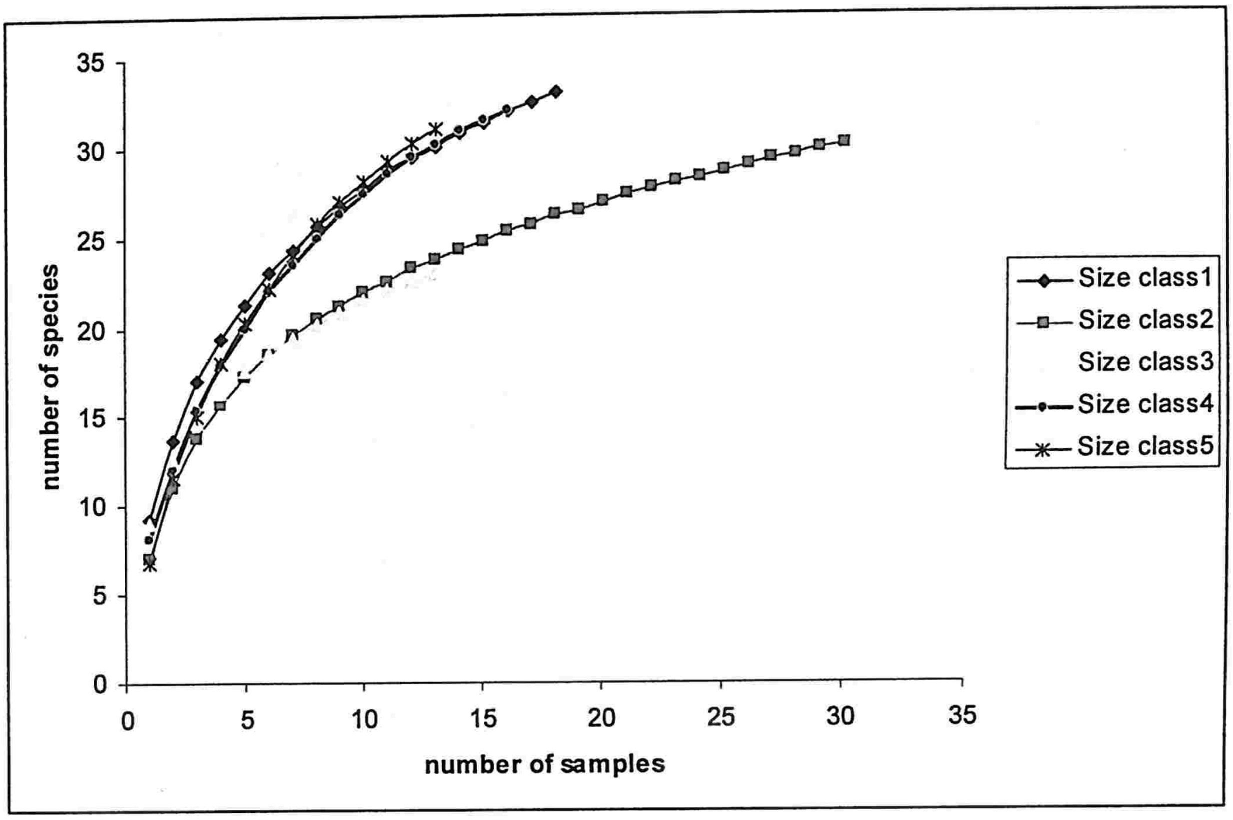



**Fig. 5.1.3e** Sample based rarefaction curves for shrubs across five size classes

At comparable number of samples, species richness curves of the five size classes seem to be coinciding into two clear groups. Size class1 (smallest) and size class4 and class5 l(largest) show identical species richness for a given number of plots. Size class2 and size class3 on the other hand have distinctly lower species richness than the other size classes. Differences in species composition could possibly explain this anomalous pattern. Though the species richness is identical for the smallest and the largest size class, there species composition could be entirely different. There are large differences in stem densities of trees between the smallest size class and the two Reserve Forest sites. Differences in canopy and light intensity could have profound effect on under storey species composition. The species present in the smallest fragment could be the ones preferring comparatively open conditions and more light than the ones which grow under the intact and dense canopy of the reserve forest.

**Table 5.1.3f** Slope values of individual based rarefaction curves for shrubs across five size classes.

| Size Class | Slope | Std. Error | Significance |
|---|---|---|---|
| 1 | 0.284075 | 0.011527 | P << 0.05 |
| 2 | 0.274632 | 0.004863 | P << 0.06 |
| 3 | 0.273141 | 0.009185 | P << 0.07 |
| 4 | 0.342399 | 0.011036 | P << 0.08 |
| 5 | 0.370418 | 0.015346 | P << 0.09 |

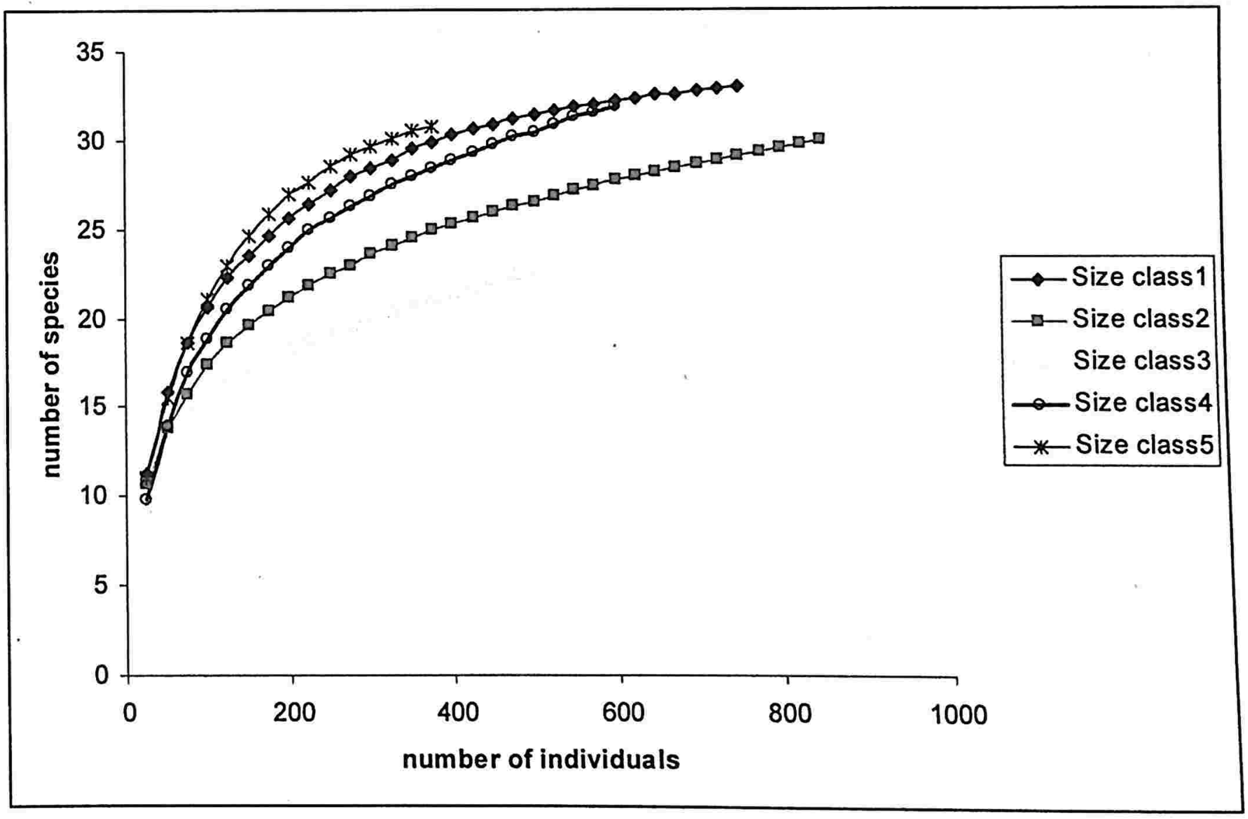



**Fig. 5.1.3f** Individual based rarefaction curves for shrubs across five size classes

The patterns shown by individual based species accumulation curves are consistent with the sample based accumulation curves. Size class3 (median size class) accumulates least number of species at given number of individuals. The extreme size classes have much higher species richness compared to the medium size classes.

**Epiphytes**

Since host tree was the basic sampling unit for epiphytes, species richness of epiphytes is a function of number of host tree and not the actual square plots. This also takes care of density of host individuals per unit area. The slope values are comparatively higher at the extremes, but the richness values were successively higher size class4, class3 and class2. Reserve forest had the least species richness, followed by the smallest size class.

**Table 5.1.3g** Slope values of sample based rarefaction curves for shrubs across five size classes.

| Size Class | Slope | Std. Error | Significance |
|---|---|---|---|
| 1 | 0.578497 | 0.024103 | $P << 0.05$ |
| 2 | 0.477252 | 0.011467 | $P << 0.05$ |
| 3 | 0.510908 | 0.026408 | $P << 0.05$ |
| 4 | 0.611055 | 0.015828 | $P << 0.05$ |
| 5 | 0.631139 | 0 | |

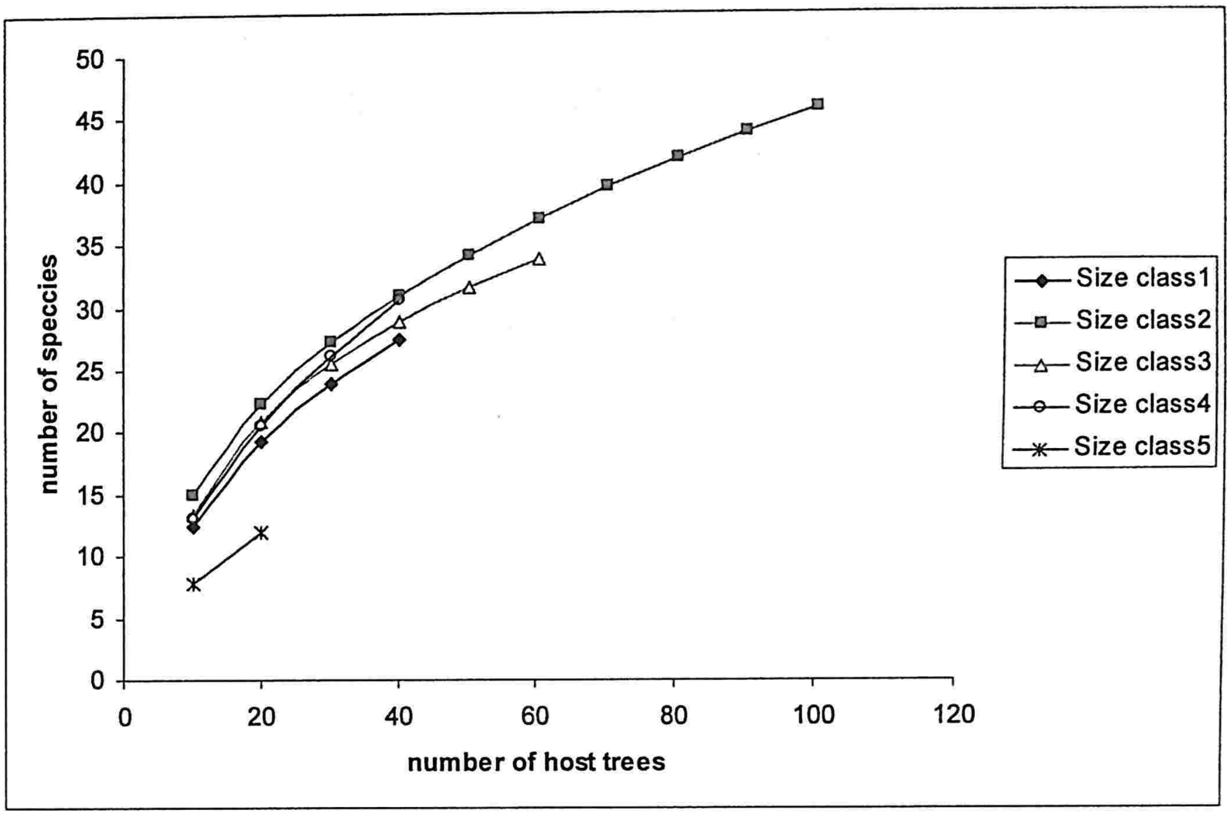



**Fig. 5.1.3g** Sample based rarefaction curves for epiphytes across five size classes

Slope values for species accumulation based on rarefied individuals per plot are given in table 5.1.3h. Size class1 shows faster accumulation of species per increase in number of epiphyte individuals. Size class3 (intermediate size class) has consistently higher estimated species richness at comparable number of individuals followed by size class4 and size class2 (Fig. 5.1.3h). Reserve forest is extremely depauperate in terms of its epiphytic flora.

**Table 5.1.3h** Slope values of individual based rarefaction curves for shrubs across five size classes.

| Size Class | B | Std. Error | Significance |
|---|---|---|---|
| 1 | 0.476864 | 0.018408 | $P << 0.05$ |
| 2 | 0.427682 | 0.008698 | $P << 0.06$ |
| 3 | 0.439154 | 0.025481 | $P << 0.07$ |
| 4 | 0.467307 | 0.014173 | $P << 0.08$ |
| 5 | 0.527097 | 0 | |

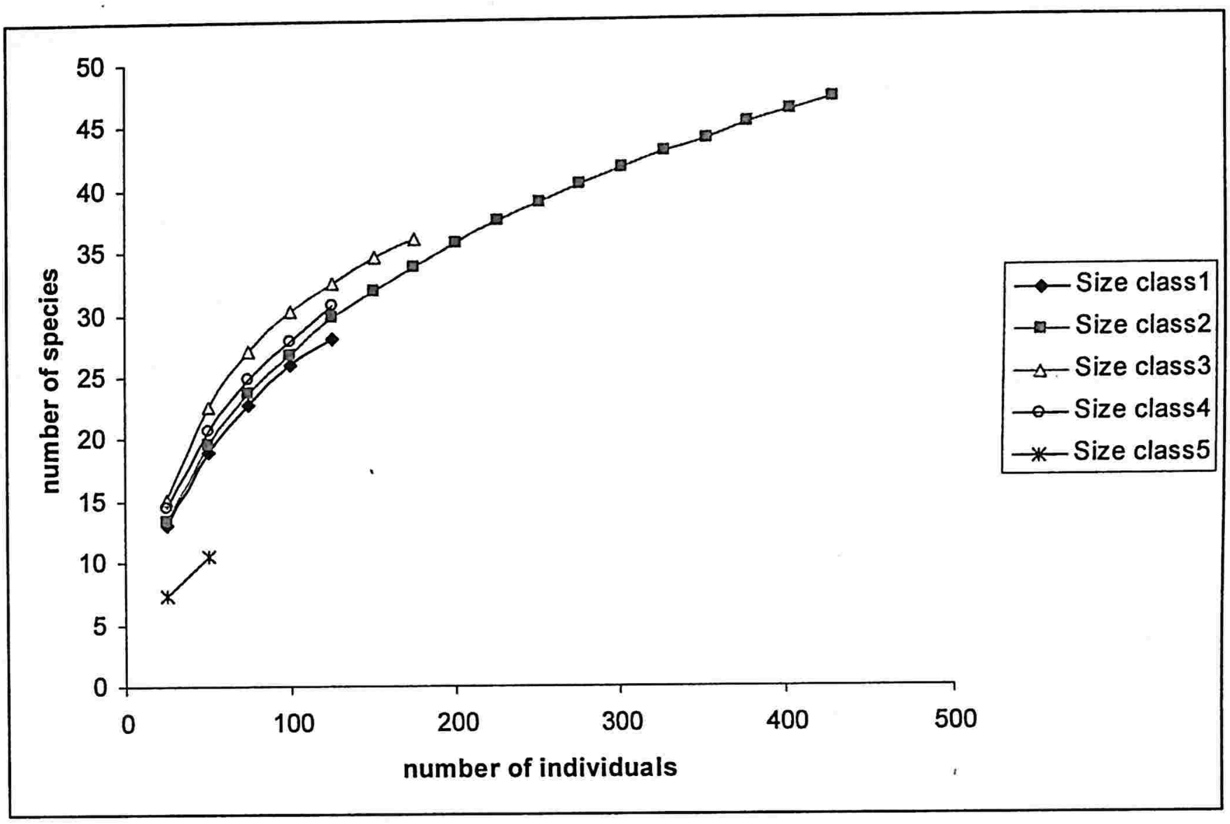



**Fig. 5.1.3h** Individual based rarefaction curves for epiphytes across five size classes

### 5.1.4 Species Abundance Across Fragment Size Classes: Commonness and Rarity

**Trees**

Size class5 represents a typical curvilinear lognormal distribution. The curve is at first steep over the low ranks of the commonest species then shallow over the species having moderate abundances and then again steep over the species with lowest abundances. Though all of them exhibit a 'S' shaped curve they differ in their degree of species richness, degree of dominance of the community by common species and number of rare species in each. The curves for size class2, class3 and class4 show a trend similar to that of size class5 but differ in their number of rare species. Size class1 however shows a uniform, steep decline over all abundance classes, indicating high dominance. The species distribution in this size class is least equitable. The commoner species are more abundant and there is absence of rare species in the size class.

**Lianas**

Rank Abundance Curves for Lianas across the fragments revealed that in the Rudraguppe (13 ha) fragment, liana species were distributed equitably across the abundance classes. Heggala and Kokka RF have very few rare species. The rank abundance curves for the rest of the fragments lie between these two curves with differing degree of evenness and number of rare species.

**Shrubs**

A few large size fragments like Palangala (47ha) and medium sized fragments like Arji(8ha) show curves similar to a lognormal curve, steep over common and rare species and shallow over moderately abundant species. Smallest fragment like Batamakki (4ha) and Deven-Tatappa (0.94 ha) show steep curve over all its abundance classes. These fragments are devoid of rare species as compared to the above mentioned ones.

**Epiphytes**

Except for the Reserve forest (Size class5), all other size classes follow lognormal distribution. Size class5 shows very steep slope which signifies high dominances (Fig. 5.1.4d).

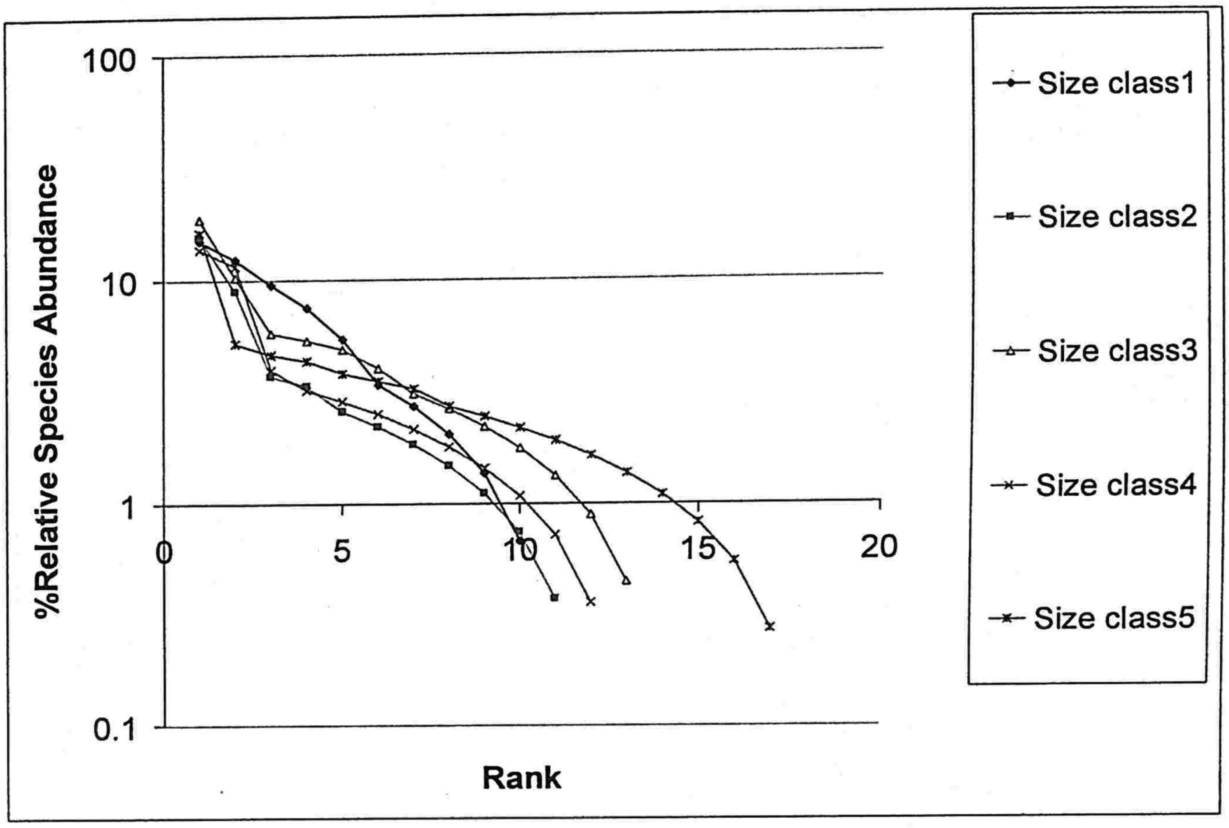
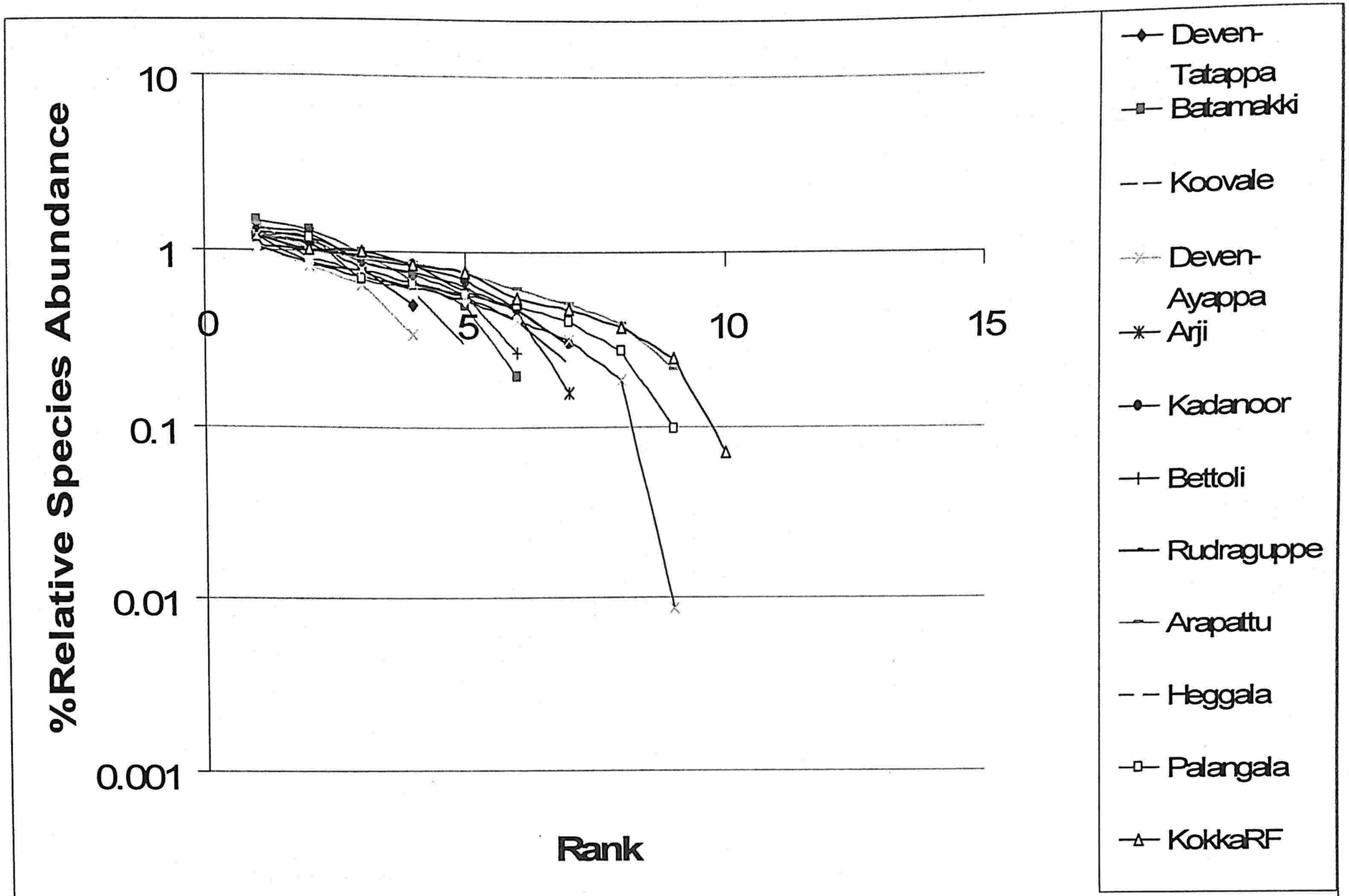



**Fig.5.1.4b** Dominance diversity curve for trees across five size classes

Fig 5.1.3 c. Rank Abundance Curve for trees across all fragments



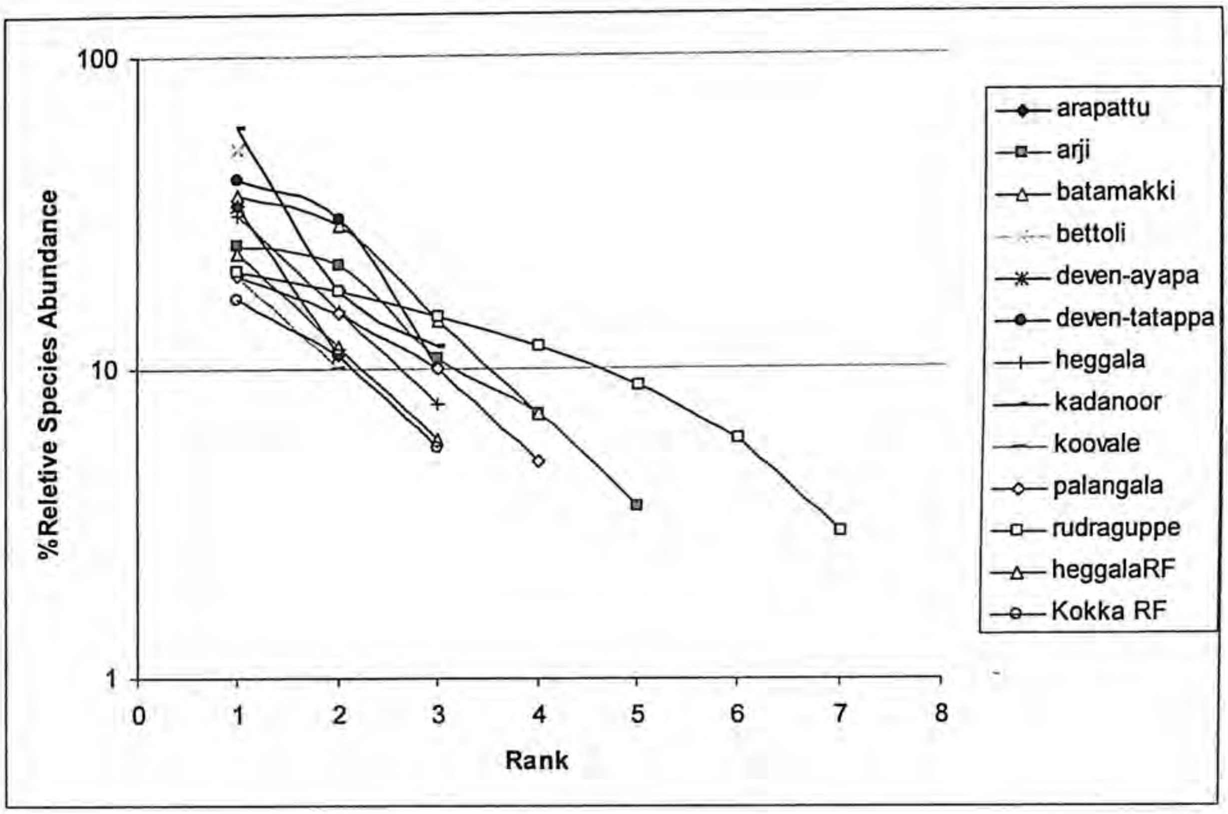



**Fig.5.1.4c** Dominance diversity curve for lianas across all fragments

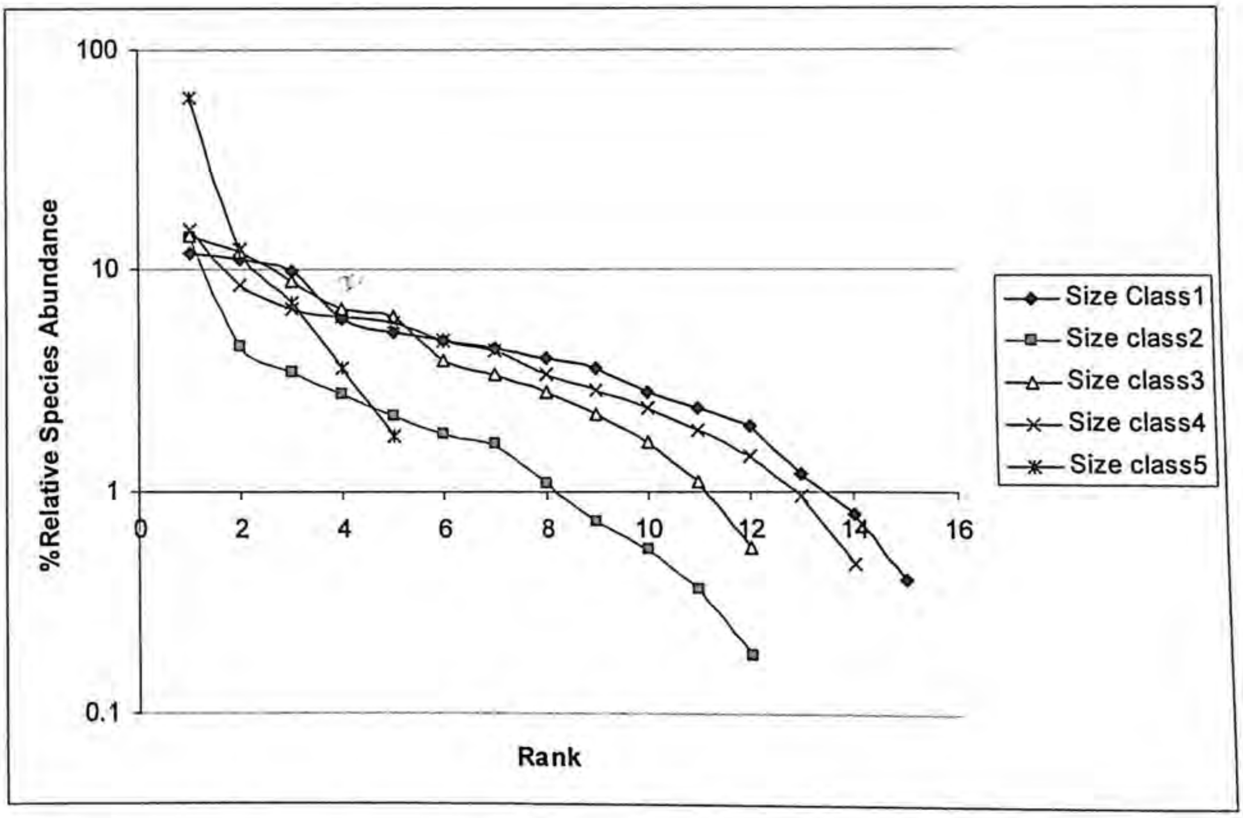
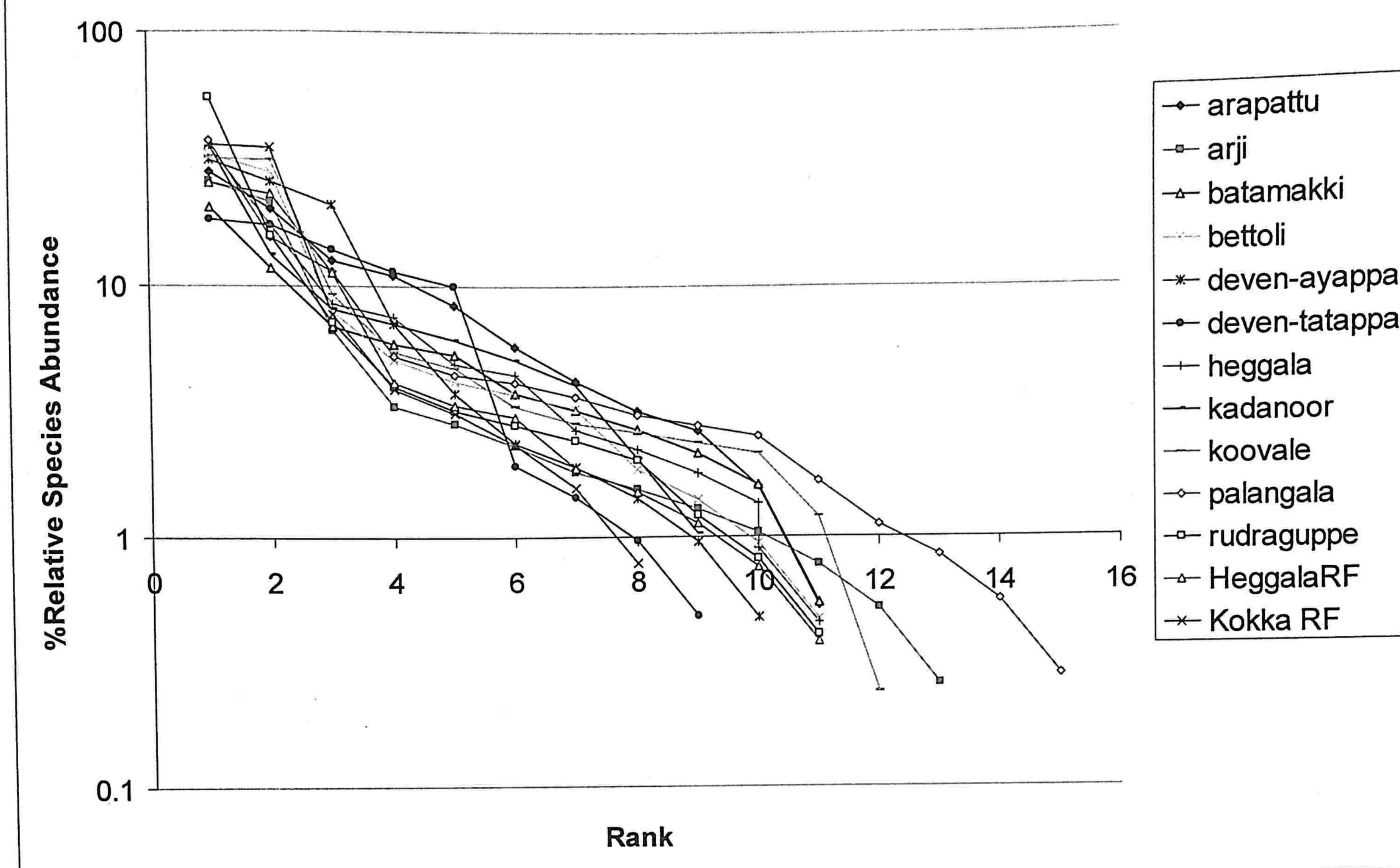



**Fig. 5.1.4e** Rank abundance Curve for Epiphytes across Five Size Classes

Fig. 5.1.3f Rank abundance curve for shrubs across all fragments



### 5.1.5 Effect of Spatial Isolation and Distance

To investigate the effect the geographical distance on plant species richness and composition, dissimilarity geographical distance matrix was compared with ecological dissimilarity distance matrices for all the four plant groups.

The test results revealed a significant positive association between geographical distance and tree species composition. Lianas and epiphyte species composition was negatively associated with geographical distance. The association however was very week and not significant. Shrubs composition was also very weekly but positive associated with geographical distance.

**Table 5.1.5 a.** Association of geographical distance with ecological distance for four groups.

| | r value | t value | Significance value |
|---|---|---|---|
| Trees | 0.404868 | 2.3683 | P < 0.05 |
| Lianas | -0.07711 | -0.4924 | P > 0.05 |
| Shrubs | 0.040372 | 0.2436 | P > 0.05 |
| Epiphytes | -0.09019 | -0.7046 | P > 0.05 |

### 5.1.6 Nestedness

Table 5.1.6 a. gives the observed scores for the six different measures of nestedness..

**Table 5.1.6 a** Nestedness measures for four plant groups.

| Nestedness Measure | Trees | | Lianas | | Shrubs | | Epiphytes | |
|---|---|---|---|---|---|---|---|---|
| | Obs. Scores | Z scores | Obs. Scores | Z scores | Obs. Scores | Z scores | Obs. Scores | Z scores |
| N0 | 415 | -11.78 | 95 | -5.1.11 | 210 | -7.91 | 415 | -11.78 |
| N1 | 267 | -6.89 | 54 | -4.58 | 162 | -3.59 | 267 | -6.89 |
| NC | 1083 | 21.39 | 281 | 12.58 | 789 | 22.4 | 1083 | 21.39 |
| UA | 61.27 | 1.66 | 8 | -0.91 | 27.17 | -0.8 | 61.27 | 1.66 |
| UP | 129.73 | -10.38 | 32 | -3.86 | 67.83 | -6.41 | 129.73 | -10.38 |
| UT | 191 | -12.17 | 40 | -6.14 | 95 | -9.57 | 191 | -12.17 |
| BR | 152 | -16.78 | 33 | -8.43 | 69 | -13.67 | 152 | -16.78 |

Negative Z scores for all measures except NC point to nestedness. For NC positive scores indicate nestedness

Table5.1.6 b summarises the results for the overall matrix temperature and along with standard deviation and Z-scores.

**Table 5.1.6 b** Summary of the Matrix Temperature for four plant groups.

| | MatTemp | Sim temp. | StdDev | Z-score | Skewness | L95%Conf | U95%Conf |
|---|---|---|---|---|---|---|---|
| Trees | 26.34 | 55.91 | 2.71 | -10.9 | -0.12 | 50.62 | 61.04 |
| Lianas | 24.63 | 47.84 | 5.27 | -4.4 | 0.18 | 38.08 | 58.82 |
| Shrubs | 31.95 | 56.65 | 3.8 | -6.5 | -0.01 | 49.09 | 64.26 |
| Epiphytes | 21.62 | 55.01 | 3.74 | -8.93 | 0.08 | 47.59 | 62.09 |

The matrix gives idiosyncratic temperature based on the unexpected occurrences/absences. Higher temperature indicated higher number of unexpected occurrence or absence. The frequency of species falling into a particular temperature class is given in Fig 5.1.6 a, b, c and d.

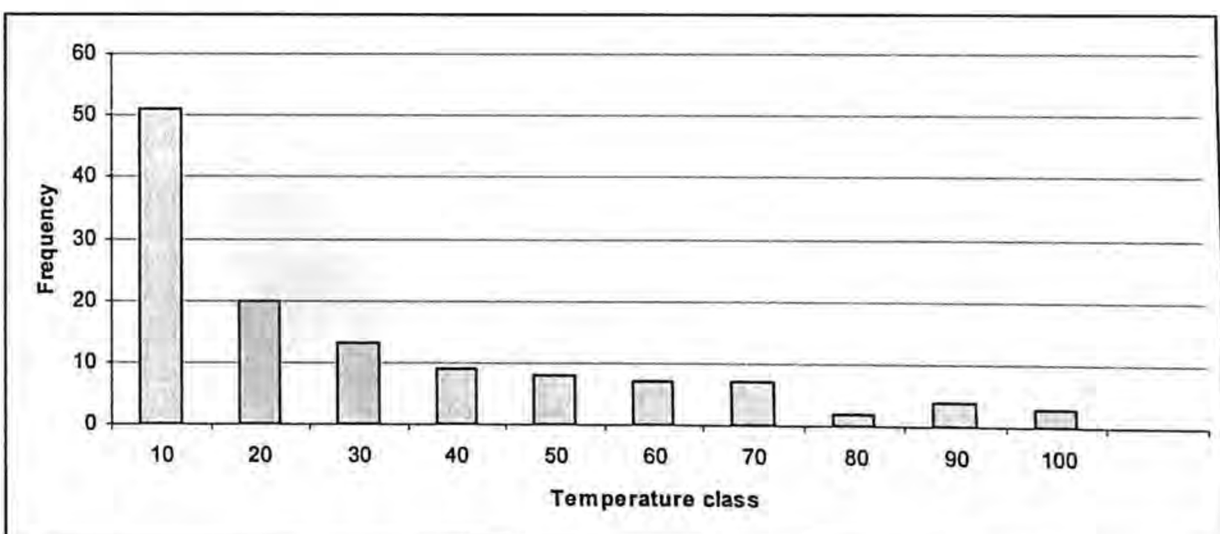



**Fig 5.1.6 a** Frequency of tree species in temperature classes.

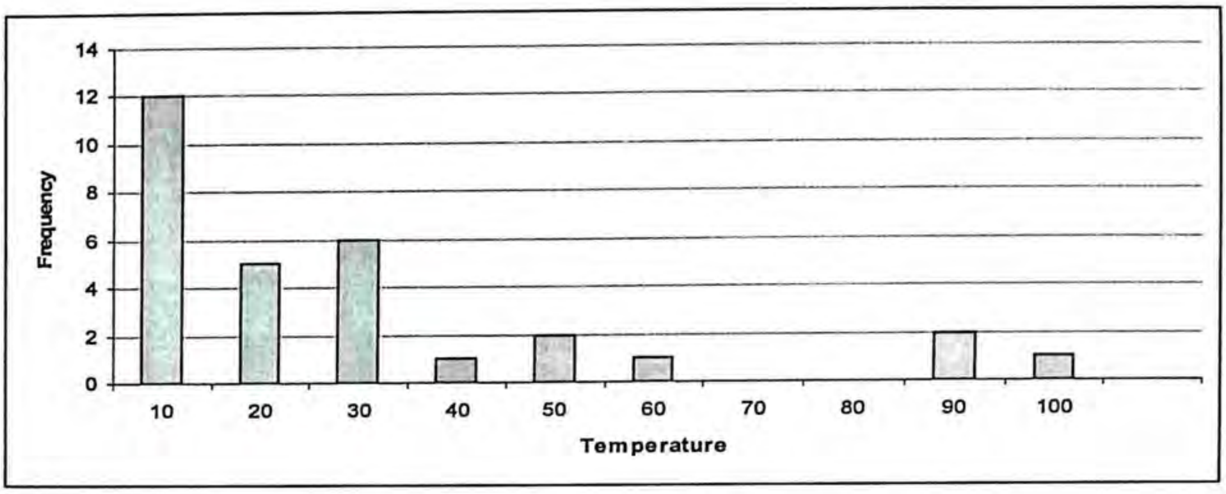



**Fig 5.1.6 b** Frequency of liana species in temperature classes

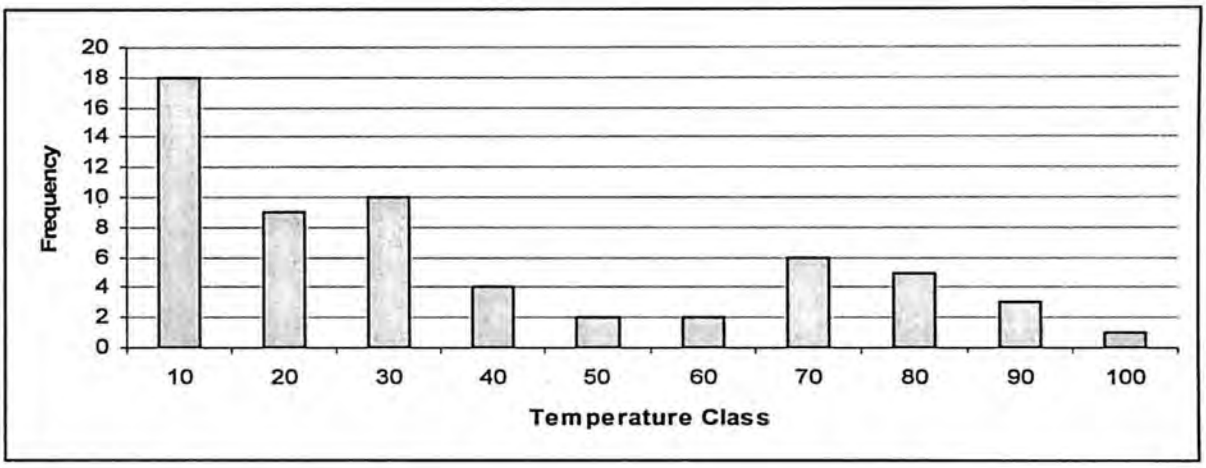



**Fig 5.1.6 c** Frequency of shrub species in temperature classes

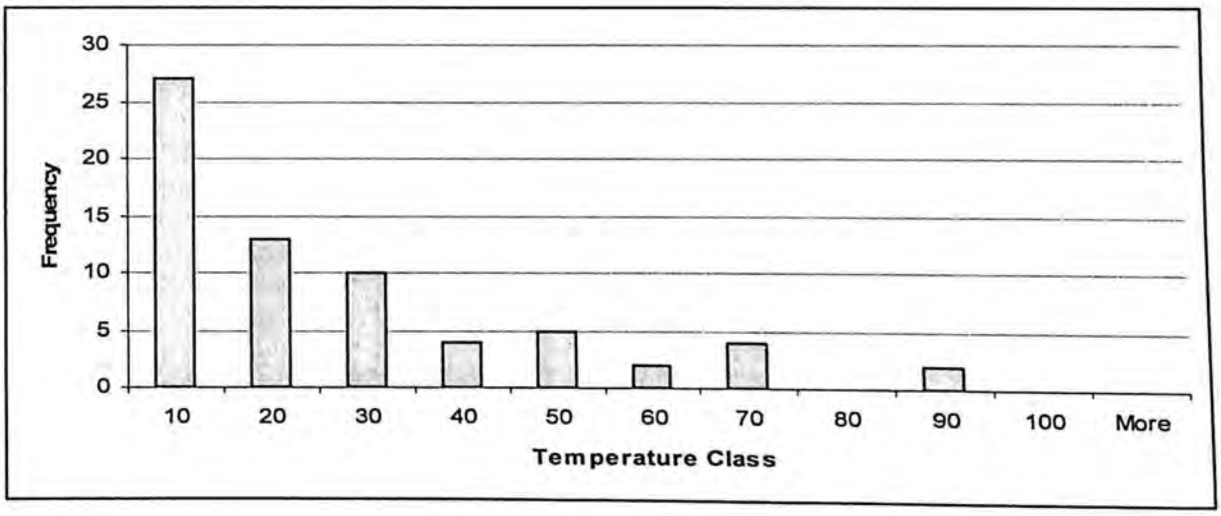



**Fig 5.1.6 d** Frequency of epiphytic species in temperature classes

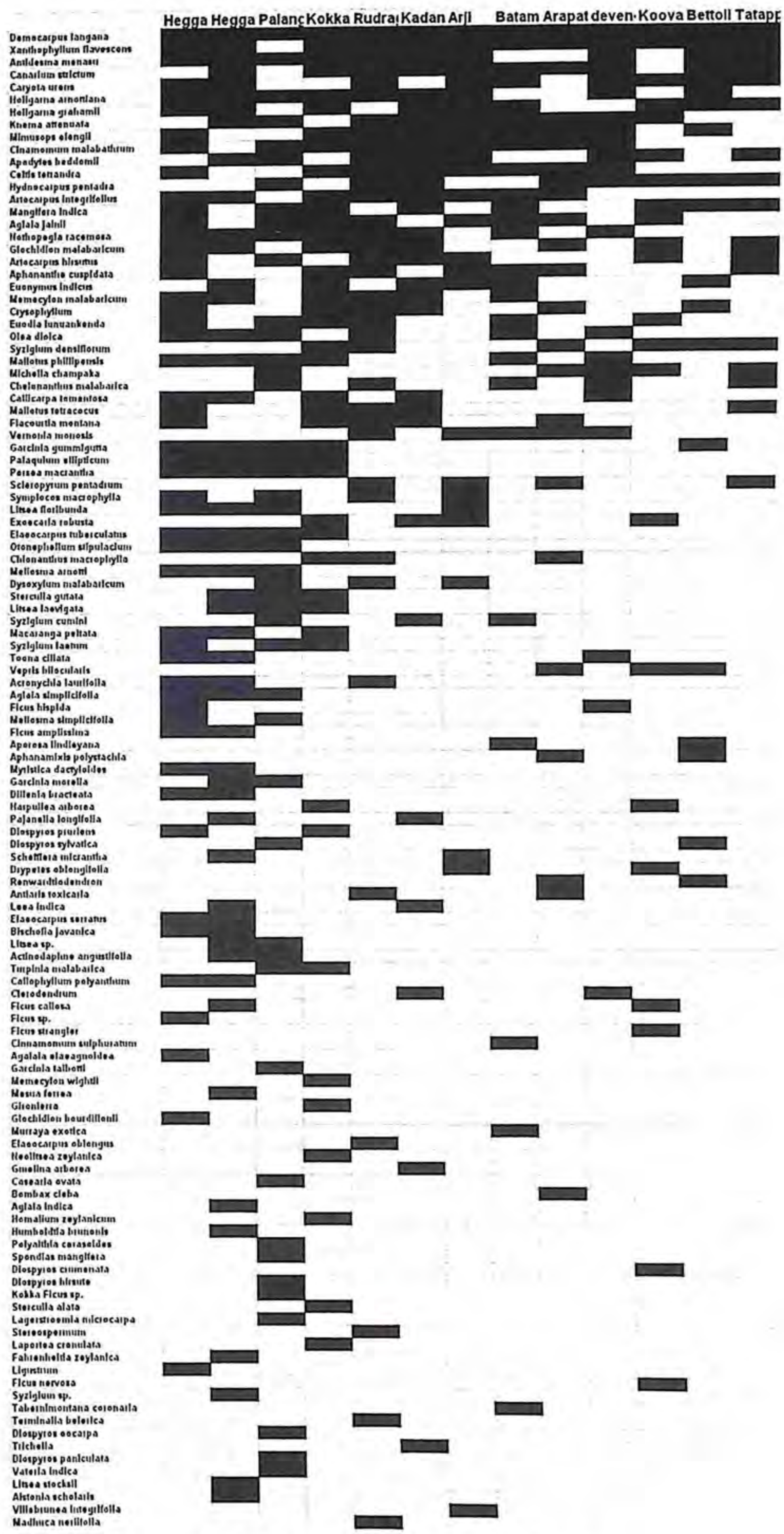



**Fig 5.1.6** Maximally packed matrix for trees.

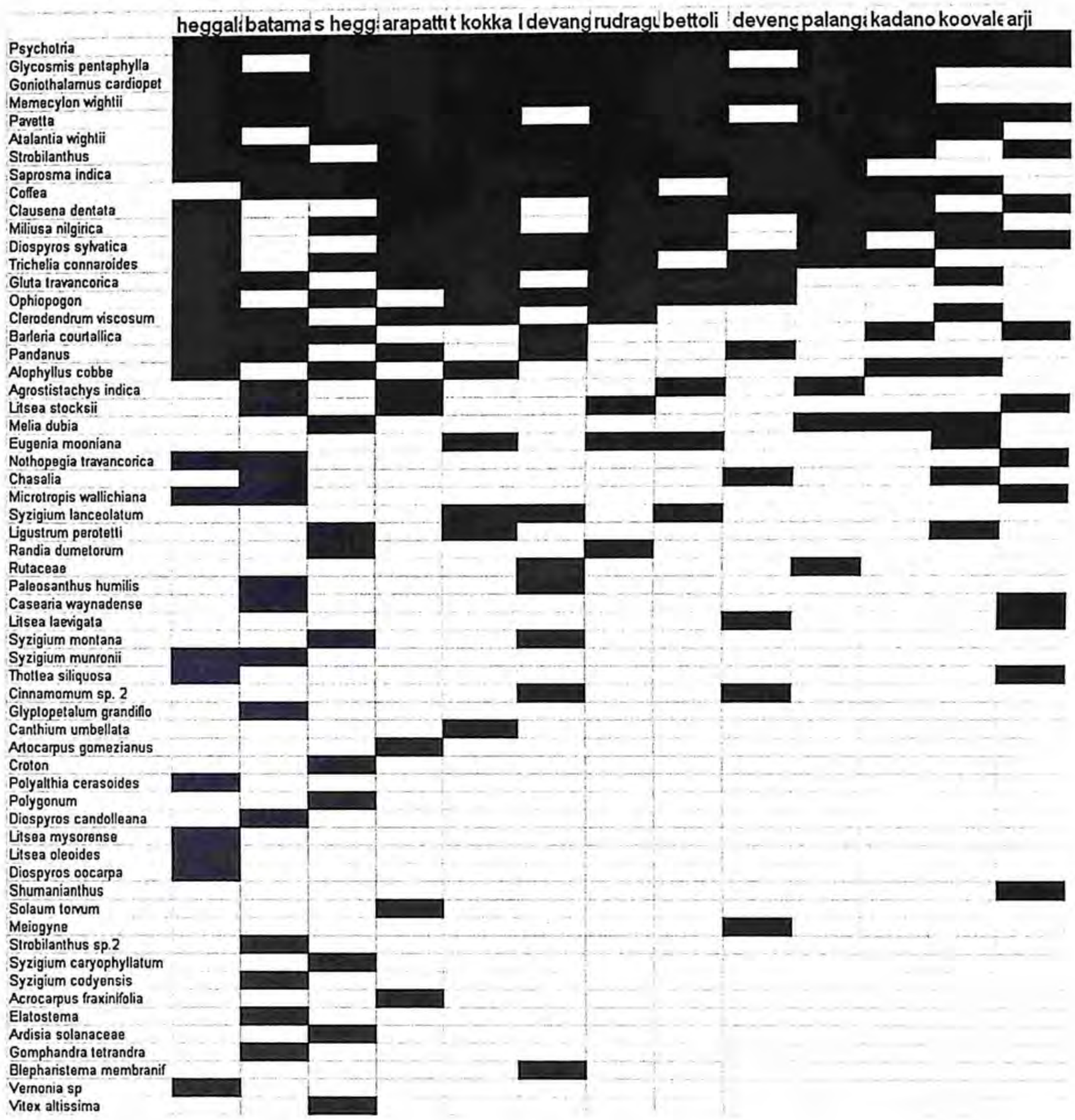



**Figure 5.1.6.g** Maximally packed matrix for shrubs.


**Figure 5.1.6.h** Maximally packed matrix for epiphytes.

### Correlation between area and matrix temperature

To test if area has any influence on patch temperature i.e. whether fragments were nested along an area gradient, rank correlation was used. The correlation between and rank order of patches in maximally nested matrix was tested.

**Table Pearson's correlation values for relation between area and temperature.**

| Plant Group | Area (Pearson's Coefficient) | Significance |
|---|---|---|
| Tree temperature | 0.869 | 0.001 |
| Liana temperature | 0.037 | 0.876 |
| Shrub temperature | 0.425 | 0.192 |
| Epiphyte temperature | -0.15 | 0.66 |

Only trees were found to be nested along the area gradient. Patch area of trees was significantly correlated with matrix temperature. None of the other three plant groups showed any significant relation. Epiphytes were infact negatively correlated with patch area.

### 5.1.7 Species Composition Among Size Classes

Cluster analysis was used to find out if the fragments form any distinct groups with respect to their species composition and abundance. Fig 5.1.7a shows the hierarchy and relationship between the sites with respect to tree species composition. Sorenson's distance measure was used for clustering the sites. The fragments which are closer to each other interns of their geographical distance are grouping together because they also have similar species composition. Patch area seems to be the influencing factor patch distance.

For lianas, (Fig 5.1.7 b) area explains the pattern better since the smaller fragments and the larger fragments have formed to separate clusters. Similarly the dendrogram for shrubs reveals that the species composition of the smaller fragments is very different from that of the reserve forest (Fig 5.1.7 c). Epiphytes also show a pattern similar to that of shrubs (Fig 5.1.7 d).

The fragments were divided into five size classes, and plant species composition was compared across each of these size classes.

Appropriate dimensions for each plant group were chosen depending upon the nature of the scree plot. The same number of dimensions was used for further analysis to test for among group (size class) and within group differences. The results of MRPP are summarized in Table 5.1.7a.

**Table 5.1.7a** Summary statistics for MRPP for four plant groups

| | Observed delta | Expected delta | Variance of delta | Skewness of delta | T | P | A |
|---|---|---|---|---|---|---|---|
| Trees | 0.81 | 1.14 | 3.83E-04 | -0.74 | -17.02 | 0.00 | 0.29 |
| Lianas | 0.68 | 1.12 | 5.1.70E-04 | -0.88 | -18.22 | 0.00 | 0.38 |
| Shrubs | 0.84 | 1.09 | 1.45E-04 | -0.77 | -20.35 | 0.00 | 0.22 |
| Epiphytes | 0.55 | 0.71 | 1.92E-04 | -0.91 | -11.42 | 0.00 | 0.22 |

In all the above cases the groups show strong differences as indicated by a negative T value and a strong chance corrected within group agreement A, associated with significant 'p' value. The results indicate that the five size classes for all four plant groups are different with respect to species composition and abundance.

Hotelling's T test for two samples was used to carry out pair wise comparisons between each size class. Table 5.1.7 b summarizes test statistics for pair wise Hotelling's T2 test. In most of the cases it was the second axis which was contributing significantly to the differences between the groups,

**Table 5.1.7 b** Summary statistics for Hotelling's T2 test

| | Size Class | Covarience Assumption | T2 | Test Prob. |
|---|---|---|---|---|
| | 1 and 2 | Unequal | 29.748 | 0.00 |
| | 1 and 3 | Equal | 60.744 | 0.00 |
| | 1 and 4 | Equal | 110.438 | 0.00 |
| | 1 and 5 | Equal | 161.303 | 0.00 |
| | 2 and 3 | Unequal | 11.296 | 0.05 |
| | 2 and 4 | Unequal | 55.1.751 | 0.00 |
| | 2 and 5 | Equal | 396.912 | 0.00 |
| | 3 and 4 | Equal | 25.816 | 0.00 |
| | 3 and 5 | Equal | 162.046 | 0.00 |
| Trees | 4 and 5 | Equal | 30.979 | 0.00 |
| | 1 and 2 | Equal | 3.32 | 0.23 |
| | 1 and 3 | Unequal | 24.852 | 0.00 |
| | 1 and 4 | Unequal | 58.509 | 0.00 |
| | 1 and 5 | Unequal | 72.55 | 0.00 |
| | 2 and 3 | Equal | 32.399 | 0.00 |
| | 2 and 4 | Unequal | 119.041 | 0.00 |
| | 2 and 5 | Unequal | 133.979 | 0.00 |
| | 3 and 4 | Equal | 58.912 | 0.00 |
| | 3 and 5 | Unequal | 79.384 | 0.00 |
| Lianas | 4 and 5 | Unequal | 8.934 | 0.03 |
| | 1 and 2 | Equal | 81.647 | 0.00 |
| | 1 and 3 | Unequal | 42.888 | 0.00 |
| | 1 and 4 | Equal | 269.247 | 0.00 |
| | 1 and 5 | Equal | 362.263 | 0.00 |
| | 2 and 3 | Unequal | 21.351 | 0.00 |
| | 2 and 4 | Unequal | 71.536 | 0.00 |
| | 2 and 5 | Unequal | 79.007 | 0.00 |
| | 3 and 4 | Unequal | 183.48 | 0.00 |
| | 3 and 5 | Unequal | 221.681 | 0.00 |
| Shrubs | 4 and 5 | Equal | 12.428 | 0.02 |
| | 1 and 2 | Equal | 15.1.559 | 0.01 |
| | 1 and 3 | Equal | 13.953 | 0.03 |
| | 1 and 4 | Equal | 83.653 | 0.00 |
| | 1 and 5 | Unequal | 137.912 | 0.00 |
| | 2 and 3 | Equal | 4.085 | 0.32 |
| | 2 and 4 | Equal | 16.441 | 0.01 |
| | 2 and 5 | Unequal | 36.471 | 0.00 |
| | 3 and 4 | Equal | 27.004 | 0.00 |
| | 3 and 5 | Unequal | 149.607 | 0.00 |
| Epiphytes | 4 and 5 | Unequal | 26.531 | 0.00 |

### 5.1.8 Indicator Species of Each Size Class

**Trees**

Table 5.1.8 a gives the indicator values (I.V.) for each of the five size classes. The species which showed significant I.V. at 95% confidence level are included in the table.

| sps | maxgrp | IV | RndmIV | SD | Significance |
|---|---|---|---|---|---|
| Hydnocarpus pentadra | 1 | 50.5 | 15.1 | 6.49 | 0.001 |
| Michelia champaka | 1 | 27.3 | 11.8 | 5.59 | 0.024 |
| Mangifer aindica | 1 | 26 | 12.8 | 5.09 | 0.025 |
| Caryota urens | 1 | 26 | 14 | 5.38 | 0.04 |
| Clerodendrun viscosum | 2 | 26.7 | 9.4 | 5.34 | 0.016 |
| Vernonia monosis | 3 | 34.2 | 11.6 | 5.62 | 0.005 |
| Cinnamomum malabaricum | 3 | 28.5 | 16.7 | 5.17 | 0.032 |
| Xanthophyllum flavescens | 3 | 32.1 | 22.8 | 4.48 | 0.037 |
| Dysoxylum malabaricum | 3 | 22.2 | 9.6 | 4.83 | 0.041 |
| Syzigiym desnsiflorum | 4 | 25 | 8.4 | 4.98 | 0.013 |
| Laportea crenulata | 4 | 25 | 8.4 | 5.35 | 0.021 |
| Holigarna grahmii | 4 | 28.4 | 16.1 | 5.17 | 0.026 |
| Palaquium ellipticum | 4 | 26.5 | 12.8 | 5.25 | 0.029 |
| Syzigium laetum | 4 | 20.8 | 9.6 | 5.43 | 0.047 |
| Elaeocarpus tuberculatus | 5 | 44.3 | 12.9 | 5.22 | 0.001 |
| Vateria indica | 5 | 41.7 | 10 | 5.47 | 0.001 |
| Olea dioica | 5 | 47.9 | 15.1 | 6.76 | 0.002 |
| Humboldtia brunonis | 5 | 33.3 | 9.6 | 5.57 | 0.004 |
| Litsea sp. | 5 | 33.3 | 9.3 | 5.34 | 0.004 |
| Myristica dactyloides | 5 | 30.8 | 11.2 | 6.16 | 0.008 |
| Democarpus longana | 5 | 35.6 | 24.7 | 3.71 | 0.009 |
| Mallotus philipensis | 5 | 28.2 | 12.5 | 4.81 | 0.012 |
| Persea micrantha | 5 | 27.8 | 11.9 | 5.24 | 0.014 |
| Garcinia morella | 5 | 25 | 8.9 | 5.3 | 0.023 |
| Otonephelium stipulaceum | 5 | 25.8 | 13 | 6.14 | 0.044 |

Indicator species show an increasing trend with increase in size class. Reserve forest has the highest number of indicator species.

**Lianas**

Table 5.1.8 b gives the indicator value of liana species at 75%confidence interval. At 95% confidence level, only size class3 shows 2 indicator species, namely *Acacia concinna* and *Alangium lamarkii*. In general Lianas don't seem to be indicative of any particular size class and site.

**Table 5.1.8 b**

| Species | Maximum group | Indicatoe Value | Random IV | SD | Significance |
|---|---|---|---|---|---|
| Mesoneurum cuculatum | 1 | 17 | 13.4 | 5.68 | 0.193 |
| **Acaia concinna** | **3** | **39.4** | **18.1** | **5.9** | **0.008*** |
| **Alangium lamarkii** | **3** | **29.6** | **16.8** | **5.87** | **0.043*** |
| Artabotrys zeylanica | 3 | 16.2 | 7.7 | 4.86 | 0.073 |
| Elaeagnus conferta | 3 | 14.2 | 8.7 | 5.14 | 0.154 |
| Salacia microsperma | 3 | 11.1 | 7 | 2.63 | 0.163 |
| Strychnos wallichian | 4 | 22.8 | 13.7 | 5.53 | 0.071 |
| Hogonia baelii | 5 | 16.7 | 7.5 | 3.65 | 0.102 |
| Jasminum malabaricum | 5 | 16.7 | 7.7 | 3.88 | 0.113 |
| Spatholobus purpureus | 5 | 16.7 | 7.8 | 4 | 0.119 |

*Significant at 95% confidence level.

**Epiphytes**

Epiphytes show a decreasing trend in number of indicator species per from smaller to larger size class. The trend is exactly opposite to that of trees. No indicator species were found for reserve forest.

Table 5.1.8 c

| Species | Maximum group | Indicatoe Value | Random IV | SD | Significance |
|---|---|---|---|---|---|
| Cymbaloe | 1 | 54 | 11 | 5.72 | **0.001*** |
| Pothscan | 1 | 39.2 | 14.2 | 6.05 | **0.004*** |
| Oberbrun | 1 | 28.4 | 12.5 | 6.27 | **0.02*** |
| Phymsp. | 1 | 20.7 | 8.6 | 4.94 | **0.042*** |
| Dendmacr | 1 | 16.2 | 8.7 | 5.03 | 0.122 |
| Taxitome | 1 | 11.1 | 7 | 2.52 | 0.13 |
| Psilnudu | 1 | 11.1 | 6.9 | 2.57 | 0.139 |
| Dendherb | 1 | 23.8 | 17.4 | 6.44 | 0.146 |
| Taxicune | 1 | 11.1 | 7 | 2.63 | 0.158 |
| Dendlawi | 1 | 11.1 | 7 | 2.63 | 0.163 |
| Lepiumbe | 1 | 11.1 | 7.1 | 2.6 | 0.163 |
| Pterbiau | 1 | 11.1 | 7.1 | 2.6 | 0.163 |
| Ptermarj | 1 | 11.1 | 7.1 | 2.6 | 0.163 |
| Drynquer | 2 | 36.7 | 14.6 | 6 | **0.011*** |
| Fageceyl | 2 | 33.8 | 16.6 | 5.71 | **0.012*** |
| Schewall | 2 | 38.6 | 25.8 | 5.41 | **0.029*** |
| Loxostra | 2 | 25 | 11.4 | 5.91 | **0.036*** |
| Medibedo | 2 | 22.5 | 14.6 | 5.98 | 0.096 |
| Pholpall | 2 | 30.9 | 22.1 | 7.29 | 0.122 |
| Aerimacu | 2 | 14.3 | 9.8 | 5.27 | 0.175 |
| Ficutsja | 2 | 12.5 | 7.7 | 5.12 | 0.234 |
| Coelbrev | 4 | 39.5 | 10.5 | 5.46 | **0.003*** |
| Ficularg | 4 | 16.7 | 7.7 | 3.88 | 0.099 |
| Schecapi | 4 | 15.6 | 11.2 | 5.61 | 0.176 |

**Shrubs**

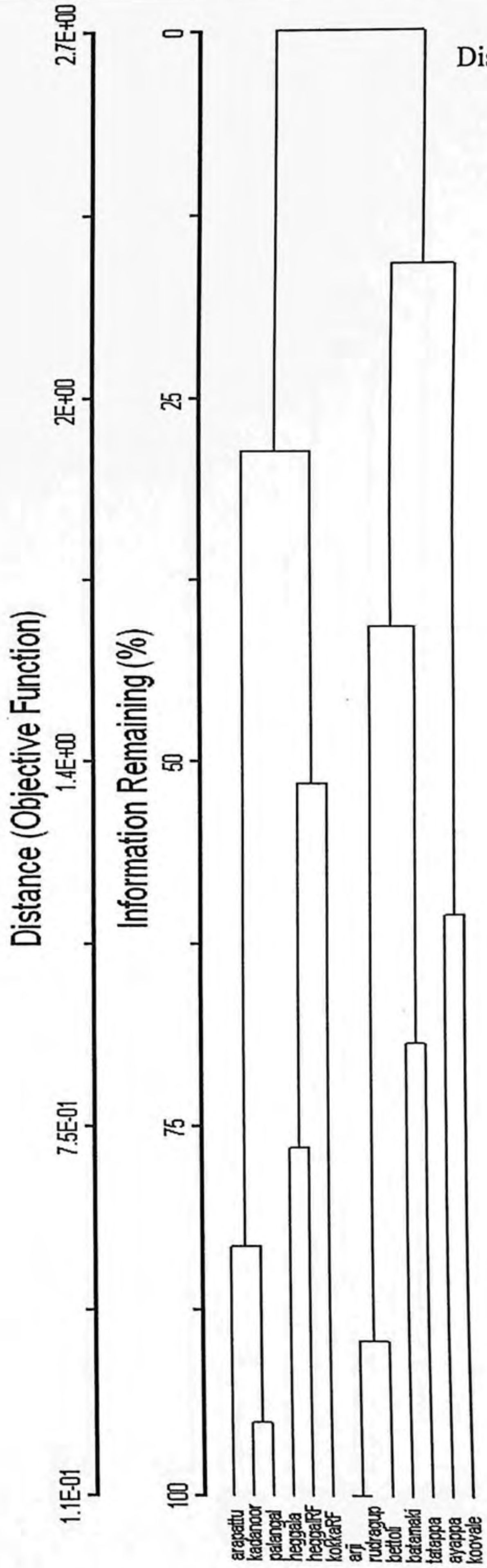
**Table 5.1.8 d**

| Species | Maximum group | Indicator Value | Random IV | SD | Significance |
|---|---|---|---|---|---|
| Pavetta indica | 1 | 46.7 | 14.6 | 4.74 | **0.001** |
| Trichelia connaroides | 1 | 51.4 | 11.9 | 4.08 | **0.001** |
| Miliusa nilgirica | 1 | 32.6 | 11.7 | 4.25 | **0.002** |
| Coffea robusta | 1 | 36.5 | 19.6 | 4.62 | **0.005** |
| Syzigium caryophyllatum | 1 | 16.7 | 5.5 | 3.63 | **0.021** |
| Melia dubia | 1 | 11.1 | 6.4 | 3.79 | 0.098 |
| Croton sp. | 1 | 11.1 | 5.5 | 2.94 | 0.105 |
| Plygonum chinensis | 1 | 11.1 | 5.5 | 2.9 | 0.111 |
| Glycosmis pentaphylla | 1 | 19 | 13.8 | 4.41 | 0.118 |
| Alophyllus cobbe | 1 | 12.3 | 7.7 | 3.89 | 0.121 |
| Syzigium montana | 1 | 10.5 | 6.4 | 3.79 | 0.14 |
| Barleria cortallica | 1 | 12.8 | 8.6 | 4.48 | 0.146 |
| Syzigium lanceolatum | 2 | 13.3 | 6.7 | 3.82 | 0.056 |
| Diospyros sylvatica | 2 | 19.5 | 13.5 | 4.6 | 0.103 |
| Litsea stocksii | 3 | 40.7 | 9.1 | 4.15 | **0.001** |
| Gomphandra tetrandra | 3 | 43.2 | 15.9 | 4.7 | **0.002** |
| Atalantia wightii | 3 | 34.7 | 17.5 | 4.12 | **0.004** |
| Goniothalamus cardiopetalus | 3 | 31.9 | 16.1 | 4.57 | **0.009** |
| Eugenia mooniana | 3 | 19.4 | 7.4 | 3.98 | **0.012** |
| Clerodendrum viscosum | 3 | 18.2 | 9.8 | 4.05 | **0.048** |
| Strobilanthus sp. | 4 | 45.9 | 18 | 4.29 | **0.001** |
| Syzigium munronii | 4 | 38.6 | 11 | 4.25 | **0.001** |
| Saprosma indica | 4 | 34 | 19.4 | 3.73 | **0.005** |
| Plolyalthia cerasoides | 4 | 12.5 | 5.3 | 2.74 | 0.063 |
| Vernonia sp | 4 | 12.5 | 6.3 | 3.1 | 0.083 |
| Litsea laevigata | 4 | 12.3 | 6.8 | 3.92 | 0.086 |
| Cinnamomum sulphuratum | 4 | 10.4 | 6.1 | 3.39 | 0.127 |
| Chasalia curviflora | 4 | 11.2 | 8.1 | 3.87 | 0.185 |
| Nothopegia travancorica | 5 | 37.9 | 9.3 | 4.01 | **0.001** |
| Paleosanthus humilis | 5 | 27.8 | 6.5 | 3.86 | **0.002** |
| Elatostema sp. | 5 | 30.8 | 6.7 | 3.82 | **0.003** |
| Casearia waynadense | 5 | 23.1 | 6 | 3.7 | **0.008** |
| Strobilanthus sp.2 | 5 | 23.1 | 5.6 | 3.53 | **0.008** |
| MicrWall | 5 | 19.2 | 6.1 | 3.73 | **0.016** |

* Significant at 95% confidence level

Shrub indicator species for 5 size classes have been listed in table 5.1.8 d. Interestingly, unlike trees and epiphytes shrubs don't show any particular trend with respect to increase in size class. Highest number of indicator species was found for size class3. Size class 2 didn't show any indicator species. the results indicate that reserve forest and smallest size class both have same number of indicator species.

**Fig 5.1.7 a** Cluster dendrogram for all fragments based on tree species




Distance measure – Sorensen (Bray-Curtis)

**Fig 5.1.7 b** Cluster dendrogram for all fragments based on liana species

Distance measure – Sorensen (Bray-Curtis)

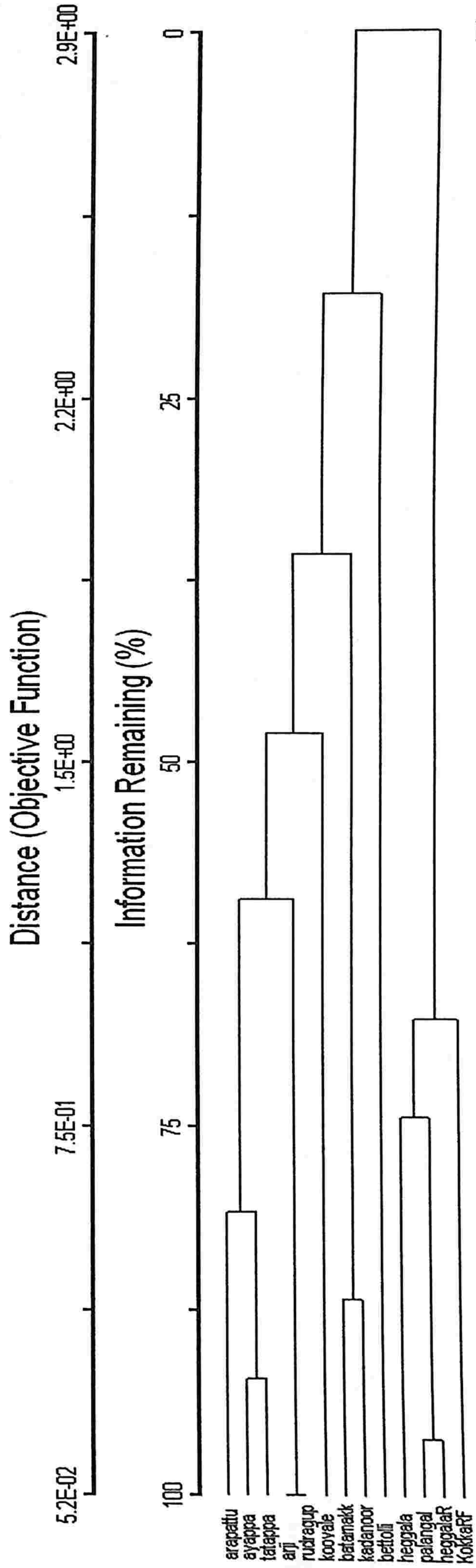


**Fig 5.1.7 c** Cluster dendrogram for all fragments based on shrub species

Distance measure – Sorensen (Bray-Curtis)

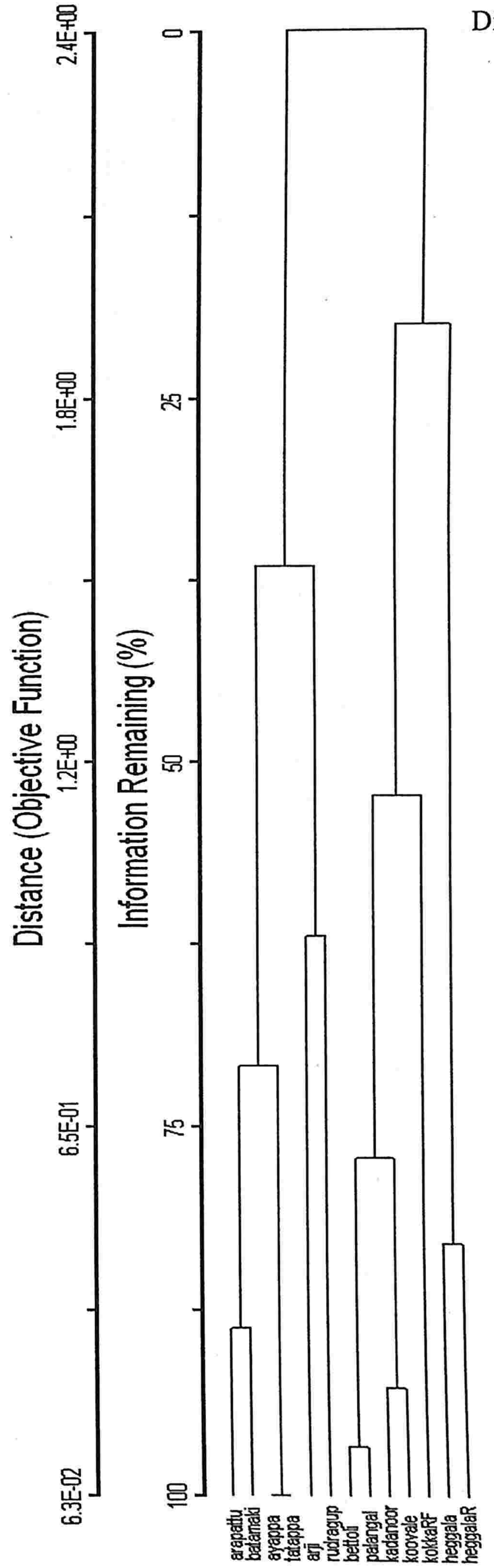
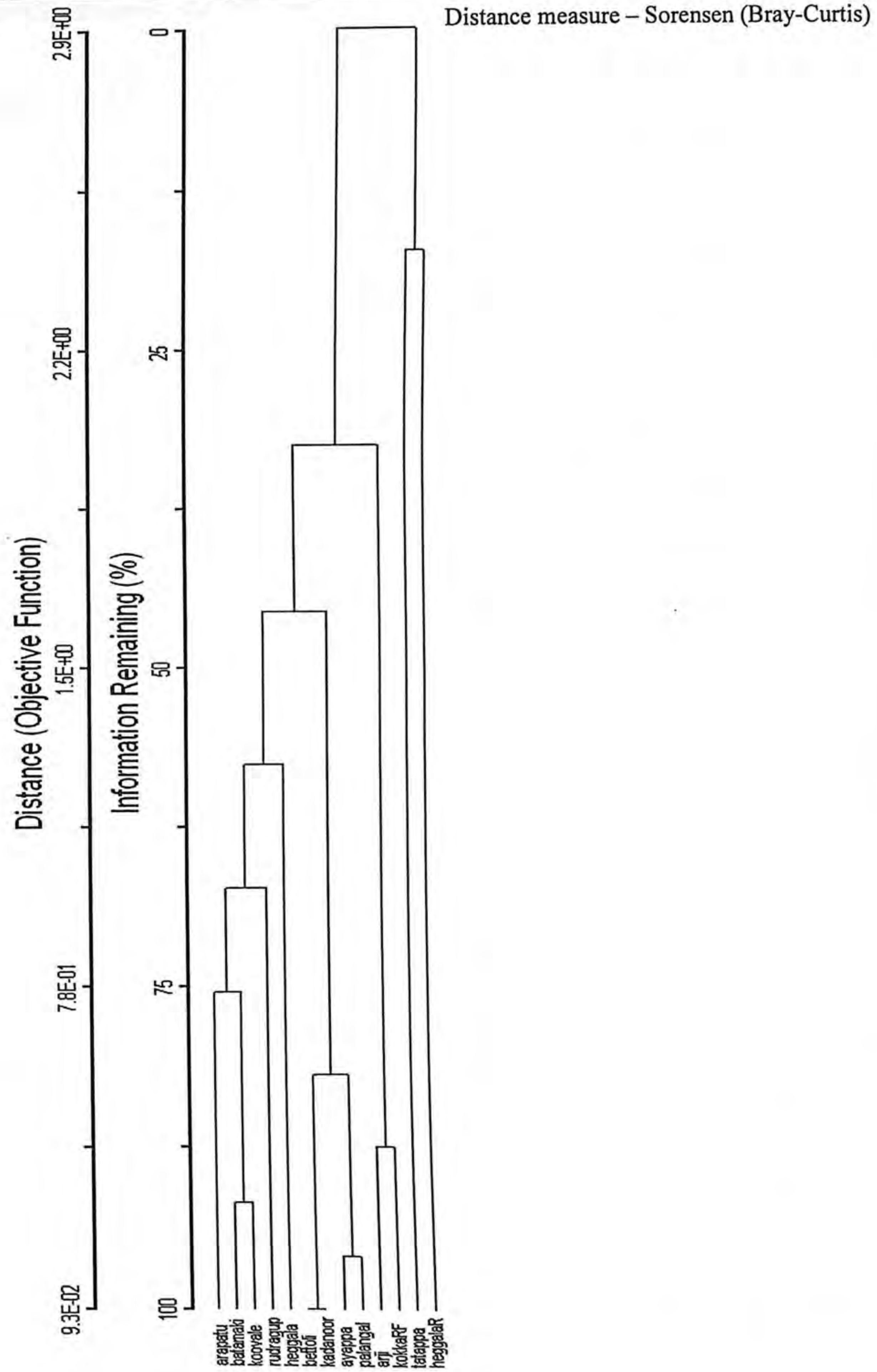


**Fig 5.1.7 d** Cluster dendrogram for all fragments based on epiphytes



## Chapter 5.2 Diversity and Distribution Patterns in Epiphytes

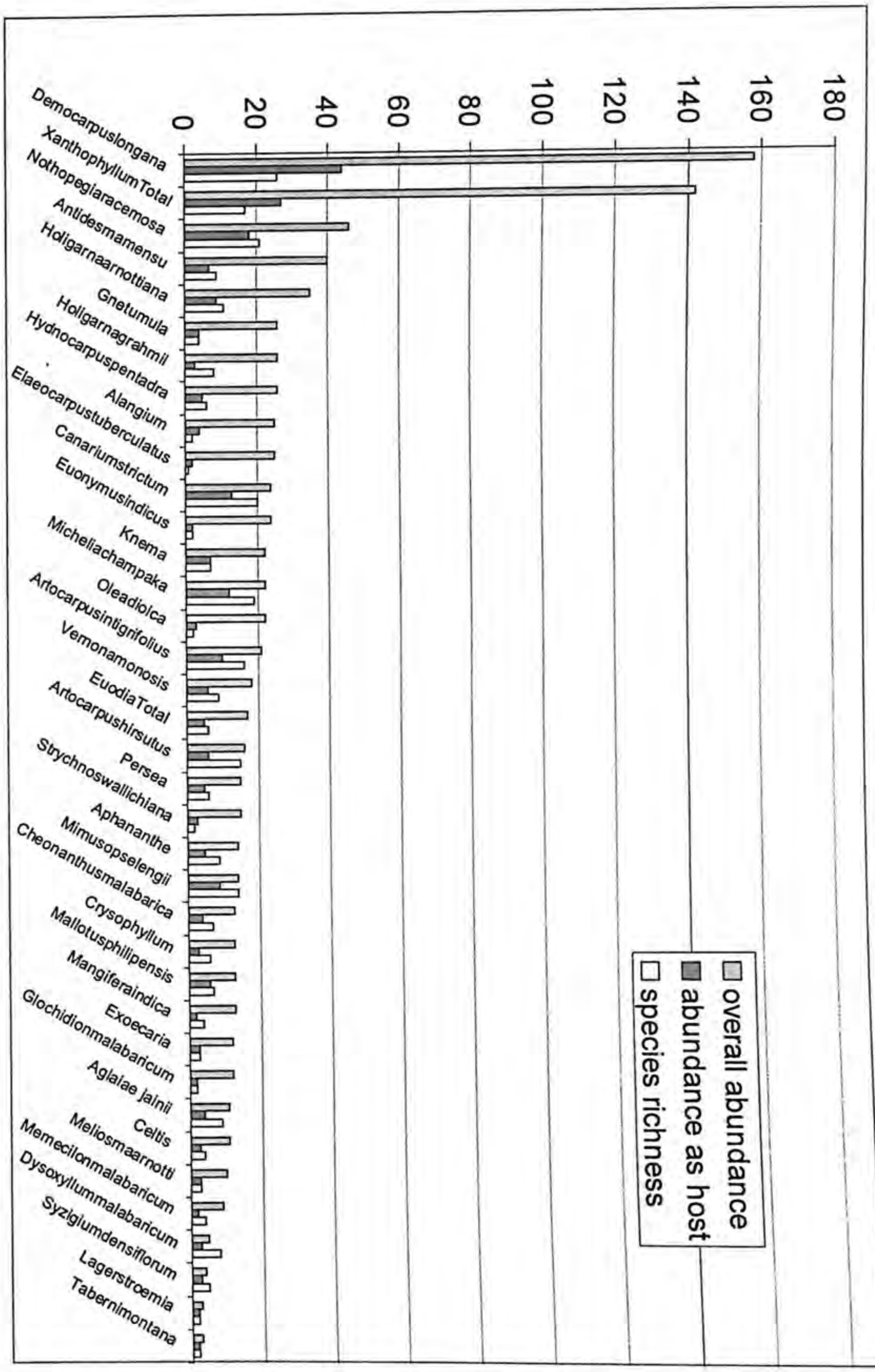
### 5.2.1 Floristic and Life Form Diversity

A total of 71 species of epiphytes were recorded during the study period distributed among 15 sites, including 2 coffee plantations and 2 reserve forests (Figures only for the study area). Of the total of 68 species, 26 species (36.6%) belonged to family Orchidaceae, 10 species belonged to group Pteridophytes (14%). Other Angiosperms (excluding orchids) constituted about 28 species, out of which 10 species belonged to family Loranthaceae. These were all predominantly hemiparasites. Hemiepiphytes constituted a total of 10 species (14%) which belonged to families like Moraceae (4 species), Araceae (2 species), Araliaceae (2 species) and followed by Verbenaceae and Loganiaceae with one species each.

*Asplenium nidus* was the most common Pteridophyte in the study area, while *Pholidota pallida* was the most common species of orchid. *Schefflera micrantha* was the most common hemiepiphyte. Species like *Smithsonia straminea* (=*Loxoma maculosa*), *Phalenopsis mysorense, Gastrochlus acaulis* and *Psilotum nudum* were found to be present only in some selected forest fragments of the study area.

Epiphytes were recorded on 78 host species including 5 species of lianas. The host species which had an abundance of 2 individuals or more as a host were included for host- epiphyte analysis. The total abundance for 37 host epiphytes along with the abundance of the same species as a host is represented in Fig 5.8 a. The total number of epiphytic species recorded on that particular species during the study duration is also represented.

**Fig 5.2.1** Abundance of 37 host species with observed species richness



*Democarpus longana* and *Xanthophyllum flavescens* were the most abundant host species in the intensive study area. Maximum number of epiphytic species was also recorded on Democarpus longana. Though *Xanthophyllum fkavescens* was the second most abundant host species it ranked third after *Nothopegia bedomii* with respect to number of vascular epiphytes it harboured

### 5.2.2 Epiphyte Diversity across the Three Zones of the Fragment.

Epiphyte species richness in each of the three zones for all the five size classes was estimated. Size class 1, 3 and 4 showed higher species richness in the interior as compared to the edge. Size class2 showed a decline in species richness from edge to interior. Reserve forest shows a reveres trend compared to forest fragments. There is sharp decline in epiphyte species richness from edge to interior (Fig 5.2.2 a).

**Fig 5.2.2 a.** Epiphyte richness across three zones in size class1.

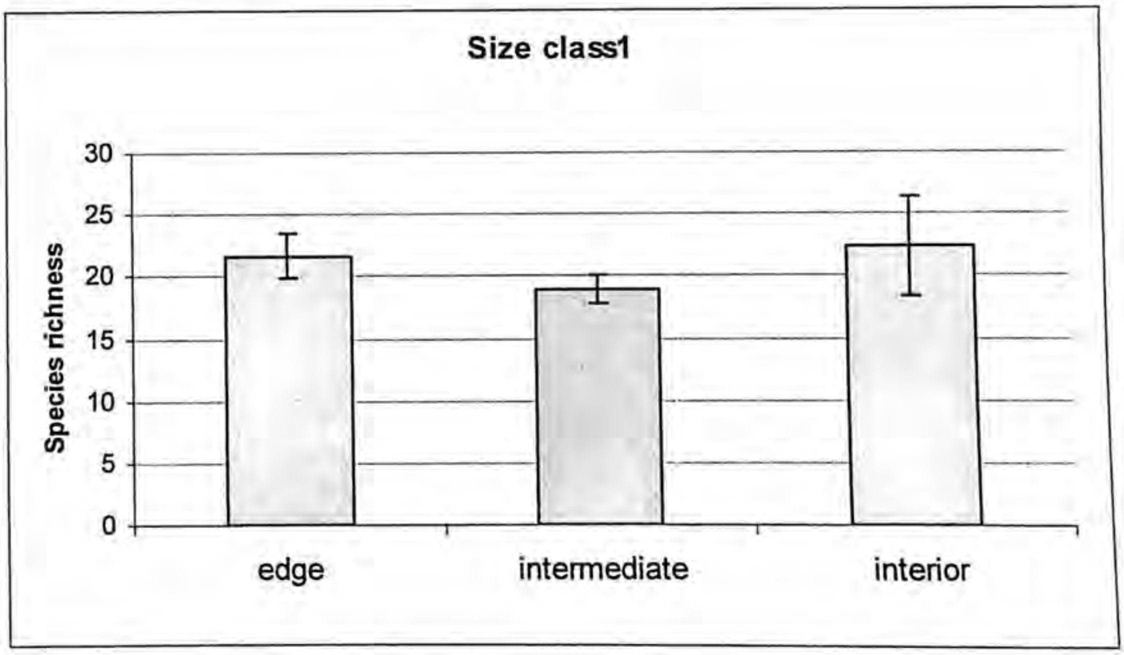


**Fig 5.2.2 b.** Epiphyte richness across three zones in size class1

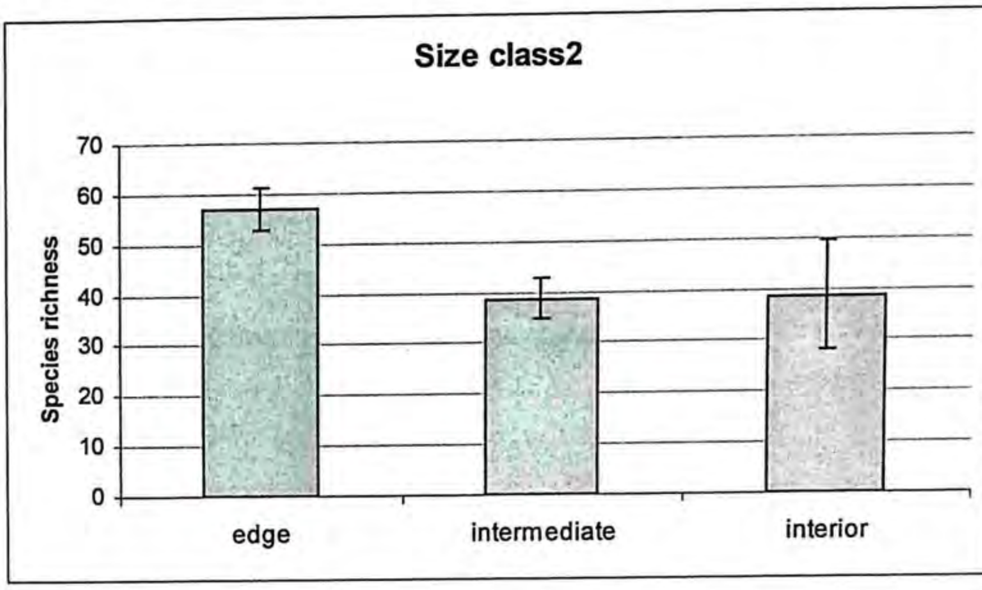



**Fig 5.2.2 c.** Epiphyte richness across three zones in size class 3

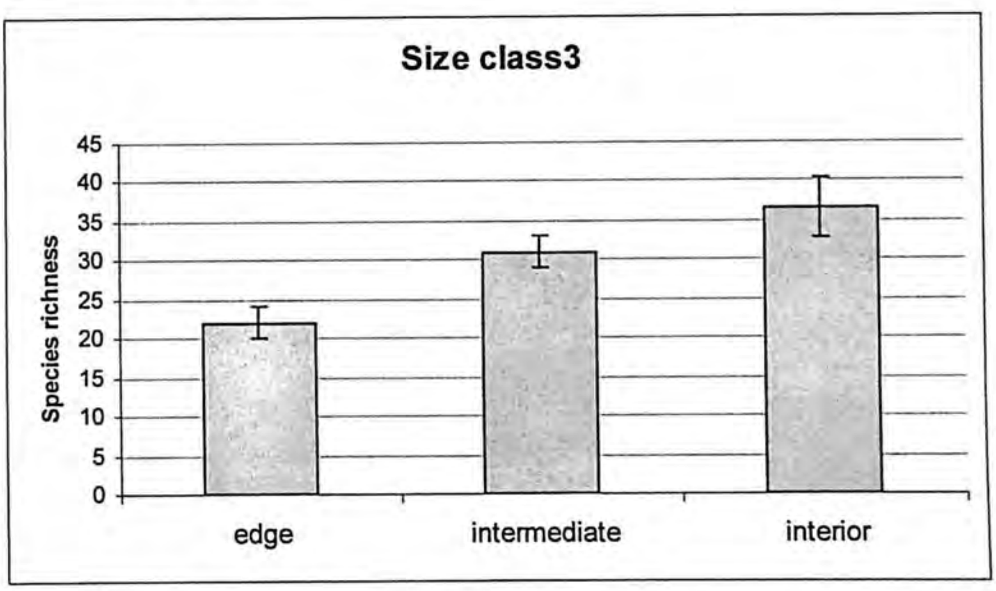


**Fig 5.2.2 d.** Epiphyte richness across three zones in size class 4

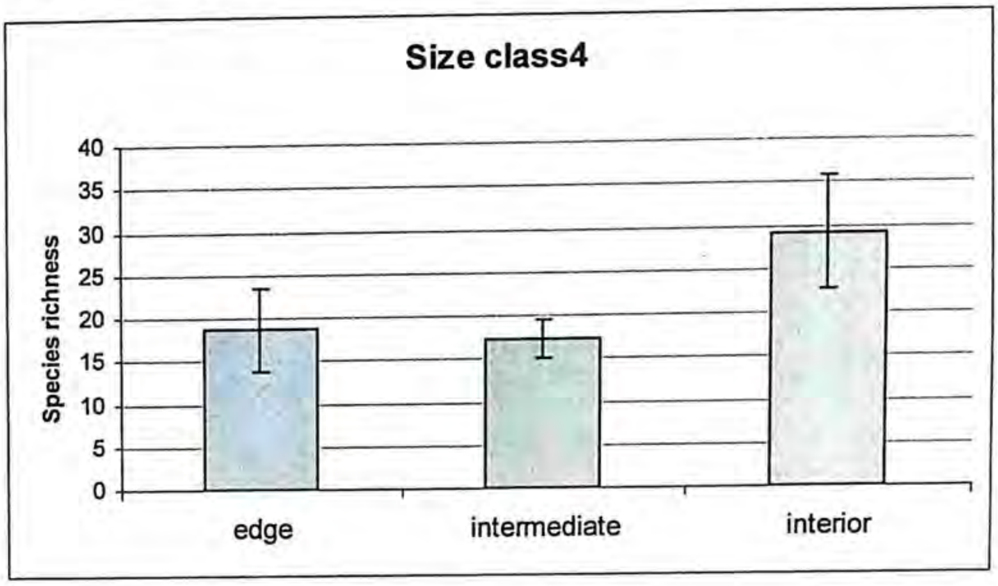
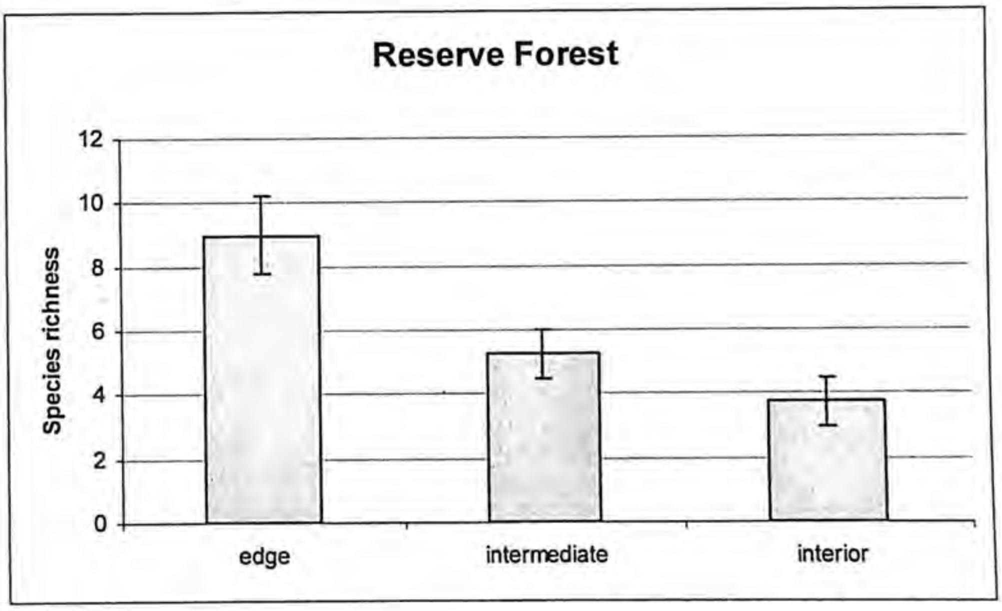



**Fig 5.2.2 e.** Epiphyte richness across three zones in size class 5




**5.2.3 Distribution along the Tree Stature**

To investigate if the mode of dispersal affects the distribution of epiphytes along the tree stature a Chi Square test was conducted to see if epiphytic species are correlated with a particular zone. The Chi Square test was carried out to test the null hypothesis that there is no difference in abundance of an epiphytic species across each zone. One of the assumptions of the Chi Square test is that only 25% of the observations can be less than zero. Therefore 15 species of epiphytes were analysed for the Chi Square goodness of fit. The results are summarised in table below.

**Table 5.2.3 a** Summary of Chi Square test for four zones of the tree.

| Epiphyte | Zone 1 Obs. | Zone 2 Obs. | Zone 3 Obs. | Zone 4 Obs. | Chi square | Significance( 0.05) |
|---|---|---|---|---|---|---|
| *Aeschinanthus* | 16 | 7 | 9 | 2 | 11.88235 | 0.01> P >0.005 |
| *Asplenium* | 67 | 46 | 33 | 10 | 43.84615 | P < 0.001 |
| *Bulbophyllum* | 4 | 3 | 3 | 5 | 0.733333 | 0.90> P >0.75 |
| *Cymbidium aloefolium* | 4 | 2 | 6 | 2 | 3.142857 | 0.50> P >0.25 |
| *Dendrobium herbacium* | 6 | 13 | 11 | 6 | 4.222222 | 0.25> P >0.10 |
| *Drynaria* | 2 | 4 | 7 | 4 | 3 | 0.50> P >0.25 |
| *Fagrea* | 3 | 7 | 10 | 1 | 9.285714 | 0.05> P >0.025 |
| *Helicanthus elasticus* | 5 | 2 | 3 | 7 | 3.470588 | 0.50> P >0.25 |
| *Hoya* | 2 | 0 | 10 | 3 | 15.13333 | 0.005> P >0.001 |
| *Loxoma straminia* | 4 | 5 | 3 | 9 | 3.952381 | 0.50> P >0.25 |
| *Medinella bedomii* | 3 | 7 | 7 | 2 | 4.368421 | 0.25> P >0.10 |
| *Oberonia brunoniana* | 0 | 11 | 5 | 4 | 12.4 | 0.01> P >0.005 |
| *Pholidata* | 23 | 22 | 16 | 8 | 8.275362 | 0.05> P >0.025 |
| *Remusatia* | 15 | 8 | 5 | 0 | 16.85714 | P < 0.001 |
| *Schefflera* | 39 | 31 | 25 | 9 | 18.61538 | P < 0.001 |

### 5.2.4 Host Preference

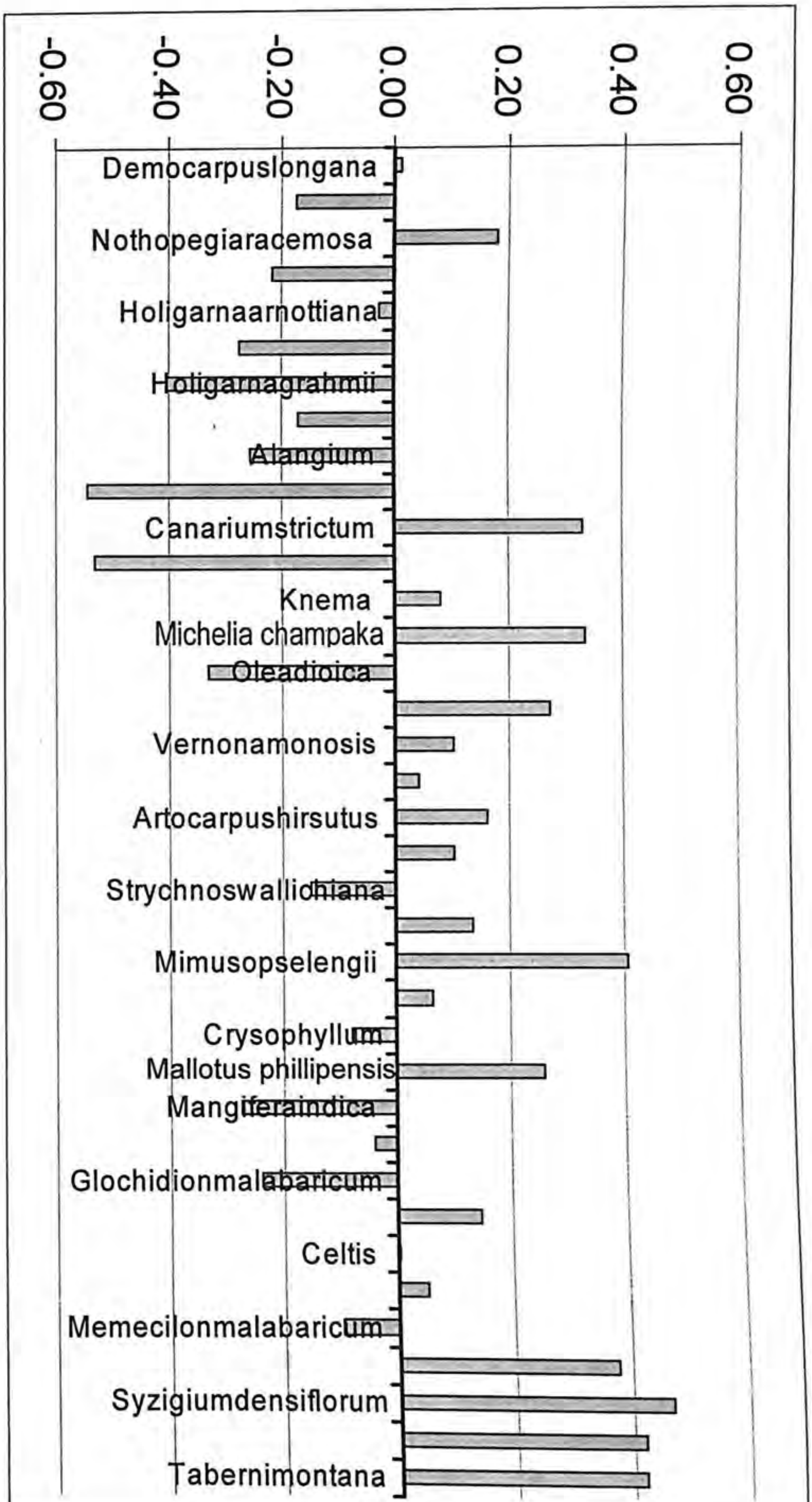
To find out which host species are favoured by epiphytes in general, Ivlev's index was calculated for 44 out of the 75 host species recorded in the study area.

Ivlev's Index = (Use - Availability) / (Use + Availability)

**Table 5.2.4 a.** Values of Ivlev's Index for 35 host species

| Host Species | Ivlev's Index |
|---|---|
| *Democarpus longana* | 0.01 |
| *Xanthophyllum flavescens* | -0.18 |
| *Nothopegia racemosa* | 0.18 |
| *Antidesma mensu* | -0.22 |
| *Holigarna arnottiana* | -0.03 |
| *Holigarnag rahmii* | -0.40 |
| *Hydnocarpus pentadra* | -0.17 |
| *Elaeocarpustu berculatus* | -0.54 |
| *Canarium strictum* | 0.33 |
| *Euonymus indicus* | -0.53 |
| *Knema attenuata* | 0.08 |
| *Michelia champaka* | 0.34 |
| *Olea dioica* | -0.33 |
| *Artocarpus intigrifolius* | 0.27 |
| *Vernonia monosis* | 0.10 |
| *Euodia lunuankenda* | 0.04 |
| *Artocarpus hirsutus* | 0.16 |
| *Persea micranths* | 0.10 |
| *Strychnos wallichiana* | -0.15 |
| *Aphananthe cuspidata* | 0.14 |
| *Mimusops elengii* | 0.41 |
| *Cheonanthus malabarica* | 0.06 |
| *Crysophyllum* | -0.08 |
| *Mallotus philipensis* | 0.26 |
| *Mangifera indica* | -0.28 |
| *Exoecaria robusta* | -0.04 |
| *Glochidion malabaricum* | -0.24 |
| *Aglaiae jainii* | 0.15 |
| *Celtis tetrandra* | 0.00 |
| *Meliosma arnottiana* | 0.05 |
| *Memecilon malabaricum* | -0.10 |
| *Dysoxyllum malabaricum* | 0.38 |
| *Syzigium densiflorum* | 0.47 |
| *Lagerstroemia microcarpa* | 0.42 |
| *Tabernimontana* | 0.42 |

Fig 5.2.4 a. **Ivlev's Index for 37 host species**

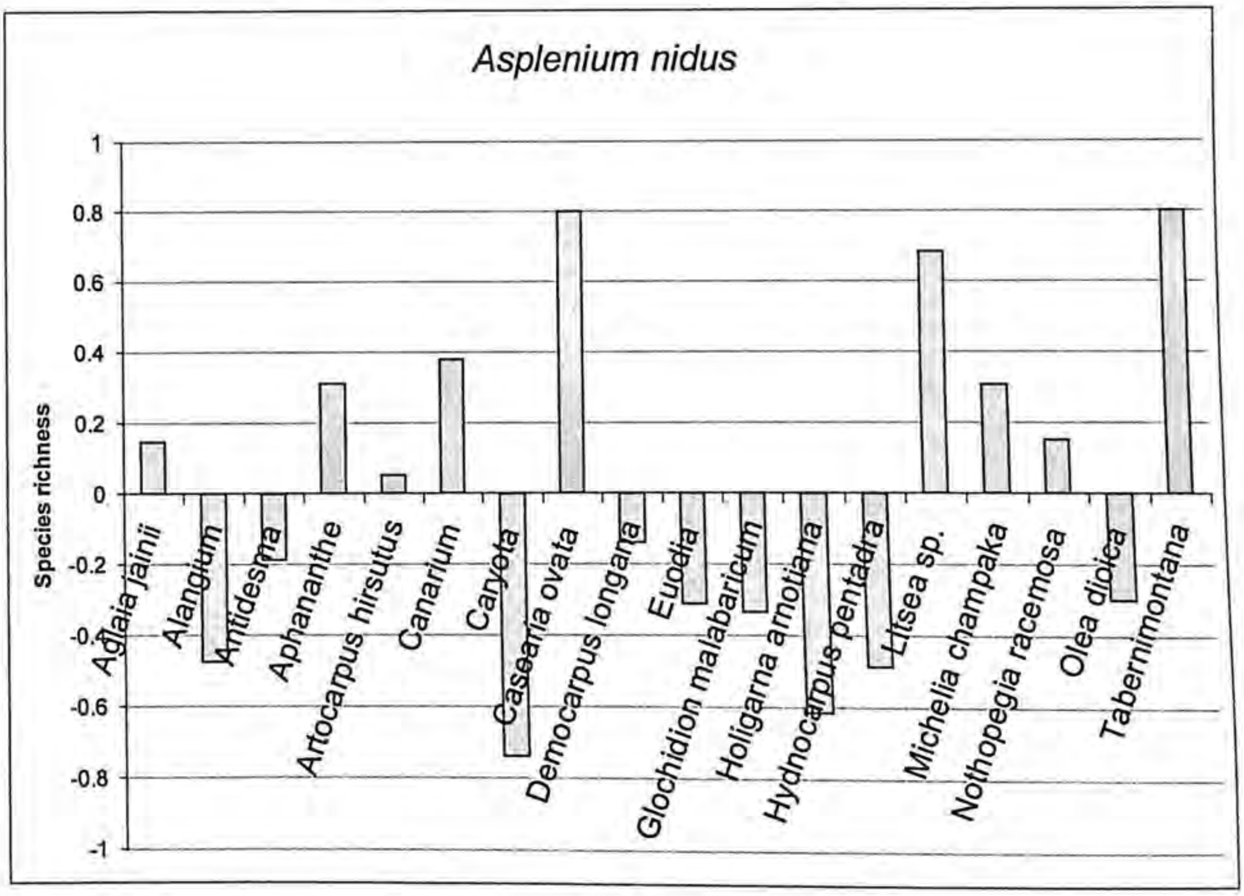


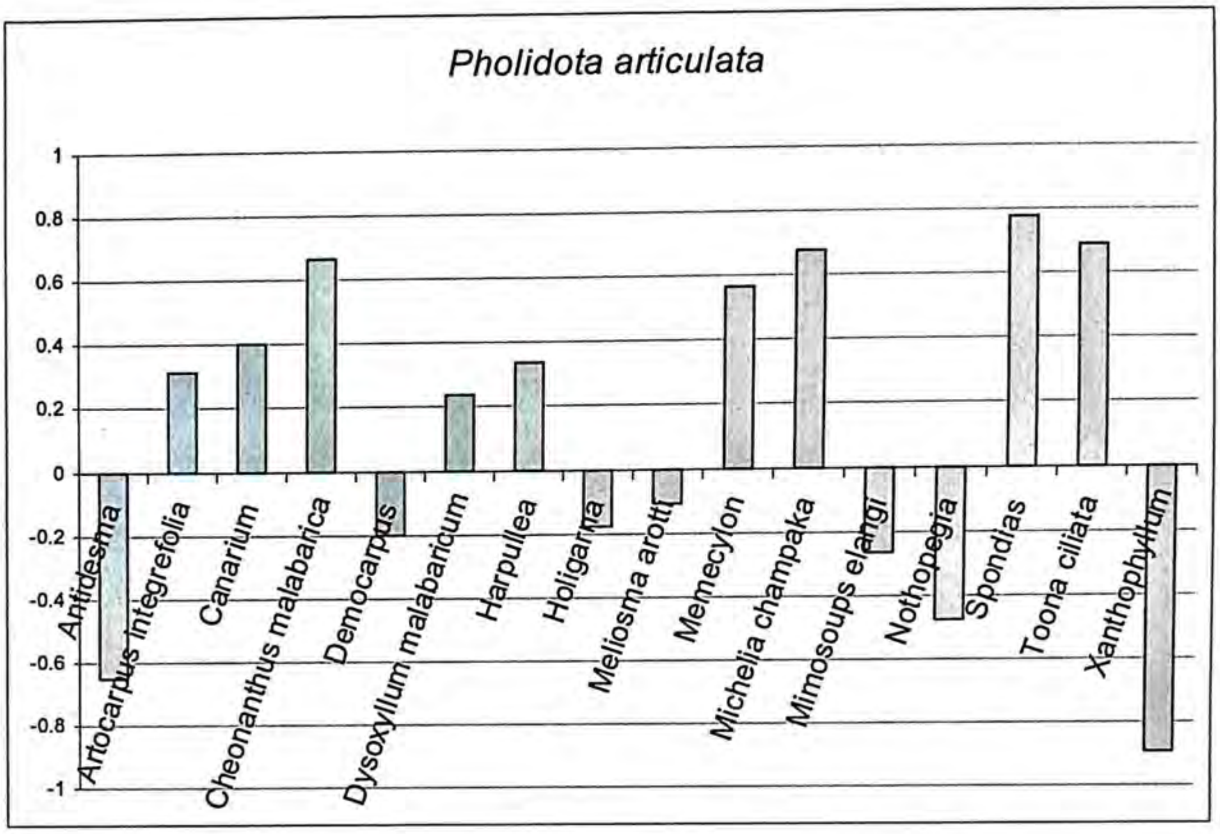
Ivlev's index is a measure of availability and use. The values range between -1 to +1. Positive values for a host species indicate that a epiphytes is using a tree proportionally more than what is available. *Canarium strictum, Michelia champaka, Mimusops elengii* and *Mallotus phillipensis* were comparatively used more than their availability (Fig 5.2.4a, Table 5.2.4a).

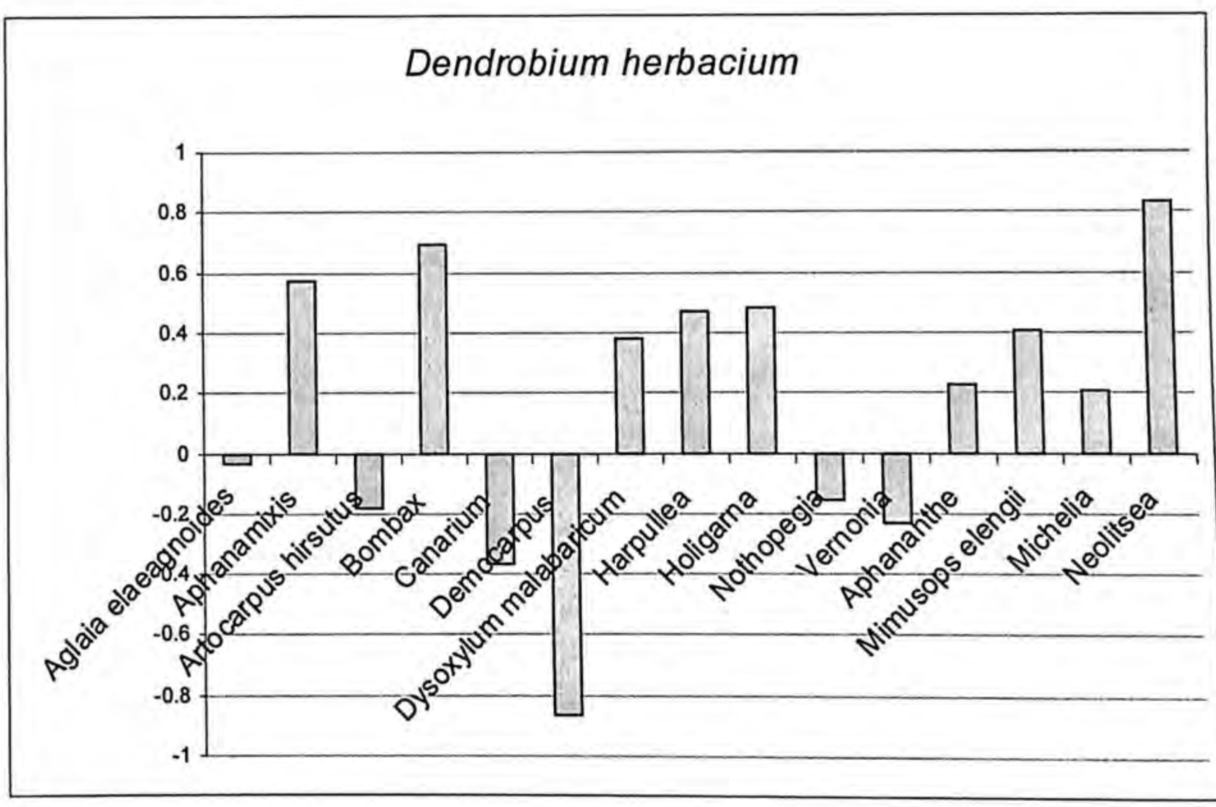
### 5.2.5. Species Specific Preference

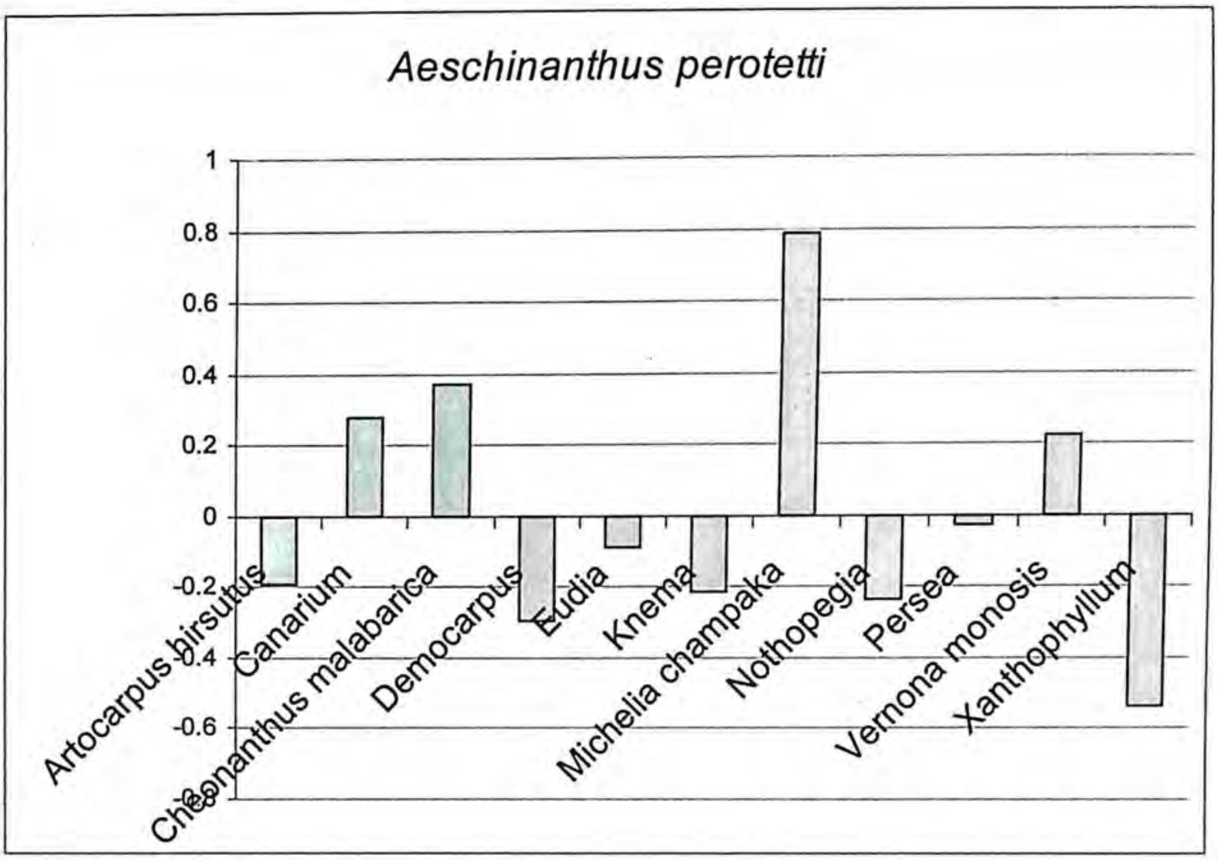
Ivlev's Index was calculated for the entire host species recorded for each of the 8 most common epiphyte species. Thus out of all the recorded host species for a particular epiphytic species, the ones which are used more than what is available and also the ones used less than what is available were found out (Fig 5.2.5).

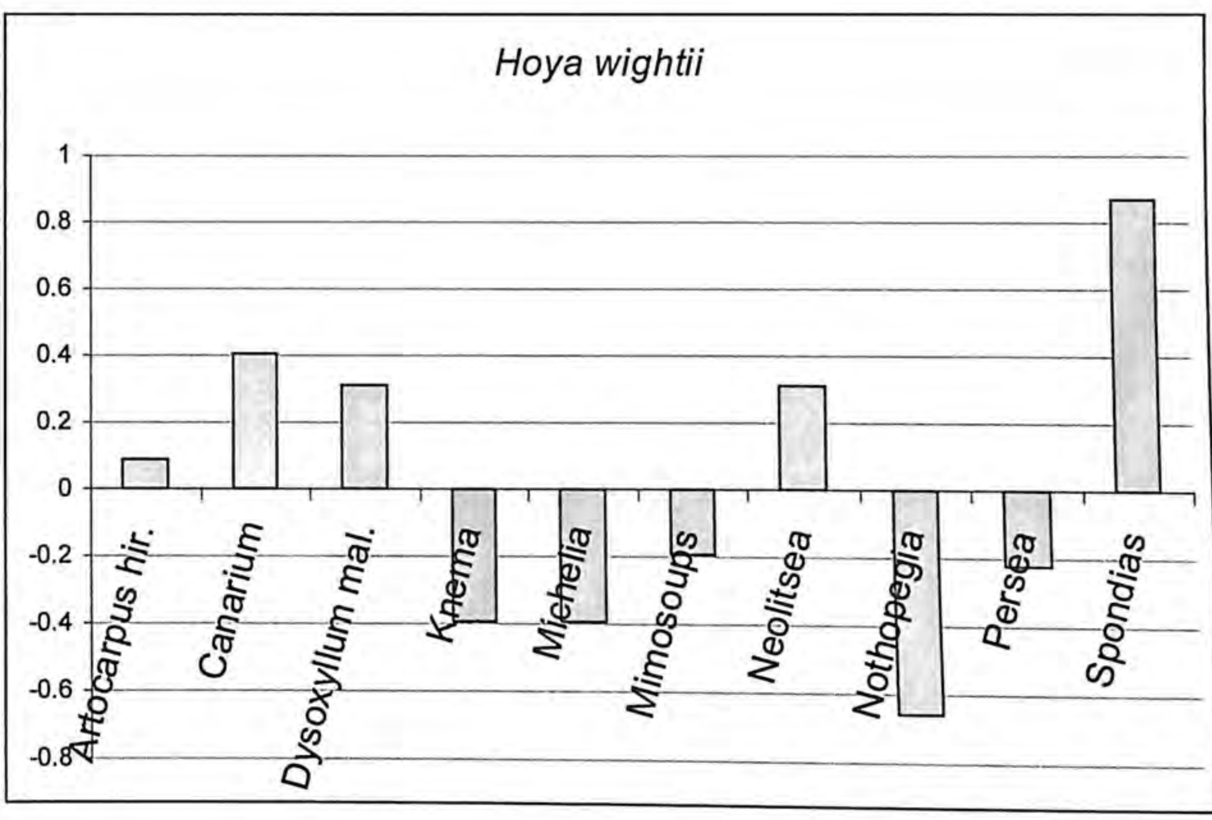
**Fig. 5.2.5 a.** Differential host use for 8 epiphytic species (in the order of their abundance).

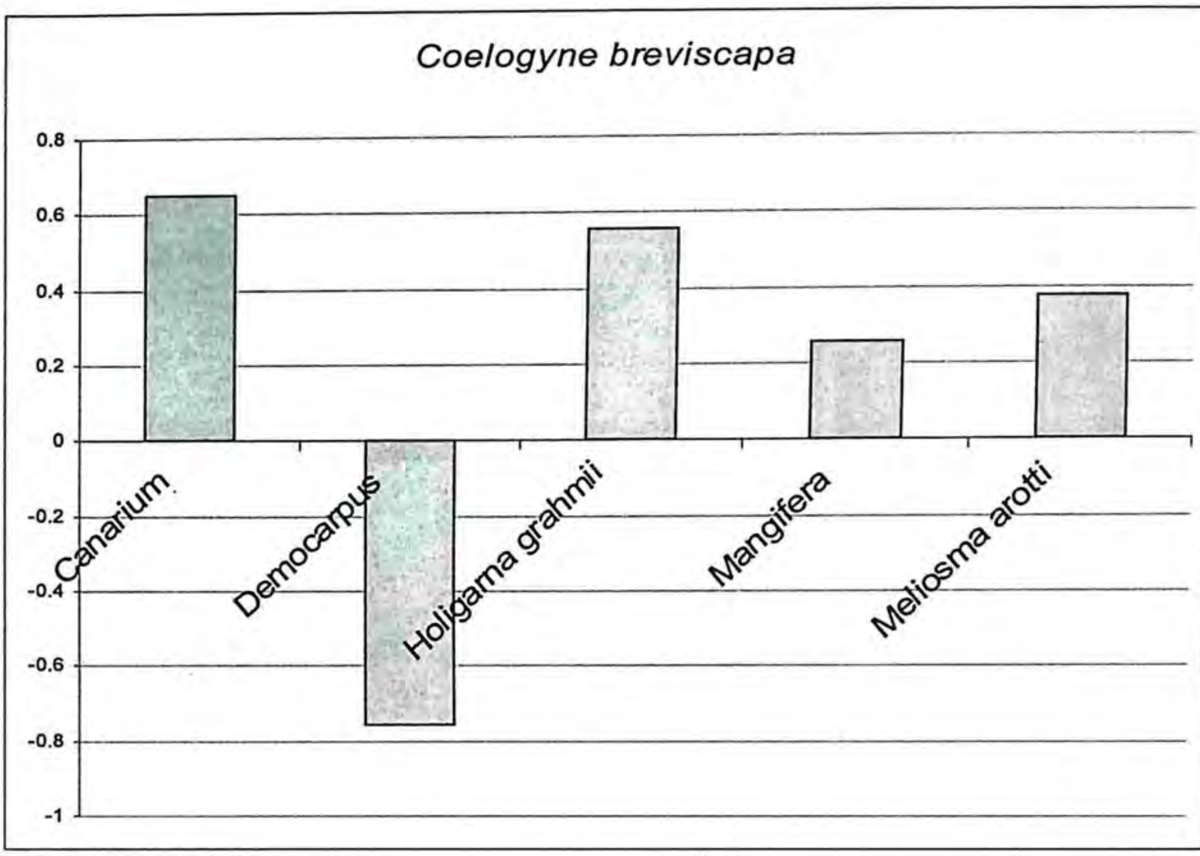



Pholidota articulata
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Antidesma
Artocarpus integrefolia
Canarium
Cheonanthus malabarica
Democarpus
Dysoxyllum malabaricum
Harpullea
Holigarna
Meliosma arotti
Memecylon
Michelia champaka
Mimosoups elangi
Nothopegia
Spondias
Toona ciliata
Xanthophyllum

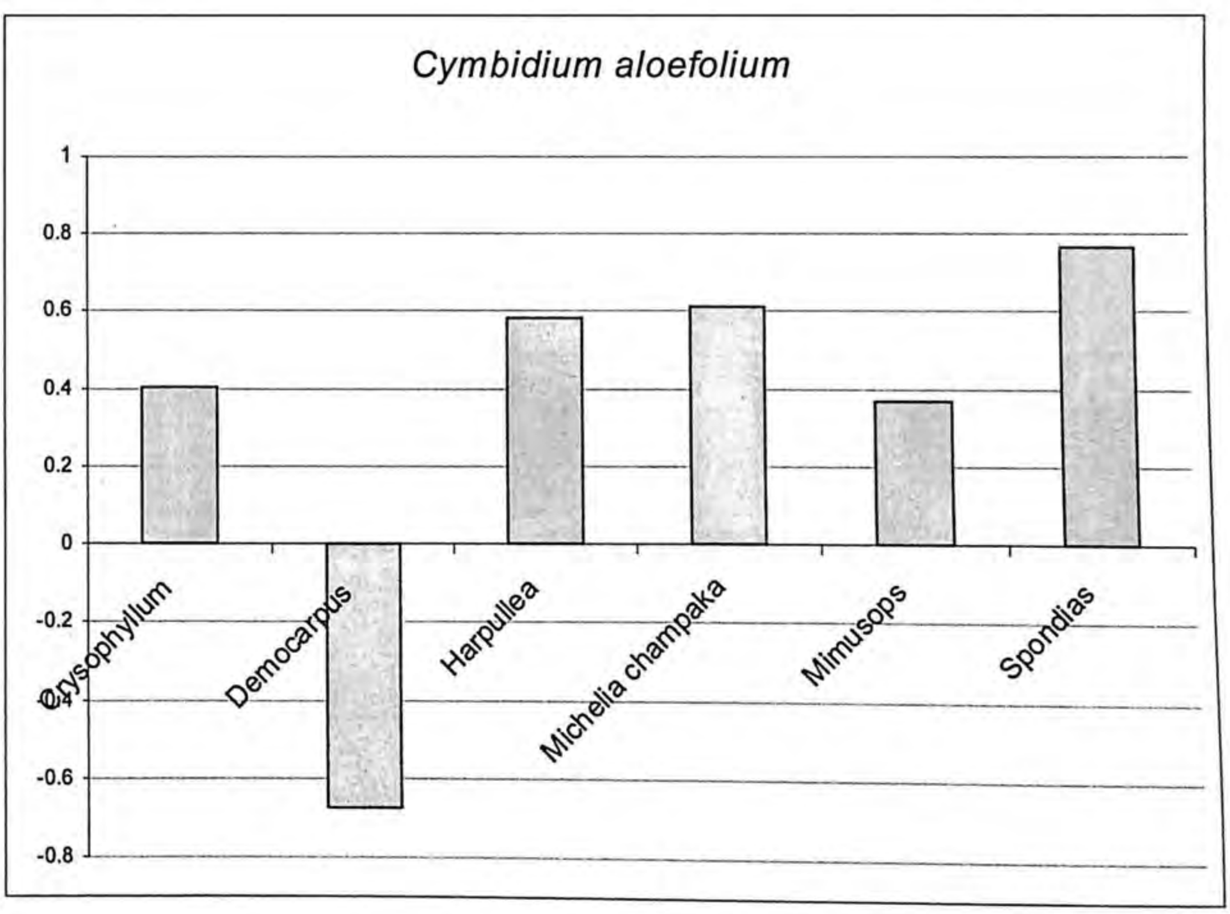

Dendrobium herbacium
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Aglaia elaeagnoides
Aphanamixis
Artocarpus hirsutus
Bombax
Canarium
Democarpus
Dysoxylum malabaricum
Harpullea
Holigarna
Nothopegia
Vernonia
Aphananthe
Mimusops elengii
Michelia
Neolitsea


Aeschinanthus perotetti
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Artocarpus hirsutus
Canarium
Cheonanthus malabarica
Democarpus
Eudia
Knema
Michelia champaka
Nothopegia
Persea
Vernona monosis
Xanthophyllum

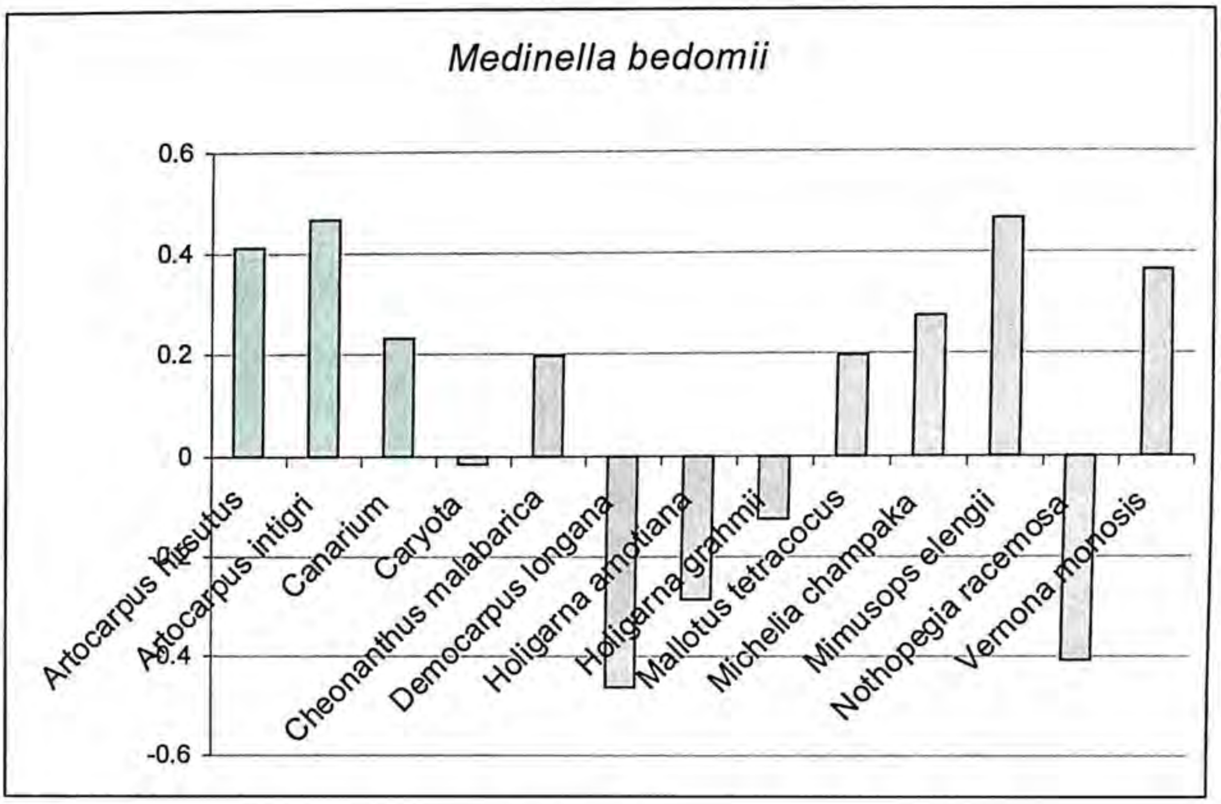

Hoya wightii
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Artocarpus hir.
Canarium
Dysoxyllum mal.
Knema
Michelia
Mimosoups
Neolitsea
Nothopegia
Persea
Spondias

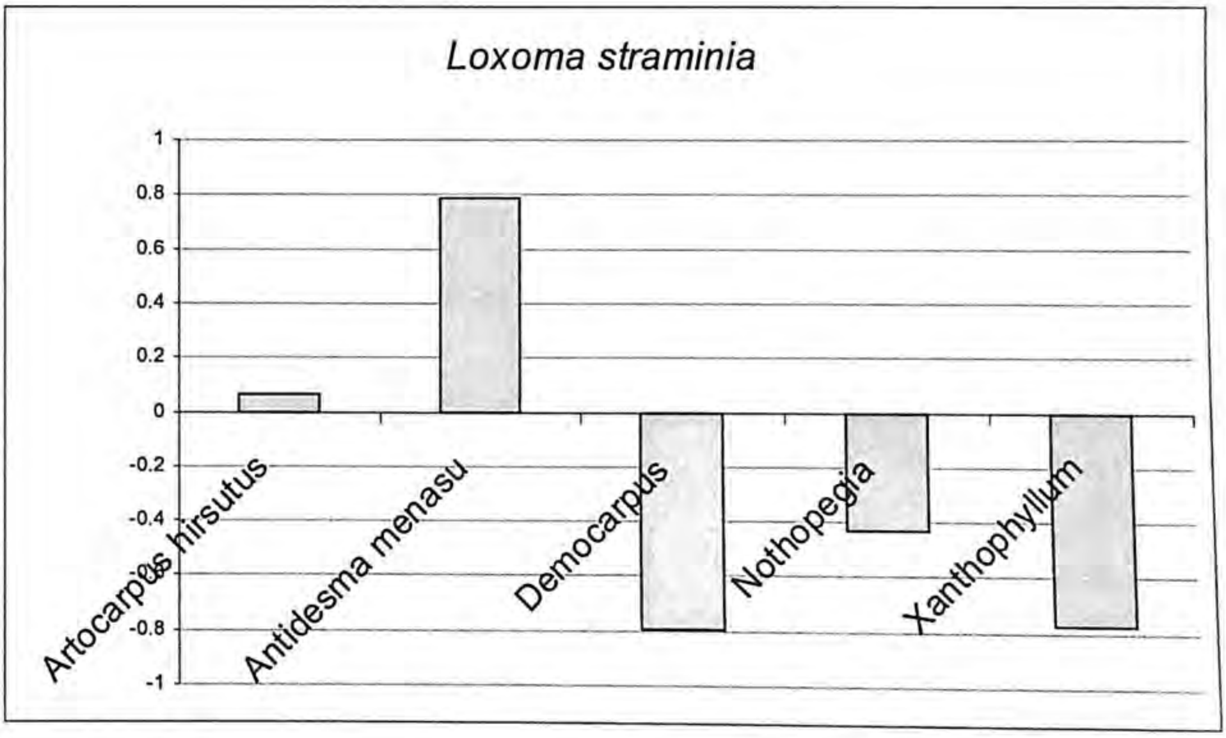


Coelogyne breviscapa
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Canarium
Democarpus
Holigarna grahmii
Mangifera
Meliosma arotti

Cymbidium aloefolium
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Crysophyllum
Democarpus
Harpullea
Michelia champaka
Mimusops
Spondias




Epiphytic species like *Schefflera wallichiana, Asplenium nidus, Pholidota pallida* were distributed on a wide range of host species. *Loxoma straminea* (= *Smithsonia straminea*) exhibited the most narrow range of host species, out of which it was almost exclusively found on *Antidesma menasu* (Fig 5.2.5 a).

## 6. Discussion

The results of this study suggest that different plant groups exhibit very divergent responses to the degree of fragmentation. This could be because of their differences in their life history traits and life history strategies.

### Plant Species Richness and Diversity

The results of the study for patterns in plant species richness for different life forms across fragments along a size gradient were not consistent. Reserve forests were more diverse than the eleven forest fragments for trees but were quite depauperate in terms of epiphytic flora. Shanon's index for habitat heterogeneity indicates that larger patches are more heterogeneous and more even than smaller ones. Lianas and shrubs showed similar trends for heterogeneity, but epiphytes showed a reverse pattern. For shrubs both reserve forest and smallest fragments had higher species richness than other size classes. These results point to inconsistent patterns in species richness and evenness, across life form groups and tend not to support area based generalisation based on thissample.

Very few studies have looked at differences among plant groups across different sites. Studies in other parts of the Western Ghats indicate increase in stem densities of trees and lianas with increase in size and decrease in degree of disturbance (Muthukumar et al, 2006). The results of the present study indicate a similar pattern in density for trees and lianas. Tree densities increased as function of patch size and were much higher in the Reserve Forest (Table 5.1.1 a). This could be because of higher site productivity in the larger sites allowing better regeneration and survival. However lianas exhibited a slightly different trend. Liana stem density was maximum in the medium sized forest fragments than the smallest and the reserve forest (Table 5.1.1 b). Shrubs exhibited a slightly contrasting trend to lianas Table (5.1.1 c). Lianas showed highest stem density in size class2 and 3 while the densities were lower in smallest fragments and also in the reserve forest. Also the larger sites are comparatively better protected than the smaller ones.

**Species –Area Relationship**

In a fragmented landscape, species area relationship differs with respect to the nature of formation, isolation and history, matrix and size. Values for islands are known to ranges between 0.25 to 0.35. Terrestrial habitat islands have lower slopes than for oceanic islands. (Rosenzweig, 1995).In a recent review by Watling and Donelly (2006) compared 'z' values between true islands and terrestrial patches. They observed significantly higher slopes for true islands than for habitat islands and infact was insignificant.

The observed slope values for trees were consistent with range of slope for habitat and oceanic islands. Trees exhibited a slope of 0.29 which is closer to the lower bound for the documented range of slope values. The slope values for lianas and shrubs however much lower for than the expected range of values for habitat islands.

Area could explain the variation in only tree and epiphyte species. This could be because among the studied life forms trees probably experience the greatest space constraint due to their large size. With increase in area more number of individuals is added and thus subsequently more number of species. Since epiphytes are distributed along the host tree space, increase in tree density offers more space for colonisation of epiphytes, provided their other habitat requirements are satisfied. Density and area could account for the more variation than area alone because higher density means more individuals per unit area. Thus site level productivity which is reflected in density could influence species richness and in conjunction with area explains the pattern better than area alone.

Area when controlled for tree density did not give significant correlation with species richness (Pearson's r = 0.472, p value = 0.142) An earlier study carried out in Kodagu by Bhagwat et al (2005) also did not find a significant correlation between patch area and rarefied species richness. Area and density were highly positively correlatedin the tree dataset, but in other groups density was contributing to the species richness independently of area. This shows that site based differences in productivity or growth conditions for different groups are important consideration in explaining richness pattern apart from area.

**Effect of Isolation and Spatial Distance**

Isolation plays an important role in driving colonisation processes and is one of the important predictors of species diversity in fragmented biotas.

Results (Table 5.1.5 a) show that tree species composition and abundance differs within pair of fragments with increase in geographical distance. This also shows that as the distance between the coherent Reserve forest and the patch increases the dissimilarity in plant species composition and abundance increases. The linear distance between patch and Reserve forest though not a good measure of isolation is indicative of general trends in differences in plant species composition, provided the surrounding matrix is similar across and between the different fragments.

**Species Richness**

The Reserve forest consistently shows highest species richness among all size classes for trees, shrubs and lianas but showed a reverse trend for epiphytes. Both Reserve forest and smallest size class have equally high species richness.

This finding is interesting because smallest size class and the Reserve forest are structurally very different with respect to stem density, canopy opening and also with respect to disturbance level. The reserve forest has relatively continuous canopy and much higher stem density. MRPP, Hotelling's T2 test and Indicator Species Analysis reveal that these two size class differ significantly with respect to their species composition and abundance. This explains the similar pattern in species richness exhibited by the two size classes. The high slope values of individual rarefaction curve for the reserve forest are indicative of the fact that, even after controlling for density the rate of accumulation of new species is much higher. In general the rarefaction curves show higher slopes for larger size classes. This means that area has some effect on species accumulation rates.

**Dominance and Diversity**

The rank abundance curves for the smaller sites are uniformly steep slopes over its abundance classes. This is because these patches have high dominance of few species and are also species poor. Such patches can only sustain a few generalist species which form dominant abundance classes in that patch. The area of such fragments cannot support any rare species, first by the virtue of its small size it is unlikely that a rare species will be present and second even if it is present there the chances of its survival are very low because of small area and small population size. The species abundance for size class 3, 4 and 5 all have a high dominance which drops after a few species, and then shallow trend is seen over moderate abundance classes and again becoming steep over rare abundances, thus showing a large group of species with moderate abundance. Reserve forest has much more rare species than the forest fragments. The shallow nature of the curves indicates that species are distributed most equitably in the Reserve forest.

Epiphytes show an exactly reverse trend. The rank abundance curve for epiphytes is extremely steep in the Reserve forest (size class5) showing dominance of very few species. This is because the habitat within the reserve forest is very homogenous. Different epiphytic species have differential requirements for different environmental variables out of which light seems to be a very important one. Due to these factors very few species can successfully colonise the undisturbed reserve forest area because of the uniformity in forest structure and intact canopy. So the reserve forest harbours only a few, shade loving species like *Asplenium nidus* which are present in much higher abundance as compared to the forest fragments. Fig 5.2.2 e illustrates the decrease in epiphytic species in the Reserve forest from edge to interior indicating the poor light penetration through the dense canopy.

**Species Composition**

Cluster analysis grouped the fragments with respect to their size and proximity to each other. This means that sites that were of similar size had similar species composition. Also the groups which were geographically near clustered together. These size groups were found to be significantly different from each other as proved through MRPP and Hotelling's T2 test done on NMS axis. Indicator Species Analysis again showed that different plant communities contributed to the indicator species of each class.

**Trees**

*Hydnocarpus pentadra* and *Caryota urens* were indicative of size class1 (Table 5.1.8 a). Both these species require sufficient amount of light. These species indicate that in the smallest size class, the uppermost canopy is not continuous or replaced by the species from the second strata.

*Clerodendrum viscosum* was the only indicator species for the class2. This species does not belong to the primary evergreen forest, but is more of an edge species and also an indicator of disturbance. This was the only species which characterised size class 2 because of presence of many canopy openings in Kadanoor and Bettoli sacred forest.

*Cinnamomum malabaricum*, *Xanthophyllum flavescens*, *Dysoxylum malabaricum*, and *Syzigium densiflorum* were peculiar of size class3. This size class shows a combination of species from the smaller size classes like *Cinnamomum* and *Xanthophyllum* which are very widely distributed common species, while the others like *Dysoxylum malabaricum* and *Syzigium densiflorum* represent the climax emergent community.

*Laportea crenulata, Holigarna grahmii and Palaquium ellipticum* are some of the indicator species from size class4. These species are typical of the sacred forests which are located very close to the reserve forest or continuous with the reserve forest.

Most of the species in size class5 (Reserve Forest) like *Persea micrantha, Otonephelium stipulacium, Garcinia morella, Myristica dactyloides* are exclusive species which are generally not represented in the fragments. These species represent the primary mid-elevation evergreen forest.

**Lianas**

Lianas are the least abundant among the four plant communities, but they are also comparatively most wide spread. This is why the lianas do not show many indicator species for different size classes.

**Shrubs**

Shrubs species contribute relatively large number as indicator species. This is because among all other plant communities, shrubs show maximum heterogeneity or in other words they are most patchily distribute and differ strongly in composition.. That is why they prove to be better indicators for a site or a size class than any other plant groups.

**Epiphytes**

Epiphytes as indicator species could significantly represent only three size classes. Maximum indicator species belonged to size class1 and 2. This shows that most epiphytes are more abundant and occur with relatively more frequency in smallest size classes. *Loxoma straminea* which is indicator of size class 2 was exclusively found in the size class ranging from 9 ha to 13 ha. This species occurred only in the interior zones of this size class.

**Nestedness**

All the plant groups included in the study showed significant nestedness, though it varied among groups. Several mechanisms have been proposed to explain this highly ordered pattern of distribution. Some authors have simply treated it as a sampling artefact while some have attributed it to nestedness structures in habitat (Cutler 1994, Lomolino 1996). But differential species extinction and differential species colonisation are widely considered as main causes of nestedness (Atmar and Patterson, 1993)

In the landscape of Kodagu, it is difficult to speculate on the possible causal mechanism for the observed moderate degree of nestedness. So both could be possibly influencing the nested structure of plant groups. The fragments of Kodagu may not be true isolates or habitat islands, in the sense that the immediately surrounding matrix which is in the form of coffee plantation maintains native tree cover. Earlier results suggest that the tree covered nature of the coffee plantation may have made an important contribution to maintain biodiversity within sacred groves. Thus the tree covered nature of matrix may have reduced the intensity of species loss because of biogeographic processes related to forest fragmentation (Bhagwat et al, 2005). However it is worth mentioning that even matrix retaining some native trees showed the strongest and species area relationship.

This provides a very interesting scenario to compare the effect of fragmentation and concomitant biogeographic processes on different groups of plants. Though the native shade in the coffee plantation maintains connectivity between forest fragments and the reserve forest, they cannot serve as potential source of pollens or propegules for the shrubs and lianas. That is why these different plant communities should show differential response to the degree fragmentation. Trees can be expected to be distributed more randomly than shrubs and lianas if the coffee plantations have actually alleviated the effect of fragmentation.

The results were contrary to what was expected. Trees, lianas and epiphytes all of them exhibited moderate degree of nestedness (Table 5.1.6 b). Though shrubs also were found to be significantly nested, the degree of nestedness was much lower than epiphytes, shrubs and lianas. Thus shrubs were distributed relatively more randomly compared to other plant communities. This means that all the plant communities could have undergone a certain degree of species relaxation and that the species with low population levels could occur only in species rich sites (reserve forest for trees). Persons Rank correlation test results indicate that only trees were nested along an area gradient (Pearson's $r = 0.869$, $p = 0.001$). Because of complexity in the surrounding matrix the role of isolation in influencing the nested patterns is difficult to evaluate. Epiphytes were found to be most nested among the four plant communities but were negatively correlated with area (Table 5.1.6 i). Habitat nestedness could be one of the possible mechanisms behind nestedness of epiphytes since they are dependant on host tree species. Since anthropogenic deforestation is not a random process, passive sampling could have little importance as causal factor (Martinez- Morales, 2005).It is difficult to asses the causality of nestedness for the shrubs and lianas.

**Vertical Distribution of Epiphytes**

The study results indicate that distribution of epiphytes along the tree stature in different zones is not strictly regulated by the mode of dispersal. The findings are not completely consistent with the earlier studies. Epiphytes distributed in the upper strata have small wind dispersed diasporas, while the one with succulent diasporas increase downwards (Kelly, 1985). The study results show that the species which have wind dispersed diasporas like *Asplenium nidus, Phymatosorus nigriscens* were found to be presently significantly more in the lower strata. This is because these species are relatively large life forms which need a certain minimum size class to thrive and to reach maturity. Also Asplenium a shade loves plant. A combination of both these factors play a role in affecting the distribution in the lower strata. On the other hand the members of family Orchidaceae like *Dendrobium herbacium, Bulbophyllum tremulum, Loxoma straminea* which have equally small diasporas show significant association with the upper and outer strata. Species like *Bulbophyllum tremulum* are very small life forms and that's why even the smaller branches can sustain these species. The hemi parasitic species of family Loranthaceae which have succulent pulpy bird dispersed fruits were exclusively restricted only to the outermost strata. .The dispersal agents of these species are very small sized birds whose movement is restricted only in the outermost zone or strata of the tree, which is why most of the members of this family get dispersed only from uppermost canopy of one tree to other (table 5.2.3 a).

Thus these findings indicate that the size of the diaspore cannot alone be responsible in determining the distribution of epiphyte along the tree height. Other parameters like the size of the life form and agent of dispersal also should be considered to assess the distribution of an epiphyte along the tree.

**Host –Epiphyte Relationship**

There has been no evidence in favour of host specificity in epiphytes (Zimmerman and Olmstead, 1992). The present study does not show any strong evidence in support of host specificity. But the study findings reveal that some tree species are more favourable to epiphytes than other (Table 5.2.4 a and Table 5.2.5 a). *Michelia champaka*was used by most of the epiphytes in grater proportion than others, though the exact correlates for presence of an epiphyte on the host tree are difficult to speculate. *Loxoma straminea* (= *Smithsonia straminea*) comes closest in exhibiting host specificity.

A very contrasting response to the degree of fragmentation was observed. These differences could well be due to the differences in life history strategies and life history traits. The differences could also be due to the complex matrix which may be hostile for some plant groups and thus having a differential influence in shaping the species composition in the fragments.

**References:**

Annaselvam, J. and N. Pathasarathy, 2001. Diversity and Distribution of herbaceous vascular epiphytes in tropical evergreen forest of Varagalaiar, Western Ghats, India. Biodiversity and conservation 10, 317-329.

Aravena, J. C., Carmona, M. R., Perez, F. and J. J. Armesto. 2002. Changes in tree species richness, stand structure and soil properties in a successional cronosequence in the northern Chiloe Island, Chile. Revista Chilena de Historia Natura;, 75, 339-360.

Atmar, W. and B. D. Patterson, 1993. The measure of order and disorder in the distribution of species in fragmented habitat. Oecologia, 96:373-382.

Azeria, E. T. 2004. Terrestrial bird community patterns on the coralline islands of the Dahlak Archipelago, Red Sea, Eritrea. Global Ecology and Biogeography, 13, 177-187.

Benzing, D. H.1978. Germination and early establishment of Tillandsia circinnata Schlecht. (Bromeliaceae) on some of its hosts and other supports in southern Florida. Selbyana 5: 95-106.

Bessey, E. A. 1908. The Florida strangling figs. The nineteenth annual report of the Missouri Botanical Garden, 25-33.

Bhagwat, S. 2002.Biodiversity and conservation of a cultural landscape in the western ghats of India. Phd Thesis. Linacre College & Oxford Forestry Institute, Department of Plant Sciences, University of Oxford, UK.

Bhagwat, S. A., Kushalappa, C. G., Williams, P. H. and Brown, N. D. 2005. A landscape, approach to biodiversity conservation of sacred groves in the western ghats of India. Conservation Biology, 19 ( 6): 1853- 1862.

Brooks, T. M., 2002. Habitat loss and extinction in the hotspots of biodiversity. Conservation Biology 16: 909–923.

Brown, J. H. and Kodric-Brown, A. 1977 Turnover rates in insular biogeography: effect of immigration on extinction. Ecology, 58: 445–449.

Burns, K. C. and J. Dawson, 2005. Pattrens in diversity and distribution of epiphytes and vines in the New Zealand forest. Australian Journal of Ecology 30: 883-891.

Cardelus, C. L., Colwell, R. K., and J. E. Watkins Jr. 2006. Vascular epiphyte distribution patterns: explaining the mid-elevation richness peak. Journal of Ecology 94: 144-156.

Catling, P. M. and Lefkovitch, L. P. 1989. Associations of vascular epiphytes in a Guatemalan Cloud forest. Biotropica, 21: 35–40.

Catling, P. M., Brownell, V. R. and Lefkovitch, L. P. 1986 Epiphytic orchids in a Belizean grapefruit orchard: distribution, colonization, and association. Lindleyana, 1: 194–202.

Chase, M. W. 1987. Obligate twig epiphytism in the Oncidiinae and other Neotropical orchids. Selbyana 10(1):24-30.

Connor, E. F., and E. D. McCoy. 1979. The statistics and biology of the species-area relationship. The American Naturalist 113:791–833.

Cordoba, J. and R. F. Del Castillo. 2001. Changes in epiphyte cover in three chronosequences in a tropical montane cloud forest in Mexico. Life forms and dynamics in tropical forest (ed. by G. Gottsberger and S. Liede), pp. 79–94. J. Cramer in der Gernbru¨der Borntraeger Verlagsbuchhandlung, Berlin."

Cutler, A.H., 1994. Nested biotas and biological conservation: matrix, mechanisms and meaning of nestedness – Landscape. Urban Plan. 28:73-82.

Elouard, C. 2000a. The role of coffee plantations in biodiverisity conservation (Coffee and Biodiversity Conservation - Chapter 6). In: Mountain Biodiversity, Land Use Dynamics, and Traditional Knowledge (eds. Ramakrishnan PS, Chandrashekara UM, Elouard C, Guilmoto CZ, Maikhuri RK, Rao KS, Sankar S & Saxena KG), pp. 120-144. Man and the Biosphere Programme, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi."

Fischer, J. and D. B. Lindenmayer. 2002. Treating the nestedness temperature calculator as a 'black box' can lead to false conclusions. Oikos, 99: 193–199.

Flores-Palacio, A. and J. G. Garcio-Franco. 2006. The relationship between tree size and species richness: testing four different hypotheses. Journal of Biogeography33, 323-330.

Frei, J. K. and C. H. Dodson. 1972. The chemical effect of certain bark substrates on the germination and early growth of epiphytic orchids. – Bull. Torrey Bot. Club 99: 301–307.

Freiberg, M. 1994. Phanomorphologie epiphytischer Gesnenaceen in Costa Rica unter besonderer Berucksichtigung Mikrokhmas - Ph.D -thesis, Ulm

FRLHT. 2000b. Medicinal plants under threat! URL Foundation for Revitalisation of Local Health Traditions http://www.frlht-india.org/Conservation.htm (Last accessed: March 2002).

Gilbert, F. S. 1980. The equilibrium theory of island biogeography: fact or fiction? Journal of Biogeography 7: 209–235.

Godoy R, Ramirez C, Figueroa H, and E. Hauenstein. 1981. Estudios ecosociologocos en Pteridofitos de comunidades boscosas valdivianas, Chile. Bosque 4, 12-24.

Gotelli, N.J. and R. K. Colwell, 2001. Quantifying biodiversity:procedures and pitfalls in the measurement and comparison of species richness.

Gotelli, N. J. and G. L. Entsminger. 2001. Ecosim: null models software for ecology, version 7.0. Acquired Intelligence Inc, & Kesey-Bear. http://www.homepages.together.net /?gentsmin/ ecosim.htm.

Guy, P. R. 1977. Notes on the host species of epiphytic figs (Ficus spp) on the flood plain of the Mana Pools Game Reserve, Rhodesia. Kirkia.10:559-562.

Halle F., R. A. A. Oldeman and P. B. Tomlinson. 1978. Tropical Trees and Forests: An Architectural Analysis. Springer-Verlag, New York.

Hintze, J. 2006. NCSS, PASS and GESS. NCSS, Kay's Ville, Utah. WWW.NCSS.COM

Ingram, S. W. and N. M. Nadkarni. 1993. Composition and Distribution of Epiphytic Organic Matter in a Neotropical Cloud Forest, Costa Rica. Biotropica 25(4): 70-383.

Ivlev, V.S. 1961. Experimental Ecology of the Feeding of Fishes, Yale Univ. Press, New Haven, CT, 1961

Johansson, D. 1974. Ecology of vascular epiphytes in West African rain forest. Acta Phytogeogr. Suec. 59: 1-136.

Jonsson, B.G. 2001. A null model for randomization tests of nestedness in species assemblages. Oecologia, 127, 309–313.

Kalam M.A. 1996. Sacred groves in Kodagu district of Karnataka (South India): A socio-historical study. Institute Francais de Pondichery, Pondichery, South India.

Kalam M. A. 2000. Devarakadus and encroachments. In: Mountain Biodiversity, Land Use Dynamics, and Traditional Knowledge (eds. Ramakrishnan PS, Chandrashekara UM, Elouard C, Guilmoto CZ, Maikhuri RK, Rao KS, Sankar S & Saxena KG), pp. 98-106. Man and the Biosphere Programme; Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi; Calcutta.

Kelly, D. L. 1985. Epiphytes and climbers of Jamaican rainforest: vertical distribution, life forms and life histories. 12, 223-241.

Kernan, C. and Fowler, N. 1995. Differential substrate use by epiphytes in Corcovado National Park, Costa Rica: A source of guild structure. Journal of Ecology, 83, 65-73.

Khumbongmayum A. D., Khan M. L., and Tripathi R. S. 2004. Sacred groves of Manipur – ideal centers for biodiversity conservation. Current Science, 87: 4, Kikuchi, T., Subedi, N.M. and Ohba, H. 1992. Communities of epiphytic vascular plants on a Himalayan mountainside in far eastern Nepal. Ecological Review, 22, 121–128.

Kress J. 1986. The systematic distribution of vascular epiphytes. Selbyana 9: 2–21.

Kushalappa C. G. and Kushalappa K. A. 1996. Preliminary Report: Impact Assessment of Working in the Western Ghats Forests. In. College of Forestry, University of Agricultural Sciences - Bangalore, Ponnampet.

Lomolino, M.V. 1984. Immigrant selection, predation, and the distributions of Microtus pennsylvanicus and Blarina brevicauda on islands. American Naturalist 123:468–483.

Lomolino, M.V. 1996. Investigating causality of nestedness of insular communities: selective immigrations or extinctions? Journal of Biogeography 23:699-703.

Lyons, B., Nadkarni, N. M. and M. P. North. 2000. Spatial distribution and succession of epiphytes on Tsuga heterophylla (western hemlock) in an old growth Douglas-fir forest. Canadian Journal of Botany 78: 957–968.

MacArthur, R. H. and Wilson, E. O. 1967. The Theory of Island Biogeography, Princeton University Press.

Madison, M. 1977. Vascular epiphytes: their systematic occurrence and salient features. Selbyana, 2, 1–13.

Magurran, A.E., 2004 Measuring Biological Diversity. Blackwell Publishing Science Martinez-Morales, M.A., 2005. Nested species assemblages as a tool to detect sensitivity to forest fragmentation: the case of cloud forest birds. Oikos 108: 634-642.

McAbendroth L., Foggo A., Rundle D., Bilton D.T. 2005- Unraveling nestedness and spatial pattern in pond assemblages. Journal of Animal Ecology. 74:41-49.

McAleece, N. 1997. BioDiversity Professional. The Natural History Museum.

McCoy, E. D. 1990. The distribution of insects along elevational gradient.Oikos, 58, 313-322.

Mueller-Dombois D. and Ellenberg H. 1974. Aims and Methods of Vegetation Ecology. Pages-39, 110. New York, U.S.A.

Muñoz, A. A., Chacón, P., Pérez, F., Barnert, E. S. and J. J. Armesto, 2003. Diversity and host tree preferences of vascular epiphytes and vines in a temperate rainforest in southern Chile. Australian Journal of Botany 51(4) 381 – 391.

Muthuramkumar, S., N. Ayyappan, N. Parthasarathy, Divya Mudappa, T. R. Shankar Raman, M. Arthur Selwyn, L. Arul Pragasan (2006) Plant Community Structure in Tropical Rain Forest Fragments of the Western Ghats, India[1] Biotropica 38 (2), 143–160.

Myers N., Mittermeier R. A., Mittermeier C. G., da Fonseca G. A. B. and Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature, 403, 853-858.

Neider, J., Engwald, S., Klawun, M. and W. Barthlott. 2000. Spatial distribution of vascular epiphytes (including hemiepiphytes) in the low land Amazonian rainforest (Surumoni Crane Plot) of Southern Venezuela. Biotropica 32(3): 385-396.

Padmawathe, R. 2001.Patterns in Species composition and distribution among vascular epiphytes in low-lying semi-evergreen forests of Arunachal Pradesh, India. M.Sc. Thesis W.I.I., Dehradun.

Pascal J. P. and V. M. Meher-Homji. 1986. Phytochorology of Kodagu (Coorg) district, Karnataka. Journal of Bombay Natural History Society, 83, 43-56.

Pascal J. P. 1988. Wet Evergreen Forests of the Western Ghats of India: Ecology, Structure, Floristic Composition and Succcession. Institute Francais de Pondichery, Pondicherry.

Patterson, B. D. and W. Atmar 1986. Nested subsets and the structure of insular mammalian faunas and archipelagoes. Biological Journal of the Linnean Society, 28, 65–82.

Patterson, B. D. 1987. The principle of nested subsets and its implications for biological conservation. Conservation Biology, 1, 323–334.

Patterson, B. D. and W. Atmar. 2000. Analyzing species composition in fragments. Pp. 9-24 in Isolated vertebrate communities in the tropics (G. Rheinwald, ed.). Bonner Zoologische Monographen 46, Bonn, Germany, 400 pp.

Piessens, K., Honnay, O., Nakaerts, K. and M. Hermy, 2004.Plant species richness and composition of heathland relics in north-western Belgium: evidence for a rescue-effect? Journal of Biogeography 31: 1683–1692.

Primm, S. L., Jones, H. L. and J. Diamond. 1988. On the risk of extinction. American Naturalist, 132: 757–785.

Preston, F. W. 1962. The canonical distribution of commonness and rarity. Ecology 43:185–215, 410–432.

Reed, D. H. 2004. Extinction risk in fragmented habitats. Animal Conservation 7:181–191.

Rickleft, R. E. and D. Schluter. 1993. Species diversity in ecological communities: historical and geographical perspectives- University Chicago Press, Chicago.

Rosenzweig, M.L. Species diversity in space and time. 1995. Cambridge University Press New York, USA.

Ruchty, A., Rosso, A. L. and B. McCune. 2001. Changes in epiphyte communities as the shrub, Acer circinatum, develops and ages. The Bryologist, 104, 274–281.

Rudolph, D., Rauer, G., Nieder, J. and W. Barthlott. 1998. Distributional patterns of epiphytes in the canopy and phorophyte characteristics in a western andean rain forest in Ecuador. - Selbyana 19(1): 27-33.

Sanford, W. W. 1968. Distribution of epiphytic orchids in semi-de- ciduous tropical forest in southern Nigeria. Journal of Ecology 56: 697–705.

Schimper, A. F. W. (1888) Die epiphytische Vegetation Amerikas. Gustav Fischer Verlag, Jena.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. BioScience, 31, 131–134.

SPSS Inc. (1999-2005) SPSS for Windows Release 14.0.0. In. SPSS Inc.

Stevens, G.C. 1992. the elevation gradient in altitudinal range: an extension of Rapaport's latitudinal rule to altitude. American Naturalist. 140: 893-911.

Stockwell, C. A., A. P. Hendry, and M. T. Kinnison. 2003. Contemporary evolution meets conservation biology. Trends in Ecology & Evolution 18: 94–101.

Ter Steege, H. and J. H. C. Cornelissen. 1989. Distribution and ecology of vascular epiphytes in lowland rain forest of Guyana. Biotropica 21: 331-339.

Terborgh, J. 1977. Bird species diversity on an Andean elevation gradient. Ecology, 58: 1007-1019.

Todzia, C. 1986. Growth habits, host tree species, and Density of hemiepiphytes on Barro Colorado Islands, Panama. Biotropica, 18(1): 22-27.

Ulrich W. 2006- Nestedness- a FORTRAN program for calculating ecological matrix temperature. www.uni.torun.pl/~ulrichw

Valdivia, P. E. 1977. Estudio bota´nico y ecolo´ gico de la regio´n del Rý´o Uxpanapa, Veracruz, No. 4. Las Epý´fitas. Biotica, 2: 55–81.

van Leerdam, A., R. J. Zagat y E. J. Veneklaas. 1990. The distribution of epiphyte growth-forms in the canopy of Colombian cloud-forest. Vegetatio 87: 59-71.

Vijaya T. P. 2000. Contemporary Society and Land Tenure (Landscape and Society - Chapter 3). In: Mountain Biodiversity, Land Use Dynamics, and Traditional Knowledge (eds. Ramakrishnan, P. S., Chandrashekara, U. M., Elouard C., Guilmoto, C. Z., Maikhuri R. K., Rao K S. Sankar and K. G. Saxena), pp. 44-53. Man and the Biosphere Programme, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Watling, J. I. and M. I. Donnelly. 2006.Fragments as Islands: a Synthesis of Faunal Responses to Habitat Patchiness. Conservation Biology 20: 4.

Went, F. W. 1940. Soziologie der Epiphyten eines tropischen Regenwaldes. Ann. Jard. Bot. Buit. 50, 1–98."

Wilcox, B. A. 1980. Insular ecology and conservation. Pages 95-118 in M.E. Soule and B.A.

Wright, D. H. and Reeves, J. H. 1992. On the meaning and measurement of nestedness of species assemblages. Oecologia, Vol 92, No.3, pp 416-428.

Yeaton, R. I. and Gladstone, D. E. 1982. The pattern of colonization of epiphytes on Calabash trees (Crescentia alata HBK) in Guanacaste Province, Costa Rica. Biotropica, 14, 137–140.

Zimmerman, J. K. and I. C. Olmstead. 1992. Host tree utilization by vascular epiphytes in seasonally inundated forest (Tintal) in Mexico. Biotropica, 24: 402-407.

Zotz, G. and B. Vollrath. 2003. The epiphyte vegetation of the palm Socratea exorrhiza-correlations with tree size, tree age and bryophyte cover. Journal of Tropical Ecology, 19: 81–90.

## Appendix 1: Checklist of Trees

**Trees**

1 *Acronychia laurifolia* Blume
2 *Actinodaphne angustifolia* Hk.f. & T.
3 *Agalaia elaeagnoides* (Juss) Benth.
4 *Aglaia indica* Harms
5 *Aglaia jainii* Viswan. & Ramach.
6 *Aglaia simplicifolia* Harms
7 *Alstonia scholaris* (L.) R. Br.
8 *Antedisma menasu* Miq. ex Tul.
9 *Antiaris toxicaria* Lesch.
10 *Aphanamixis polystachia* Bl.
11 *Aphananthe cuspidata* Planch.
12 *Apodytes beddomii* Mast.
13 *Aporosa lindleyana* Baill.
14 *Artocarpus hirsutus* Lam.
15 *Artocarpus integrifolius* L.f.
16 *Bischofia javanica* Blume
17 *Bombax cieba* L.
18 *Callicarpa tomentosa* Murr.
19 *Callophyllum polyanthum* Wall. ex Choisy
20 *Canarium strictum* Roxb.
21 *Caryota urens* Jacq.
22 *Casearia ovata* Wall.
23 *Celtis tetrandra* Wall.
24 *Cheionanthus malabarica* Heyne ex Wall.
25 *Chionanthus macrophylla* Blume
26 *Cinamomum malabathrum* Miq.
27 *Cinnamomum sulphuratum* Nees
28 *Clerodendrum*
29 *Crysophyllum*
30 *Democarpus longana*
31 *Dillenia bracteata* Wight
32 *Diospyros crumenata* Thwaites
33 *Diospyros hirsuta* L.f.
34 *Diospyros oocarpa* Thwaites
35 *Diospyros paniculata* Dalzell
36 *Diospyros pruriens* Dalzell
37 *Diospyros sylvatica* Roxb
38 *Drypetes oblongifolia* (Bedd.) Airy Shaw
39 *Dysoxylum malabaricum* Bedd. ex DC.
40 *Elaeocarpus oblongus* Gaertn. ex Sm.
41 *Elaeocarpus serratus* Benth.
42 *Elaeocarpus tuberculatus* Roxb.
43 *Euodia lunur-ankenda* Merr.
44 *Euonymus indicus* Heyne ex Wall.
45 *Excoecaria robusta*
46 *Fahrenheitia zeylanica* (Thwaites) Airy Shaw
47 *Ficus amplissima* Miq.
48 *Ficus callosa* Willd.
49 *Ficus hispida* Roxb. ex Wall.
50 *Ficus nervosa* Roth.
51 *Ficus sp.*

52 *Ficus strangler* Elmer
53 *Flacourtia montana* J.Graham
54 *Garcinia gummi-qutta* (L.) N.Robson
55 *Garcinia morella* Desr.
56 *Garcinia talbottii* Raiz.
57 *Gironierra*
58 *Glochidion bourdillonii* Gamble
59 *Glochidion malabaricum* Bedd.
60 *Gmelina arborea* Roxb.
61 *Harpullia arborea* (Blanco) Radlk.
62 *Holigarna arnottiana* Hk.f.
63 *Holigarna grahamii* Kurz.
64 *Homalium zeylanicum* Benth.
65 *Humboldtia brunonis* Wall.
66 *Hydnocarpus pentadra* ( Buch.-Ham.) Oken.
67 *Knema attenuata* Warb.
68 *Kokka Ficus sp.*
69 *Lagerstroemia microcarpa* Wight
70 *Laportea crenulata* Wight
71 *Leea indica* Merr.
72 *Ligustrum*
73 *Litsea floribunda* Gamble
74 *Litsea laevigata* Gamble
75 *Litsea sp.*
76 *Litsea stocksii* Hk.f.
77 *Macaranga peltata* Müll.-Arg.
78 *Madhuca neriifolia* H.J.Lam
79 *Mallotus philippinensis* Müll.-Arg..
80 *Mallotus tetracoccus* Kurz.
81 *Mangifera indica* Blume
82 *Meliosma arnottiana* Walp.
83 *Meliosma simplicifolia* Walp.
84 *Meliosma simplicifolia* Walp. *ssp. pungens*
85 *Memecylon malabaricum* Kostel.
86 *Memecylon wightii* Thwaites
87 *Mesua ferrea* L.
88 *Michelia champaka* L.
89 *Mimusops elengii* Wight
90 *Murraya exotica* L.
91 *Myristica dactyloides* Wall.
92 *Neolitsea zeylanica* Merr.
93 *Nothopegia racemosa* (Dalz.) Ramam.
94 *Olea dioica* Roxb.
95 *Otonephelium stipulaceum* Radk.
96 *Pajanelia longifolia* Schum.
97 *Palaquium ellipticum* Engl.
98 *Persea macrantha* (Nees ) Kosterm.
99 *Polyalthia cerasoides* (Roxb.) Hk.f. & T.
100 *Renwardtiodendron*
101 *Schefflera micrantha* Gamble
102 *Scleropyrum pentadrum* (Dennst.) Mabb
103 *Spondias mangifera* Willd.
104 *Sterculia alata* Wall.
105 *Sterculia guttata* Roxb.

106 *Stereospermum*
107 *Symplocos rosea*
108 *Syzygium densiflorum* Wall.
109 *Syzygium cumini* (L.) Skeels
110 *Syzygium laetum* (Ham.) Gandhi
111 *Syzigium sp.*
112 *Tabernaemontana coronaria* Willd.
113 *Terminalia belirica* Roxb.
114 *Toona ciliata* M. Roem.
115 *Trichelia*
116 *Turpinia malabarica* Gamble
117 *Vateria indica* L.
118 *Vepris bilocularis* Engl.
119 *Vernonia monosis* Benth. ex Cl.
120 *Villebrunea integrifolia* Gaudich
121 *Xanthophyllum flavescens* Roxb.

## Appendix2: Checklist of Lianas

**Lianas**

1 *Acacia concinna* Wall.
2 *Alangium lamarkii* Thw.
3 *Artabotrys*
4 *Asclepiadaceae*
5 *Capparis cleghornii* Dunn.
6 *Carissa inermis* Vahl.
7 *Combretum extensum* Roxb.
8 *Derris pinnata* L.
9 *Desmos lawii* Safford
10 *Embelia ribes* Burm.f.
11 *Gnetum ula* Brongn.
12 *Gouania leptostachya* DC.
13 *Grewia umbellata* Roxb. & DC.
14 *Hugonia batesi* Willd.
15 *Jasminum malabaricum* Wight
16 *Liana (prop roots)*
17 *Liana (prop roots)*
18 *Luvunga sarmentosa* Kurz
19 *Mesoneurum*
20 *Opp leaves*
21 *Plectronia rheedii* Bedd.
22 *Randia uliginosa* (Retz.) DC.
23 *Scutia indica* Brongn.
24 *Spatholobus*
25 *Strychnos wallichiana* Benth.
26 *Toddalia asiatica* Pers.
27 *Uvaria*
28 *Ventilago*
29 *Ziziphus oenoplia* (L.) Mill.

## Appendix3: Checklist of Shrubs

**Shrubs**

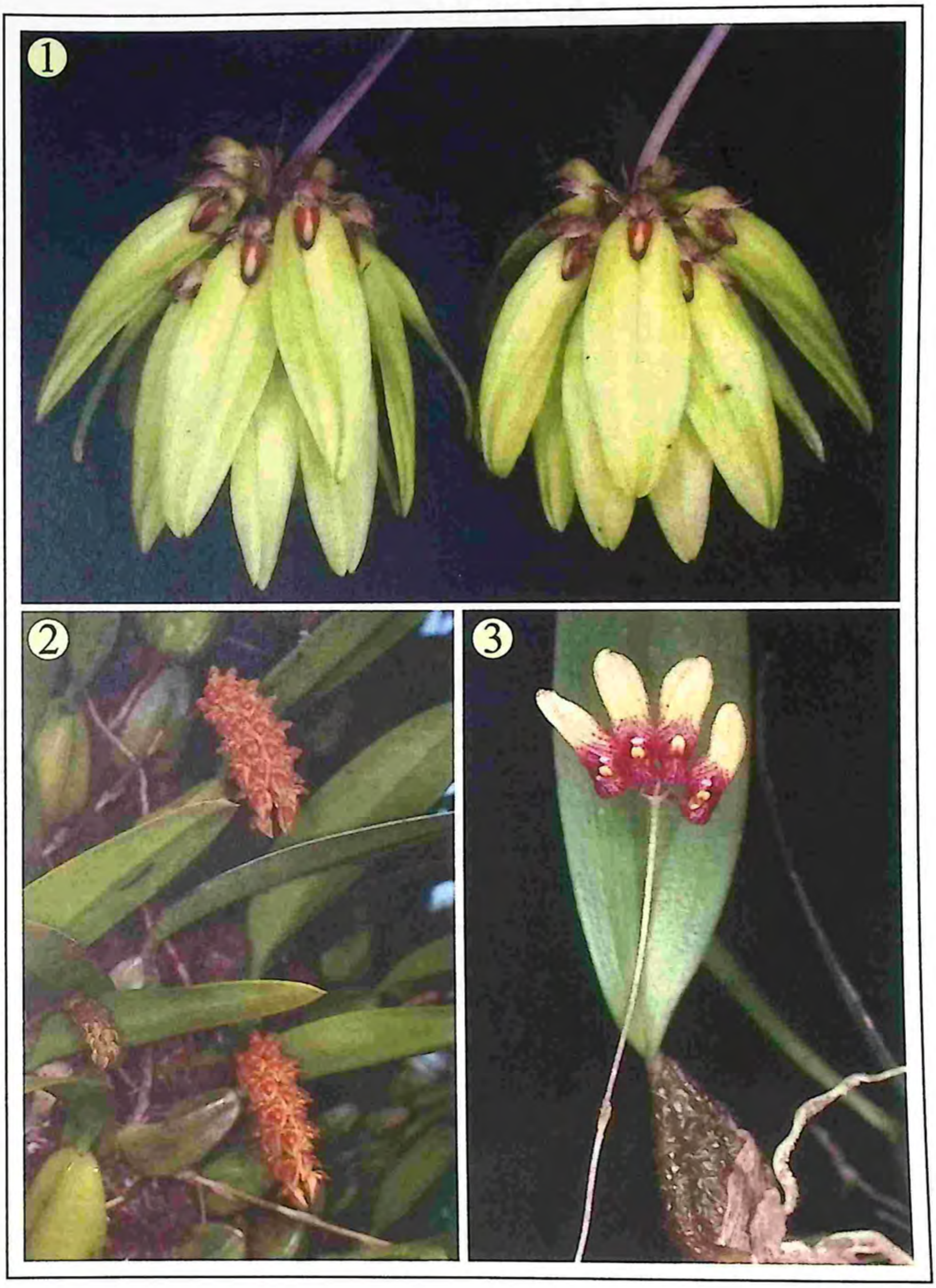
1 *Acrocarpus fraxinifolius* Wight & Arn
2 *Agrostistachys indica* Dalzell
3 *Alophyllus cobbe*
4 *Ardisia solanacea* Roxb
5 *Artocarpus gomezianus* Wall. ex Trécul
6 *Atalantia wightii* Tanaka
7 *Barleria courtallica* Nees
8 *Beilschmiedia membranifolia* Kosterm.
9 *Canthium umbellatum* Wight
10 *Chasalia*
11 *Cinnamomum sp. 2*
12 *Clausena dentata* M.Roem.
13 *Clerodendrum viscosum* Vent.
14 *Coffea*
15 *Croton*
16 *Diospyros candolleana* Thwaites
17 *Diospyros oocarpa* Thwaites
18 *Diospyros sylvatica* Wall.
19 *Elatostema*
20 *Eugenia mooniana* Wight
21 *Gluta travancorica* Bedd.
22 *Glycosmis pentaphylla* (Retz.) DC.
23 *Glyptopetalum grandiflorum* Bedd.
24 *Gomphandra tetrandra* (Wall.) Sleumer
25 *Goniothalamus cardiopetalus* Hk.f. & T.
26 *Ligustrum perrottetii* A.DC.
27 *Litsea laevigata* Gamble
28 *Litsea mysorensis* Gamble
29 *Litsea oleoides* Hk.f.
30 *Litsea stocksii* Hk.f.
31 *Meiogyne*
32 *Melia dubia* Cav.
33 *Memecylon wightii* Thwaites
34 *Microtropis wallichiana* Wight ex Thwaites
35 *Miliusa nilagirica* Bedd.
36 *Nothopegia travancorica* Bedd. ex Hk.f.
37 *Ophiopogon*
38 *Peliosanthes humilis* Baker
39 *Pandanus*
40 *Pavetta*
41 *Polyalthia cerasoides* (Roxb.) Bedd.
42 *Polygonum*
43 *Rutaceae*
44 *Saprosma indicum* Dalzell
45 *Shumanianthus*
46 *Solanum torvum* Buch.-Ham. ex Wall.
47 *Strobilanthus*
48 *Strobilanthus sp.2*
49 *Syzygium caryophyllatum* Alston
50 *Syzygium codyensis* (Munro) Chandr.
51 Syzygium lanceolatum *Wight & Arn.*

52 Syzygium montanum *Gamble*
53 *Trichilia connaroides* (Wight & Arn.) Bentvelzen
54 *Vernonia sp*
55 *Vitex altissima* L.f.

## Appendix 4: Checklist of Epiphytes

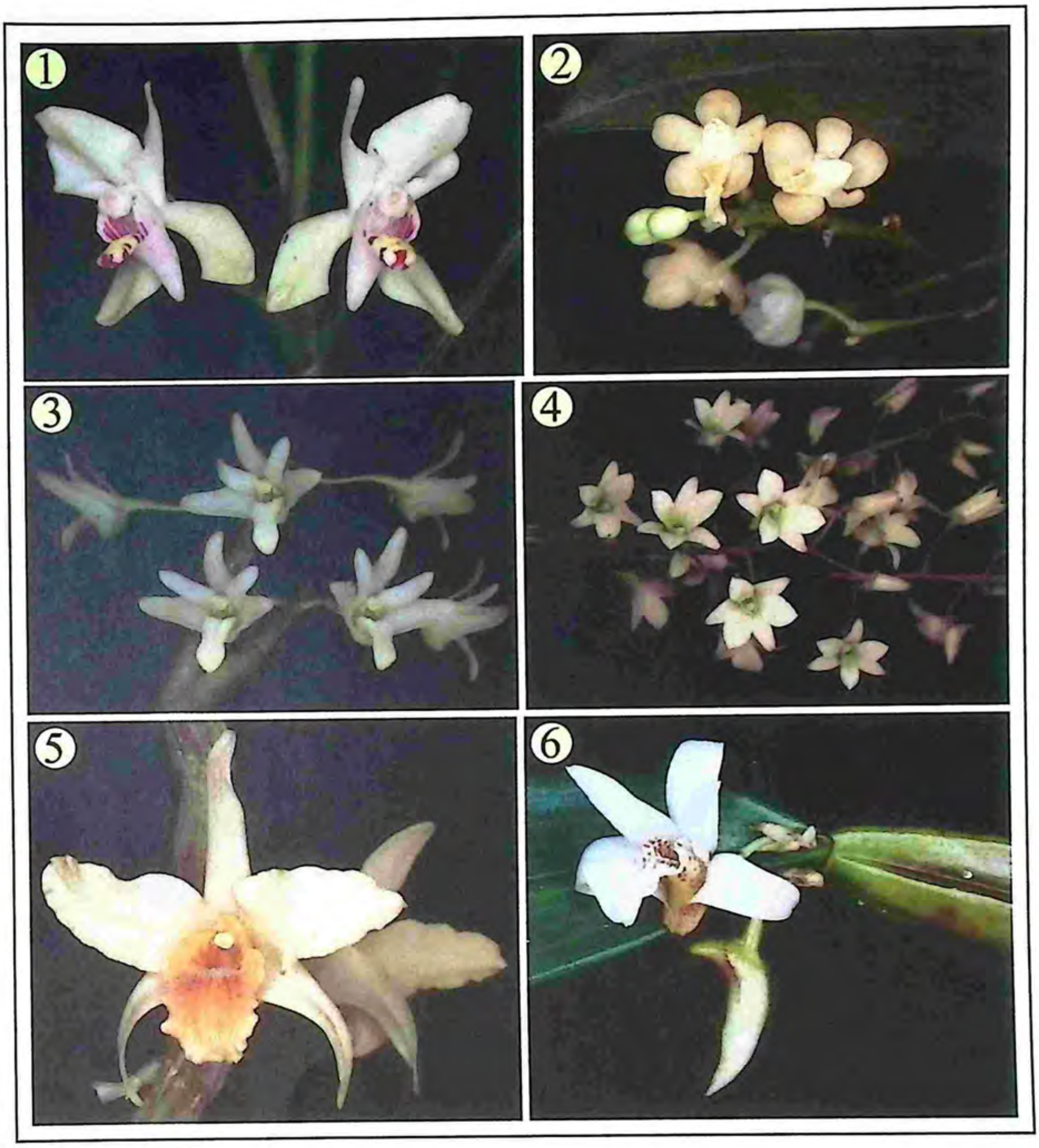
| | Epiphytes |
|---|---|
| 1 | *Aerides maculosum* Lindl |
| 2 | *Aeschynanthes perrottetii* DC. |
| 3 | *Asplenium sp. 2* |
| 4 | *Asplenium nidus* L. |
| 5 | *Bulbophyllum neilgherrense* Wight |
| 6 | *Bulbophyllum tremulum* Wight |
| 7 | *Coelogyne breviscapa* Lindl. |
| 8 | *Commelina* |
| 9 | *Cottonia peduncularis* Thwaites |
| 10 | *Dendrobium aqueum* Lindl. |
| 11 | *Dendrobium herbaceum* Lindl. |
| 12 | *Dendrobium lawanum* Lindl. |
| 13 | *Dendrobium macrostachyum* Lindl. |
| 14 | *Dendrobium ovatum* Kraenzl. |
| 15 | *Dendrophthoe falcata* Blume |
| 16 | *Dendrophthoe trigona* (Wight & Arn.) Danser ex Santapau |
| 17 | *Drynaria quercifolia* |
| 18 | *Epiphytic grass* |
| 19 | *Fageria* |
| 20 | *Ficus large leaf* |
| 21 | *Ficus mysorensis* Heyne ex Roth |
| 22 | *Ficus sp* |
| 23 | *Ficus tsiela* Roxb. |
| 24 | *Flickingeria* |
| 25 | *Gastrochilus acaulis* Kuntze |
| 26 | *Helicanthes elastica* (Desr.) Danser |
| 27 | *Helixanthera obtusata* Danser |
| 28 | *Hemiepiphyte* |
| 29 | *Hoya* |
| 30 | *Huperzia* |
| 31 | *Lepianthes umbellata* (L.) Raf. |
| 32 | *Lepisorus sp.* |
| 33 | *Lipparis viridiflora* Lindl. |
| 34 | *Loxoma straminea* (Saldanha) Pradhan |
| 35 | *Luisia zeylanica* Lindl. |
| 36 | *Macrosolen capitellatus* (Wight & Arn. ) Danser |
| 37 | *Macrosolen parasiticus* (L.) Danser |
| 38 | *Medinilla beddomei* Cl. |
| 39 | *Oberonia brunoniana* Wight |
| 40 | *orchid-1* |
| 41 | *Peperomia tetraphylla* Hk. & Arn. |
| 42 | *Phalaenopsis mysorensis* Saldanha |
| 43 | *Phymatosorus sp.* |
| 44 | *Piper* |
| 45 | *Piper sp 2* |
| 46 | *Pothos scandens* Wall. |
| 47 | *Premna* |
| 48 | *Psilotum nudum* (L.) P.Beauv |
| 49 | *Pteris biaurita* L. |
| 50 | *Pteris sp. Margin sori* |

51 *Remusatia*
52 *Rhaphidophora*
53 *Schefflera capitata* Harms
54 *Schefflera elliptica* Harms
55 *Schefflera wallichiana* Harms
56 *Scurrula cordifolia* G.Don
57 *Taxillus cuneatus* Danser
58 *Taxillus tomentosus* Tiegh.
59 *Trias stocksii* Benth. ex Hk.f.
60 *Viscum monoicum* Wight ex Wall.




1. ***Bulbophyllum fimbriatum***
2. ***Bulbophyllum nilgherrense***
   **(*Bulbophyllum sterile*)**
3. ***Bulbophyllum fishcheri***

PLATE - II

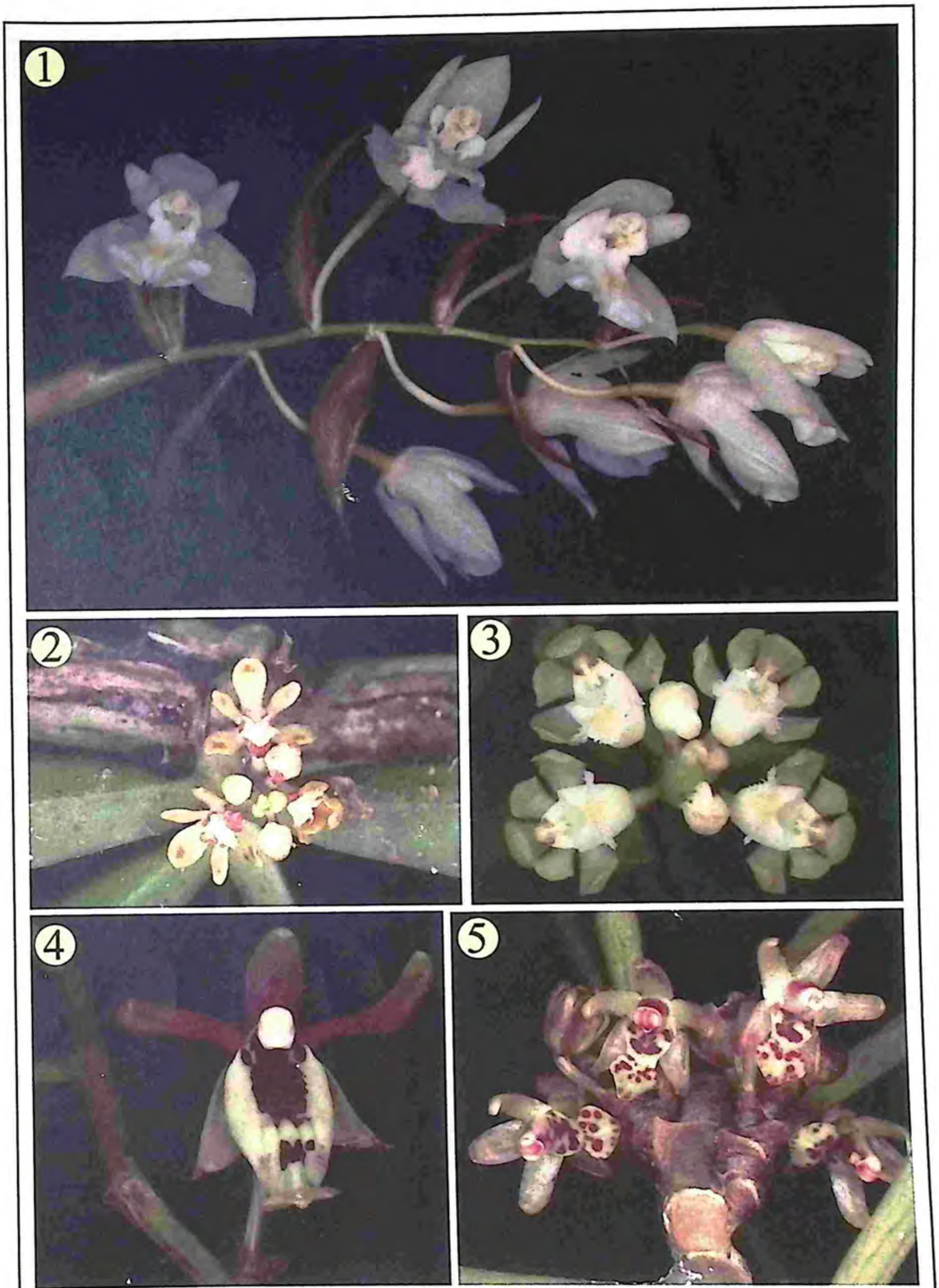



1. *Papilionanthe subulata*
2. *Phalaenopsis mysorensis*
3. *Dendrobium herbaceum*
4. *Dendrobium ovatum*
5. *Dendrobium heterocarpum*
6. *Flickingeria nodosa*

**PLATE - III**

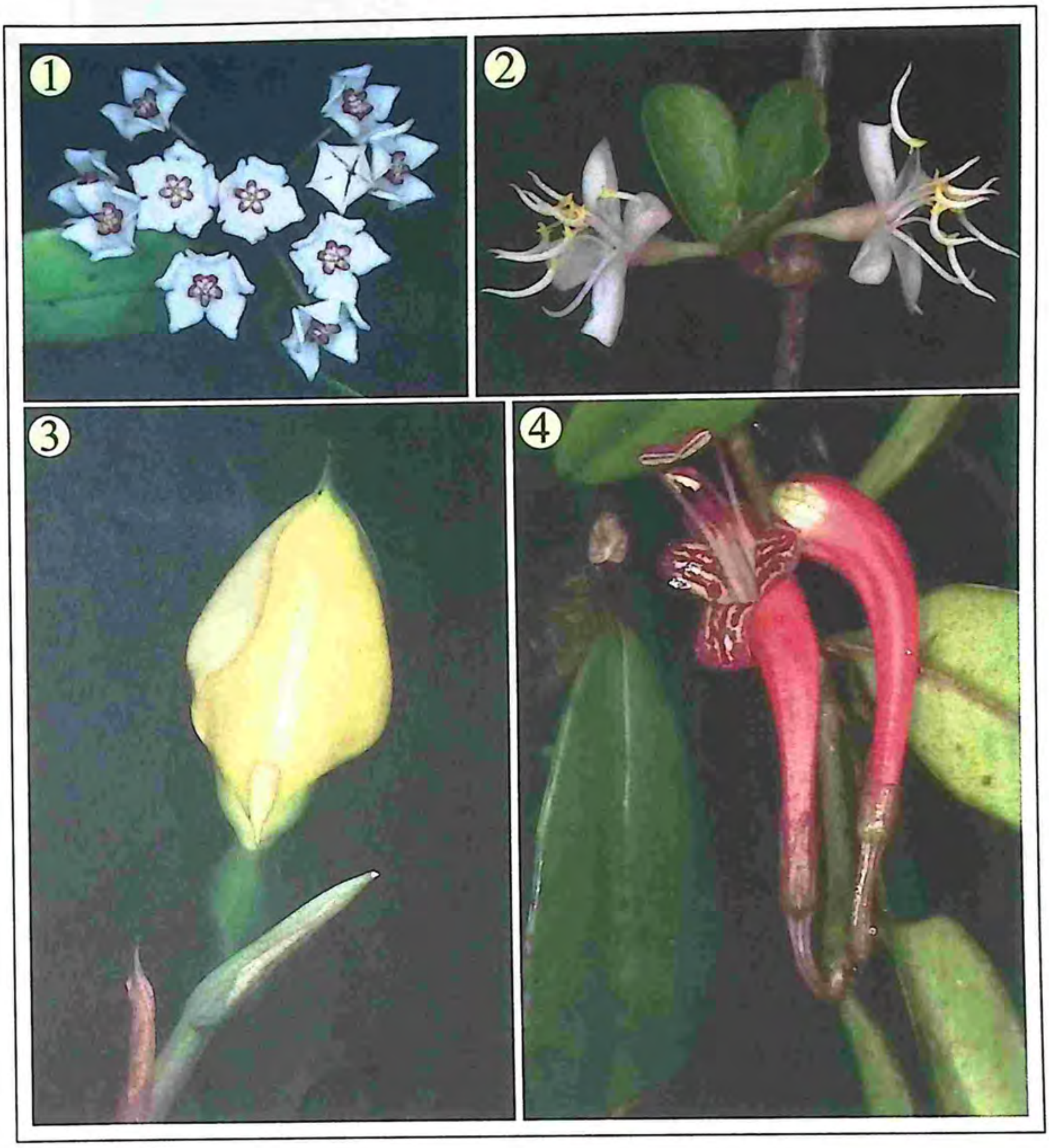

1. *Pholidota pallida*   2. *Oberonia brunoniana*
3. *Porpax jerdoniana*

**PLATE – IV**



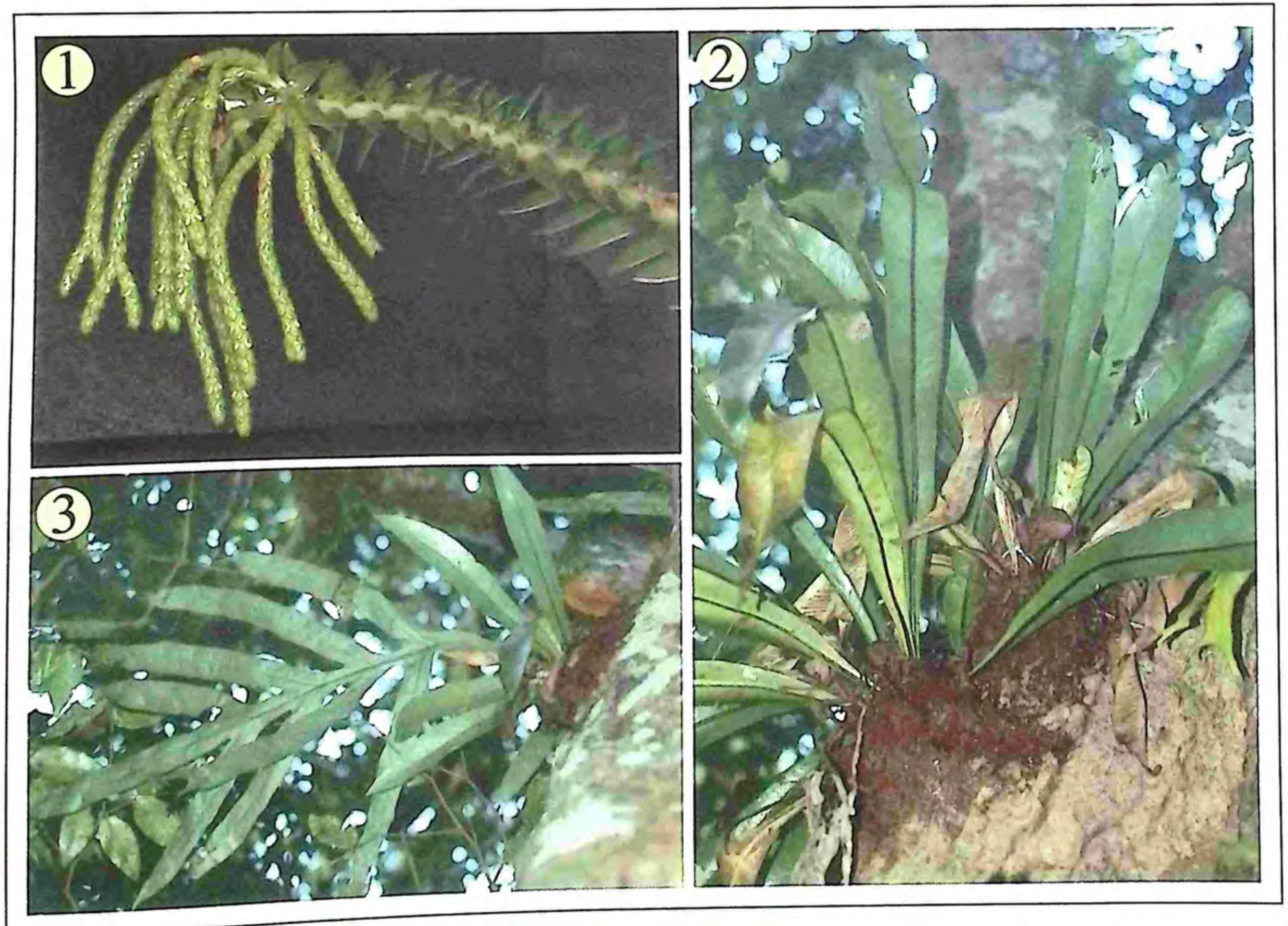

1. ***Coelogyna berviscapa***
2. ***Smithsonia straminea***
3. ***Gastrochilus acaulis***
4. ***Luisia micrantha***
5. ***Luisia sp.***

**PLATE - V**




1. ***Hoya wightii***
2. ***Medinilla beddomei***
3. ***Remusatia vivipara***
4. ***Aeschynanthes perotteti***

PLATE - VII




1. ***Huperzia macrostachya***
2. ***Phymatosorus nigrescens***
3. ***Asplenium nidus***