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Ecological Studies and long-term Monitoring of Biological Processes in Silent Valley National Park

Kerala Forest Research Institute
Peechi - 680 653 Kerala.
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Contents

1. INTRODUCTION

Director
Kerala Forest Research Institute

The Silent Valley National Park constitutes part of the core area of India's first bioshphere reserve - the Nilgiri Biosphere Reserve (NBR), established in September 1986. The concept and objectives of biosphere reserves, with particular reference to the NBR, were fully described in a project document published by the Indian National Man and Biosphere committee, Department of Environment, Govt. of India (GOI, 1980). Broadly, the biosphere reserves are protected sites consisting of undisturbed landscapes together with their man-modified surroundings, established for the purpose of:

- conserving the existing diversity of plants, animals and microorganisms as part of natural ecosystems,
- facilitating long term monitoring of changes in the ecosystem in relation to various levels and forms of human activities,
- generating scientific knowledge on ecosystem dynamics and biological diversity, and
- providing facilities for education and training.

Govt. of India (Department of Environment) (1980) Establishment of Biosphere Reserves in India, Project Document 1, The Nilgiri Biosphere Reserve, 59 pp.

Gadgil, M and Sukumar, R. (1987) Research priorities in the Nilgiri Biosphere Reserve- An overview.pp 132-139 In: Biosphere Reserves. Proc. first National Symposium, Udhagamandalam, Ministry of Environment and Forests, Govt. of India, New Delhi.

Research is thus one of the main activities contemplated in biosphere reserves. An excellent framework of reserach priorities in the NBR was given by Gadgil and Sukumar (1987). In August 1987, about a year after the establishment of the NBR, the Ministry of Environment and Forests, Govt. of India, approved a research programme under the broad title "Ecological studies and long term monitoring of biological processes in Silent Valley National Park" to be carried out by the Kerala Forest Research Institute. The present study is the result of this initiative.

With a modest budget of Rs. 1.851 lakhs over a period of two years, this research programme covered studies on five components.

1. Lepidopteran fauna
2. Community ecology of birds
3. Feeding and ranging patterns of lion-tailed macaque
4. Soil-plant community relationship, and
5. Establishment of permanent sample plots for long-term monitoring of ecological processes.

One scientist in each relevant discipline was responsible for each component, and the results of the study are organised here into five separate sections, written by the respective investigators. Each section is self-contained, except for a common description of the study area given in the section that follows this introduction.

The investigators have carried out the study within the constraints of budget and facilities available and have brought out very valuable scientific data for this comparatively undisturbed and little studied area of the typical West Coast Tropical Evergreen Forest. In the study of lepidopteran fuana, 500 species were collected, of which 340 are identified and listed - 95 secies of butterflies and 245 species of moths. Of these, 13 species are very rare and 5 belong to the list of protected species. The 160 unidentified species belong to microlepidoptera for which taxonomic knowledge is poor and some of these are likely to turn out to be new species. This study has also brought out information on species diversity of Lepidoptera in the different habitats within Silent Valley.

The study on birds covered two sites, one in the Silent Valley and the other at Mukkali in the buffer zone of the biosphere reserve. Using observational methods in variable width line transects, 59 species of birds were recorded in Silent Valley and 46 in Mukkali; 11 of the species encountered were immigrants. Information is also presented on vertical distribution of birds, foraging ecology and seasonal abundance.

The study on lion-tailed macaques (LTM) was conducted in about 2000 ha of evergreen forests covering the southern portions of the Silent Valley and Attappady Reserves, and 13 troops with about 171 individuals were encountered. Canopy continuity was found to be a limiting factor restricting the movement of LTM populations. Based on this study it has been suggested that the Panthanthode forest beat of

Attappady Reserve which fell within the home range of at least 7 of the 13 troops encountered in the study and where there are increasing evidence of human interference, be added to the Silent Valley National Park in order to sustain a large viable population of LTM. Silent Valley represents, apart from Agastyamalai in Tamil nadu, the most viable habitat of this endangered primate endemic to Western Ghats. In the study of relationship between soil and plant community, the soil properties of 7 distinctive plant associations found in the Silent Valley were investigated. Wide variations were found in soil properties and an attempt is made to arrive at generalisations.

The fifth component of the project concerned establishment of permanent sample plots for long term monitoring of ecological processes. Twelve plots, 50m x 50m, were laid out in 4 representative locations in Silent Valley and baseline data gathered to facilitate future monitoring.

It is obvious that this research programme covered only some aspects of insects, birds, a monkey, and soils. We have scarcely scratched the surface of the immense mine of information that is hidden in Silent Valley. Yet, we have made a good beginning, and in addition to the scientific data gathered, we have gained experience in organising and implementing studies in this difficult area. It became evident that in spite of high motivation, logistics plays an important role in successful accomplishment of research tasks. Ecological research is a long term effort and it is necessary to provide adequate infrastructural support to accomplish results. Approachability of scientists to work sites is a serious problem in Silent Valley. Methods of facilitating movement and construction of field stations at strategic locations must be given serious attention, if research in NBR must outgrow the traditional floristic and faunistic inventories and encompass quantitative ecological studies, much needed for understanding the dynamics of the tropical forest ecosystem. Some of these facilities must be built up through an imaginative Management Plan for the NBR. By now about 10 research projects in NBR have been supported by the Department of Environment and Forests, Govt. of India, to be implemented by various institutions. It is also necessary to develop a mechanism for exchange of information and research results among the investigators. It is hoped that the Department of Environment and Forests will develop suitable mechanisms to coordinate the research efforts in biosphere reserves and to provide infrastructural facilities.

Two aspects arising out of this study deserve special mention. First is the recommendation, based on the lion-tailed macaque study, that the Panthanthode area of Attappady Reserve be added to the Silent Valley National Park (and to the core zone of the NBR) to ensure a large, viable population of this endangered animal in the area. Second is the need to continue sustained ecological observations in the 12 permanent plots established in Silent Valley as part of this project and for which baseline data have been gathered.

2. THE STUDY SITE

The study was conducted in the Silent Valley National Park, one of the core zones of the Nilgiri Biosphere Reserve, situated in the Palghat District of Kerala between latitude 11° 3' and 11° 15' N and longitude 76° 23' and 76° 30' E. The area was declared as a National Park in 1984. As per the world classification of Udvardy (1975) the area falls under the Malabar Rainforest Realm. Covering an area of about 90 km^2 this reserve is situated more or less on a plateau of about 1000 m. The boundaries are formed by the Nilambur Forest Division and part of Nilgiris in the north, the Vested Forests of Palghat and Vested Forests of Nilambur Forest Divisions in the south, Attappady Reserved Forests in the east. There are several hillocks within the forest, and water drains into Kunthipuzha a tributary of Bharathapuzha.

Fig. 2.1 shows the Silent Valley and surrounding areas. Due to steep slopes on all sides, accessibility to this area is restricted and this has contributed to the area remaining more or less undisturbed. Attappady reserve which lies to the east of Silent Valley has suffered severe disturbance in the eastern portion lying close to the Vested Forests of Palghat. The eastern part of Attappady reserve merges with the rain shadow part of the Vested Forests of

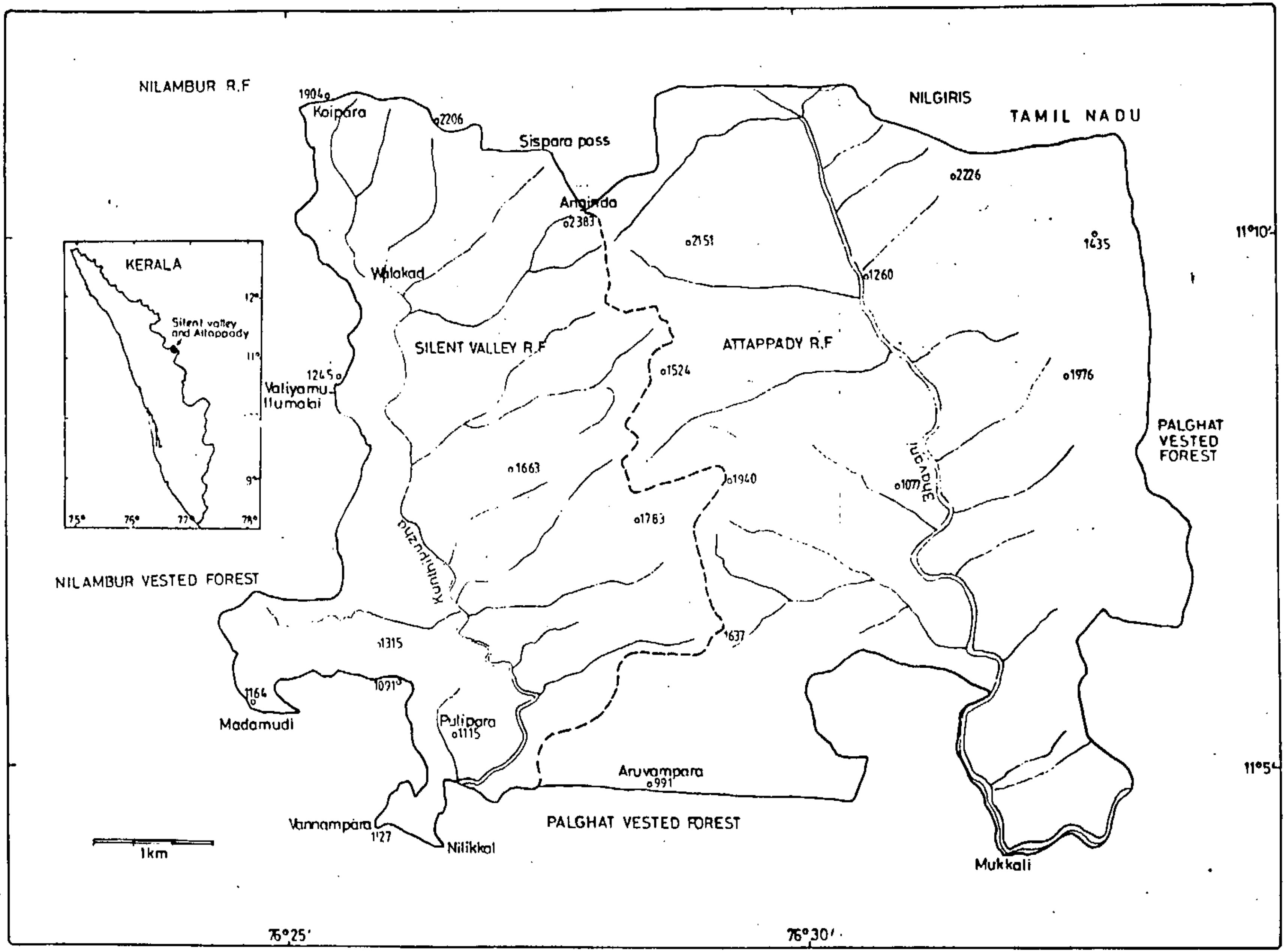

Fig.2.1. SILENT VALLEY AND SURROUNDINGS

Palghat. River Bhavani and its tributaries drain this area. The total area covered by the Attappady reserve is approximately 13,000 ha.

The region is characterised by heavy summer rains. Mean annual rainfall is about 4400 mm spread over both southwest and northeast monsoons. However, the bulk of the precipitation, accounting for about 80%, occurs during the southwest monsoon lasting from June to September. The northeast monsoon from October to December contributes about 12% of the rain. Premonsoon thundershowers during May account for about 6% of the rains and a small quantity, 2%, is received during the dry season.

The mean annual temperature is 20.2°C. April and May are the hottest seasons of the year when the mean temperature goes upto 23.5°C. December, January and February are the coolest when mean temperature is around 18 °C. A maximum of 30°C and an absolute minimum of 8°C have been recorded. From June to December relative humidity is consistently high often around 95%.

Due to climatic, edaphic and altitudinal variations, the forests exhibit considerable variation in floristic composition, physiognomy and life forms. The types of forests recognized are a) West Coast Tropical Evergreen forests; b) Subtropical Broad leaved Hill forests;

c) Montane Wet Temperate forests and d) Grassland - low and high level. The characteristics of each type are given below.

West Coast Tropical Evergreen forests

It is the climax vegetation type in this area and is commonly encountered between 600 to 1100 m. These forests measure about 45m high and atleast three strata can be recognised. The trees are often buttresed at base and the boles are clean and cylindrical to two thirds of their height with a spreading or umbrella shaped crown. The middle stratum is candle shaped and the lower, characteristically conical. Trees are often festooned with an array of aroids, orchids, ferns and mosses. Characteristic trees of these forests are *Artocarpus heterophyllus, Calophyllum elatum, Canarium strictum, Cullenia exarillata, Dysoxylum malabaricum, Elaeocarpus tuberculatus, Holigarna* spp. *Mesua ferrea, Palaquium ellipticum, Persea macrantha* and *Poeciloneuron ellipticum,*

Subtropical broadleaved hill forests

This type encountered between 1300 and 1800 m elevation. Typical species are *Calophyllum elatum, Cinnamomum* spp., *Elaeocarpus* spp., *Garcinia* spp. *Memecylon* spp. and various other members of the families of Lauracae and Myrtaceae. Though floristically rich, this forest is not commercially valuable as most of the trees are dwarf and crooked, not exceeding 20 m. in height.

Montane Wet Temperate Forests

This type of forest is seen in cliffs and sheltered folds above 1800m where water is available in surplus. Because of wind and high altitude these forests are stunted, the trees seldom attaining a height above 10 m. They are interspersed with rolling grasslands. Lauraceous and myrtaceous members constitute the bulk of the flora and as the name suggests the flora has a strong affinity towards temperate zone species.

Grasslands

Two types of grasslands are encountered in Silent Valley, low level (<1500m) and high level (>1500 m.). The low level grasslands are characterised by tall grasses of *Cymbopogon* and *Themeda* spp. often reaching 3 high. Fire hardy tree species like, *Careya arborea, Emblica officinalis, Phoenix humilis, Wendlandia notoniana* and *Zizyphus rugosa* occur mixed with this grasses. High level grasslands are stunted and carpet like and are dominated by species like, *Arundinella, Bothriochloa* and *Heteropogon. Gaultheria fragrantissima* and *Rhododendron nilagiricum* are the two common species associated with these grasslands.

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3. STUDIES ON THE LEPIDOPTERAN FAUNA OF SILENT VALLEY

George Mathew

Division of Entomology

Contents

3.1. Abstract

Of about 500 species of Lepidoptera collected from the Silent Valley National Park, 95 species of butterflies and 245 of moths have been identified.

The butterflies collected, belonged to 9 families. The maximum number of species belonged to the families Nymphalide and Papilionidae. Habitat preferences of the various groups of butterflies were studied and five distinct biocoenoses with characteristic fauna were recognised, viz., interior forests, forest clearings and edges, forest canopies, grass lands and river banks. Of the various species collected, 13 were endemic to South India which are now very much restricted in thier distribution. This included 5 species having protected status.

The moths recorded in this study belonged to 15 families: Pyralidae, Noctuidae, Geometridae and Arctiidae being dominant. Some groups like Sphingidae, Lasiocampidae, Drepanidae, Epiplemidae, Saturnidae and Cossidae were only poorly represented.

Preliminary data suggested insect species diversity in well regenerating forest as compared to those subjected to disturbances like incidence of fire. In general, the fauna bears a close resemblance to that of Sri Lanka although it is characterised by the presence of several endemic species showing affinities with the Malayan elements.

Conservation of the whole forest ecosystem in this region, including the core area, the Silent Valley, will be very essential for protecting the rich lepidopteran fauna represented here.

3.2. Introduction

Insects constitute the largest assemblage of organisms on the earth accounting for about 3/4th of the whole animal kingdom. About 0.75 - 1 million species of insects constituting about half of the insect fauna have so far been described.

At least 50% of the world insect fauna is reported to be in the tropics. Of this, a large share is expected to be occurring in the tropical rainforests, which covers only 6.3% of the total land area. According to an estimate, the biomass of soil insects in the forest, is estimated to far exceed that of other bigger animals like birds and mammals found above the soil. On account of their vast number and diverse habits they are considered to be important components in the production and decomposition stages of the forest ecosystem. They also play a major role in the maintenance of soil structure, soil fertility, as pollinators and as agents of plant dispersal (Wells, Pyle and Collins, 1983)

The tropical rainforests which are the results of over 60 million years of evolution, are by far the most stable and ecologically sensitive as compared to the temperate forest which have been only recently recolonized. Because of its fragile nature, even a slight change in the forest ecosystem is likely to upset the delicate balance between its various components. Man induced changes leading to changes in the land, water, flora and fauna are the major factors which upset this balance. As a result of the disturbances in the biome many species particularly the insects become extinct. Since most of the tropical rainforests are located in under-developed or developing countries, lack of adequate scientific expertise is a major constraint in undertaking ecological studies in order to develop sound management strategies. As a result even the disappearance of many species remain undocumented before establishing their economic importance. Therefore there is an urgent need to study the fauna in these regions.

Among insects, the Lepidoptera which includes, the butterflies and moths are economically very important being the primary consumers in the forest ecosystem. They are very diverse in their habits and are adapted to a variety of conditions. Being highly sensitive to changes in the environment they are easily affected by even relatively minor perturbations in the habitat so much so they have been considered as indicators of environmental quality (Rosenberg et al., 1986).

Silent Valley which forms the core area of the Nilgiri Biosphere Reserve is a typical humid tropical rain forest situated on a plateau about 1000 m above mean sea level. It covers an area of 9000 ha and exhibits considerable variations in the floristic composition, physiognomy etc., mainly due to the climatic, edaphic and altitudinal variations. Four types of vegetations are encountered viz., (a) west-coast tropical evergreen forests (b) subtropical broadleaved hill forests, (c) montane wet temperate forests and (d) grasslands.

As has been stated earlier, basic information on the flora and fauna is very important in any ecological study. As far as Silent Valley is concerned no concerted attempt has so far been made to study the invertebrate fauna particularly the insects. Considering the importance of Lepidoptera in forest ecosystems it was proposed to be studied first. The present work is conceived as a preliminary attempt to collect baseline data on these insects and to study their role in the ecosystem.

3.3. Materials and Methods

3.3.1. Sampling methods

Sampling of butterflies was carried out by collecting with a hand net during day time in the different habitats. For collecting moths a modified Pensylvanian - type light trap operated by a 6 V battery (Fig 3.1) was used. An 8 Watt UV tube was used in the trap for illumination. The trap was operated overnight on all days (from 6 PM to 6 AM on the next day). An automatic switching device (Fig 3.1) was

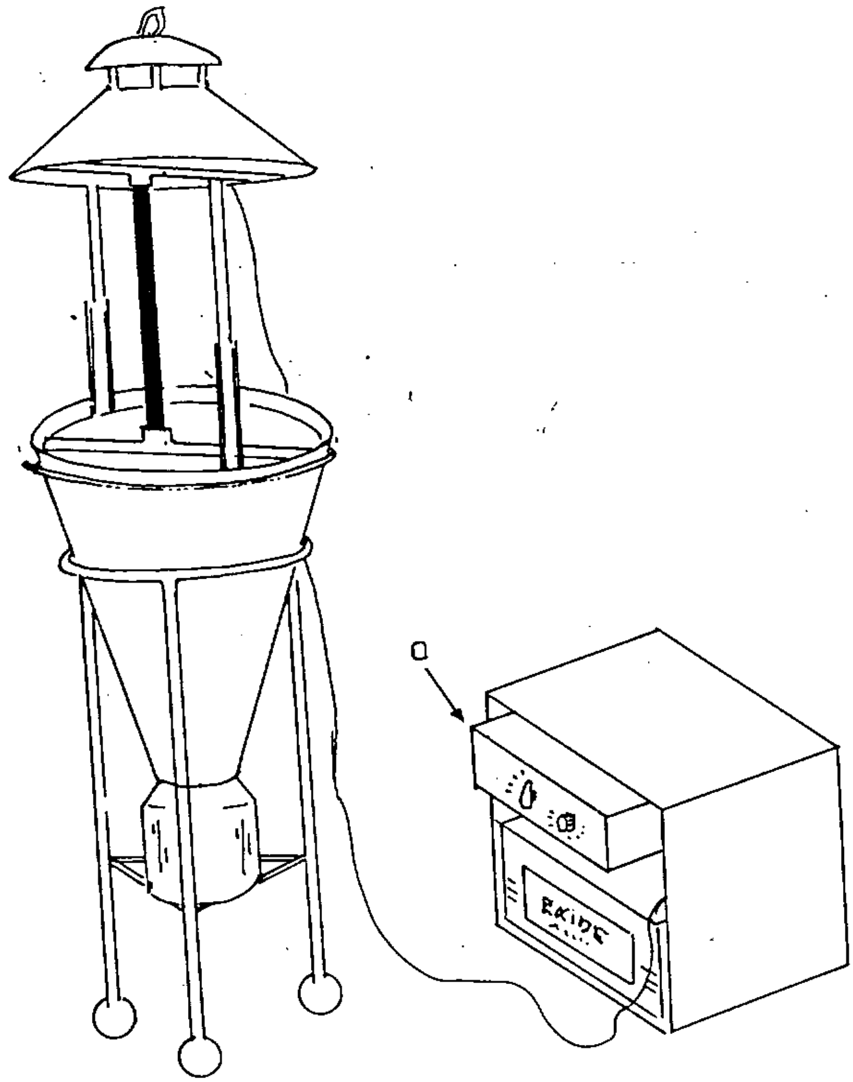

Fig. 3.1. Battery operated light trap used for moth sampling.

(note the timer, a)

developed to facilitate the self operation of the trap in the deep forests at the timings stipulated above. The trap was set up on a stand, about 1.2 m in height, on the ground in small forest clearings.

3.3.2. Insect diversity

In order to study the faunal diversity, regular sampling was carried out in four locations - Campsite (2 areas), Poochappara and Neelikkal within the Sanctuary. The insects collected on each night were sorted out into the respective species and their number recorded. The first locality (Campsite, Ist area) represented a well regenerating forest area. The second area at Campsite was similar to the first but subjected to fire in the past. The third and fourth localities represented relatively undisturbed forest types. At each location, monthly sampling was carried out for 5 successive days for a period of 5 months. In addition to this, occasional sampling of fauna was carried out during visits to the other parts of the sanctuary, for information on the insect fauna. The insects collected in this study were identified by reference to literature or by sending to the Commonwealth Institute of Entomology, London.

3.3.3. Statistical analysis

For calculating the diversity index for the various localities, Shannon-Weiner formula was used:

$$\text{Diversity index } (H^{1}) = - \sum_{i} Pi \ln (Pi)$$

Where Pi is the proportion of the ith species in the community and ln is the log with base "e" (natural logarithm) (Pielou, 1975).

In order to assess to overall similarity of different localities with respect to species diversity, the index of smililarity (IS) was also worked out. A modified version of Jaccard's formula as suggested by Sorenson (1948) was used. According to this,

$$\text{the index of similarity (IS)} = \frac{2C \times 100}{(A+B)}$$

where C = number of common species in two 'releves', 'A' = total number of species in a Plot and B = total number of species in another Plot.

3.4. Results

About 100 species of butterflies and 400 species of moths were collected in this study. Of these, the identitity of 95 sp. of butterflies and 245 of moths could be confirmed so far. Others are in the process of identification. The insects so far identified are listed in Table 3.1.

3.4.1. Butterflies

The butterflies collected in this survey belonged to 9 families. Maximum number of species collected belonged to the families Nymphalidae and Papilionidae. Some species were present only in certain seasons whereas some others were present throughout the year.

Butterflies, as in most other Lepidoptera, show distinct patterns of habitat associations. Each fraction of the forest habitat is very characteristic and harbours a specific assemblage of fauna. The nature of vegetation, humidity, sunshine, availability of water, presence of larger wild animals etc. are all factors that determine the survival of a given speices in a particular habibat. For instance, there are species fond of bright sunshine, species which occur only in the cool darkness of dense forests, species frequenting the forest canopy, species that puddle in the muddy shores near streams, species that visit a particular type of fruit, animal excreta and so on. Information on such habitat preferences will be very useful in developing appropriate conservation stratagies for the various species in future. Based on observations made in this study, five important biocoenoses supporting a characteristic assemblage of butterflies have been are recongnized in the Silent Valley National Park. A summary of species occuring in the various biocoenoses is given below:

a. In dense forests

These are essentially species that love the shade and coolness of dense forests and they seldom venture out into the open. They are usually dull coloured to match the surroundings and generally subsist on over-ripe fruits or sappy exudation of trees or on the nectar from plants belonging to the lower strata. As such, they are not in the habit of flying at high elevations and are confined to the Forest floor. *Melanitis leda, M. phedima varaha, Ypthima sp., Mycalesis* sp., and *Lethe* sp. were present very abundantly throughout the year. In the case of *M. leda,* wet and dry season forms were present causing confusion in the species identification. All these species were found in well regenerating wet evergreen forests and were not very common in other habitats.

b. In the canopies

Butterflies frequently found in forest canopies are swift fliers. An exception to this was *Idea malabarica* (Nymphalidae) which was found to glide gracefully through the dense forests. Most of the species found at higher elevations were comparatively bigger in size and were beautifully coloured and adorned with markings of various shapes, resembling birds while in flight. Many such specis were found to feed at the flowers of various forest trees or twiners although, occasionally they were also observed to come to lower levels to feed at the flowers of plants like *Clerodendrum viscosum*, or on over-ripe fruits found on the ground or for settling on the damp mud near streams. The nymphalids *Parthenos sylvia virens, Vindula erota soloma, Cirrochroa thais thais;* the papilionids *Papilio budha* and *P. paris tamilana* and the danaid *I. malabarica* were the common species found in this strata. *I. malabarica* was often found in large numbers in the evergreen patches near Panthanthode and Campsite areas in the National Park. Most of the above species are now restricted in their distribution and are mostly confined to the evergreen habitats in the Western Ghats.

c. In forest clearings, forest edges, etc.

The forest edges as well as clearings are occupied by species that prefer bright sunlight. Such species often tend to be brighter in colouration and they subsist on nectar of various shrubby vegetation found growing in such locations. At Silent Valley, the openings are colonised by profuse growth of plants like *Clerodendrum viscosum, Blumea alata, Ageratum conizoides, Vernonia canisoides, Desmodium* sp., *Barleria* sp., etc. Most of the papilionids (*Papilio polytes thesus, P. polytes romulus, Pachliopta aristolochiae, P. hector*); pierids (*Appias indra, Cepora nadina, Catopsilia* spp., *Eurema laeta, E.* sp. nr. *lacteola)* and the nymphalids (*Hypolimnas missipus, H. bolina, Neptis* spp., *Moduza procris, Cethosia nietneri*) were the common butterflies found in this habitat. Aggregation of butterflies was also characteristic in this zone. *Appias* spp., *C. nadina, Catopsilia* spp., *Eurema* spp., etc., were the common species found gregareously.

d. In grasslands

The grasslands in Silent Valley are very extensive in area and support several species of shrubby plants. In low level grass lands tall grasses like *Cymbopogon* sp., *Themeda* sp., and shrubs like *Wendlandia thyrsoidea* and *Zizyphus rugosa* are the most common plants. Frequently weeds like lantana, *Chromolaena* sp., *Crotalaria* sp. etc. also occur in patches.

The above plants support a very characteristic assemblage of butterflies. Danaid butterflies like *Tirumala limniace leopardus, T. sepentrionis dravidarum, Danaus genuita*, the nymphalids *Euploea core, Vanessa cardui*, Pierids like *Eurema hecabe, E. brigitta*, etc., were the species generally found in this region. Small scale population build up and local migration of some species like *T. limniace, T. sepentrionis, D. genuita, E. core* and *Eurema* spp., was observed during February-April, 1988.

e. On the banks of streams and rivers

Butterflies found in this habitat are frequent visitors to wet mud or damp moss along the banks of streams and rivers. Such species generally hover over the streams, visiting flowers in the vicinity and aggregating on damp soil or excreta of wild animals licking the water out of it. Lycaenids, some papilionids and nymphalids belong to this category. Often groups of butterflies belonging to single or several species could be observed in such swarms. *Jamides celeno, J. alecto, Udara akasa, Castalius rosimon, Caleta caleta* (Lycaenidae); *Graphium doson doson, G. sarpedon teredon* (Papilionidae); *Cyrestis thyodamas* and *Kaniska canace haronica* (Nymphalidae), were the common species found in this habitat.

3.4.2. Moths

The moths identified in this study belonged to 15 families. Altogether 245 species could be identified. The families Geometridae, Noctuidae and Pyralidae contained the maximum number of moths collected. A large number of species belonging to several other microlepidopteran families still remain to be identified.

3.4.2.1. Species diversity

A preliminary study was made on the diversity of moth fauna in four Plots representing four different habitats. The Plots were taken at Campsite (Plots 1 &2), Poochappara (Plot 3) and Neelikkal (Plot 4). Plot 1 represented a well regenerating forest which was subjected to logging operations in the past; Plot 2 formed part of the same but had suffered incidence of fire repeatedly for some years in the past; Plots 3 and 4 were moderately undisturbed patches. Only the moths were included in the sampling since they could be easily sampled by relatively simple techniques like setting up of light traps.

The number of insects collected from the various Plots are given in Table 3.3. The highest number of insects collcted was from Plot I and lowest from Plot 4 with the species diversity index (Table 3.4) ranging from 3.4 in Plot I to 0.4 in Plots 3 and 4. Although Plot 2 was adjacent of Plot 1, the former registered a low value as compared to Plot I and this was attributed to the incidence of fire in the former in the previous years. However, with regard to Plots 3 and 4 where the structural quality of flora was far superior, the values obtained were quite unexpected. The exact reasons for the low diversity index is not certain but probably it could be due to some defects in the selection of sampling sites or due to influence of seasons on trap catches or due to the differences in the plant community. Moreover since the study was conducted only for a short period of 5 months it was not possible to evaluate the influence of the above factors on trap catches.

In order to examine the accuracy of the data gathered, a collector's curve was prepared by plotting the number of insects collected upto the ith period (i = 1,2,3,4,5 month; Pielou, 1974, p. 288). The curves (Fig.3.2) were found to rise continuously in all the localities indicating that the sampling was not sufficient and that further collections are necessary to take stock of the faunal diversity of these areas.

3.4.2.2.Family diversity

The relative abundance of the various groups of moths was another aspect studied. In all the four Plots, the families Pyralidae, Noctuidae, Geometridae and Arctiidae were the dominant groups (Fig. 3.3). Families like Sphingidae, Lasiocampidae, Saturnidae and

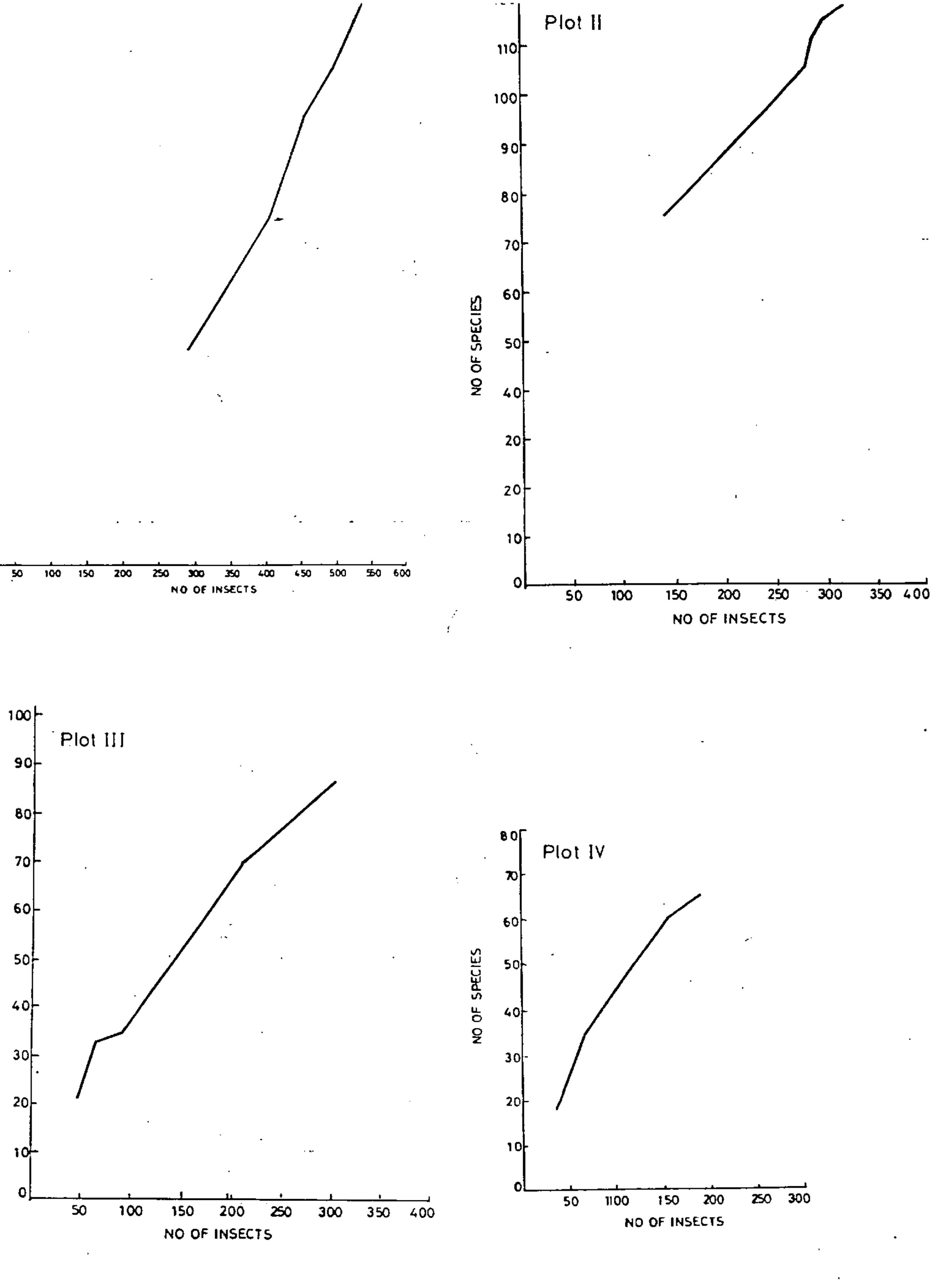

Fig. 3.2. Collector's curve for Plots 1, 2, 3 and 4.

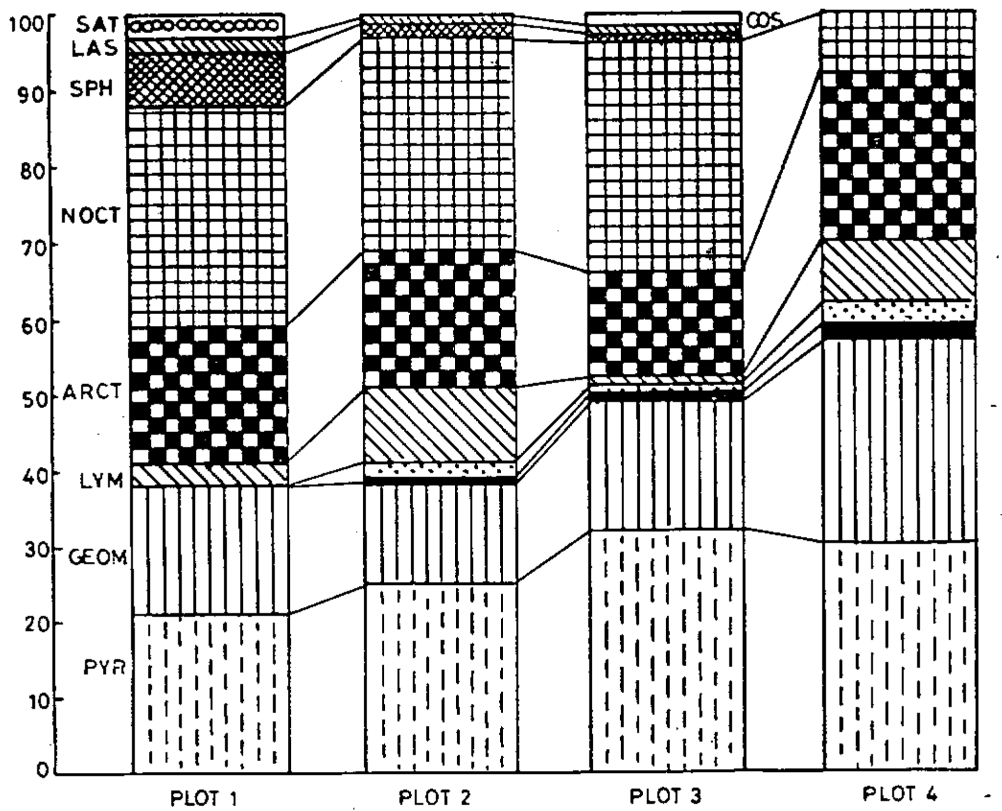

Fig. 3.3. Proportions of various major taxonomic groups in four sampling sites (Pyr - Pyralidae; Geom - Geometridae; Sph - Sphingid Lym - Lymantriidae; Arct - Arctiidae; Noct - Noctuidae; Sat - Saturnidae; Cos - Cossidae)

Cossidae were very scarce in the trap catches. Maximum number of families was recorded in Plot 3 (10; Poochappara) followed by Plot 2 (9; Campsite). Least number recorded was for Plot 4 (7; Neelikkal). The occurrence of certain families in some of the Plots is interesting. The family Saturnidae was represented only in Plot I and Cossidae in Plot 3. The distribution of some of these families might prove to be of importance in that their occurrence could probably be associated with specialities in the floral composition in a particular habitat.

Although one of the objectives of this project was to evaluate the usefulness of moths as indicators of environmental quality, it could not be accomplished, due to the short tenure of the project which limited the possibility of studying the inter-relationships of flora and fauna in habitats of different levels of disturbance for drawing possible conclusions on this aspect.

3.4.2.3. Faunal similarity

The faunal similarity of the four Plots was studied and the indices of similarity are given in Table 3.5. The Plots 1, 2 and 3 had more or less same values, compared to that obtained for Plot 4 which was low. The reason for this is not known but could be due to differences in the floral composition. Further studies are needed to ascertain this aspect.

3.4.3. Endemism in the fauna

Information on the range of various species is very important in species conservation programmes. As a result of deforestation and also due to intensive agriculture, the natural habitats of many species of insects have been destroyed threatening the survival of their native populations. As a result, the original range of many species is now confined to the forest regions only. In order to ascertain their current distribution detailed surveys on the various insect groups are necessary. As far as the Nilgiri Biosphere Reserve is concerned, more or less complete information is available on the butterflies in the Nilgiri area (Larsen, 1987, 1988). However no information is available on the butterfly and moth fauna of the other areas including Silent Valley.

Of about 300 species of butterflies recorded from southern India (Wynter Blyth, 1957) with few exceptions, all have been, recently recorded from the Nilgiri area (Larsen, 1988) indicating a rich faunal diversity. This also included several species that are reported to be South Indian endemics. Conservation of the forest habitats in this region is considered to be the main reason for the survival of these insects.

However it may be pointed out here that many species originally reported to be endemic to the South Indian Region are now found only in the natural forests. Table 3.2 shows some of the butterflies which are very scarce and now confined to such habitats. Of the 66 species listed in the Table, 13 species have been recorded from the Silent Valley area in this study. This include 5 species listed under the various schedules of Indian Wildlife Act (1982).

Our knowledge on the moth fauna of this region is largely based on the previous studies made by Hampson (1892-1896). Although a few species reports have been made by subsequent workers, no recent attempt has been made to consolidate the available information in order to update the moth fauna of this region. The extent of endemism in the moth fauna is also not very clear but based on the available literature, nearly 60 species have been tentatively ranked as endemic to southern India in general and to Nilgiri Biosphere Reserve in particular (Table 3.1)

3.4.4. Faunal affinities

The fauna of Silent Valley bears a close resemblance to that of Sri Lanka although the latter is characterised by the occurrence of several endemic genera and disjunct species groups which do not have any relatives in S. India (Larsen, 1987). The low land evergreen forests of Silent Valley have a good representation of South Indian species although the forest patches at higher altitudes as well as the sholas contain several species which bear a close resemblance to that of Sundaland although they have developed into distinct races over years of isolation. Holloway (1974) and Larsen (1988) are of the opinion that Indian fauna is one largely formed as a result of displacement by invaders from other regions of the Oriental region, after its separation from Gondwanaland and merger with Asia. Most of the endemic species in the Western Ghats had their origin elsewhere in the Oriental region and are still surviving in isolated specialised habitats. The butterflies *Psolos fuligo subfasciatus, Matapa aria, Oriens goloides, Parnara nasobada* and *Caltoris kumara Kumara* (Larsen, 1988) and the moths *Loepa sikkima, Trabala ganesha, Oxyambulyx subocellata, Theretra nessus, Macroglossum aquila, Tarsolepis rufobrunne malayana, Phalera sundana, Cyana peronata, Eliema tetragona, Oeonistis entella, Spilosoma anada, Tridrepana fulvata,* etc., (Barlow, 1982) are some of the species having Malayan affinities recorded from the Nilgiri Biosphere Reserve. A small fraction of insects were having Palaearctic (*Borbacha sp., Eumelia rosalia, Ozarba punctifera, Rhodogastria* sp., *Euproctis bipunctapex*); Australian (*Maceda mansueta, Pyrausta phoenicealis, Crocidolomia* sp; and Ethiopian (*Pingasa ruginaria, Britta* sp., *Sauris* sp.) affinities.

3.5. Discussion

The study has indicated that the lepidopteran fauna of Silent Valley is rich and diversified. Of about 310 species of butterflies reported from southern India, 300 species have been recorded from the Nilgiri area of this Biosphere Reserve . Of this about 100 species have been collected from the Silent Valley National Park in the present study. A large number of moths have also been collected of which 245 species have so far been identified. Collections could be made only for a short period of 5-6 months in a year since the accessability was poor during the rainy season due to blockade of roads as a result of landslides, tree falls etc. The project was operated only for a period of 2 years. The species diversity indices obtained for the various localities there- fore do not actually indicate the exact values. The fact that further samplings are necessary, is indicated by the collector's curve, which shows an upward rise. However the values obtained are of interest in that, well regenerating forest was rich in species diversity (3.42). The possible adverse effect of fire on fauna was also shown by in the drastic reduction in the diversity index in fire affected forests (1.9).

The fauna of Silent Valley, and of the Nilgiri Biosphere Reserve for that matter is very specialised due to the very complex ecological conditions produced as a result of interaction between the typical rainfall patterns, temperature and topographical features. The various specialised ecological zones formed as a result of this, support a characterestic fauna containing several endemic species. With the destruction of local habitats the range of many species of butterflies and moths is now very much restricted and several species are now limited to certain forest patches only. Sixty six species of butterflies and about 60 species of moths which are currently rare in their distribution (Tables 3.1, 3.2) have been reported from the Biosphere area. This include 25 species of butterflies having protected status under the Indian Wildlife Act. Intensive studies will yield more valuable information on the faunal diversity of this area.

The tropical rainforests which are the results of over 60 million years of evolution, are the centres of rich species diversity. Man induced disturbances are the main factors that affect the sustenance of many natural communities and although extinction of species is supposed to create diversity due to a diversification and adaptation of the surviving ones, destruction of species is unlikely to generate very much diversity in the rainforests because of its complex structure (Turner, 1984). The occurrence of a rich and diversified fauna in some parts of Nilgiri Biosphere region was largely attributed to the conservation of the forests in this region (Larsen, 1987, 1988). Conservation of the natural habitats is very essential for the existence of many species of lepidopterans. The survival of a large number of very specialised endemic as well as protected species in the Silent Valley area warrants frequent monitoring of the ecological processes besides adoption of appropriate conservation strategies in order to safeguard its rich genetic diversity.

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Literature Cited

Barlow, H.S. (1982) *An introduction to the moths of South East Asia.* E.W. Classey Ltd. 305 pp.

Hampson, G.F. (1892-1896) *The moths of India,* London, 4 Vols.

Holloway, J.D. (1974) In: Mani, *Ecology and Biogeography in India,* pp.473-499 Junk, den Haag.

Larsen, Torben, B. (1987) The Butterflies of the Nilgiri mountains of South India (Lepioptera: Rhopalocera). *J.Bombay Nat. Hist. Soc. 84(1): 26-54; 84 (2): 291-316; 84 (3): 560-584.*

Larsen, Torben, B (1988) The Butterflies of the Nilgiri mountains of South India (Lepioptera Rhopalocera) *J. Bombay Nat. Hist. Soc.* 85(1):26-43.

Pielou, E.C. (1974) *Population and Community Ecology: Principles and Methods,* Gerdon and Breach Science Publ., New York, 424pp.

Pielou, E.C. (1975) *Ecological diversity,* John Wiley and Sons, 165pp.

Rosenberg, David M., Danks, H.V. and Lehmkuhl, Dennis, M.C (1986) Importance of insects in Environmental Impact Assessment. Environmental Management, 10 (6) pp. 773-783.

Sorenson, T. (1948) A method for establishing groups of equal amplitude in plant sociology based on similarity of the species content. *Eet. Kong. Danske Vidensk. Selsk Biol. Skr. (Copenhagen)* 5 (4): 1-34.

The Indian Wildlife (Protection) Act (1982) The Gazette of India *(Extra ordinary) Part II - Section (3) Subsection (1) Amendment of the Act 1972.*

Turner, John R.G (1984) Extinction as creative force: The butterflies of the Tropical Rainforest: *The Leads Symposium,* pp. 195-204.

Wells, Susan M., Pyle, Robert, M. and Collins, Mark N. (1983) *The IUCN Invertebrate red data book.* IUCN, Switzerland, 632 pp.

Wynter-Blyth, M.A. (1957). Butterflies of the Indian region. The Bombay Nat. Hist. Soc. Bombay 523 pp.

Table 3.1. List of insects collected from Silent Valley

Group/Family	Details of distribution (from literature)			
	S.India	Sri Lanka	Several places in India	Several countries
RHOPALOCERA (BUTTERFLIES)				
Danaidae				
Tirumala sepentrionis dravidarum Fruhstorfer	+	+	+	+
T. limniace leopardus Butler	-	+	-	-
Parantica nilgiriensis Moore	+	+	-	-
P. aglea aglea Stoll.	-	-	+	+
Danaus genuita genuita Cramer	+	-	-	-
Idea malabarica malabarica Moore	+	-	-	-
Nymphalidae				
Hypolimnas missipus Lin.	+	-	-	-
H. bolina Lin.	-	-	-	+
Euthalia sp.				
Euploea core core cramer	+	-	-	-
Parthenos sylvia virens Moore	+	-	+	+
Vindula erota soloma de Niceville	-	-	+	+
Moduza procris Cramer	-	-	+	+
Cyrestis thyodamas ganescha Kollar	-	-	+	+
Neptis hylas varmona Moore	+	+	+	-
Neptis perius perinus Fruhstorfer	-	-	-	-
Phalanta phalanta Drury	-	-	+	+
Cirrochroa thais thais Fb.	+	-	-	-
Cethosia nietneri mahratta Moore	+	-	-	-
Vanessa cardui Lin.	-	-	+	+
Vanessa indica nubicola Fruhstorfer	+	+	-	-
Cupha erymanthis maja Fruhstorfer	+	-	-	-
Ariadne merione Cramer	+	-	-	-
Junonia hierta Fb.	+	-	+	+

J. lemonias vaisya Fruhstorfer	+	+	-	-
J. almana Lin.	-	-	+	+
J. atlites Lin.	-	-	+	+
Kaniska canace haronica Moore	+	+	-	+
Hesperiidae				
Tagiades litigiosus Moschler	-	-	-	-
Celaenorhinus leucocera (Kollar)	-	-	-	-
C. ambareesa (Moore)	-	-	-	-
Potanthus pava pava Fruhstorfer				
P. palnia Evans				
Taratrocera sp.? *ceramas* (Hewitson)	-	-	-	-
Telicota sp				
Caltoris canaraica Moore				
Lycaenidae				
Cheritra freja (Fabricius)	-	-	-	+
Jamides celeno (Cramer)	-	-	-	-
J. alecto (Felder)	-	-	-	-
Jamides sp.				
Udara akasa Horsfield	-	-	-	-
Celestrina lavendularis Moore	-	-	-	+
Castalius rosimon (Fabricius)	-	-	-	+
Caleta caleta Hewitson	-	+	+	-
Curetis sp.? *thetis* Drury	-	+	+	-
Arhopala centaurus	-	-	-	-
A. amantes (Hewitson)	-	-	-	-
Riodinidae				
Abisara echerius Stoll.	-	-	-	-
Papilionidae				
Troides minos Cram.	+	-	+	-
Chilasa clytia Lin.	-	-	+	+
Pachliopta pandiyana Moore	+	-	-	-
P. aristolochiae ssp. nr. *sawi* Evans	-	-	-	-
P. aristolochiae goniopeltis Roths.	-	-	-	-
P. aristolochiae f. *aristolochiae* Fb.	-	-	-	-
P. hector Lin.	+	+	-	+
Papilio polymnestor parinda Moore	-	-	-	-

P. paris tamilana Moore	+	-	-	-
P. helenus Lin.	-	-	+	+
P. budha Westwood	+	-	-	-
P. liomedon Moore	+	-	-	-
P. demoleus demoleus Lin.	+	+	+	+
P. polytes thesus Cramer	-	-	-	+
P. polytes romulus Cramer	-	-	+	+
Graphium sarpedon teredon Felder	+	+	-	-
G. doson doson Felder	-	-	-	-
G. agamemnon agamemnon Lin.	-	-	-	+

Satyridae

Melanitis leda Lin.	-	-	-	+
M. phedima varaha Moore	+	-	-	-
Elymnias caudata Butler	+	-	-	-
Ypthima sp? *ceylonica* Hewitson	+	+	-	-
Ypthima sp.				
Mycalesis patnia Moore	+	-	-	-
M. igilia Fb.	+	-	-	-
M. anaxias Hewitson	+	-	+	-
Zipactis saitis Hewitson	+	-	-	-
Lethe rohria yoga Fruhstorfer	-	-	-	-
L. rohria neelgheriensis Guerin	+	+	-	-
L. europa Fabricius	-	-	-	-

Pieridae

Appias pauline galene Felder	-	-	-	-
A. lagela (Moore)	-	-	-	-
A. libythea	-	-	-	-
A. indra Moore	+	-	+	-
Delias eucharis Drury	+	+	+	+
Cepora nadina? cingala Moore	-	+	-	-
Cepora sp.				
Eurema blanda Boisduval	-	-	-	+
E. hecabe Lin.	+	+	+	+
E. laeta Boisduval	+	+	+	-
E. brigitta Stoll.	-	+	+	+
E. sp nr. *lacteola* Dist.	-	-	-	+
Catopsilia pomona Fb.	-	-	-	+
C. florella	-	-	-	-
C. pyranthe	-	-	-	-
Catopsilia sp.	-	+	+	+

Leptosia nina (Fabricius)	-	+	+	+
Libytheidae				
Libythea myrrha Godart	-	-	-	-
HETEROCERA (MOTHS)				
Drepanidae				
Teldenia Sp.				
Phalacra vidhisara Walker	-	-	-	-
Tridrepana fulvata	-	-	-	-
Thyrididae				
Striglininae				
Banisia myrtaea (Drury)	-	-	-	-
Pyraloidea				
Pyralinae				
Tyndis hypotialis (Swinhoe)	+	-	+	-
Peoriinae				
Prophtasia pyrostrota (Hampson)	-	-	-	-
Evergestiinae				
Crocidolomia pavonana (Fabricius)	-	-	-	+
Culladia admigratella Ragonot	+	-	-	+
Ancylolomia chrysographella Kollar	+	-	+	+
Pyraustinae				
Musotima suffusalis Hampson	+	+	-	-
Cataclysta blandialis Walker	+	+	-	-
Pycnarmon caberalis Guenee	+	+	+	-
Agrotera basinotata Hampson	+	+	+	-
Aetholix flavibasalis Guenee	+	-	+	-
Pagyda salvalis Zeller	+	+	-	+
P. traducalis Zeller	+	+	+	+
Cnaphalocrocis sp.	+	+	+	+
Marasmia venilialis Walker	+	+	+	+
Syngamia abruptalis Walker	+	+	+	+
S. abjungalis Walker	+	+	-	-
Aethaloessa floridalis Zeller	+	+	-	-
Dichocrocis punctiferalis Walker	+	+	+	+

D. plutusalis Walker	+	-	+	-
Botyodes asialis Guenee	+	+	+	+
Sylepta lunalis Guenee	+	+	+	+
S. quadrimaculalis Kollar	+	-	+	+
S. derogata Fabricius	+	-	+	+
S. tibialis (Moore)	+	-	-	-
S. balteata Fabricius	+	-	-	-
Agathodes ostentalis Hubner	+	+	+	+
Artroschista hilaralis Walker	+	+	-	+
Parotis marinata Fabricius	+	-	-	-
P. marginata Hampson	+	+	+	+
P. vertumnalis Guenee	+	+	+	+
Glyphodes stolalis Guenee	+	+	+	+
G. itysalis Walker	+	+	+	+
G. bivitralis Guenee	+	+	+	+
G. caesalis Walker	+	+	+	-
G. bicolor Swainson	+	-	-	-
G.indica Saunders	+	-	+	+
Phlyctaenia tyres Cramer	+	+	+	+
Eucalsta filigeralis Lederer	+	-	-	-
E. defamatalis Walker	+	-	-	-
Nausinoe perspectata Fabricius	+	-	-	-
N. geometralis Guenee	+	+	+	+
Leucinodes orbonalis Guenee	+	+	+	+
Crocidophora ptyophora Hampson	+	+	+	+
Pachyzanca licarsisalis Walker	+	+	+	+
P.cynaralis Walker	+	+	-	-
Eutectona machaeralis Walker	+	+	+	+
Maruca testulalis Geyer	+	+	+	+
Filodes fulvidorsalis (Hubner)	-	-	+	+
Daulia afralis Walker	+	-	-	+
Pardomima distorta (Moore)	+	+	+	-
Hyalobathra miniosalis (Guenee)	+	+	+	+
Pyrausta phoenicealis Hubner	+	+	+	+
Phycitinae				
Ephestia cautella (Walker)	+	+	+	+
Nephopteryx artisquamella Hampson	-	-	-	-
Epicrocis lateritialis Walker	+	+	+	+
Hyalospila leuconeurella Ragonot				
Etiella zinckenella Treitschke	+	+	+	+
Euzophera? subarcuella Meyrick	+	+	+	+

Geometridae

Astygisa Sp.				
Fascellina plagiata Walker	-	-	-	-
Gasterocome pannosaria Moore	-	-	+	-
Corymica pryeri Butler	+	+	+	+
Hypephyra cyanosticta Hampson	-	-	+	-
Luxiaria postvittata Walker	-	-	-	-
L. sp.? *subrasata* Walker	-	+	+	-
Buzura sp. ? *suppressaria* Guenee	-	+	+	+
Cleora Sp. prob. *alienaria* Warren	-	+	+	+
Cleora sp.				
Cleora sp.				
Menophra sp ? inouei Sato	-	-	-	-
?Eurytaphria sp.	+	-	-	+
?Catoria sp.	-	-	-	+
Ectropis sp. ?*breta* Swinhoe	-	-	-	+
Hypomecis pallida Hampson	-	-	-	-
H. sp. nr. *dentigerata* Warran				
?Hypomecis sp.				
Xanthorhoe sp. ?*molata* Felder	-	-	-	+
Scopula sp. ?nr. *pulverosa* Prout	-	-	-	-
Scopula Sp.				
Timandra sp. ?*nelsoni* Prout	-	-	-	+
Ptochophyle togata Fabricius	+	+	+	-
Polynesia sunandava Walker	+	+	+	-
Petelia sp. of *medardaria* Herrich-Schaffer group-	-	+	+	-
Fascellina sp. ?*chromataria* Walker	+	+	+	-
Hypochrosis festivaria Fabricius	-	+	+	-
H. pachiaria Walker	-	-	+	-
H. sp.?*abstractaria* Walker	+	+	+	-
Sabaria costimaculata Moore	-	-	+	-
S. sp. nr. *rondelaria* Fabricius				
S. incitata Wlt.				
Semiothisa sp. prob. *nora* Walker	-	-	-	-
S. quadraria Moore				
S. sp. prob. *myandaria* Walker	+	-	+	+
Ourapteryx marginata Hampson	-	-	-	-
Borbacha sp.	+	+	+	+
Lonographa sp. ?*simpliciaria* Walker	-	+	-	+
Abraxas sp. of *poliaria* Swinhoe group	+	-	-	-
A. sp. near *latizonata* Hampson	-	-	-	-
Scardamia rectilinea Warren	-	-	+	+

Plutodes sp ?*discigera* Butler	-	-	+	-
Ecliptopera subapicalis Hampson	-	-	-	-
E. dissecta Moore	+	+	+	-
Uliocnemis partita Walker	-	-	+	+
U. biplagiata Moore	-	+	-	-
Archaeobalbis cristata Warren	-	+	-	-
Pachyodes luteipes Felder	-	-	-	-
?*Hemithea* Sp.				
Combaena inductaria Guenee	-	-	-	+
Neromia carnifrons Butler				
Pingasa ruginaria Guenee	-	-	+	+
Eumelia rosalia Stoll	-	+	+	+
Sauris sp.	-	+	+	+
Elpho Sp.				
Anisephyra ocularia (Fabricius)	-	-	-	-
Callidulidae				
Cleoseris catamitus Humbner	-	-	-	-
Uranidae				
Psuedomicronia Sp.				
Callidulidae				
Cleoseeris catamitus Hubner	-	-	-	-
Noctuidae				
Neochera dominia Cramer	-	-	-	-
Condica illecta Walker	-	-	-	-
Achaea janata Fabricius	-	-	+	+
Ercheia cyllaria Cramer	-	+	+	+
Callopistria rivularis Walker	+	+	-	+
Paracrama latimargo Warren	-	-	-	-
Earias flavida Felder	-	+	-	+
Maceda mansueta Walker	+	+	-	-
Labanda fasciata Walker	+	+	-	-
Nycteola grisea Hampson	-	-	-	-
Blenina lucretia Dalman	+	+	-	+
Lophoptera illucida Walker	-	-	-	-
Hadennia sp. ?*prunosa* Moore	-	+	-	-
Bocana manifestalis Walker	+	+	-	+
Rhynchina curvilinea Hampson	-	-	+	+
Britha pactalis Walker	-	-	-	-
Pseudogyrtona perversa Walker	-	-	-	-
Eustrotia marginata Walker	-	-	-	-
Ozarba sp. ?*punctigera* Walker	-	-	+	+
Maliattha erecta Moore	-	-	-	+

Corgatha semiparata Walker	-	-	-	-
Anomis sabulifera Guenee	-	-	-	+
Tinolius quadrimaculatus Walker	-	-	-	-
Nola cingalesa Moore	+	-	+	-
Masalia bimaculata Moore	-	-	-	-
Janseodes melanospila Guenee	-	-	-	-
Sasunaga sp. *?tenebrosa* Moore	-	-	-	-
Mythimna curvilinea Hampson	-	-	-	+
M. reversa Moore	-	-	-	-
M. vittata Hampson				
Mythimna sp.				
Tirracola plagiata Walker	-	-	-	-
Athetis renalis Moore	-	+	-	-
Xenotrachea albidisca Moore	-	-	-	-
Mudaria (= *Plagideicta*) sp. *?leprosticta* Hampson	-	-	+	-
Digama marchalli Guerin	-	-	-	-
Blenina sp. nr *lichenosa* Moore	-	-	-	-
Carea endophaea Hampson	-	-	-	-
Ericeia sp. *?inangulata* Guenee	-	-	-	-
Rhesala moestalis Walker	-	-	+	+
Saroba pustulifera Walker	-	-	-	-
Hydrillodes sp. prob. *nilgirialis* Hampson	+	-	-	-
Thyas honesta Hubner	-	+	+	+
Rhytia hypermnestra (Stoll)	-	-	-	-
Elygea materna (Linnaeus)	-	+	+	+
Othreis fullonia (Clerck)	-	-	-	+
Episparis liturata (Fabricius)	-	-	-	+
Targalla ludatrix (Walker)	-	-	-	-
Erebus caprimulgus	-	+	-	+
E. ephesperis				
Arte sp.				
Sarobides sp.	-	-	+	-
Oxyode sp.	-	-	+	+
Arctiidae				
Amata extensa Walker	-	+	+	+
Argina syringa Cramer	-	+	+	+
A. astrea Drury	-	+	+	-
Pericallia sp. of *ricini* Fabricius complex	+	+	-	+
Eilema tumida Walker	-	+	-	+
E. sp. ? *obliterans* Walker	-	+	+	-
Eilema tetragona Walker	-	-	+	-
? Eilema sp.				
Eilema sp.				

Macotasa sp.? *nubecula* Moore	-	-	-	-
Nilgiricola sicciana Hampson				
Siccia taprobanis Walker	+	+	+	-
Cyme gratiosa Guerin - Meneville	-	-	-	+
Asura metamelas Hampson	-	-	-	-
A. sp. *?obsoleta* Moore	-	-	-	-
A. arcuata Moore	-	+	+	-
A. rubricosa Moore	-	-	-	-
Asura sp.	+	+	+	-
Eugoa sp. of *bipunctata* Walker complex	-	-	-	-
Cyana sp. nr. *bianca* Walker	-	-	+	+
Spilosoma sp. *?mona* Swinhoe	+	-	-	-
S. ananda Roepke	-	-	-	+
Spilosoma sp.				
Pangora matherana Moore sp. *rubelliana* Swinhoe	-	-	+	-
Paraplastis hampsoni Swinhoe	+	-	+	-
Lemyra sp.				
Paraona splendens Butler	-	-	+	-
Ceryx transitiva Walker				
Evessa sp.				
Oeonislis entella Cramer	-	-	-	+
Cyana sp.	+	+	+	+
Cyana malayensis Hampson	+	+	+	+
Rhodogastria astveus Drury				
Asota plana Walker				
Asota producta Butlen				
Nyctemera coleta Cramer	-	-	+	+
Nyctemera adversala Shallev				
Nyctemera baulus Boisduval	-	-	+	+
Lymantriidae				
Cispia charma Swinhoe	+	+	-	-
Lymantria sp. probably *kanara* Collenette	-	-	-	-
Aroa sp. of *plana* walker complex	-	-	-	-
Redoa sp.				
Redoa sp.	-	-	-	+
Euproctis bipunctapex Hampson	+	-	+	-
E. fraterna Moore	-	-	-	-
Notodontidae				
Poliostauropus grisea Hampson	-	-	-	-
Tarsolepis rufobrunnea Nakamura	-	-	-	-
Phalera javana Walker	-	-	-	-
Dadusa nobilis Walker	-	-	-	-
Cerura sp.	-	-	-	-

Limacodidae				
Miresa argentifera Walker	-	-	-	-
Caissa gambita Hering	-	-	-	-
Scopelodes sp. prob. *venosa* Walker	-	-	+	+
Susica sp. *?himalayana* Holloway	-	-	-	-
Bombycidae				
Penicillifera sp. prob. *apicalis* Walker	-	-	-	-
Tortricidae				
Nenomoshia poetica Meyrick	-	-	-	-
Olethreutes paragramma Meyrick	-	-	-	-
Lasiognatha mormopa Meyrick				
Dactyloglypha harmonica (Meyrick)				
Gelechidae				
Dichomeeris sp.				
Cossidae				
Xyleutes sp.	+	+	+	+
Zeuzera indica Herrich Schaffer			+	+
Saturnidae				
Argema maenas Doubleday	+	+	+	+
Attacus atlas Linnaeus	+	+	+	+
Loepa Sikkima Moore	-	-	+	+
Lasiocampidae				
Cyclophragma sp.				
Sphingidae				
Acherontia lachesis Fabricius	-	+	+	+
Meganoton sp.				
Oxyambulyx sp.				
Agrius sp.				
Hippotion boerhaviae Fabricius	+	+	+	+
Theretra sp.	-	-	+	+
Macroglossum aquila Biosduval	-	-	-	-

+ Species present

Table 3.2.

List of some rare butterflies recorded from the Nilgiri Biosphere Reserve

Family/Species	Species recorded specifically from Silent Valley in the present study(*)	Remarks
Papilionidae		
Chilasa clytia clytia Lin.	*	Protected, Sch. I
Troides minos Cramer	*	
Pachliopta pandiyana Moore	*	
Papilio liomedon Moore	*	Protected, Sch. I
P. dravidarum Woodmason	-	
P. budha Westwood	*	Unable to survive in distrubed forests
Graphium doson eleias Fruh.		Evergreen forests
Pathysa antipathes alcibiades Fb.	*	Wettest rainforest
Pieridae		
Cepora nadina remba Moore		Wested rainforest
Colias nilagiriensis Feld. & Feld.		South Indian endemic
Celatoxia albidisca Moore		Montane Sholas
Prioneris sita Feld. & Feld.		Protected, Sch. IV
Appias indra shiva Swinhoe		Protected, Sch. II
A. libythea libythea fb.		Protected, Sch. IV
A.lyncida latifascia Moore		Protected, Sch. II
A.albina darada Feld. & Feld.		South Indian endemic
Lycaenidae		
Arhopala canaraica Moore		Rare
A. abseus indica Riley		Rare
Zinaspa todara todara Moore		Scarce
Spindasis abnormis Moore		Scarce
Castalius rosimon rosimom Fb.	*	Protected Sch. I
Rachana jalindra macarita Fruh.		Very Rare
Chilaria othona othona Hewit.		Rare
Rapala lankana Moore		
Tarucus callinara Butl.		Protected, Sch. II
Lampides boeticus Lin.		Protected. Sch. II

Nacaduba pactolus		Protected, Sch. II
Spindasis elima elima Moore		Protected, Sch. II
S. lohita Moore		Protected, Sch. II
Pratapa deva Moore		Protected, Sch. II
Tajuria cippus-cippus (Fb)		Protected, Sch. II
Danaidae		
Parantica nilgiriensis Moore	*	Rare
Idea malabarica Moore	*	Rare
Satyridae		
Zipactis saitis Hewit.	*	Wettest rainforest Protected, Sch. II
Mycalesis anaxias anaxias Hewit.		Protected. Sch. II
Amathusinae		
Discophora lepida lepida Moore		Wettest rainforest
Nymphalidae		
Cirrochroa thais thais Fb.	*	Wettest rainforest
Cethosia nietneri mahratta Feld	*	Wettest rainforest
Doleschallia bisaltide malabarica Fruh.		Rare
Hypolimnas missippus Lin.	*	Protected, Sch. I
Neptis soma palnica Eliot		Very rare, wettest rainforest Protected, Sch. II
N. columella nilgirica Moore		Very rare, Wettest rainforest
Parthenos sylvia Moore		Protected, Sch. II
Euthalia telchinia Men.		Protected, Sch. II
Gerosis bhagava bhagava Moore		Rare
Sarangesa dasahara davidsoni Swinhoe		Rare, In lowland forest
Tapena twaithesi twaithesi Moore		Rare, In lowland evergreen forests
Odontoptilum angulata angulata Feld. & Feld.		Rare, In lowland forests
Polyura schreiber wardii Moore		Very rare, wettest rainforest
Caprona alida vespa Evans		Very rare
Aeromachus pygmaeus Fb.		Limited to W. Ghats
Sovia hyrtacus de Niceville		S. Indian endemic

Thoressa honorei de Niceville	S. Indian endemic
T. sitala de Niceville	S. Indian endemic
T. astigmata Swinhoe	S. Indian endemic
T. evershedi Evans.	S. Indian endemic
Udaspes folus Cramer	Rare
Arnetta mercara Evans	Endemic to W. Ghats
A. vindhiana nilgiriana Moore	Endemic to S. and Central India
Cupitha purreea Moore	Scarce
Quedara basiflava de Niceville	Rare, S. Indian endemic
Oriens concinna Elwes & Edwards	S. Indian endemic found in montane & sub tropical forests
Potanthus pallida Evans	Rare
Pelopidas subochracea subochreacea Moore	Rare
Polytremis lubricans lubricans Herr. Schf.	Rare, found in Wettest evergreen forests
Caltoris canaraica Moore	S. Indian endemic

Table 3.3 Number and percentage of species in each family collected from the study plots (% given in brackets)

Families	Plot I	Plot II	Plot III	Plot IV	Total
Pyralidae	26 (21.14)	21 (25.30)	26 (32.13)	12 (30.00)	85
Geometidae	21 (17.07)	11 (13.25)	14 (17.28)	11 (27.50)	57
Drepanidae	-	1 (1.20)	-	-	-
Eipiplemidae	-	2 (2.41)	1 (1.23)	1 (2.50)	4
Notodontidae	-	-	1 (1.23)	1 (2.50)	2
Lymatriidae	4 (3.25)	8 (9.64)	1 (1.23)	3 (7.50)	16
Arctiidae	22 (17.88)	15 (18.07)	11 (13.58)	9 (22.50)	57
Noctuidae	36 (29.27)	23 (27.73)	24 (29.63)	3 (7.50)	86
Sphingidae	9 (7.32)	1 (1.20)	1 (1.23)	-	11
Lasiocampidae	2 (1.63)	1 (1.20)	1 (1.23)	-	4
Saturnidae	3 (2.44)	-	-	-	3
Cossidae	-	-	1 (1.23)	-	1
Total Number of species	123	83	81	40	

Table. 3.4 Species diversity index for the four plots sampled

Plot No. and locality	No. of families	No. of species	No. of individulas	Species diversity index
Plot 1	8	123	580	3.42
Plot 2	9	83	319	1.9
Plot 3	10	81	327	0.43
Plot 4	7	40	180	0.4

Table 3.5 Similarity index values for the four localities studied

	Similarity index values			
Plot Nos.	I	II	III	IV
I		61	64	42
II			60	59
III				56
IV				

4. COMMUNITY ECOLOGY OF BIRDS IN SILENT VALLEY

E.A. Jayson

Division of Wildlife Biology

Contents

4.1 Abstract

The objectives of the study were to find out the composition and abundance of avifauna, to study the vertical distribution of bird community and to work out the foraging ecology of birds. The study was based on observational methods, using variable-width line transects. Out of the two study areas selected one was near Sairandri and another one at Mukkali. Fiftythree species were recorded from the first study plot and 46 species from the second one. An increase in total number of birds, density and species was observed during dry months. Eleven migrant species were recorded from the area. One group of birds showed stable density through out the months while the other group showed reduction during monsoon months. Species diversity of first site was 3.06 and at the second site it was 2.95. Similarity index between first and second study site was 0.65. Most of the species prefered height upto 20m. Out of the five foraging methods identified the most commonly used one was probing and the main food site was foliage. The reasons for the reduction of birds during monsoon months and the presence of more generalistic feeders were discussed.

4.2. Introduction

Kerala is rich in bird fauna and a total of about 400 species has been recorded from the State. Earlier studies on birds in the State was mainly centered on survey and listing of species (Vijayan 1978, Cherian 1983, Nair *et al.* 1985). in various wildlife sanctuaries. Few detailed studies on the biology and ecology of different species viz. drongos, crow pheasants, and babblers also were undertaken previously by some workers of University of Calicut and only a few studies have been undertaken in the State on birds at the community level. Altogether about hundred species of birds were recorded from Silent Valley by the earlier workers (Anonymous,1977). While doing environmental studies on the birds of Malabar region, Palat (1984) recorded different aspects of vertical distribution of birds in Silent Valley.

Bird communities constitute one of the important components of the fauna in natural forests and plantations. Insectivorous birds have a prominent role in reducing insects both in natural forest and plantations. Frugivorous birds form a vital link in seed distribution and natural regeneration of trees. Mac Mahon *et al.* (1978) defined animal communities as "groups of interacting populations, among which no gene exchange is taking place, but whose demography or gene pools are affected by the interaction" Another definition of biotic community is that it is an assemblage of populations living in a prescribed area or physical habitat. It is considered to be an organised unit to the extent that it has characteristics additional to its individual and population components and functions as a unit through coupled metabolic transformations. The primary reason why a community approach should be taken to study species is that as the community goes, so goes the organism. Due to this, the best way to maintain or control a species, whether we wish to encourage or discourge it, is to modify the community, rather than to make a direct influence on the organism. Some of the objectives of the community level studies are to identify recurrent patterns of species composition, guild structure, diversity and such other parameters.

It has been reported that populations of tropical bird species are stable as compared to temperate countries (Wright, 1979). He had shown that most insectivorous understory birds do not differ significantly in abundance between various study sites, despite demonstrated difference in food availability and species density of potential competitors. Greenberg (1986) had also demonstrated that some species of tropical forest birds have very stable populations even in the phase of environmental fluctuations. Reason for this stability is attributed to climatic features like stable photoperiod, availability of food, absence of long range migration and in some cases even local migration. This hypothesis of stability is also discussed in the study. Further, any study at community level is feasible in the case of birds rather than other vertebrate groups because birds are conspicuous and easy to census. Another aim of the study was to provide information on the requirements of birds which will help forest managers to maintain suitable habitats for the diverse avifauna.

The objectives of the present study:

1. To find out the composition and abundance of avifauna in Silent Valley.
2. To find out the seasonal occurrence of birds
3. To study the vertical distribution of bird community
4. To record the foraging ecology of birds.

Study area

Two intensive study areas were selected. One was at old dam site (Sairandri) and another one at Mukkali (Fig.4.1). Forests of both areas are partially disturbed. Most disturbance had taken place in late seventies and early eighties while felling and pre construction work of the proposed dam was undertaken. But after the declaration of the 90 Km^2 area as Silent Valley National Park in 1984, this tract got maximum protection from poaching and fire. Consequent to this, the bird community is going to change in species composition with in a few years along with the progress in the succession of the vegetation.

The second study site comes under the buffer zone of Nilgiri Biosphere Reserve. On one side of this transect was coffee and pepper plantations and on the other side semi-evergreen forest. These two study sites presented, two bird communities separated by about 20 km, but with varying levels of disturbance and vegetation structure and first one was in core area and the second one in the buffer zone of Nilgiri Biosphere Reserve. Comparatively undisturbed forests are available at far away places in the core area but logistics and

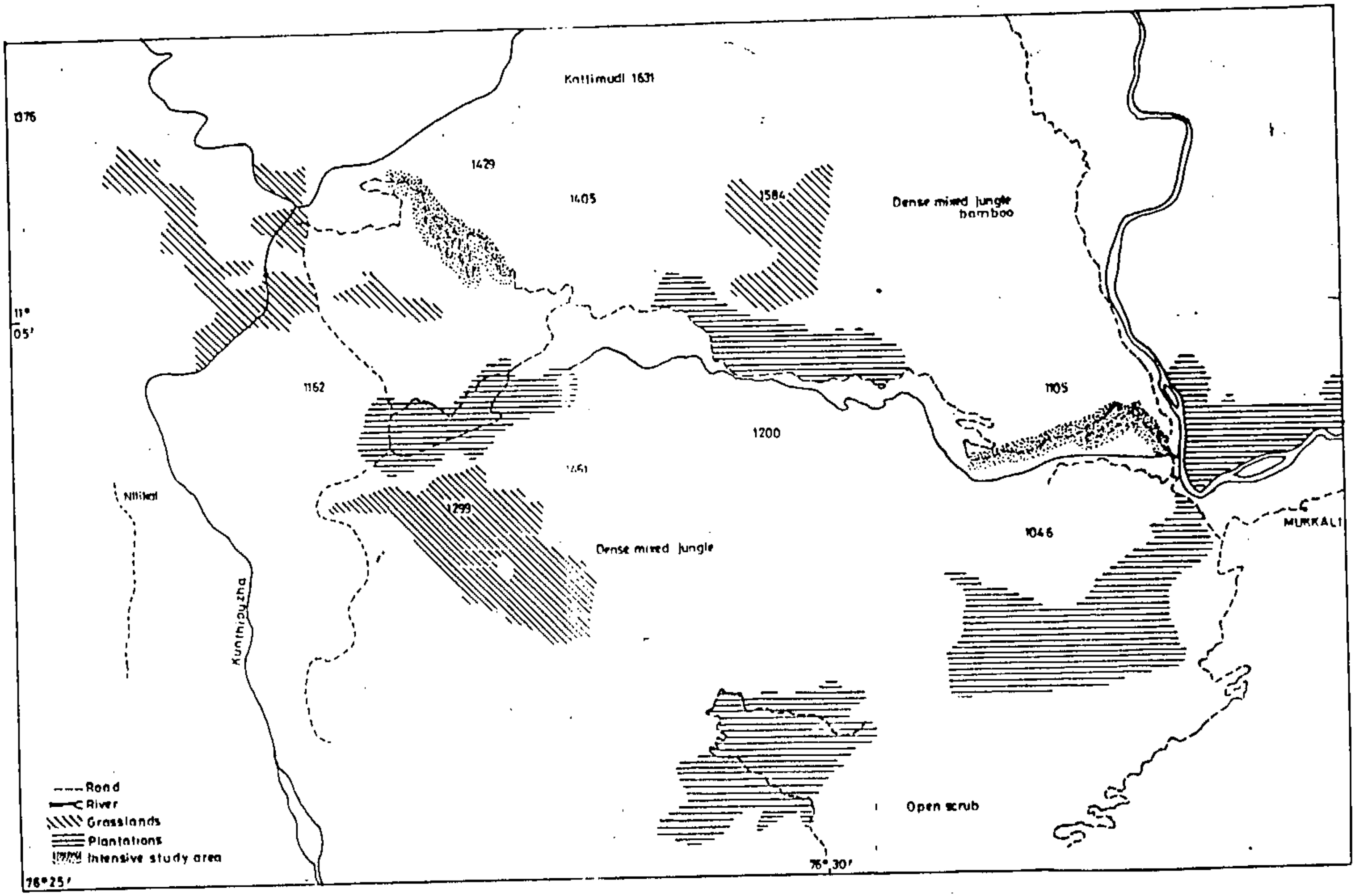


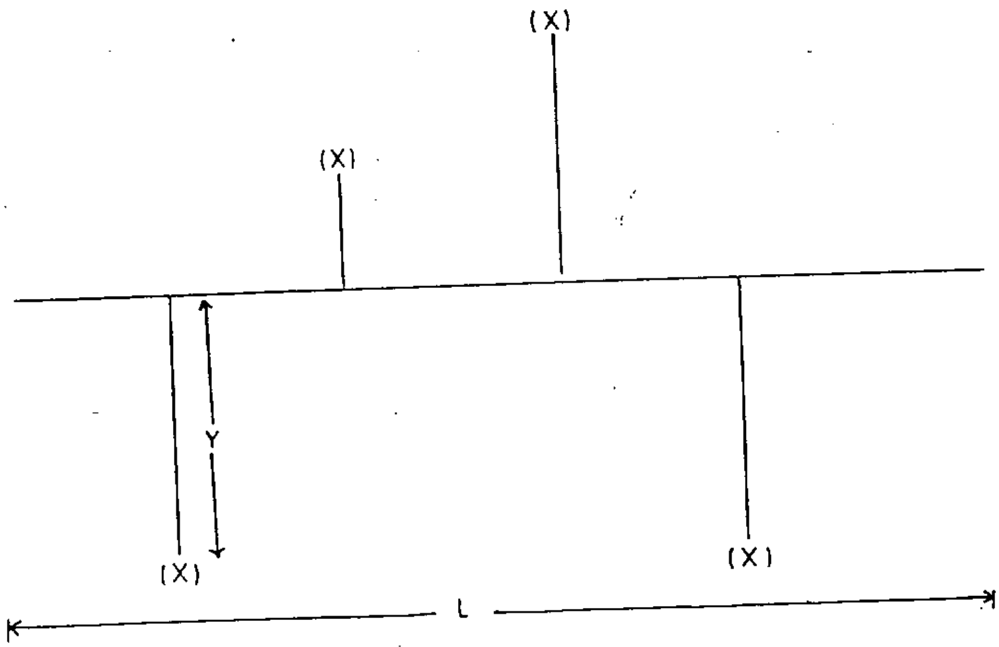
Fig.4.1. Intensive Study area.

resources for including such tracts as study sites were not available.

4.3. Methods

Counting of birds in tropical evergreen forests is riddled with intricate problems. Main difficulties are in locating the bird in the thick canopy and in identifying the bird visually in the shortest time. Another method is to identify the bird based on songs and calls. Different methods are available for estimating densities of terrestrial birds (Pyke 1984). Some of the methods use line transects of fixed or variable width and point transects (Bell 1980, Recher *et al.* 1983b, Bell and Ferrier 1985, Ford *et al.* 1985), circular plots (Recher, *et al.* 1983b) and mapping of terrestrial birds (Loyn,1980). Shields (1979) had reviewed the avian census techniques. After considering all the above mentioned methods, variable width line transects (King census method) was adopted for this study (Sale and Berkmuller, 1988).

In this method the observer walks through a fixed path (a) fig.4.2 tallying the birds seen or heard on both sides of the path (x) and recording the perpendicular distance (Y) of the bird from the



X _ Position of the bird
Y _ Perpendicular distance
L _ Total length

Fig.4.2. Schematic representation of variable - Width line transect

path. Whenever a bird is spotted, it is identified and details like number of birds in the group, height at which it is located in the canopy, habitat, and foraging behaviour also were noted down. Altogether two line transects were selected one each in the each intensive study area. Each transect was 4 km in length. The first transect covered the representative habitats of the area like evergreen forest, grasslands, burned areas, and the second transect covered the habitats like grasslands, deciduous forests, coffee estates, and fire burned forests. Census was carried out twice in each month starting from May 1988 to December 1989 in the first transect and once in each month in the second transect. No data was collected on nocturnal birds.

Calculation of density

Density is calculated from the following formula (King census method).

$$\text{Density (D)} = \frac{n}{Y \times 2 \times L}$$

Where
- n - number of birds seen or heard on both sides of the transect.
- L - total transect length
- 2 - indicates two sides of the transect
- Y - mean perpendicular sighting distance.

Following assumptions were made while doing the census. Observer always covered the distance of 4 km within a fixed duration of 90 minutes, thus covering 2.6km/hour and this speed was maintained throughout the census. In order to maintain uniformity all the the census were completed between 7 A M and 10 A M. Seasonal difference in detectability are common for most of the bird species (Emlen,1971). These differences result from changes in weather and habitat structure. Increasing foliage density decreased the visibility of birds. But in Silent Valley habitat structure was identical in all seasons and only rainfall had some influence on detectability.

The main lacunae of this method is the under estimation of density either because the bird moves away from the observer before being located or because birds are overlooked. It is reported that by using fixed width line transect, there is a chance to miss at least 50% of density (Franzneb, 1981 and Hilden, 1981). Bell and Ferrier (1985) reported that transect census underestimated densities of many species but that those of variable width (Emlen, 1971) are reliable than fixed-width transects.

Similarity index

An index of similarity between the two transects was calculated using the following formula. (Odum, 1971).

$$\text{Similarity (S)} : \frac{2C}{A + B}$$

A- number of species in sample A

B- number of species in sample B

C- number of species common to A and B

Species diversity

Species diversity was calculated using the Shannon index of general diversity ($\bar{H}$) (Odum, 1971).

$$\bar{H} = -\sum \left(\frac{ni}{N}\right) \log \left(\frac{ni}{N}\right)$$

$$= -\sum Pi \log Pi$$

Where ni = importance value for each species

N = total of importance values

Pi = importance probability for each species = $\frac{ni}{N}$

Phenology

Phenology was observed in each month on the line transect I, and following observations were made.

1. Number of tree, shrub and herb species in fruits, flowers, new leaf or yellow leaf along the transect.

Insect abundance

Insects on the ground, among herbs and grass were collected each month by sweeping. Every month one and half hours were spent for sweep netting. This was done on the line transect I in the same direction and in same place in each month.

Seasonality

Seasonal variation in species occurrence was worked out from the observational data. The main seasons are wet season (June to December) and dry season. (January to April).

Vertical distribution

Data for this was collected during the census of birds. Whenever a bird was noted the height at which the bird was observed was also noted down. This was used to calculate the vertical distribution of birds in the canopy. Data from both the transects were pooled separately and classified into six groups, 0-4 m, 5-9m, 10-19 m, 15-19m, 20-29m and 30-50m as in the case of foraging analysis. From this, prefered height for each species is calculated.

Foraging

Data on foraging was collected while doing the census, by direct observation and all data were pooled for analysis. Whenever a bird was observed it was followed until it made a successful foraging attempt like sucking honey from a flower or capturing an insect. A single foraging record was then taken and allowing not less than 2 minutes for recording another attempt. For each observation, foraging method, substrate, food site and height of feeding also were recorded. The five categories of foraging methods are given below :-

1. Probe - Perched bird inserting beak at least partly into a substrate for collecting food

2. Glean - Perched bird taking food from a substrate
3. Sallying - Take food while both bird and food were in flight
4. Snatch- Take food in flight by snatching
5. Hover - Hovering in the air and picking the food

Similar foraging categories were used by Bell (1983), Ford (1986) and Recher *et al.* (1985) . The substrates were trunk, twigs, bark, air, ground and flower. In the case of bark, the bird was using the bark as a substrate to feed on the insects found in the bark. Food sites were trunk, foliage, bark, flower, air and ground. This is the actual site from where food was consumed by birds. Heights of foraging observations were classified in to six groups (0-4m, 5-9m, 10-14 m, 15-19m, 20-29m, and 30-40 m). All the data were pooled and subjected to clusture analysis.

4.4. Results

4.4.1. Occurrence of species

Line transect I covered all representative habitats, met with in the area except the riparian patches. Seven percent of this line transect went through grasslands, twenty percent through burned forests and about 69% went through evergreen forest. Riparian patches were excluded after an initial survey as it contained only a few water birds and the main objective of the study was to collect information on forests birds rather than on water fowls. Visibility was poor during monsoon due to heavy mist. The second intensive study area was sampled with another line transect. Visibility was good during all the seasons here.

Fiftynine species were recorded from the first study plot and 46 species were recorded from the second study plot. A variation in species occurrence was observed during different months of the years. Availability of species in different months for the two study areas is presented in Table 4.1 and 4.2. An increase in number of species was observed during dry season. Birds were classified into six groups according to their presence or absence during different months.

Very Rare	(VR)	-	Present	in	1 - 4	months
Rare	(R)	-	"	"	1 - 8	"
Common	(C)	-	"	"	1 - 12	"
Very common	(VC)	-	"	"	1 - 16	"

Based on the above classification, four species were found to be very common, nine species were common, eight species were rare and 32 species were very rare. This gives an indication of change of species in different months. Out of 122 species located in the study area 11 were migrants and others residents. Silent Valley is not a major wintering area of palaearctic migrants and most of the birds were showing only local movements. The migrants which are recorded from here are wagtails, orioles and rose finch. No wintering water fowls were recorded from the area. Most of the doves, pigeons , parakeet and black bulbuls were not recorded during rainy season, but were seen returning to the area with the retreat of the rain. Due to heavy mist and low activity of birds during monsoon their detectability was poor and this may be one reason for the lower number of species recorded during rains. In the case of second study area, out of the 46 species record, only 8 were seen more than 5 months and all others were recorded less than 5 months. A drop in the species diversity during monsoon is observed here also (Fig. 4.3) but not in same scale as that of the earlier one.

Table 4.1 Occurrence of species in different months, Transect-I

Species	Status	M	J	J	A	S	O	N	D	J	F	M	A	M	J
1. Southern tree pie	VC	p	p	p			p	p	p	p	p	p	p		
2. Paddy bird												p			
3. Hill myna	C	p				p		p	p	p	p	p	p		
4. M. whistling thrush	C		p	p		p	p			p	p	p	p		
5. T. flower pecker	R	p	p		p	p						p			
6. Bush chat	VR								p			p			
7. Imperial wood pigeon	C									p	p	p	p		
8. Yellowbrowed bulbul	VC	p	p	p	p	p	p	p	p	p	p	p	p		
9. G. woodpecker	C					p	p	p	p	p	p	p	p	p	
10.Scarlet minivet	R					p	p			p		p			
11.Sun bird	VC		p	p	p	p	p	p	p	p	p	p			
12.Grey jungle fowl	C	p	p		p		p	p		p	p	p	p	p	
13.Redvented bulbul	C			p	p		p	p	p	p	p	p	p		
14.Yellow wagtail	R					p	p	p	p			p			
15.Black bulbul	R							p	p	p	p	p	p		
16.Bush quail	R			p	p					p	p	p			
17.Parakeet	C	p		p	p	p	p	p		p	p	p			
18.Southern green pigeon	VR											p			
19.Racket tailed drongo	R			p				p			p	p	p	p	
20.Small green barbet	C					p	p	p	p	p	p	p	p	p	p
21.Blackwinged kite	VR				p							p			
22.Black drongo	R						p	p	p	p	p	p			
23.Swallow	R				p	p	p	p			p	p			
24.Jungle babbler	C			p	p	p	p	p			p		p		
25.Whitethroated munia	VR				p						p				
26.Lesser toed woodpecker	VR										p				
27.Paradise flycatcher	VR								p	p	p				
28.Spotted dove	VR								p						
29.Bluewinged parakeet	VR							p	p				p		
30.Spotted munia	VR								p						
31.Blossomheaded parakeet					p					p	p				
32.Blacknaped oriole	VR								p						
33.Emerald dove	VR								p				p		
34.Lorikeet	VR						p	p	p						
35.Chloropsis	VR								p						

36.Nilgiri flycatcher	VR						p						
37.Rubythroated yellow bulbul	VR							p					
38.Shikra	VR	p				p							
39.Nilgiri white eye	VR					p			p				
40.Grey wagtail	VR						p						
41.Warbler	VR						p						
42.Brahminy kite	VR				p								
43.Redwhiskered bulbul	R			p	p					p	p		p
44.Crested serpent eagle	VR		p		p						p		
45.Grey hornbill	VR			p									
46.Blackheaded oriole	VR									p			
47.Jungle crow	VR										p		
48.Wood pigeon	VR										p		
49.Chestnutheaded bee-eater												p	
50.Heart spotted woodpecker	VR											p	
51.Great black woodpecker												p	
52.White t.ground thrush	VR								p				
53.Great Indian hornbill	VR								p				
54.Forest wagtail	VR								p	p			
55.Rose finch													
56.Yellowcheeked tit	R				p								
57.Velvetfronted nuthatch	VR								p	p			
58.Black bird	VR										p		
59.Black eagle	VR									p	p		

VC- Very common, C- Common, R- Rare, VR- Very rare,

Table 4.2 Occurrence of species in differrent months- II Transect

Species	Jul	Sep	Nov	Jan	Mar	May	Jun	Jul	Sep	Dec
1.B.drongo	P	P	P	P	P		P	P	P	P
2.G.b.woodpecker	P	P		P			P		P	
3.Babbler	P		P	P			P	P	P	
4.R.v.bulbul	P	P	P	P		P	P		P	P
5.S.g.barbet	P	P	P	P	P	P	P	P		
6.Scarlet minivet	P	P	P		P				P	P
7.R.drongo		P	P	P		P	P		P	
8.Thrush		P								
11.Flower pecker			P			P				
12.R.w.bulbul			P	P	P	P		P	P	
13.S.t.Pie			P			P	P	P		
14.Tree pie			P							

15.Swallow	P		P				P	
16.W.h.babbler	P		P					
17.Warbler	P							
18.Black bulbul		P						
19.Flycatcher		P	P					
20.G.f.chloropsis		P						
21.G.j.fowl		P						
22.Sun bird		P	P	P		P		
23.Y.wagtail		P	P				P	
24.B.backed shrike			P			P		
25.Black eagle			P					
26.Bush chat			P		P			
27.Cukoo shrike						P		
28.P.flycater			P					
29.Common myna				P				
30.Crow-pheasant				P				
31.G.f.green pigeon				P				
32.Jungle owlet				P				
33.M.lorikeet				P				
34.R.r.parakeet				P				
35.Threetoed woodpecker				P				
36.Magpie robin					P			
37.Velvetfronted nuthatch					P			
38.Y.b.bulbul							P	
39.B.headed oriole							P	
40.Bronze drongo							P	
41.H.S.w.pecker							P	
42.Malabar trogon	P						P	
43.R.y.bulbul							P	
44.C.h.b.eater								P
45.Bush chat								P
46.C.s.eagle								P
47.G.hornbill								P

[B.drongo= Black drogo; G.b.woodpecker= Goldenbacked woodpecker; R.v.bulbul= Redvented bulbul; S.g.barbet= Small green barbet; R.drongo= Racket tailed drongo; R.w.bulbul= Redwhiskered bulbul; chloropsis= Goldfronted chloropsis; G.j.fowl= Greyjungle fowl; Y.wagtail= Yellow wagtail; P.flycatcher= Paradise flycatcher; G.f.green pigeon= Greyfronted green pigeon;M.lorikeet= Malabar

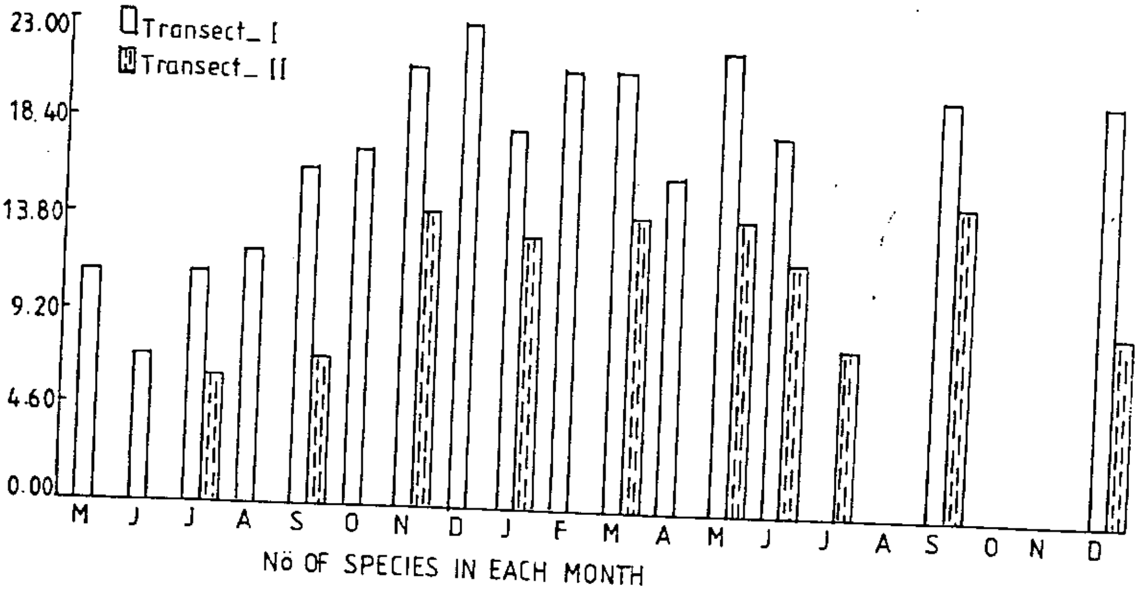


Fig. 4.3. Month-wise presence of species

lorikeet; Y.b.bulbul= Yellowbrowed bulbul;B.oriole= Blackheaded oriole; H.s.woodpecker= Heart spotted woodpecker; R.y.bulbul= Rubythroated yellow bulbul; C.h.b.eater=Chestnutheaded bee-eater; C.s.eagle= Crestedserpent eagle;G.hornbill= Grey hornbill].

4.4.2. Abundance of different species

Species density

The mean density of each species at each site is given in table 4.3 and 4.4. Out of 69 species observed in the intensive study areas, density of 28 and 39 species respectively have been calculated. Occurrence data of parakeets, quails, babblers and doves were pooled together for calculating density.

Birds can be grouped into two, based on difference in density over months. First group of resident birds showed almost a stable density while the second group registered an increase in density during dry months. The first group comprises grey jungle fowl, malabar whistling thurush, southern tree pie, yellowbrowed bulbul, small green barbet and bush chats. The second group is of parakeets, and doves, which showed an increase during dry months and a decrease in number during wet season while in some months they were absent. Small green barbet and parakeets showed maximum density during dry months in the second area. Compared to the first study site, overall density of different species was less in the second transect and here also there was slight increase in density during winter. Some species show consistent abundance in both the areas. Yellowbrowed bulbul was showing stablity in abundance in the first area while scarlet minivet and small green barbet in the second area.

Table 4.3 Density of birds in each month -Transect I (Birds/ha.)

Species	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Sep
B.drongo						0.69	2.10	3.25	0.13	0.1	0.42		0.63		0.56
Black w.kite				0.16							0.23				
B.w.woodpecker													0.58		0.63
B.h.oriole									0.31	0.13					
Bush chat									2.68		0.63	4.38	1.88	4.02	0.4
Crested serpent eagle					0.06		0.06							0.02	
Doves	0.78			0.03			1.04	0.33	0.39	0.39	1.25	2.70		9.58	
G.b.woodpecker	0.08				0.04	0.25		0.23	0.16	0.27	0.13		0.05	0.06	0.03
G.j.fowl	0.06		0.10		0.63		1.25	0.7	0.71	1.76		0.63		0.77	
Grey hornbill					0.13									0.16	
Hill myna	0.07				0.59	2.07	0.10	0.63	0.81	0.98	0.93	0.93	3.40	0.43	1.7
J.babbler			1.88	3.24		3.75	4.58		7.52		9.37	6.25	1.88		
M.lorikeet							0.63	0.18	0.63						
Mala.w.thrush		0.25	0.13		0.03	0.12			0.07			0.08	0.11	0.12	
Munia				0.11			2.05	0.5							
Parakeet	0.32		1.44	0.55	0.81	0.49	0.73	2.04	4.30	11.88	3.13	1.50	2.54	5.0	8.73
Quail		5.0	0.5	0.31					1.25	0.71	0.63	0.63	1.88		
R.t.drongo	0.32		0.06				0.08		0.08	0.05	0.63	0.54	1.07		
R.v.bulbul			0.25	0.42			1.25	0.13							
R.w.bulbul		0.25			0.2	1.85		1.50	0.25		1.25		1.25		1.67
S.g.barbet	0.14				0.63	0.35	3.75	1.89	0.3	0.14	0.15	1.12	0.63	0.13	0.63
S.t.pie	0.65	0.13	0.03			0.11	0.13	2.19	0.16	0.01	0.24	0.07	1.28	0.06	
Scarlet minivet					0.29		5.00		0.06		0.19	0.63	0.04		
Sun bird		0.33	0.69	0.35	0.52	1.51		2.23	0.83	18.25	1.79			1.67	
Swallow				0.31	1.25	6.50	0.15	10.00		12.5				9.38	22.5
Warbler					0.19		0.28			0.13					
Y.b.bulbul	0.48	0.41	0.50	1.35	2.87	2.15	1.60	2.94	3.84	3.67	3.03	4.67	6.38	5.42	
Y.wagtail					0.63	0.63		0.63				0.23		3.13	

Table 4.4 Density of birds in each month Transect II (Birds/ha.)

Species	July	Sep	Nov	Jan	Mar	May	Jun	Jul	Sep	Dec
B.drongo	0.04	1.94	0.25	0.43	0.13		2.50	0.1	0.21	0.45
Black bulbul				0.42						
Black eagle					0.13					
Bronze drongo			0.83					1.25		
Bush chat					1.25		1.30			2.5
C.myna						1.25				
Crow pheasant						1.25				
Cukoo shrike				0.14						
Flower pecker			0.38			2.5				
Flycatcher				3.75	1.25					
G.b.woodpecker	0.13	0.21		0.04			1.25	1.25		
G.f.chloropsis				0.75			10.00	0.63		
G.j.fowl				0.31						
Grey hornbill									0.08	
H.s.woodpecker								1.25		
J.babbler	0.67	6.97		2.00		1.19	1.82		4.06	
Jungle owlet						1.25				
M.lorikeet						3.74				
Magpie robin							2.5			
Malabar trogon									1.25	
P.flycatcher					1.25					
Parakeet			1.40		1.25	7.5				
R.drongo		1.56	0.13	0.25		1.25	0.42		1.25	
R.v.bulbul	0.58	0.83	0.25	2.50		2.5	0.91		0.12	0.94
R.w.bulbul			0.79	1.75	2.92	3.22			4.35	0.42
Ruby throat.y.bulbul									1.25	
S.g.barbet	0.03	0.25	11.25	0.93	0.83	1.25	1.14	0.46		
S.t.pie			0.83			2.5	5.0			
Scarlet minivet	1.00	5.00	5.00		0.75	0.02	3.75			
Smaller g.c.shrike										
Sun bird				2.5	5.00	2.08				0.73
Swallow			2.5		0.13				2.5	
Three toed woodpecker						0.08				
Thrush	0.42									
Tree pie			0.63							
V.f.nuthatch							1.25			
W.h.babbler			0.25	0.23						
Y.b.bulbul							1.25	1.08	1.25	
Y.wagtail					2.5				6.25	

Similarity index

A = 56

B = 45

C = 33

$$S = \frac{2 \times 33}{56 + 45}$$

$$S = \frac{66}{101} = 0.65$$

Similarity index between Transect I/Transect II = 0.65

Similarity index shows no variation between the two study sites. Only 33 species were common to both sites. The difference in species composition is mainly due to the difference in vegetation structure and variation in the disturbance.

Species diversity

Ratio between the number of species and "Importance Values" (numbers) of individuals is called species diversity (Odum, 1971). It is directly correlated with the stability of the ecosystem and will be high in biologically controlled systems. Species diversities were 3.06 and 2.95 in the first and second sites.

Total density

Total number of birds seen in each month for each calendar year is reported in the Fig.4.4 and density is shown in Fig.4.5. Number of

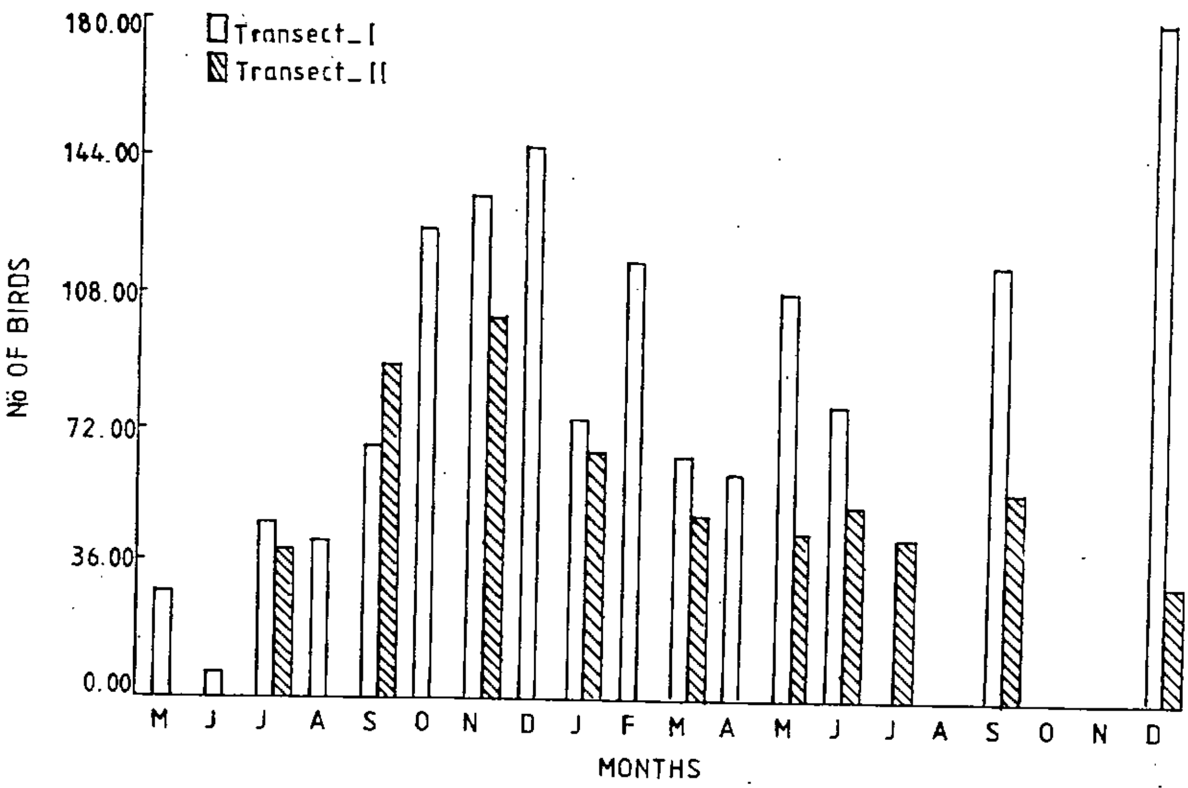


Fig. 4.4. Total number of birds seen each month at transect - I and transect - II.

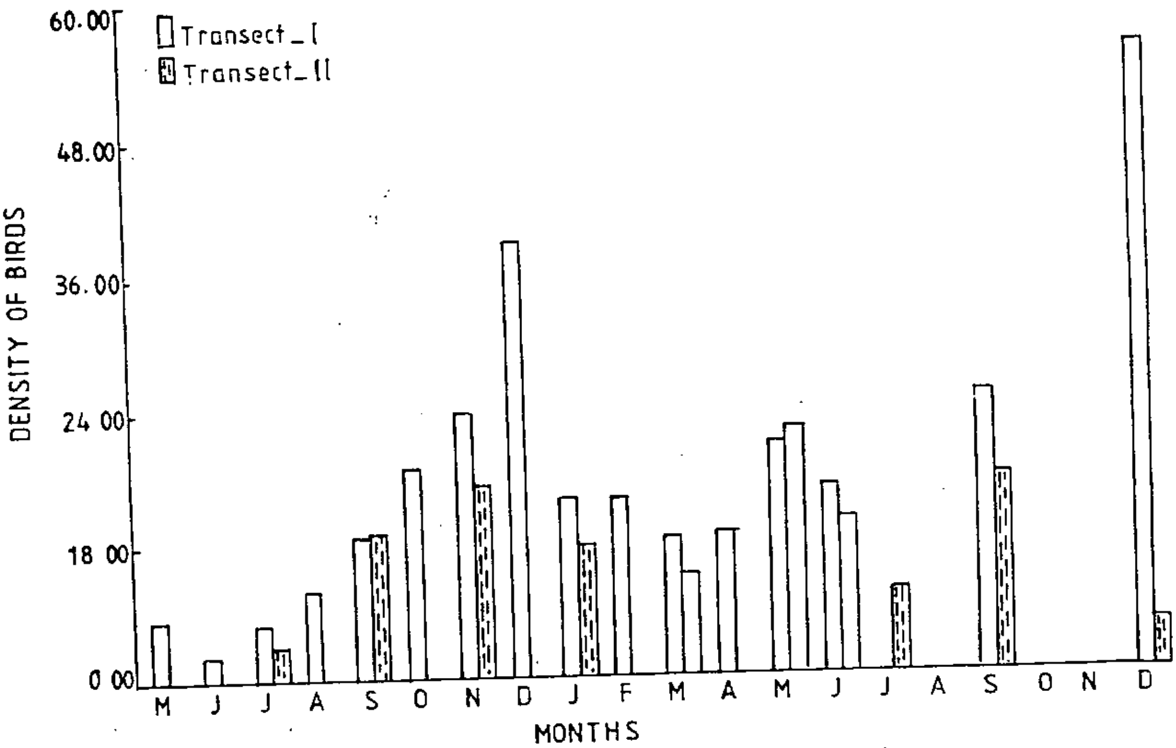


Fig. 4.5. Density of birds seen each month at transect - I and transect - II

birds were ranging from 7 to 180 in the first area and 30 to 102 birds in the second area. Density also showed same trends which is an index of abundance of birds. A slight reduction in the total number of birds, density and species was seen during monsoon months. The lower number of birds recorded in first year monsoon was due to the unfamiliarity with the area and conditions. Otherwise the population was almost stable. Such a drop during adverse climate was reported by Palat (1983). Reduction of birds during non-winter period and their increase during winter has been reported by Morrisson *et al* (1980). A similar trend was noticed in the second study site.

Insect abundance

Insects were monitored every month to correlate the abundance of birds with that of the available food. All the insects were identified up to the orders.They were *Orthoptera, Lepidoptera, Hymenoptera, Coleoptera, Hemipteroidea, Diptera, Odonata, Hymenoptera* and *Dictyoptera*.

Insect fauna showed two peaks of abundance. The first one was in the months of November - December and the second in the month of May. The first peak is after the south-west monsoon and the second with the first showers of south-west monsoon in May (Fig.4.6).

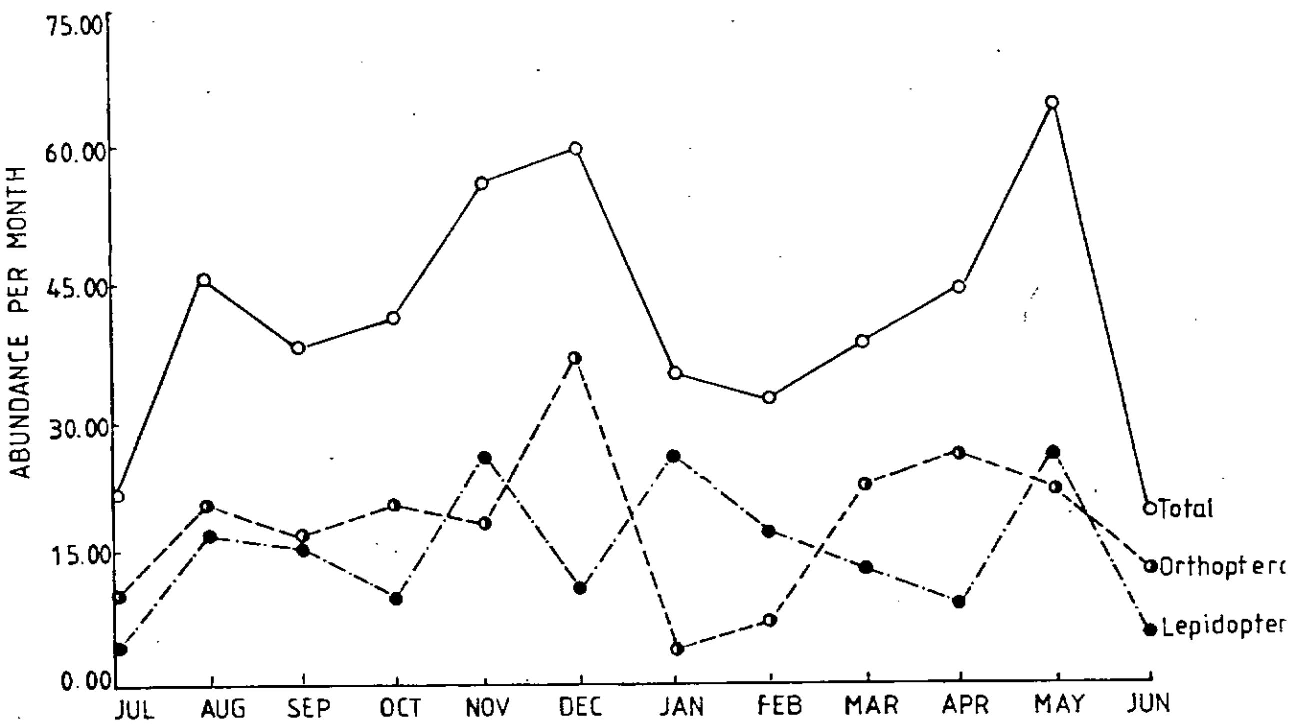


Fig.4.6.Insect abundance

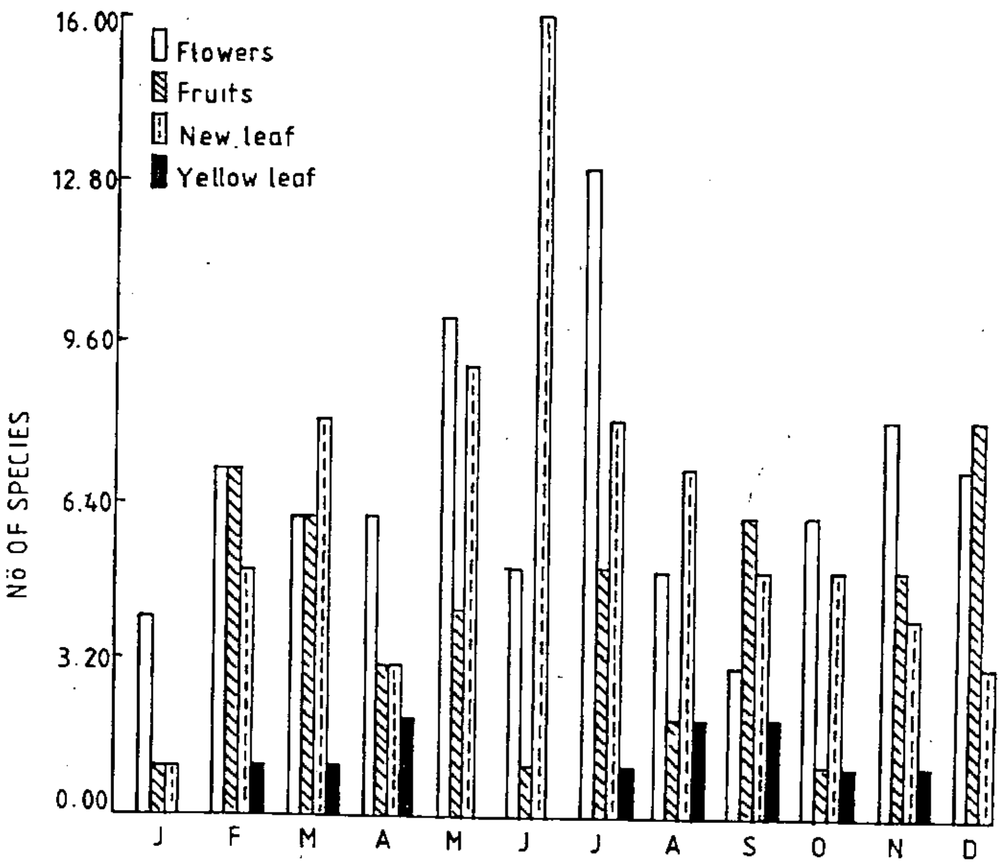


Fig. 4.7. Phenology (Trees, Herbs, Shrubs).

As only one method was employed for the collection of insects, information on insects in canopy levels is absent. But according to Pyke(1984) the correspondence between the seasonal patterns of insectivore density and the abundance of flying insects is not very high and is not improved by focusing on birds that fed mostly on flying rather than non-flying insects. Eventhough sampling was concentrated on ground and herb level, an indication on the change in insect abundance in various months was available with this collection method.

4.4.3. Vertical stratification in the canopy

Biological diversity is manifested in the tropical evergreen forests through various mechanisms and one such mechanism is the vertical distribution of different congeneric species in the the multitier canopy. Birds also adopt the same strategy for the use of resources in a multi-tier canopy. This allows different species of birds to occupy the same habitat at the same time.

Of the six classes of height categories in the first transect, only eleven species of birds used all of them, ie. the generalists, prominent among them being blackbulbul and black drongo. Eight species were ground feeders using the heights between 0-4 meters (Table 4.5). The height upto 20 m were extensievly utilised by large number of species than above 20 mt. Birds of prey like crested serpent eagle and blackwinged kite were seen always in the top canopy.

More or less similar observations were obtained from the second transect also. (Table 4.6). The height upto 20 m was used extensively. The birds which were expected above 30 m were almost absent except a few parakeets which were utilising the upper canopy. This habitat being a degraded one the hight of the canopy was short than the first area. Only seven species were found to use all the first five height categories here.

Table 4.5 Vertical height occupation (Transect-I)

Species	0-4	5-9	10-14	15-29	20-29	30-50
Black bulbul	5	1	2	2	6	3
Black drongo	12	8	4	4	1	5
Babbler	19					
Black bird	1					
B.headed oriole	1			1		1
B. winged kite	1					2
B.headed parakeet	4	2		1		2
Brahmniny kite	1					
Bush chat	29	3	1			
Bush quail	13					
Dove	8	1	1	1	2	5
Emerald dove	1	1				
Flower pecker	4	2	1			
Flycatcher	5	1				
G.j.fowl	21					
G. hornbill	2		1			
Ground thrush	2					
Hill myna	7	6	5	7	10	16
Lotten's sunbird	1		1	1		
M.lorikeet	1				1	1

M.whistling thrush	4	1	9	1	5	5
Munia	3	1				
N.w.eye	6	1				1
P.flycatcher	2					
Paddy bird	1					
Parakeet	10	3	4	4	9	10
Purple r. sunbird	1					
R.t.drongo	4		6	3	5	2
R.r.parakeet	4			3	2	
R.v.bulbul	4	1	3			
R.w.bulbul	13	4	4	1	1	
Rose finch	1	1				
S.g.barbet	18	5	4	7	4	10
S.minivet	3	1	1	1	2	2
Shikra	1					1
Sp.dove	1					
Sun bird	31	6	3	2	5	1
J.b.flowerpecker	2		1			
T.b. flycatcher	1					
V.f.nuthatch	1		1			
W.h.babbler	1					
Warbler	4					
Y.b.bulbul	58	44	45	24	10	11
Y.Cheeked tit	1					
Yellow Wagtail	10					
B.woodpecker		1	1			
G.b.woodpecker		6	2	5	2	
Imperial pigeon		1	1			3
Swallow		2	2	2		10
G.f.green pigeon			2			
S.tree pie			1			
R.t.y.bulbul			1			
Warbler			1			
Black eagle					1	2
Crested serpent eagle					2	1
G.f.chloropsis					1	
Lesser toed woodpecker					1	
Great Indian hornbill						1

Vertical height occupation(Transect II)

Species	0-4	5-9	10-14	15-19	20-29	30-50
Black drongo	4	3	2	4	4	
J.babbler	5	4	3			
Baybacked Shrike	1	1	1			
Bush chat	4	4	6			
Flower Pecker	1			1	1	
Flycatcher	2			1	1	
G.J. fowl	2					
M. trogon	1					
P.flycatcher	1					
Parakeet	1		1			4
R.t. drongo	2	4	2	1	1	
R.V.bulbul	4	3	3	1	1	
R.W. bulbul	4	6	7	4	4	
R.T.Y.bulbul	1					
S.g.barbet	3	1	7	1	1	
S.t. pie	2		2	1	1	
S.minivet	2		3	2	2	
Shrike	1	1				
S.g.cuckooshrike	1	1				
Sun bird	5	2	1	3	13	
Swallow	2		1	1	1	
Tree pie	1			1	1	
V.f.nuthatch	1					
W.h.babbler	1	1	1			
Y.b.bulbul	2	1	1	1	1	
Y.wagtail	7					
G.b.woodpecker		3	1	1	1	
G.f.Chloropsis			1	1	2	2
H.s.woodpecker			1			
Jungle owlet			1			
M. lorikeet			1			
Magpie robin		1				
R.r.parakeet		1				
Three t. woodpecker		1				
Black bulbul			1			
Black eagle			1			
Crested serpent eagle			1			
Crow-pheasent			1			
G.f.green pigeon			1			
B.h. Oriole				1	1	
Bronze drongo				2	2	
C. Myna				1	1	
Grey hornbill				1	1	
Thrush				1	1	

4.4.4. Foraging ecology of selected species

One of the key factors which contributes to the species diversity in evergreen forests is the specialisation in feeding. This specialisation is accomplished at different levels while feeding. The variations are in the nature of food, substrate on which food is searched, feeding method, the site of food and the height at which food is collected. All the above components are found to vary for each species.

Food

On the basis of food preference it is found that out of 61 species, majority were insectivorous (42%), followed by frugivorous (32%), graminivorous (15%), vertebrate feeders (7%) and omnivorous (4%). Food was abundant through out the year in the form of fruits and insects.

Trees on which some birds were found to feed

1. Goldenbacked woodpecker ------ *Lancium sp.*
2. Velvetfronted nuthatch ------ *Parcia macrura, Melia dubia*
3. Small green barbet ------ *Eelaeocarpus* sp. (fruit).
4. Southern tree pie ------ *Macaranga* sp.
5. Nilgiri white eye ------ *Trema orientalis*

6. Racket tailed drongo ------ *Grewia tiliifolia*

7. Greyfronted green pigeon ------ *Ficus racemosa* (fruit).

8. Redwhiskered bulbul ----- *Ficus racemosa* (fruit).

9. Goldfronted chloropsis ----- *Ficus racemosa*

10. Black drongo ----- *Erythrina suberosa* (honey).

11. Lotten's sunbird ------ *Lantana* sp. (honey).

12. Yellowbrowed bulbul ---- *Ficus racemosa, Bischofia javanica*

Foraging methods

Birds were found to use, basically 5 foraging methods which are given in the table 4.7. This difference in foraging method allows the different species to explore various specialised niches in the same habitat. Only 15 species were studied in detail with more than 5 to 30 observations per species. From these observations it was concluded that gleaning is the principal foraging method used by 13 species followed by probing.

Three species namely black bulbul, redwhiskered bulbul and black drongo used four methods while the most common species yellowbrowed bulbul was seen using all the five methods. Small greeen barbet was mainly gleaning and does occassional snatching also. In the same way hill myna used the methods of gleaning and probing. Blackwinged kites were hovering well above the canopy and pounced to the ground after spotting the prey. Insectivorous birds like scarlet minivet used to do the sallying and returned to the same branch or to another branch. Birds like yellow wag tail, grey jungle fowl and bush quail were mainly feeding on the ground employing probing. Bark feeders like goldenbacked woodpecker, velvetfronted nuthatch and malabar lorikeet were seen feeding on both live and dead trees.

Substrates

Birds search for food on different substrates and for this they have morphological adaptations. Common substrates are ground, bark, flower, air, foliage and trunk. Five species were ground foragers and they prefered different types of ground such as bare ground, grass and littered grass. Yellow wagtails were seen mostly on bare ground while jungle babbler, bush quail, and greyjungle fowl were seen on ground with litter. A number of species were feeding on twigs and foliage also (Table 4.8). Eight species obtained their prey from air, as they were insectivorous birds.

Food Site

The actual place from where the food is consumed is called food site. In some cases substrate and food site happens to be the same such as bark, where birds use the bark as a substrate and search for food on it. This is the case with trunk and foliage also. But in the case of honey suckers they will be using either twigs, air or in some case flower itself as the substrate. Majority of the birds collected their food from foliage (Table 4.9) and this was followed by flower and bark.

Foraging height

Ten species were seen feeding in the height category 0-4m and 9 species in the next category 5-9m (Table 4.10). Only a few species were seen feeding on the upper heights of 20 m and above. Racket-tailed drongo, goldenbacked woodpecker, scarlet minivet, paradise flycatcher and southern tree pie were middle canopy feeders, while hill myna and different species of parakeets specilised on the top canopy.

Guild structure

All the above mentioned factors were used for cluster analysis to elucidate feeding guilds. No separate clusters were arrived at by this analysis. Main reasons for this is that even though more than 50 species were present in the area, data on foraging for only 15 species were available.

Table 4.7 Proportion of observations for each foraging method
n=Sample size

Species	Probe	Glean	Salley	Snatch	Hover	(n)
S.g barbet	0.286	0.571		0.143		(14)
Hill myna	0.400	0.500		0.100		
Black bulbul	0.333	0.445	0.111		0.111	(10)
Black drongo	0.091	0.045	0.773		0.991	(24)
R.w.bulbul	0.273	0.545	0.091		0.091	(12)
Sun bird	0.385	0.153	0.077		0.385	(13)
Y.wagtail	0.400	0.600				(10)
Y.b. bulbul	0.053	0.578	0.263	0.053	0.053	(20)
G.b.woodpecker	0.875	0.125				(10)
S. minivet	0.167		0.833			(6)
J.babbler	0.400	0.600				(5)
R.t.drongo	0.091	0.818	0.091			(11)
P.flycatcher	0.636		0.364			(11)
B.h.parakeet	0.857		0.143			(7)
S.tree pie	0.500	0.167		0.333		(6)
F.pecker	0.333				0.667	(4)
Quail	1.000					(4)
Rose finch		1.000				(2)
Jungle fowl	1.00					(3)
V.f.nuthatch	0.400	0.600				(5)
Ground thrush		0.500			0.500	(2)

[S.g. barbet = Small green barbet; R.W. bulbul = Redwhiskered bulbul; Y. Wagtail = Yellow wagtail; G.b. Woodpecker = Goldenbacked woodpecker; S.minivet = Scarlet minivet; J. babbler = Jungle babbler; R.t. drongo = Racket tailed drongo; P. flycatcher = Paradise flycatcher; B.h. Parakeet = Blossomheaded parakeet; S.tree pie = Southern tree pie; F. pecker = Flower pecker; V.f. nuthatch = Velvet fronted nuthatch; Y.b. bulbul = Yellowbrowed bulbul; N.W.eye = Nilgiri white eye; S. bird = Sunbird; H.S. woodpecker = Heartspotted woodpecker]

Table 4.8 The proportion for each species on each substrates

Species	Trunk	Twig	Bark	Air	Ground	Flower
S.g.barbet	0.214	0.786				
Hill myna		1.000				
Black bulbul		0.889		0.111		
Black drongo	0.045	0.091		0.818		0.045
R.w.bulbul		0.636	0.091	0.182		0.091
Sunbird		0.385		0.385		0.230
Yellow wagtail					1.000	

Y.b.bulbul	0.100	0.550		0.350		
G.b.woodpecker	0.250	0.625		0.125		
Scarlet minivet		0.167	0.167	0.667		
J.babler					1.000	
R.t.drongo		0.182		0.818		
P.flycatcher	0.364		0.273	0.364		
B.h.parakeet	0.143	0.857				
S.t.pie		1.000				
Flowerpecker				0.667		0.333
Rose finch		1.000				
Jungle fowl					1.000	
Quail					1.000	
V.f.nuthatch	0.200	0.800				
Ground thrush				1.000		
N.w.eye		1:000				
H.s.woodpecker		0.500		0.500		

Table 4.9 The proportion of species on each foodsite

Species	Trunk	Foliage	Air	Ground	Bark	Flower
S.g.barbet	0.214	0.714				0.071
Hill myna		0.300			0.100	0.600
Blackbulbul		0.778				0.222
Black drongo		0.091	0.818			0.091
R.w.bulbul		0.417	0.083			0.500
Sunbird		0.154	0.077			0.769
Yellow wagtail				1.000		
Y.b.bulbul		0.842	0.053		0.053	0.053
G.b.woodpecker					1.000	
Scarlet minivet		0.333	0.667			
J.babbler		0.200		0.800		
R.t.drongo		0.909				
P.flycatcher	0.273		0.364	0.364		
B.headed parakeet		1.000				
S.t.pie		1.000				
Flower pecker		0.250				0.750
Quail				1.000		
Rose finch		1.000				
Jungle fowl				1.000		
V.f.nuthatch					1.000	

Table 4.10 Proportion of observations on each height category

Species	0-5m	5-10m	10-15m	15-20m	20-30m	30-40m
S.g.barbet	0.286		0.071		0.286	0.357
H.myna	0.111	0.222			0.222	0.445
Black bulbul	0.143	0.143		0.285		0.429
B.drongo	0.182	0.182	0.227	0.273		0.136
R.w.bulbul	0.273	0.182	0.182	0.273		0.910
S.bird	0.769	0.077		0.154		
Y.wagtail	1.000					
Y.b.bulbul	0.263	0.158	0.421	0.158		
G.b.woodpecker			0.500		0.125	0.375
S.minivet			0.500	0.167	0.167	0.167
J.babbler	1.000					
R.t.drongo		0.600	0.300		0.100	
P.flycatcher	0.200	0.200	0.600			
B.h.parakeet					0.200	0.800
S.t.pie		0.143	0.571	0.286		
Flowerpecker	0.667	0.333				
Quail	1.000					
Rose finch						1.000
Jungle fowl	1.000					
V.f.nuthatch			0.400	0.200		0.400
Ground thrush	1.000					
N.w.eye	0.333	0.333		0.333		
H.s.woodpecker			1.000			

4.5. Discussion

The broad aim of the study was to collect information on the present status and to generate basic data on various aspects of bird community. Tropical forests are supposed to support a stable population of birds throughout the seasons in comparison to the temperate forests, where there is marked variation in tune with change of seasons. The available data shows that total number of birds, total density and individual species density in some cases show slight reduction during monsoon months and an increase during dry months. The main reason for the drop in number of birds and species during monsoon months is due to the local migration of some species to avoid unfavourable climate. This is obvious from the fact that there is a reduction of total species presence during the months of monsoon. (Fig.4.3), which indirectly contributes to the decrease in total bird abundance. Species like black bulbul, various doves, pigeons and parakeets are practically absent during this season. Local movements in search of optimum habitats are possible due to the availability of other habitats in the vicinity. In contrast, other tropical countries where vast stretches of tropical forests are present the study area was only a small stretch of land and was only 20 km away from different forest types namely semi-evergreen and moist deciduous. Wind speed being very high during the monsoon and might have influenced the bird abundance.

Similar trends were reported from other countries also. Variation in rainfall and soil moisture makes tropical bird fauna seasonal (Greenberg and Gradwohl, 1986). According to him this is due to the influence of rainfall on patterns of leaf, flower and fruit production (Fig.4.7), which in turn have an effect on the population trends of arthropods (Fig.4.6). Arthropods showed an increase during summer months just after the rain with a corresponding increase in bird fauna. A study conducted by Price (1979) in the Eastern Ghats of India also showed the same trends in annual cycles of bird fauna due to the seasonality of rainfall. But as mentioned earlier, a few species of birds like yellowbrowed bulbul (Table 4.3) showed stability in population even in the fluctuating environment.

Resource partitioning is a strategy to survive on available means. For this, vertical stratification of species in different levels of canopy is one method. Most of the species were found to concenterate on heights up to 20 m because at this level more food was available. Few species which dwell above 20 m are frugivorous which consume fruits even from the tall trees. Birds which live above 30 m are birds of prey which hover in the sky above the canopy in search of prey.

From the above facts it is seen that there is some preference to a particular height category. However most of the birds tend to be generalists using a broad height range. Generalists are observed more in the mid and lower canopy levels. Highly specialised species which prefer certain height classes have been reported from other countries. Same type of specialisation is not seen at the study site. Two reasons can be attributed to this. The site being a worked evergreen forest, vegetation structure is disturbed and due to this more generalists are found. As the place is having an undulating topography birds can approach any height without much effort. Active feeding observations also support this generalists behaviour (Table 4.10).

The centre point of studies on foraging is to find out the patterns of resource use among co-existing species or guilds (Holmes, 1980). Advantage of guild analysis is that it can contribute to the knowledge of resources used by species and thus provide better insight into the structure of communities. (Landers and MacMahon,1980). Comparative foraging behaviour of birds have been studied in Australia and England also (Ford *et al.* 1986). Usually these studies concentrated on the whole communities in one area or on closely related, ecologically similar species. In the present study, as most of the species were insectivorous, probing and gleaning were the main methods used for feeding, and most of the species were obtaining their food from foliage. As the data on feeding for all species was lacking, no separate guilds were obtained in cluster analysis.

It will be of interest to repeat the study after 5 or 10 years to record the change in the species composition which will change in accordance with modification of vegetation structure due to intensive protection. Such a change as reported by Holmes and Sherry (1986) shows that change in habitat structure, related to forest succession as one of the factors which modifies the bird population from a 16 year old study. The management of forests should be directed to maintain the different levels of the canopy so that diversity of avian species is maintained. Endangered species like great Indian hornbill is recorded from the first study site which further emphasises the need for protection of the forest in totality.

4.6. Acknowledgements

I am thankful to Dr. C.T.S. Nair (Former Director) for initiating the study on Nilgiri Biosphere Reserve, and to the present director Dr. K.S.S. Nair for his keen interest in the progress and completion of the study. I am indebted to Dr. P.Vijayakumaran Nair for assisting in the computer analysis of data, discussion on various points. Editorial suggestions of Dr. T.G. Alexander, Dr. R.V. Varma and Dr. K.K.N. Nair were of immense help in improving the report. Sri. P.N. Unnikrishnan, IFS (Wildlife Warden) and Shri. T. Sabu (Assist. Wildlife Warden) were of immense help in the field. I am thankful to Dr. D.N. Mathew, Professor, University of Calicut for introducing me in to the field of birds.

4.7. Literature cited

Anonymous (1977) Impact of hydrolectric Project on Wildlife, report sof the first phase of study. K.F.R.I. P. 111(Mimeo)

Bell, H.L. (1980) A bird community of lowland rain forest in new Guinea 1. Composition and density of the avifauna. *The Emu* 82:24-41.

Bell, H.L. (1983). A bird community of low land rain forest in New Guinea. 6. Foraging ecology and community structure of the avifauna. *The Emu* 84(Part 3): 142-158.

Bell, H.L.and S.Ferrier (1985). The reliability of estimates of density from transect counts. *Corella* 9: 3-13.

Cherian, P.T. (1983). Ecological impact studies with particular reference to changes in the fauna. (including plantation) at Idukki, A mid term report Dept. of environment, New Delhi (255-273).

Emlen, J.T. (1971). Population densities of birds derived from transect counts. *Auk* 88: 323 - 342.

Franzeb, K.E. (1981). The determination of avian densities using the variable - strip and fixed - width transect surveying methods. *Stud. Avian Biol.* 6 : 139-145.

Ford, Hug A., Susan Noske and Lynda Bridges (1986). Foraging of birds in eucalypt wood land in North - Eastern New South Wales. *The Emu* 86(3): 168-179.

Ford, Hugh A., Lynda Bridges and Susan Noske (1985). Density of birds in eucalypt woodland near Armidale, North - Eastern New South Wales. *Corella* 9 (4): 97 - 107.

Greenberg, Russell and Judigh Gradwohl (1986). Constant density and stable territoriality in some tropical insectivorous birds. *Oecologia* 69: 618-625.

Hilden, O. (1981). Sources of error involved in the Finnish line - transect method. *Stud. Avian Biol.* 6: 152-159.

Holmes, R.T. and H.F.Recher (1980). Search tactics of insectivorous birds foraging in Australian eucalypt forest. *The Auk* 103:515-530.

Holmes, Richard T.,W. Sherry and Franklin W. Sturges (1986). Bird community dynamics in a temperate deciduous forest: long - term trends at Hubbard Brook. *Ecological monographs* 56 (3): 201- 220.

Landers, Peter B. and James A. MacMahon (1980). Guilds and community organization: Analysis of a oak woodland avifauna in Sonora, Mexico. *The Auk* 97: 351-365.

Loyn, Richard H. (1980). Bird populations in successional forests of Mountain Ash *Eucalyptus regars* in Central Victoria. *The Emu* 85 (4): 213-215.

Mac Mahon, J.A., D.L. Phillips, J.V. Robinson and D.J. Schinpf (1978). Levels of biological organization: An organism - centered approach. *Bioscience* 28: 700 - 704.

Morrison, Michael L., Kimberly A. With and Irene C. Timossi (1980). The structure of a forest bird community during winter and Summer *Wilson bull.* 98 (2) 214 - 230.

Nair, P.V., K.K. Ramchandran,V.S. Vijayan, P.S. Easa and P.V. Balakrishnan (1985). An ecological study in Periyar tiger reserve with special reference to Wildlife. Kerala Forest Research Institute Research Report 24, Peechi.

Odum, Eugene, P. (1971). Fundamentals of ecology. W.B. Saunders company London. P-144.

Palat, Ramakrishnan (1983). Environmental studies on the birds of Malabar forest. Ph.D. Thesis, University of Calicut.

Price Trevor D. (1979). The seasonality and occurrence of birds in the Eastern Ghats of Andhra Pradesh. *J. Bombay Nat. Hist. Soc.* 76(3): 279 -409.

Pyke, Graham H. (1984). Seasonal patterns of abundance of insectivorous birds and flying insects. *The Emu* 85(1):34-39.

Recher, H.F., Growing G.Kavanagh, R., J.Shields and Rohan Jones, W. (1983b). Birds, resources and time in a tablelands forest. *Proc. Ecol. Soc. Aus.* 12:101-123.

Recher, H.F., R.T. Holmes, M. Shultz, J. Shields, and R. Kavanagh

(1985). Foraging patterns of birds in eucalypt forest and woodland on the tablelands of South eastern Australia. *Aust. J. Ecol.* 10: 399-421.

Rice, Jake Berlin; W. Anderson and Robert D. Ohmart.(1984). Comparison of the importance of different habitat attributes to avian community organization *J. Wildl. Manage.* 48(3):895-911.

Sale, J.B.and K.Berkmuller(1988). Manual of wildlife techniques for India. Wildlife institute of India,Dehradun.

Shields, William M.(1979). Avian census techniques: an analytical review in. The role of insectivorous birds in forest ecosystems. P.23-49. Academic Press Inc.

Vijayan V.S (1978). Parambikulam wildlife sanctuary and its adjacent areas. *J. Bombay Nat. Hist. Soc.* 75(3):885-900.

Wright, J.S. (1970). Competition between insectivorous lizards and birds in Central Panama. *Amer. zool.* 19: 1145-1156.

4.8. Appendix

List of birds recorded from Silent Valley
(After Anonymous,1977; Palat,1983; and present study)

Common Name	Scientific Name	No.of species from reserve	From Kerala
Family Ardeidae		1	14
1. Indian pond heron	*Ardeola grayii*		
Family Accipitridae		7	31

2. Blackwinged Kite	*Elanus caeruleus*		
3. Ceylon shikra	*Accipiter badius*		
4. Black eagle	*Ictinaetus malayensis*		
5. Grayheaded fishing eagle	*Icthyophaga ichthyaetus*		
6. Short-toed eagle	*Circaetus gallicus*		
7. Crested serpent eagle	*Spilornis cheela*		
Family Falconidae		1	7
8. Falcon	*Falco* Sp.		
Family Phasianidae		3	10
9. Busha quail	*Perdicula* sp.		
10. Travancore Red Spurfowl	*Galloperdix spadicea*		
11. Grey jungle fowl	*Gallus sonneratii*		
Family Turnicidae		1	3
12. Common bustard-quail	*Turnix suscitator*		
Family Columbidae		6	11
13. Southern green pigeon	*Treron phoenicoptera*		
14. Jerdon's Imperial Pigeon	*Ducula badia*		
15. Nilgiri wood pigeon	*Columba elphinstonii*		
16. Indian spotted dove	*Streptopelia chinensis*		
17. Emerald dove	*Chalcophaps indica*		
18. Greyfronted green pigeon	*Treron phonenicoptera*		
Family Psittacidae		3	5
19. Bluewinged parakeet	*Psittacula columboides*		
20. Blossomheaded parakeet	*Psittacula cyanocephala*		
21. Malabar lorikeet	*Loriculus vernalis*		
Family Cuculidae		2	14
22. Brainfever bird	*Cuculus varius*		
23. Southern crow-pheasant	*Centropus sinensis*		
Family Strigidae		7	13
24. Indian great horned owl	*Otus bakkamoena*		
25. Forest eagle-owl	*Bubo nipalensis*		
26. Brown fish owl	*Bubo zeylonensis*		
27. Malabar jungle owlet	*Glaucidium radiatum*		
28. South indian hawk-owl	*Ninox scutulata*		
29. Southern spotted owlet	*Athene brama*		
30. Brown wood owl	*Strix leptogrammica*		
Family Caprimulgidae		1	5
31. Indian jungle nightjar	*Caprimulgus indicus*		
Family Apodidae		2	7
32. Brown throated spinetail swift	*Chaetura gigantea*		
33. Whiterumped spinetail swift	*Chaetura sylvatica*		
Family Trogonidae		1	1
34. Malabar trogon	*Harpactes fasciatus*		

Family Alcedinidae		1	8
35. Indian-whitebreasted	*Halcyon smyrnensis*		
36. kingfisher			
Family Meropidae		2	4
37. Chestnutheaded bee-eater	*Merops leschenaulti*		
38. Small green bee-eater	*Merops orientalis*		
Family Bucerotidae		2	4
49. Malabar grey hornbill	*Tockus griseus*		
40. Great indian hornbill	*Buceros bicornis*		
Family Capitonidae		1	4
41. Small green barbet	*Megalaima viridis*		
Family Picidae		7	12
42. South indian small yellownaped			
43. woodpecker	*Picus chlorolophus*		
44. Little scalybellied green			
45. woodpecker	*Picus myrmecophoneus*		
46. Malabar goldenbacked threetoed woodpecker	*Dinopium Javanense*		
47. Goldenbacked woodpecker	*Dinopium benghalense*		
48. Indian great black woodpecker	*Dryocopus javensis*		
49. Heartspotted woodpecker	*Hemicircus canente*		
50. Southern larger golden-backed woodpecker	*Chrysocolaptes lucidus*		
Family Pittidae		1	1
51. Indian pitta	*Pitta brachyura*		
Family Hirundinidae		3	5
52. Dusky crag martin	*Hirundo concolor*		
53. Nilgiri house swallow	*Hirundo tahitica*		
54. Redrumped swallow	*Hirundo durica*		
Family Lanidae		1	3
55. South Indian greybacked shrike	*Lanius schach*		
Family Oriolidae		3	3
56. Indian golden oriole	*Oriolus oriolus*		
57 Blackheaded oriole	*Oriolus xanthornus*		
58. Blacknaped oriole	*Oriolus chinensis*		
Family Dicruridae		3	6
59. South Indian black drongo	*Dicrurus adsimilis*		
60. Bronzed drongo	*Dicrurus aeneus*		
61. Racket- tailed drongo	*Dicrurus paradiseus*		
62. Indian grey drongo	*Dicrurus leucophaeus*		
Family Sturnidae		3	7
63. Common myna	*Acridotheres tristis*		

64. Grey headed myna	*Sturnus malabaricus*		
65. Hill myna	*Gracula religiosa*		
Family Corvidae		4	4
66. Whitebellied treepie	*Dendrocitta leucogastra*		
67. Tree pie	*Dendrocitta vagabunda*		
68. Jungle crow	*Corvus macrorhynchos*		
69. House crow	*Corvus splendens*		
Family Campephagidae		4	9
70. Pied flycatcher - shrike	*Hemipus picatus*		
71. Large wood shrike	*Tephrodornis virgatus*		
72. Scarlet minivet	*Pericrocotus flammeus*		
73. Cuckoo shrike	*Coracina sp.*		
Family Irenidae		3	4
74. Common iora	*Aegithina tiphia*		
75. Fairy bluebird	*Irena puella*		
76. Goldfronted chloropsis	*Chloropsis aurifrons*		
Family Pycnonotidae		5	8
77. Rubythroated yellow bulbul	*Pycnonotus melanicterus*		
78. Redwhiskered bulbul	*Pycnonotus jocosus*		
79. Redvented bulbul	*Pycnonotus cafer*		
80. Yellowbrowed bulbul	*Hypsipetes indicus*		
81. Black bulbul	*Hypsipetes madagascariensis*		
Family Muscicapidae		24	63
82. Spotted babbler	*Pellorneum ruficeps*		
83. Scimitar babbler	*Pomatorhinus (Schisticeps)*		
84. Blackheaded babbler	*Rhopocichla atriceps*		
85. Rufous babbler	*Turdoides subrufus*		
86. Yellowbreasted laughing thrush	*Garrulax delesserti*		
87. Quaker babbler	*Alcippe poioicephala*		
88. Greyheaded flycatcher	*Culicicapa ceylonensis*		
89. Bluethroated flycatcher	*Muscicapa ceylonensis*		
90. Tickell's blue flycatcher	*Muscicapa tickelliae*		
91. Brownbreasted flycatcher	*Muscicapa muttui*		
92. Verditer flycatcher	*Muscicapa albicaudata*		
93. Black and orange flycatcher	*Muscicapa nigrorufa*		
94. Paradise flycatcher	*Terpsiphone paradisi*		
95. Blacknaped blue flycatcher	*Monarcha azurea*		
96. Streaked fantail warbler	*Cisticola juncidis*		
97. Wren-warbler	*Prinia hodgsonii*		
98. Largebilled leaf warbler	*Phylloscopus magnirostris*		
99. Dull green leaf warbler	*Phylloscopus trochiloides*		
100. Bright green leaf warbler	*Phylloscopus nitidus*		
101. Large crowned leaf warbler	*Phylloscopus occipitalis*		

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100. Bright green leaf warbler	*Phylloscopus nitidus*		
101. Large crowned leaf warbler	*Phylloscopus occipitalis*		

102. Malabar whistling thrush	*Myiophonus horsfieldii*		
103. Whitethroated groundthrush	*Zoothera citrina cyanotus*		
104. Orangeheaded groundthrush	*Zoothera citrina*		
105. Black bird	*Turdus merula*		
Family Paridae		1	2
106. Yellowcheeked tit	*Parus xanthogenys*		
Family Sittidae		1	1
107. Velvetfronted nuthatch	*Sitta frontalis*		
Family Motacillidae		4	13
108. Paddyfield pipit	*Anthus novaeseelandiae*		
109. Yellow wagtail	*Motacilla flava*		
110. Grey wagtail	*Motacilla caspica*		
111. Large pied wagtail	*Motacilla maderaspatensis*		
Family Dicaeidae		2	3
112. Tickell's flowerpecker	*Dicaeum erythrorhychos*		
113. Thickbilled flower-pecker	*Dicaum agile*		
Family Nectariniidae		2	6
114. Small sunbird	*Nectarinia minima*		
115. Little spiderhunter	*Arachnothera longirostris*		
Family Zosteropidae		1	1
116. White-eye	*Zosterops palpebrosa*		
Family Ploceidae		5	10
117. House sparrow	*Passer domesticus*		
118. Yellowthroated sparrow	*Petronia xanthocollis*		
119. Rufousbellied munia	*Lonchura kelaarti*		
120. Whitethroated munia	*Lonchura malabarica*		
121. Spotted munia	*Lonchura punctulata*		
Family Fringillidae		1	1
122. Common rosefinch	*Carpodacus erythrinus*		

5. FEEDING AND RANGING PATTERNS OF LION-TAILED MACAQUE - IN SILENT VALLEY NATIONAL PARK

K. K. Ramachandran

Division of Wildlife Biology

Contents

5.1. Abstract

This is the first long-term study on lion-tailed macaque (*Macaca silenus*) in Silent Valley National Park. In the intensive study area consisting of about 2000 ha of evergreen forests, 13 troops were observed with a total of about 171 individuals. Three distinct lion-tailed macaque populations were observed. The first consisting of five troops with a total of 49 individuals was restricted to the areas west of Kunthipuzha like Nilikkal (980 m to 1050 m). The second population consists of at least four troops with 80 individuals was restricted to eastern side of Kunthipuzha encompassing areas like Valiyaparathodu (1000 m to 1300 m), Kummattanthodu (900m to 1100 m), Kattuvara mudi (1100 m to 1300 m) and lower slopes of Kattimudi (1200 m to 1400 m). This area is contiguous to the Attappady RF. The third population was restricted to Panthanthodu (850 m to 1000 m), Aruvampara (1100 m), and south of the road from Mukkali to Silent Valley, and consisted of four lion-tailed macaque troops with 42 individuals.

In all the locations, most sightings were in the Cullenia-Palaquium tree association. The macaques fed heavily on the seeds and flowers of *Cullenia exarillata* from May to December when the flowers or seeds were available in different parts of the study area.

It is suggested that the Panthanthode forest beat of Attappady, Block I RF may be added to Silent Valley National Park, as this area fall within the home range of at least seven of the thirteen lion-tailed macaque troops encountered in this study.

5.2. Introduction

Lion-tailed macaque, *Macaca silenus* is one of the most endangered primate restricted to the evergreen forests of Western Ghats. Studies on the distribution and the status survey of the species have been conducted by Kurup (1978) and in Karnataka by Karanth (1984). Some detailed studies on the species have been conducted in the Kalakkad area (Green and Minkowski, 1977 ; Green, 1978 and Johnson 1980) and in the Varagaliar area (Kumar, 1987) all in Tamil Nadu, south of the Palghat gap. Earlier studies on wildlife in Silent Valley by Vijayan and Balakrishnan (1977) reported that the area between Kunthipuzha river and Bhavani river is fairly undisturbed and it will be a viable lion-tailed macaque habitat.

Recently much emphasis has been made on the conservation of lion-tailed macaque as priorities of primate conservation in India. Silent Valley is one of the best habitat where lion-tailed macaque still maintains a viable breeding population other than the Ashambu hills. There has not been any detailed study of the species in Silent Valley area probably due to the rugged terrain and inhospitable weather condition. This study is the first long-term study on lion-tailed macaque in the Silent Valley National Park.

Objectives of the present investigation were to study the ranging pattern, feeding habits and troop dynamics of lion-tailed macaque(LTM). This study has generated base line data on the population ecology of lion-tailed macaque in Silent Valley area. Though considerable data on the troop size and ranging pattern was obtained, there is only limited data on the food habits during different seasons of the year.

5.3. Study Area

Silent Valley (11° 5' to 11° 25' N latitude and 76° 21' to 76° 33' E longitude) is 8952 ha and forms one of the core areas of Nilgiri Biosphere Reserve. The altitude varies from 685m and 2383m.

5.3.1. Intensive study area

Intensive study area is between 11° 3' and 11° 7' N latitude and 76° 24' and 76° 30' E longitude. Fig 5.1 and 5.2 indicates the location of the intensive study area and the important places in the area. Fig 5.3 illustrates the altitudinal profile along $11^{\circ}4'30''$ and $11^{\circ}5'30''$ N latitude.

5.4. Methods

The study was conducted at Silent Valley National Park and adjacent areas during a total of 79 days were spent in the field over a period of 14 months. Details are given in Table 5.1. General

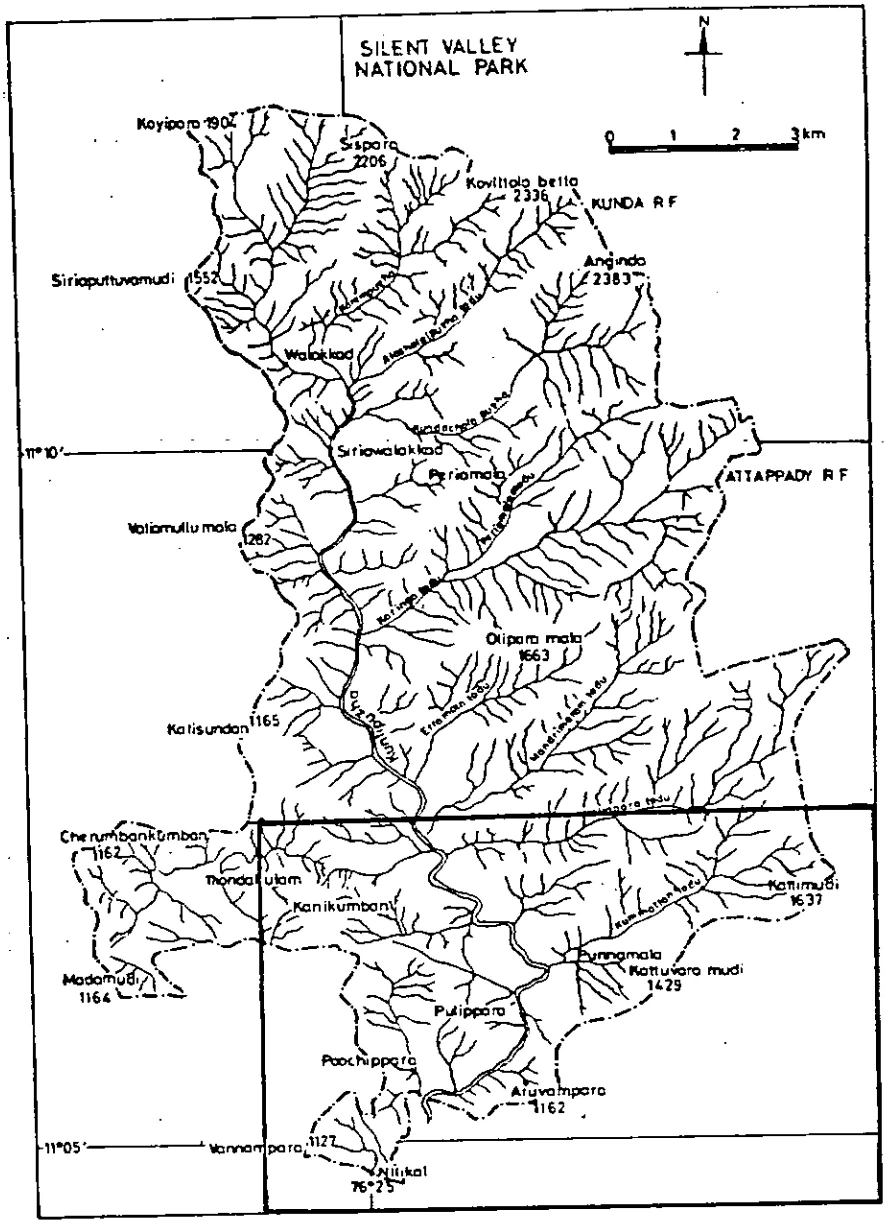

Fig. 5.1. Map of Silent Valley National Park showing intensive study area in inset

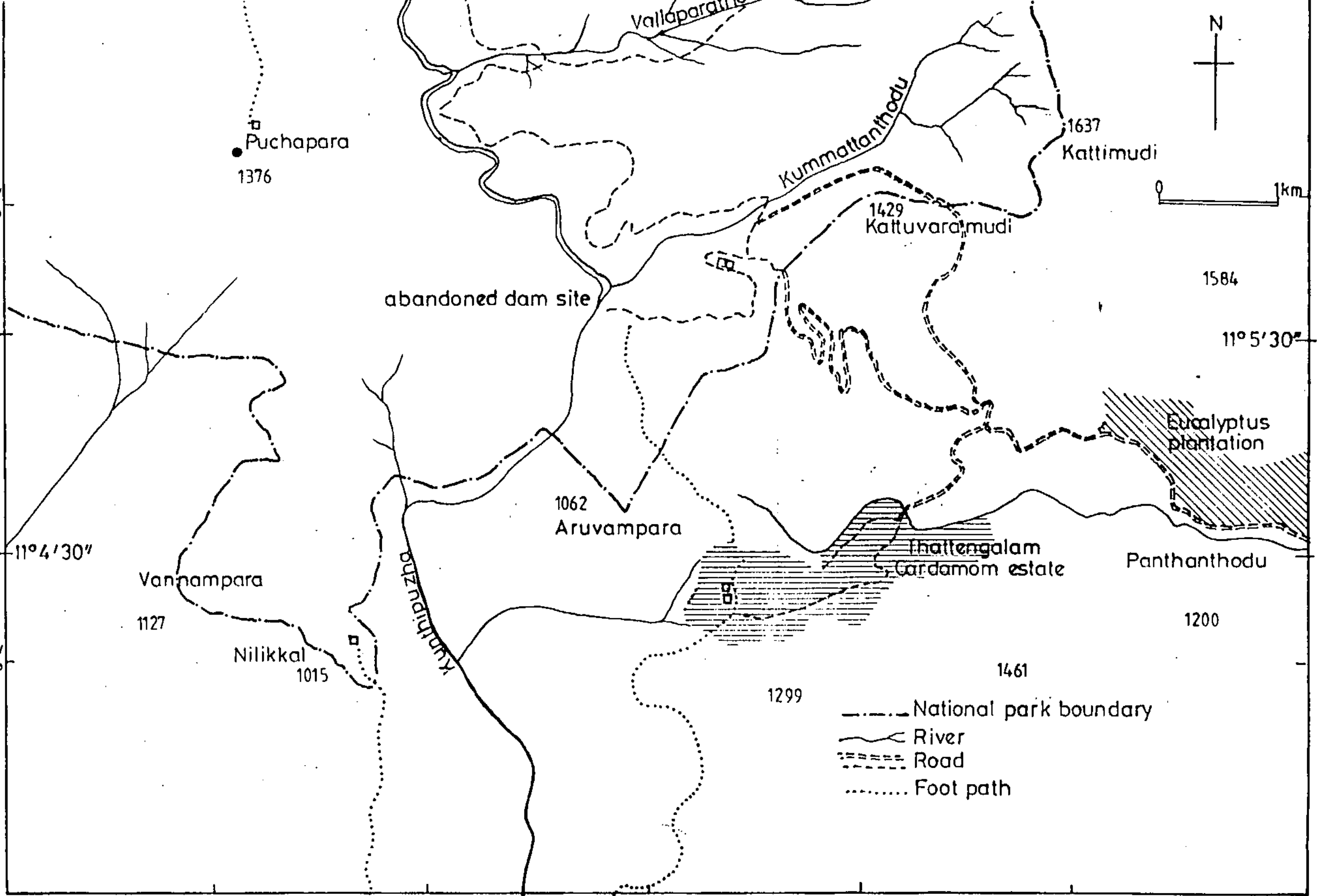

Fig. 5.2. Detailed map of intensive study area showing important places

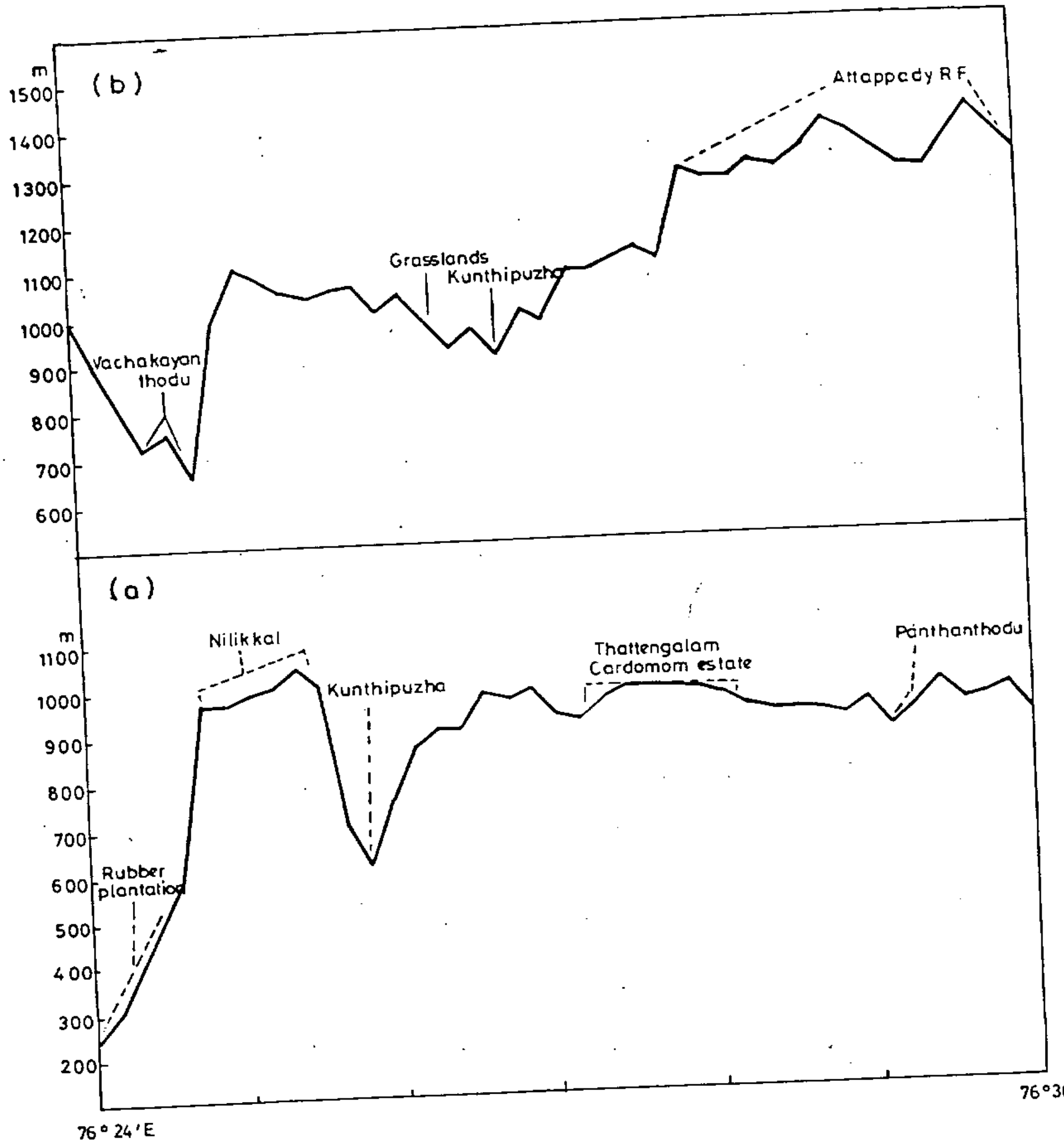

Fig. 5.3. Altitudinal profile along (a) 11° 4' 30" N and (b) 11° 5' 30" N latitudes

surveys were made in the areas like Nilikkal, Vannampara, Thondakulam, Walakkad, Cheriawalakkad, Walakkad, Sispara, etc. Population estimate of lion-tailed macaques in the Silent Valley was arrived at by three different methods. (1) by conducting surveys in the remote areas (2) by participating in the animal census conducted by Forest Department (3) by studying selected lion-tailed macaque troops and their feeding and ranging. Visited those areas where lion-tailed macaques were sighted during the census, undertaken by the Forest Department, in Silent Valley National Park, and repeated surveys were conducted in those areas to get a reliable count on the troop size. Evergreen forest areas adjoining Silent Valley National Park in the south eastern side of the Park were intensively perambulated to know the general status and distribution of lion-tailed macaque.

The lion-tailed macaque populations in Nilikkal area and Kummattanthodu area are perhaps isolated to a great extent by the barrier Kunthipuzha river. Population in the Nilikkal area was not selected for intensive study of ranging as it was not feasible to get logistic support throughout the year. Areas like Kattuvaramudi, Kummattanthodu, Valiyaparathodu, lower slopes of Kattimudi, Aruvampara, south side of the road from Mukkkali-Silent Valley and

Pantanthodu area was accessible could be covered on foot during wet months also.

Table 5.1. Number of days spent in the field excluding travel to Silent Valley National Park and adjacent areas.

Month & Year		No of days
February	1988	3
March	1988	12
April	1988	4
May	1988	7
June	1988	0
July	1988	5
August	1988	6
September	1988	3
October	1988	5
November	1988	5
December	1988	9
January	1989	10
February	1989	6
March	1989	4
	Total	79 x 6 hrs= 474 hours

5.4.1. Home range estimation

A troop was selected and its movement was monitored. Due to the rugged terrain and the shy nature of the lion tailed macaque it was impossible to habituate the troops. There was difficulty in locating the same troop during subsequent months. But as far as possible the same troop was located and the movement followed. The sightings of the various troops were plotted on a detailed map of the area based on Survey of India Topo sheets.

5.5. Results

5.5.1. Population of lion-tailed macaque in Silent Valley area

Lion-tailed macaque in Silent Valley area is restricted to the Cullenia-Palaquium tree association. During the study period 13 lion-tailed macaque troops were located and a fairly good estimate of the troop size was obtained. Sighting of lone males were excluded from the troop number since lone males are likely to range vast areas. Troop numbers and counts were checked several times to gain fairly good estimate and the highest number of individuals for a particular troop is given as the troop size. Number of individuals in different troops are given in Table 5.2. Panthenthodu area comprising

Panthenthodu, Podumaram area (near the large *Cassine glauca*), Aruvampara and south side of the road from Mukkali-Silent valley has five troops numbering 49 individuals. Kummattanthodu area consists of four troops numbering about 80 individuals. Nilikkal area consists of four troops with at least 42 individuals. Highest number of individuals seen in a troop is 31 (including infants), and the lowest number seen is three in the Panthanthodu area which was observed opposite to the Panthanthodu Eucalyptus plantation. Fig 5.4 gives the location of sightings of the various lion-tailed macaque troops.

Based on the sightings of different groups at various places in the intensive study area there are three distinct lion-tailed macaque populations,

the first, restricted to the areas west of Kunthipuzha like Nilikkal(980 m to 1050 m), Thondakulam and Chembotti(1000 m);

the second, in the eastern side of Kunthipuzha restricted to Valiyaparathodu(1000 m to 1300 m, Kummattanthodu(900 m to 1100 m), Kattuvaramudi(1100 m to 1300 m) and lower slopes of Kattimudi(1200 m to 1300 m);

the third, restricted to Panthanthodu (850 m to 1000 m), Aruvampara (1100 m) and south of the road from Mukkali to Silent Valley.

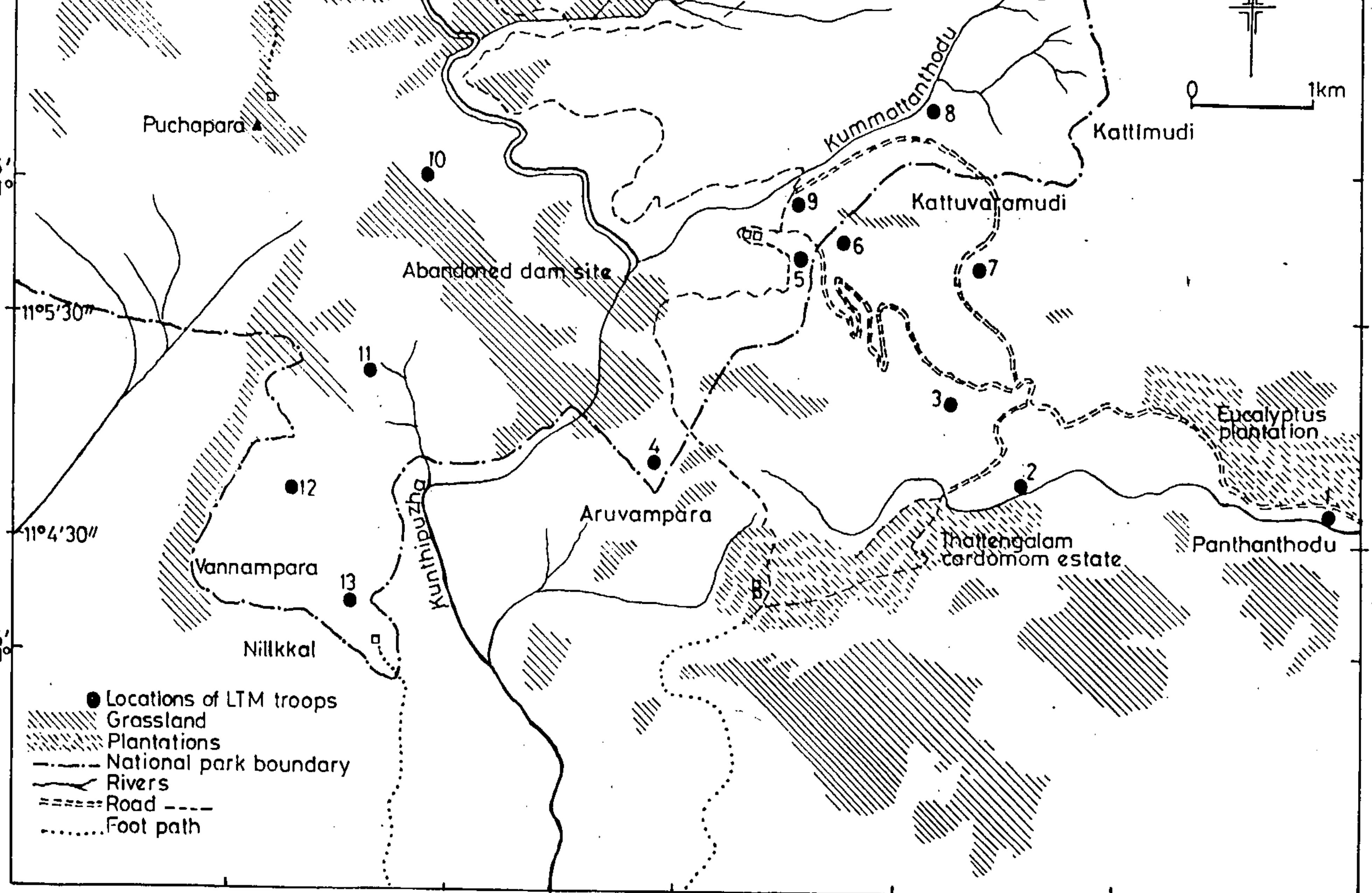

Fig. 5.4. Map of the study area showing grasslands and plantations with sighting locations of LTM troops. No. given near " " corresponds to serial No. in Table. 5.2.

Table 5.2 Different lion-tailed macaque troops sighted and approximate number of individuals in each troop.

Serial No.	Troop Name	Approximate No. of individuals
Panthanthodu area		
1	Panthenthodu I	3
2	Panthenthodu II	7
3	Podumaram	18
4	Aruvampara	12
5	Valley troop	9
Kummattanthodu area		
6	Kattuvaramudi	31
7	Kattimudi southern slope	28
8	Punnamala	13
9	Kummattanthodu	8
Nilikkal area		
10	Chembotti	8
11	Poochapara	6
12	Nilikkal I	16
13	Nilikkal II	12
Total	13 Troops	171 individuals

5.5.2. Home range

The troops in the Kummattanthodu has large home range and the troop in the Panthanthodu area has very limited home range Fig 5.5. Smaller home ranges of the Panthanthodu troop is due to the degeneration of the habitat and reduction in the available area in the Panthanthodu area. Thattengalam cardamom estate occupies about 186 ha of area south of the Mukkali-Silent Valley road which is a prime lion-tailed macaque habitat. There is not much canopy continuity on either side of road. The area of evergreen forests within the study area is about 2000 ha and in that area there are about 13 lion-tailed macaque troops. The home range of the two troops works out to about 153 ha each. Green and Minkowski, 1977 have reported large home ranges of about 5 km^2 in Ashambu hills for liontailed macaque troop, while their home range in Anaimalai Wildlife Sanctuary was about 1 km^2 (Kumar, 1987).

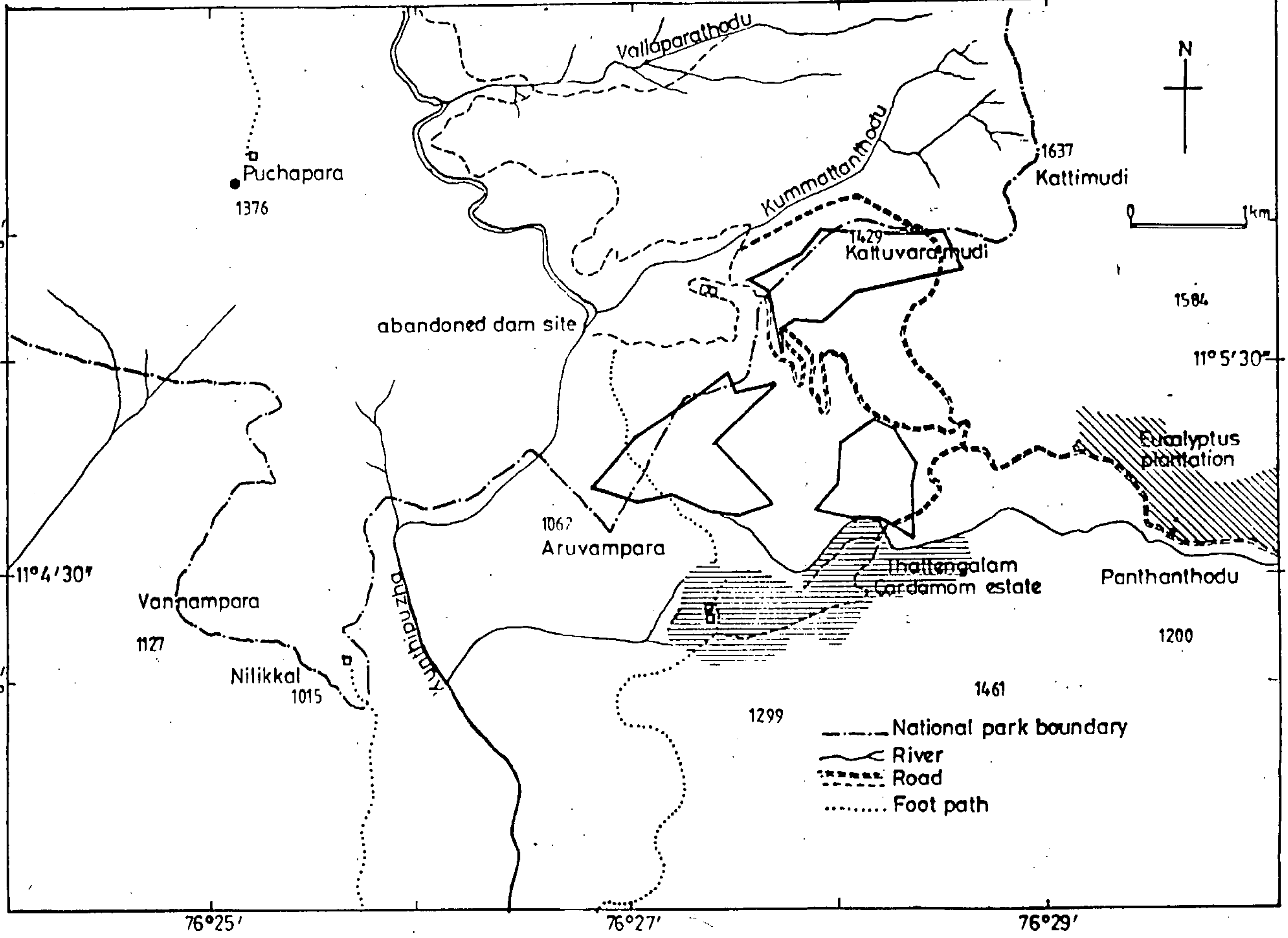

Fig. 5.5. Home ranges of selected LTM troops

Table 5.3. Feeding records of Lion-tailed macaques observed during the study in Silent Valley National park and adjacent areas.

Date	Plant/Animal	Plant part
23 March 1988	Mangifera indica	Immature fruits
19 May 1988	Cullenia exarillata	Seeds
	Palaquium ellipticum	fruit
24 May 1988	Cullenia exarillata	seeds
	Knema attenuata	fruit
	Insects	
26 May 1988	Cullenia exarillata	seeds
13 July 1988	Cullenia exarillata	seeds
14 July 1988	Cullenia exarillata	seeds
14 July 1988	Cullenia exarillata	seeds
21 August 1988	Cullenia exarillata	seeds
13 Sept. 1988	Cullenia exarillata	seeds
14 Sept. 1988	Cullenia exarillata	seeds
8 Nov. 1988	Cullenia exarillata	Flowers
9 Nov. 1988	Cullenia exarillata	Flowers
10 Nov. 1988	Cullenia exarillata	Flowers
11 Nov. 1988	Cullenia exarillata	Flowers
16 Dec. 1988	Cullenia exarillata	Flowers
19 Dec. 1988	Cullenia exarillata	Flowers
26 Dec. 1988	Cullenia exarillata	Flowers

5.6. Discussion

Census survey in the remote areas like Walakkad. Cheriawalakkad, on the way to Sispara etc., (upstream of Kunthipuzha) did not yield any sighting of LTM in those areas. No lion-tailed macaque troops were encountered in those areas. Most of the sightings of lion-tailed macaque troops were in the *Cullenia-Palaquium* association in the Kummattanthodu, Valiyaparathodu, Aruvampara, Kattuvaramudi, Panthanthodu, etc. It was estimated by Vijayan and Balakrishnan, (1977) that there could be approximately 20 troops making a population of 200 individuals. They had also reported that LTM was found in the submergible areas of the abandoned dam. During the present study most of the sightings was away from the submergible area of the abandoned dam but very near to it. Probably this shift in range is due to the selective removal of trees above 125 cm from the would be submergible area of the abandoned dam during 1977-80. It is worthwhile to recollect the study conducted by Vijayan and Balakrishnan (1977) on the impact of hydroelectric dam on wildlife, in which they had specifically reported the occurrence of three LTM troops in the submergible area and two troops near the proposed dam area.

Total area of continuous forests adjoining Silent Valley reserve is about 40,000 ha (Balakrishnan, 1984). But total continuous forest is not the only criterion for making a good lion-tailed macaque habitat. Absence of *Cullenia-Palaquium* tree association in the upper reaches of Kunthipuzha, in the Walakkad region, though a near natural habitat, the absence of lion-tailed macaques in these areas is remarkable. Aiyyar (1932) has described the northern limit of Cullenia-Palaquium tree association as follows:- "In the Silent Valley it is remarkable that its occurrence is confined to the south of the Chembotti stream, and thence across the Kunthipuzha to the south of Kummattanthodu. It is not found to the north of this line. In the Attappady valley it is confined to the Panthanthodu and Anaganthodu valley which are the south of the northern limit of this association in the Silent Valley". Absence of *Cullenia-Palaquium* tree association in the Walakkad area is also reported by Manilal et. al., 1988 and 1989. Animal census conducted during March 1989 by forest department with the help of 36 census parties accompanied by tribal guides also did not sight any lion-tailed macaque in those areas. Intensive study area included tree enumeration compartments (Chand Basha, 1977) 1, 2, 3, 12, 12a, 13, 14 and 14a of former Silent Valley RF and compartments 15 and 16 coming under the Panthenthodu beat of Attappady Block I RF. Of these compartments 1, 2 and 3 come under the Nilikkal area of the present study. Compartment numbers 12, 12a, 13, 14 and 14a are on the eastern side of Kunthipuzha and adjoins compartments 15 and 16 of Attappady Block I RF. These were the areas were lion-tailed macaques movement was noticed and is of considerable importance floristically regarding the presence of *Cullenia-Palaquium* tree association. Lion-tailed macaques were not found to cross across the road from Mukkali to Silent Valley since there is no canopy continuity along the road. Probably this is due to the felling of some trees along the road during 1977-80 for widening it and also most of the areas were fire affected resulting in the discontinuity of canopy corridor which is very much limiting to the ranging of lion-tailed macaque.

5.6.1. Problems of conservation

Main disturbances to the habitat of lion-tailed macaque habitat are as follows:- Panthanthodu area is very rich in the Cullenia-Palaquim tree association which is one of the best habitat for lion-tailed macaque in this locality. Since the Tattengalam estate lies in the east-west axis in the Panthanthodu area, there is a break in canopy continuity except for a small strip of forest between the estate and the road from Mukkali to Silent Valley. This area is fire affected and it requires intensive management and protection to take it back to its pristine nature. Thattengalam cardamom estate is situated between the altitude 940m and 1000m which is the prime habitat for lion-tailed macaque in the vested forest adjacent to Attappady area. Some details on the crucial region in the intensive study area is deliberately included. Thattengalam "cardamom" estate is about 186 ha in extent. It has about 74 ha rain-fed cultivation of cardamom and another 74 ha of cardamom cultivation area under sprinkler irrigation system and about 37 ha of area under cultivation of coffee and pepper. About 100 labourers are employed in the estate. About half of the area (south-west portion) drains to Kunthipuzha and the other half drains to Panthanthodu which ultimately drains to the Bhavani river. Though cardamom cultivation is not harmful to liontailed macaques as such, and does not severe the canopy continuity of the area but coffee and pepper requires more light and so there is no canopy continuity in those areas. Conservation of Silent Valley and consolidation of the boundary of this reserve is of prime national importance. For maintaining ecological boundary for LTM habitat it is desirable for bringing sufficient area of *Cullenia-Palaquium* tree association, which is crucial for lion-tailed macaque, under the National Park administration. Hence the Panthanthodu beat of Attappady RF should be added to the Silent Valley National Park.

In Silent Valley selection felling was restricted to 7 - 8 trees per hectare and species such as *Mesua ferrea, Cullenia exarillata, Calophyllum elatum, Palaquium ellipticum,* etc., During 1977-80, selective removal of trees above 125 cm was carried out in the would be submergible area of 800 ha (now abandoned) Silent Valley hydroelectric project (Chand Basha, 1987). About 2682 trees were removed from the submergible area for converting into railway sleepers. This might have resulted in the discontinuity of canopy corridor connecting either side of Kunthipuzha river. Previous instances of fire in some parts of Attappady RF adjacent to Silent Valley has deteriorated the *Cullenia- Palaquium* tree association to a great extent.

There was evidence of monkeys (Nilgiri langur) being trapped. The method employed was to isolate a group of trees with monkeys and cutting down adjoining trees for isolating the specific troop to be captured. This evidence was noticed on the side of the formerly jeepable road which passes through compartment number 15 of Block I, Attappady RF to the lower slopes of Kattimudi.

Debarking of *Symplocos* sp. trees for medicinal purposes by people from the peripheral areas of Silent Valley was encountered at Vannampara and Nilikkal area. This was brought to the notice of Wildlife Warden and timely protection measures were implemented. Temporary sheds of unauthorized cardamom collectors were seen in Kummattanthodu area, Punnamala area and Panthanthodu stream side.

5.6.2. Further scope for research

Survey of lion-tailed macaque in the New Amarambalam RF (proposed Kurathimala Wildlife Sanctuary), surrounding areas of Silent Valley National Park, especially in the Anaganthodu area of the western catchment of Bhavani river and population ecology of the arboreal mammals of the Kerala part of the Nilgiri Biosphere Reserve.

5.6.3. Suggestion for management

Panthanthodu forest beat of Attappady Block I RF may be added to Silent Valley National Park. The Silent Valley and adjacent areas are one of the two viable habitats for lion-tailed macaques.

5.7. Acknowledgments

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5.8. Literature cited

Aiyyar, T.V.V., 1932. The sholas of the Palghat division -A study in the ecology and silviculture of the tropical rain- forests of Western ghats. *Indian Forester*: 414-432.

Balakrishnan, M. 1984. The larger mammals and their endangered habitats in Silent Valley forests in South India *Biol. Conserv.* 29(3):277-286

Chand Basha,S. 1987. *Studies on the ecology of evergreen forests of Kerala with special reference to Silent Valley and Attappady (South India).* Ph.D. Thesis, University of Kerala, Trivandrum. 232p.

Green, S., and Minkowski, K. 1977. The lion-tailed monkey and its South Indian rainforest habitat. In: HRH Rainer; Bourne,G(Eds). *Primate Conservation*. Academic Press New York.

Green, S.M., 1978. Feeding, spacing, and movements as correlates of troop size in the lion-tailed macaque. In: Chivers, D.J. and Herbert, J (Eds): *Recent Advances in Primatology. Vol I. Behaviour.* New York. Academic Press, p343.

Johnson, J.M., 1980. The status, ecology and behaviour of lion-tailed macaque (*Macaca silenus*). *J. Bombay nat. Hist. Soc.* 75(Suppl.) 1017.

Karanth,U., 1984. *Conservation plan for the lion-tailed macaque and its rain forest habitats in Karnataka.* Department of Ecology and Environment, Bangalore.

Kumar, A. 1987. *The ecology and population dynamics of the lion-tailed macaque (*Macaca silenus*) in South India.* Ph.D. Dissertation , University of Cambridge, 174p.

Kurup, G.U. 1978. Distribution and status survey of the lion-tailed macaque, *Macaca silenus. J. Bombay nat. Hist.Soc.* 75:321-340

Manilal, K.S., A.K. Kandya and T. Sabu (1988). Phytosociological studies on the Silent Valley Forests, Kerala. *J.Trop.For.* 4(4):362-379.

Manilal, K.S., A.K. Kandya and T. Sabu (1989). A study of natural regeneration of 12 important tree species of Silent Valley, tropical rain forests, Kerala, India. *J.Trop.For.* 4(4):362-379.

Vijayan,V.S. and M. Balakrishnan. 1977. *Impact of hydroelectric project on wildlife.* Report of the first phase of study, 111p. Kerala Forest Research Institute, Peechi.

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6. SOIL AND PLANT COMMUNITY RELATIONSHIPS IN WET EVERGREEN FORESTS OF SILENT VALLEY

M. Balagopalan

Division of Soil Science

Contents

6.1. Abstract

This investigation was undertaken to study the physical and chemical properties of soils in these seven plant communities. Study sites were selected in the following plant communities- *Palaquium ellipticum -Cullenia exarillata; Palaquium - Mesua ferrea; Palaquium-Poeciloneuron indicum; Mesua - Calophyllum elatum; Mesua - Cullenia; Ochlandra*(Reed) *-Calophyllum; Ochlandra* (Reed) - *Poeciloneuron*. Sample plots of 50 x 50 m were laid out randomly in each community. Three soil pits were taken from each plot and pooled samples from 0-20, 20-40 and 40-60 cm layers were used for the analysis.

Air dried samples were analysed for particle- size separates, pH, organic carbon, exchange acidity, exchangeable bases, total N, extractable P, K, Ca and Mg. Particles >2 mm (gravel) were determined. Soil organic matter fractionation of surface samples (0-20 cm) was also done.

Soils in general are loam and strongly acidic in all the three layers. Analysis of variance of soil properties reveals that gravel, clay, exchange acidity, extractable P, K, Ca and Mg in the 0-60 cm layer and humic and fulvic acids in the 0-20 cm differ significantly. Correlation studies show that organic carbon is correlated with total N and extractable Ca is highly correlated with Mg. In all other cases, the properties follow different pattern.

The soils in the seven plant communities exhibit great variation in many physical and chemical properties: *Mesua-Calophyllum* and *Mesua - Cullenia* form a group, *Palaquium- Poecileruon* stands aloof while the remaining four vary markedly from each other and also with the former three. There is sound environment for enzymatic activity. The humus substances decompose to fulvic type in *Palaquium - Mesua, Mesua-Calophyllum, Mesua - Cullenia* and Reed - *Calophyllum* while in the remaining, they decompose to humic type.

6.2. Introduction

Contemporary ideas on vegetation and the underlying soils have developed as a result of many years of study (Armson, 1977; Aweto, 1981; Lescure and Boulet, 1985; Richards, 1979). It has been reported that the distribution of floristically defined forest types within moist dipterocarp forests of Brunei State is more or less associated with variations in soils and their parent materials (Ashton, 1964). Similar results have been observed by Baillie (1987), Baillie and Ashton (1983) and Baillie et al (1989) in the mixed dipterocarp forests of Sarawak. Also striking correlation between soil conditions and forest communities from British Guiana has been recorded (Yadav, *et al.* 1970). In the tropical lowland rainforests, on sites of similar topography, the variations in the species composition of trees is associated with variations in soils (Austin et al 1972).

In the wet evergreen forests, the number of inhabiting species is high and communities with only one dominant species are exceptional. But distinct communities comprising more than one dominant species or variations of such communities have been reported. Floristic and physiognomic heterogeneity of tropical rainforests is attributed to silvigenesis (Halle, *et al.* 1978). Lack of competition, edaphic factors, physiography, rainfall or special conditions imparting regeneration of certain dominant species favour the occurrence of different plant communities. However, the influence of soils on the composition and structure of tropical rainforest communities is also of prime importance (Ashton and Brunig, 1975, Hase and Folster, 1982). The plant communities have their own requirements and varying capacities for uptake of soil nutrients and participate in nutrient cycling. Preferential mineral uptake and release in each community will impart differences in soil properties. A systematic study of the soils will lead to greater understanding of the conditions which influence plant growth. In the wet evergreen forests of Silent Valley, seven plant communities have been reported (Ayyar, 1935). These in general offer a unique opportunity to unravel the relation between each community and environment, especially soils. This investigation was undertaken to study the physical and chemical properties of soils associated with these seven plant communities.

6.3. Materials and Methods

Study sites were selected in areas associated with the following seven plant communities in the wet evergreen forests of Silent Valley. The plant communities are *Palaquium ellipticum - Cullenia exarillata, Palaquium - Mesua ferrea, Palaquium - Poeciloneuron indicum, Mesua - Calophyllum elatum, Mesua - Cullenia, Ochlandra* (Reed) - *Calophyllum and Ochlandra* (Reed) - *Poeciloneuron.*

The location of study sites is presented in Fig.6.1. and their description is given in Table 6.1. Sample plots of 50 x 50 m were laid out randomly in each plant community. Three soil pits were taken from each plot and samples were collected from 0-20, 20-40 and 40-60 cm layers and composited. Soils were air dried, passed through 2 mm sieve and particles >2mm (gravel) were determined. Analyses were carried out for particle-size seaprates (hydrometer method), pH (20:40 soil - water suspension), organic carbon (potassium dichromate-sulphuric acid wet digestion), exchange acidity (BaOAc extraction), exchangeable bases (HCl extraction), total N (Kjeldahl digestion, followed by spectrophotometry using Nessler's reagent), extractable P (HCl + NH_4F extraction, followed by spectrophotometry, ascorbic acid as the reducing agent) (Alexander and Robertson, 1972), extractable K (extraction with NaOAc and spectrophotometric determination using sodium cobaltinitrite), extractable Ca and Mg (NH_4OAc extraction and titration with EDTA). Soil organic matter fractionation was done using the procedure of Stevenson (1965). Only surface samples (0-20 cm) were subjected to soil organic matter fractionation. The description of different layers of soil pits and their properties are given in Tables 6.2 to 6.36. Mean values of soil properties in different plant communities are given in Tables 6.37 to 6.43. Soil properties in the 0-60 cm layer are derived from those of 0-20, 20-40

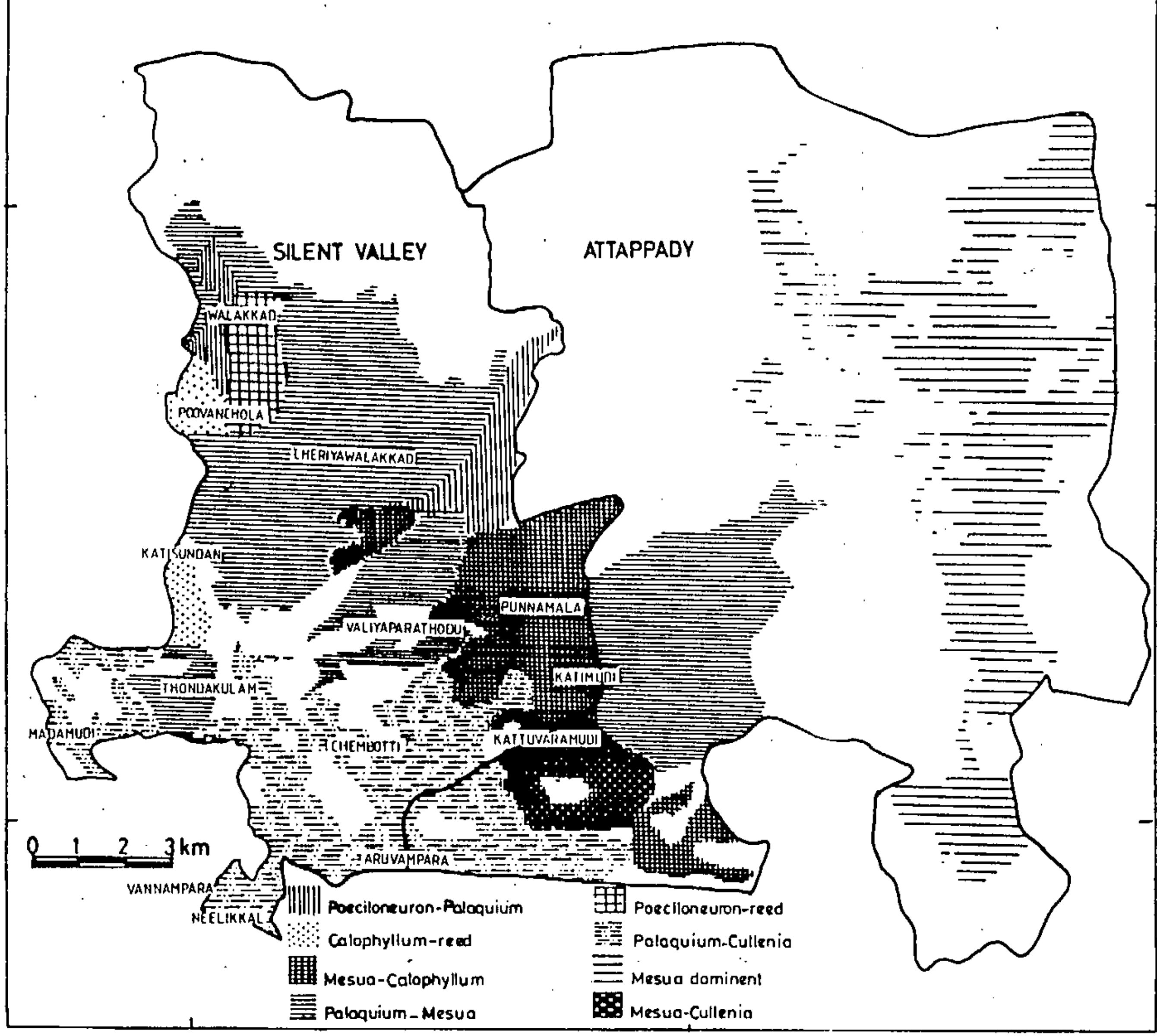

Fig. 6.1. Different plant communities in the wet evergreen forests of Silent Valley and Attappady reserves

and 40-60 cm layers and mean values are reported in Table 6.44. Mean values of humic and fulvic acids in the 0-20 cm layer are presented in Table 6.45.

6.4. Results

6.4.1. Mean values of soil properties in different layers

It can be seen from Tables 6.37 to 6.43 that in general gravel and sand contents follow no trend with depth and the soils are found to be moderately gravelly. Silt and clay increase with depth. The soils in general are loam in the surface as well as in deeper layers and are strongly acidic in the three layers in all communities except in the surface in Reed-Calophyllum where it is very strongly acid and in the 40 - 60 cm layer in Palaquium-Mesua where it is medium acid. Soil organic carbon contents decrease with depth in all communities except in Reed-Calophylum and Reed-Poeciloneuron where no trend is observed. Exchange acidity follows no trend except in Palaquium-Cullenia and Mesua-Cullenia where it decreases. As regards exchangeable bases, no pattern is seen. Total N follows no general trend in Mesua-Cullenia and Reed-Poeciloneuron whereas in all other cases it decreases.

Extractable P, Ca and Mg diminish with depth in all cases, so also extractable K excepting Palaquium-Cullenia where no pattern is observed. Organic carbon: total N increases with depth in Palaquium-Mesua and Reed-Calophyllum while in all other, no trend is followed. The values are greater than 10. The humic acid: fulvic acid ratio is less than 1 in Palaquium-Mesua, Mesua-Calophyllum, Mesua-Cullenia and Reed-Calophyllum.

6.4.2. Mean values of soil properties in the 0-60 cm layer

Soils in Palaquium - Cullenia plant community have relatively higher silt, clay and extractable P contents while gravel, sand and extractable K are lower.

Gravel contents are relatively higher in soils of Mesua-Calophyllum and lower in Cullenia -Palaquium and Palaquium - Mesua. As regards sand, the maximum and minimum values are in Mesua - Cullenia and Cullenia - Palaquium, respectively. Silt and clay contents are highest in Cullenia - Palaqium and lowest in Palaquium - Mesua, Mesua - Cullenia and Reed - Calophyllum for the former and Mesua - Cullenia for the latter. For pH and exchange acidity, Palaquium - Mesua has the maximum while Reed-Poeciloneuron and Mesua - Calophyllum have the minimum values, respectively. Organic carbon is heighest in Mesua-Cullenia and lowest in Reed-Calophyllum. In the case of exchangeable bases and total N, the upper values are in Mesua - Cullenia and Mesua - Callophyllum, respectively while the lower for both are in Reed - Calophyllum. Extractable P is highest in Cullenia - Palaquium, Palaquium - Mesua, Reed-Calophyllum, Reed-Poeciloneuron and lowest in Mesua - Calophyllum. As regards extractable K, the upper value is in Reed-Poeciloneuron and lower is Cullenia - Palaquium. For extractable Ca and Mg, the maximum values are in Palaquium - Cullenia and minimum is in Mesua - calophullum and Mesua-Cullenia.

Thus soils in Palaquium - Cullenia plant community possess relatively higher silt, clay and extractable P. Palaquium-Mesua soils are less acidic and contain more exchange acidity, extractable Ca and Mg. Soils in Mesua - Calophyllum comprise higher gravel and total N while sand and exchangeable bases contents are more in Mesua - Cullenia. Reed-Poeciloneuron soils have more extractable K than others. As regards lower values, soils in Cullenia Palaquium plant community possess lower gravel and sand; Mesua-Calophyllum contain lower exchange acidity and extractable P, Ca and Mg; Mesua-Cullenia soils have less clay, extractable Ca and Mg; Reed-Calophyllum soils contain less organic carbon, exchange acidity, exchangeable bases and total N while Reed-Poeciloneuron are more acidic.

In the case of humic and fulvic acids in the 0-20 cm layer, they are relatively higher in Palaquium - Mesua and vice versa for Mesua-

Cullenia. Humic acid:fulvic acid ratio is found to be lowest in Mesua-Calophyllum and highest in Mesua-Cullenia.

6.4.3. Relation between soil properties in the 0-60 cm layer

Palaquium - Cullenia

Sand is negatively correlated with clay and Mg. There is high correlation between silt and exchangeable bases, Ca and Mg while the latter two are correlated themselves. As regards clay, it is correlated with P while for organic carbon, there is high correlation with total N and exchange acidity. In the case of exchange acidity, there is high correlation with N and exchangeable bases is correlated with Mg (Table 6.48).

Palaquium - Mesua

Sand is negatively correlated with clay. As regards organic carbon, there is high correlation with exchange acidity, exchangeable bases, N, Ca and Mg while exchange acidity is correlated with N. Exchangeable bases is correlated with Ca and Mg whereas the latter two are correlated themselves (Table 6.49).

Palaquium - Poeciloneuron

Silt is correlated negatively with Mg while for pH there is high correlation with exchangeable bases and N. Total N shows high correlation with organic carbon and exchangeable bases whereas Ca and Mg are highly correlated themselves (Table 6.50).

Mesua - Calophyllum

In the case of sand, it is correlated negatively with silt and clay while the latter two are positively correlated themselves. There is high correlation between organic carbon and N so also between Ca and Mg (Table 6.51).

Mesua - Cullenia

As regards gravel, there is high correlation with exchangeable bases. Sand is correlated negatively with silt, clay and pH whereas the latter two are correlated themselves. Clay is also correlated with N. Organic carbon shows high correlation with N (Table 6.52)

Reed - Calophyllum

In the case of gravel, there is high negative correlation with sand and positive with pH and exchangable bases. Snd is correlated negatively with silt. For clay, there is high correlation with organic carbon while the latter is also correlated negatively with P. Extractable K shows high correlation with Ca (Table 6.53).

Reed - Poeciloneuron

Sand is correlated negatively with silt and clay whereas the latter is correlated negatively with N. There is high correlation between K and Ca (Table 6.54).

Thus, in general, sand is negatively correlated with silt and clay and organic carbon shows high correlation with N. Extractable Ca and Mg are also highly correlated. In all other cases the pattern of correlation between other properties vary differently.

Analysis of variance of soil properties (Tables 6.46 and 6.47) reveals that gravel, clay, exchange acidity, extractable P, K, Ca and Mg in the 0-60 cm layer and humic and fulvic acids in the 0-20 cm layer differ significantly. Further, Mulitple Comparison Among Means (MCAM) of soil properties shows that gravel in Palaquium - Poeciloneuron, Mesua - Calophyllum and Mesua - Cullenia differs significantly from Palaquium - Cullenia, Palaquium - Mesua and Reed - Calophyllum. As regards clay, Palaquium - Cullenia shows significant difference from all others except Reed - Poeciloneuron. In the case of exchange acidity and K, there is significant difference between Palaquium - Cullenia, Palaquium - Mesua, Palaquium - Poeciloneuron and the remaining four for the former and all except Reed-Calophyllum for the latter. For P, Mesua-Calophyllum differs significantly from all others except Palaquium - Poeciloneuron and Mesua-Cullenia. There is also significant difference between Palaquium-Cullenia and Reed-Calophyllum for P.

In the case of Ca, Palaquium - Mesua differs significantly from Mesua - Calophyllum, Mesua - Cullenia, Reed - Calophyllum and Reed - Poeciloneuron. Also Palaquium - Cullenia and Palaquium - Poeciloneuron show significant difference from Mesua-Calophyllum and Mesua - Cullenia for Ca. As regards Mg, Palaquium - Mesua differs from all except Palaquium - Cullenia and Palaquium - Poeciloneuraon and there is also significant difference between Palaquium-Poeciloneuron and Mesua - Calophyllum and Mesua - Cullenia. Humic acid in Palaquium - Mesua shows significant difference form all others except Palaquium - Poeciloneuron and Reed - Calophyllum while humic acid in Palaquium - Poeeciloneuron differs significantly from Reed - Poeciloneuron. In the case of fulvic acid in Palaquium - Poeciloneuron and Reed - Calophyllum varies significantly from Palaquium - Cullenia and Reed-Poeciloneuron. There is also significant difference between fulvic acid in Palaquium - Mesua and that in others except Palaquium - Poeciloneuron and Reed - Calophyllum.

6.5. General Discussion

The soils in general are rich in clay fraction. With depth, clay contents increase indicating the infiltraion of finer particles into deeper layers. The generally high values for organic carbon except in Reed-Calophyllum in the surface as well as deeper layers could be due to the relatively higher amounts of addition of leaf litter. Another possible reason that could be adduced for the existence of higher levels of organic matter is due to the fact that the proportion of finer fractions are found to be high and consequently these fractions aided the stabilization of organic matter, resulting in closer binding and subsequent accumulation. This has been reported by several workers (Lenedeva, 1971; Craswell and Waring, 1972). Also that slow and even lethargic activity of microbes under conditions of high acidity (Firosova, 1967; Primavesi, 1968) corroborates its effect on decomposition processess. The strongly acidic conditions of soils is achieved partly by this process. Moreover the total N values support this observation. Since the soils examined in the present study have pH values lying in a narrow range, it is difficult to draw any definite conclusion on this aspect. In the case of Reed-Calophyllum although large quantities of litter are added to the soil every year, the organic matter content is not high owing chiefly to the rapid rate of decomposition under more favourable conditions. All the soils are associated with low P availability. It can be seen that as a result of pronounced leaching caused by heavy rainfall, the soil have been impoverished in bases like Ca and Mg and are acidic in nature. The humic acid: fulvic acid ratio manifests that fulvic acid is the dominant fraction in Palaquium-Mesua, Mesua-Calophyllum, Mesua-Cullenia and Reed-Calophyllum while in others humic acid is the dominant fraction. This suggests that humus substances in the soils of former four decompose to fulvic type while in the remaining three to humic acid due to the nature of vegetation. It can also be pointed out that the nearing equilibrium stage (0.84 - 1.26) is an indicator of favourable condition for enzymatic activities in the soils (Mato, *et al.* 1972).

Detailed analysis of soils in the 0-60 cm layer in the seven plant communities reveal that there is considerable difference in soil properties. Mesua-Calophyllum and Mesua-Cullenia form a group; Palaquium-Poeciloneuron stands aloof and the remaining four vary from each other as well as from the former three.

Correlation studies reveal that organic carbon is correlated highly with total N. This supports the findings of Foster (1981) McGill and Cole (1981), Minhas and Bora (1982), Nandram and Raman (1981) and Singh and Datta (1987).

6.6. Conclusion

Soils in the seven plant communities exhibit great variation in many physical and chemical characteristics. Although the role of climate is of far reaching significance in governing soil development, the plant communities appear to display varied adaptability and preference for the different soils and contribute greatly in modifying their properties. The growth and distribution of plant communities are therefore influenced by the type of soil, especially in a homoclimatic region. Mesua-Calophyllum and Mesua Cullenia form a group; Palaquium - Poeciloneuron stands aloof while the remaining four vary markedly from each other and also with the former three. Organic carbon has a positive effect on total N. Extractable Ca is highly correlated with Mg. Thereis sound environment for enzymatic acitivity. The humus substances decompose to fulvic type in Palaquium-Mesua, Mesua-Calophyllum, Mesua-Cullenia and Reed-Calophyllum while in the remaining they decompose to humic type.

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Literature Cited

Alexander, TG and Rpbertson, JA. 1972. EDTA extractable phosphorus in relation to available and inorganic phosphorus forms in soils. *Soil Science*, 114: 69-72.

Armson, KA. 1977. Forest Soils: Properties and Processes. Univ. Toronto Press, Toronto. 390 p.

Ashton, PS. 1964. Ecological studies in the mixed dipterocarp forests of Brunei state. Oxford Forest Memoir. 25. Oxford university Press, Oxford.

Ashton, PS and Brunig, EF. 1975. The variation of tropical moist forest in relation to environmental factors and its relevance to land use planning. *Welforstwirtehaft*, 109:59-86.

Austin, MP; Ashton, PS and Greig Smith, P. 1972. The application of quantitative methods of vegetation survey III. A re-examination of rainforest data from Brunei. *J. Ecol.*, 60: 305-324.

Aweto, AO. 1981. Secondary succession and soil fertility restoration in S.W. Nigeria. Soil and vegetation interrelationships. *Ecol.*, 69: 941-957.

Ayyar, TVV. 1935. A working plan for the Ghat Forests of the Palghat Division. 1933-34 to 1942-43. Govt. Press, Madras. 202 p.

Baillie, IC. 1987. Soil characteristics and classification in relation to the mineral nutrition of tropical wooded ecosystems. Paper presented in the British Ecological Society Seminar, Stirling, September, 1987.

Baillie, IC and Ashton, PS. 1983. Some aspects of nutrient cycle in mixed dipterocarp forests in Sarawak. In: Tropical rainforests: ecology and management. (S.L. Sutton, et al ed.), pp. 347-356. Blackwell Scientific, Oxford.

Baillie, IC; Ashton, PS; Court, MN; Anderson, JAR; Fitzpatrick, EA and Tinsley, J. 1987. Site characteristics and distribution of tree spcies in moist dipterocarp forests on tertiary sediments in Central Sarawak, Malaysia. *J. Trop. Ecol.*, 3: 201-220.

Craswell, ET and Waring, SA . 1972. Effect of grinding on the decomposition of soil oganic matter I. The mineralisation of organic nitrogen in relation to soil type. *Soil Biol. Biochem.*, 4: 427-433.

Firosova, VP. 1967. Forest Soils of the Northern Krensurral region. *Soviet Soil Sci.*, 3: 300-308. Halle, F; Oldeman, RAA and Tomlinson, PB. 1978. Tropical Trees and Forests: An architectural analysis. Springer-Verlag, Berlin and New York. 441 p.

Hase, H and Folster, H. 1982. Bioelement inventory of a tropical semievergreen forest on eutrophic alluvial soils, Western Ilanos, Venezuela. *Acta Oecol., Oecol Gener.*, 3: 331-346.

Foster, HL. 1981. The basic factors which determine inherent soil fertility in Uganda. *J. Soil Sci.*, 32: 149-160.

Lenedeva, II. 1971. Effect of soil parent material on humus accumulation in the leached chernozems of the Mordvinian ASSR. *Pochvovedeniye*, 3: 48-62.

Lescure, JF. and Boulet, R. 1985. Relationship between soil and vegetation in a Tropical rain forest in French Guiana. *Biotropica*, 17: 155-164.

Mato, MC; Gonzaloz Alonso, IM and Mendez, I. 1972. Inhibition of enzymatic indoleacetic acid oxidation by soil fulvic acids. *Soil Biol. Biochem.*, 4: 475-478.

Minhas, RS and Bora, NC. 1982. Distribution of organic carbon and the forms of nitrogen in a topographic sequence of soils. *J. Ind. Soc. Soil Sci.*, 30: 135-139.

McGill, WB and Cole, CV. 1981. Comparative aspects of cycling of organic carbon, N, S and P through soil organic matter. *Geoderma*, 26: 267-286.

Nandram and Raman, KV. 1981. Characteristics of humic and fulvic acids extracted from different Indian soils. *J. Ind. Soc. Soil Sci.*, 29: 177-183.

Primavesi, A. 1968. Organic matter and soil production in the tropics and subtropics. In: Study week on Organic matter and soil fertility. North-Holland Publishing Co., Amsterdam. p. 653-699.

Richards, PW. 1979. The Tropical Rainforest. Cambridge Univ. Press. 450 p.

Singh, OP and Datta, B. 1987. Phosphorus Status of some hill soils of Mizoram in relation to pedogenic properties. *J. Indian Soc. Soil*

Sci., -35: 699-705. Stevenson, FJ. 1965. Gross chemical fractionation of organic matter. In: Methods of Soil Analysis. part II. Black, C.A. *et al* (ed). American Society of Agronomy, Madison. p. 1409-1421.

Yadav, JSP.; Pathak, IC. and Mahi, GS. 1970. Soil investigations in evergreen forests of Western Ghats. *Indian For.*, 96: 635-649. .pa

Table 6.1. Description of study sites in different plant communities

Plant Community	Description
1. Palaquium-Cullenia	1. Neelickal, 1150 m asl, hilly, poorly drained, two soil pits (1 & 2)
	2. Chembotti, 1050 m asl, hilly, poorly drained, one soil pit (3)
	3. Aruvampara, 1100 m asl, hilly, moderately well drained, two soil pits (4 & 5).
2. Palaquium-Mesua	1. Thondakulam, 1150 m asl, hilly, poorly drained, two soil pits(6 & 7)
	2. Valiyaparathodu, 1075 m asl, hilly, poorly drained, one soil pit (8)
	3. Cheriyawalakkad, 1200 m asl, hilly, poorly drained, two soil pits (9 & 10)
3. Palaquium-Poeciloneuron	1. Walakkad, 1350 m asl, hilly poorly drained five soil pits (11 to 15)
4. Mesua - Calophyllum	1. Kattimudi, 1400 m asl, hilly, poorly drained, three soil pits (16, 17 & 18)
	2. Punnamala, 1215 m asl hilly, poorly drained, two soil pits (19 & 20)
5. Mesua - Cullenia	1. Kattuvaramudi, 1300 m asl, hilly, poorly drained, five soil pits (21 to 25)
6. Reed-Calaphyllum	1. Poovanchola, 1150 masl, hilly, poorly drained, three soil pits (26 to 28)
	2. Katisundan, 1100 m asl, hilly poorly drained, two soil pits (29 & 30).
7. Reed-Poeciloneuron	Walakkad, 1350 m asl, hilly, poorly drained, five soil pits (31 to 35)

Table 6.2. Soil pit No. 1 Neelickal: Palaquium-Cullenia

00-20 cm Dark brown, loam, granular, very friable, slightly gravelly, abundant coarse roots, common medium and larger voids of roots, very strongly acid.

20-40 ". Dark yellowish brown, clay loam, blocky, slightly gravelly, abundant medium roots, distinct in decayed root channels, very strongly acid.

40-60 " Strong brown, clay loam, blocky, slightly gravelly slightly firm, many medium roots, very strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	114	58	125	99
Sand "	602	564	412	526
Silt "	12	142	143	135
Clay "	163	236	320	240
Soil pH	4.9	4.8	4.8	4.8
Org. carbon g/kg	35.8	24.4	19.3	26.5
Exch. acidity mg/kg	79	48	40	56
Exch. bases "	260	150	130	180
Total N g/kg	252	1.61	1.73	1.95
Extr. P mg/kg	35	15	10	20
Extr. K "	87	62	83	77
Extr. Ca "	72	12	10	31
Extr. Mg. "	31	8	8	16
Humic acid g/kg	3.53			
Fulvic acid	3.17			
Org. carbon: Total N	14.21	15.15	11.16	13.51
Humic acid: Fulvic acid	1.11			

Table 6. 3. Soil pit No. 2 Neelickal: Palaquium-Cullenia

00-20 cm Dark brown, clay loam, granular, very friable, moderately gravelly, abundant coarse roots, decaying leaves forming a mat on and closely below surface, medium acid

20-40 " Dark yellowish brown, loam, blocky, moderately gravelly, abundant medium roots, strongly acid.

40-60 " Dark brown, clay loam, massive, moderately gravelly, slightly firm, many medium roots, very strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	281	356	275	304
Sand "	432	403	387	407
Silt "	108	119	152	126
Clay "	179	122	186	163
Soil pH	5.7	5.1	4.7	5.2
Org. carbon g/kg	30.2	21.1	19.5	23.6
Exch. acidity mg/kg	49	56	51	52
Exch. bases "	290	250	540	360
Total N g/kg	2.13	1.61	1.06	1.60
Extr. P mg/kg	16	8	2	9
Extr. K "	37	137	52	75
Extr. Ca "	62	52	24	46
Extr. Mg. "	30	17	10	19
Humic acid g/kg	2.82			
Fulvic acid	2.03			
Org. carbon: Total N	14.19	13.95	18.33	15.49
Humic acid: Fulvic acid	1.39			

Table 6. 4. Soil pit No. 3 Chembotti:Palaquium-Cullenia

00-20 cm Strong brown, sandy loam, granular, very friable, slightly gravelly, abundant coarse roots, common medium and larger voids of roots, strongly acid.

20-40 " Strong brown, loam, blocky, slightly gravelly, many medium roots, strongly acid.

40-60 " Brown, loam, blocky, slightly gravelly, slightly firm, many medium roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	200	163	197	187
Sand "	609	588	508	568
Silt "	83	90	121	98
Clay "	108	159	174	147
Soil pH	5.2	5.4	5.1	5.2
Org. carbon g/kg	18.3	16.2	14.3	16.3
Exch. acidity mg/kg	44	44	37	42
Exch. bases "	170	170	140	160
Total N g/kg	1.19	0.84	0.88	0.97
Extr. P mg/kg	7	3	2	4
Extr. K "	87	112	86	95
Extr. Ca "	26	14	8	16
Extr. Mg. "	12	9	5	9
Humic acid g/kg	2.57			
Fulvic acid	2.19			
Org. carbon: Total N	15.33	19.31	16.24	16.96
Humic acid: Fulvic acid	1.17			

Table 6. 5. Soil pit No. 4 Aruvampara: Palaquium-Cullenia

00-20 cm Dark brown, loam, granular, very friable, slightly gravelly, abundant coarse and medium roots, strongly acid.

20-40 " Dark brown, loam, blocky, slightly gravelly, abundant medium roots, scattered faunal voids mainly termite channels and chambers, strongly acid.

40-60 " Dark yellowish brown, loam, massive, slightly firm, slightly gravelly, many medium and fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	46	93	119	86
Sand "	683	593	571	616
Silt "	106	143	117	122
Clay "	165	171	193	176
Soil pH	5.4	5.5	5.5	5.5
Org. carbon g/kg	33.4	20.6	13.1	22.4
Exch. acidity mg/kg	64	40	36	47
Exch. bases "	250	180	150	193
Total N g/kg	2.19	1.45	0.69	1.44
Extr. P mg/kg	7	14	6	9
Extr. K "	162	75	63	100
Extr. Ca "	28	28	16	24
Extr. Mg. "	13	12	7	11
Humic acid g/kg	2.65			
Fulvic acid	2.53			
Org. carbon: Total N	15.22	14.33	19.12	16.17
Humic acid: Fulvic acid	1.05			

Table 6. 6. Soil pit No. 5 Aruvampara: Palaquium-Cullenia

00-20 cm Brown, loam, granular, very friable, slightly gravelly, abundant coarse roots, medium acid.

20-40 " Strong brown, clay loam, blocky, slightly gravelly, clay-humus infiltration along old root and termite channels, many medium roots, strongly acid.

40-60 " Reddish brown, clay loam, massive, slightly firm, slightly gravelly, many fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	37	47	43	42
Sand "	693	592	586	624
Silt "	117	134	120	120
Clay "	153	227	251	207
Soil pH	5.7	5.4	5.5	5.5
Org. carbon g/kg	18.2	14.8	10.1	14.4
Exch. acidity mg/kg	37	36	29	34
Exch. bases "	120	140	140	133
Total N g/kg	1.28	0.82	0.89	1.00
Extr. P mg/kg	14	10	6	10
Extr. K "	61	83	62	69
Extr. Ca "	34	14	10	19
Extr. Mg. "	18	9	6	11
Humic acid g/kg	2.24			
Fulvic acid	2.01			
Org. carbon: Total N	14.25	18.13	11.30	14.56
Humic acid: Fulvic acid	1.11			

Table 6. 7. Soil pit No. 6 Thondakulam: Palaquium-Mesua

00-20 cm Dark brown, sandy loam, granular, very friable, slightly gravelly, abundant coarse roots, organic debris at surface, strongly acid.

20-40 " Strong brown, sandy loam, blocky, slightly gravelly, abundant medium roots, strongly acid.

40-60 " Reddish brown, sandy loam, blocky, slightly gravelly, abundant medium roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	57	193	168	139
Sand "	120	605	639	655
Silt "	99	84	93	92
Clay "	124	118	100	117
Soil pH	5.4	5.5	5.8	5.6
Org. carbon g/kg	33.9	24.8	10.2	23.0
Exch. acidity mg/kg	58	63	35	52
Exch. bases "	270	210	160	213
Total N g/kg	2.64	1.41	0.74	1.60
Extr. P mg/kg	12	7	5	8
Extr. K "	75	61	87	74
Extr. Ca "	74	32	11	39
Extr. Mg. "	35	14	5	18
Humic acid g/kg	2.98			
Fulvic acid	3.07			
Org. carbon: Total N	12.86	17.62	13.71	14.73
Humic acid: Fulvic acid	0.97			

Table 6. 8. Soil pit No. 7 Thondakulam: Palaquium-Mesua

00-20 cm Dark brown, loam, granular, very friable, slightly gravelly, abundant coarse roots, earthworms, medium acid.

20-40 " Strong brown, loam, blocky, moderately gravelly, infiltration of humiferous materials from upper layers, many medium roots, medium acid.

40-60 " Yellowish red, loam, massive, moderately gravelly, many medium and fine roots, distinct in decayed root channels, medium acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	186	275	225	229
Sand "	595	518	537	550
Silt "	98	77	97	91
Clay "	121	130	141	131
Soil pH	5.6	5.7	5.9	5.7
Org. carbon g/kg	31.2	22.4	14.4	22.7
Exch. acidity mg/kg	52	53	37	47
Exch. bases "	220	200	180	200
Total N g/kg	1.91	1.30	0.93	1.38
Extr. P mg/kg	12	8	6	9
Extr. K "	112	87	37	79
Extr. Ca "	54	24	18	32
Extr. Mg. "	27	14	11	17
Humic acid g/kg	4.52			
Fulvic acid	4.53			
Org. carbon: Total N	16.32	17.25	15.53	16.37
Humic acid: Fulvic acid	1.00			

Table 6-9. Soil pit No. 8 Valiyaparathodu: Palaquium-Mesua

00-20 cm Dark brown, loam, granular, very friable, slightly gravelly, decaying leaves forming a mat on and closely below surface, medium acid.

20-40 " Yellowsih red, sandy loam, blocky, slightly gravelly, abundant medium roots, distinct in decayed root channels, strongly acid.

40-60 " Yellowish red, loam, massive, slightly gravelly, slightly firm, many mmdium and fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	113	183	95	130
Sand "	647	601	600	616
Silt "	110	78	149	113
Clay "	130	138	156	141
Soil pH	5.6	5.6	5.5	5.6
Org. carbon g/kg	19.8	11.7	8.00	13.2
Exch. acidity mg/kg	34	30	29	31
Exch. bases "	170	120	150	147
Total N g/kg	1.60	0.76	0.56	0.97
Extr. P mg/kg	14	6	3	8
Extr. K "	163	143	100	135
Extr. Ca "	32	10	12	18
Extr. Mg. "	17	6	7	10
Humic acid g/kg	2.20			
Fulvic acid	3.17			
Org. carbon: Total N	12.34	15.49	14.21	14.01
Humic acid: Fulvic acid	0.69			

Table 6. 10. Soil pit No. 9 Cheriyawalakkad: Palaquium-Mesua

00-20 cm Dark brown, loam, granular, very friable, slightly gravelly, abundant coarse and medium roots, decaying leaves forming a mat on and closely below surface, strongly acid.

20-40 " Dark brown, loam, blocky, slightly gravelly, many medium roots, decaying organic matter mixed in lower horizons, strongly acid.

40-60 " Dark brown, loam, massive, slightly gravelly, few fine roots, medium acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	103	72	109	95
Sand "	617	607	579	419
Silt "	127	152	128	136
Clay "	153	169	184	169
Soil pH	5.1	5.3	5.6	5.3
Org. carbon g/kg	37.0	27.9	20.0	28.3
Exch. acidity mg/kg	74	24	73	57
Exch. bases "	300	180	170	217
Total N g/kg	1.82	2.43	1.04	1.76
Extr. P mg/kg	15	6	2	8
Extr. K "	188	137	111	145
Extr. Ca "	80	14	38	44
Extr. Mg. "	43	9	17	23
Humic acid g/kg	7.83			
Fulvic acid	7.99			
Org. carbon: Total N	20.34	11.47	19.26	17.02
Humic acid: Fulvic acid	0.98			

Table 6. 11. Soil pit No. 10 Cheriyawalakkad: Palaquium-Mesua

00-20 cm Reddish brown, loam, granular, very friable, slightly gravelly, abundant medium roots, plentiful decomposing organic litter, very strongly acid.

20-40 " Dark reddish brown, loam, blocky, slightly gravelly, clay-humus infiltration along old root channels, many medium roots, srongly acid.

40-60 " Yellowish, red sandy clay loam, blocky, slightly gravelly, many medium and fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	99	95	181	125
Sand "	634	607	569	603
Silt "	98	124	74	99
Clay "	169	174	176	173
Soil pH	4.9	5.2	5.4	5.2
Org. carbon g/kg	32.1	26.5	10.2	22.9
Exch. acidity mg/kg	30	51	64	55
Exch. bases "	220	170	160	183
Total N g/kg	2.54	1.56	0.63	1.58
Extr. P mg/kg	26	12	6	15
Extr. K "	113	100	38	84
Extr. Ca "	58	16	18	31
Extr. Mg. "	27	9	6	14
Humic acid g/kg	6.83			
Fulvic acid	7.07			
Org. carbon: Total N	12.66	17.04	16.16	15.29
Humic acid: Fulvic acid				

Table 6. 12. Soil pit No. 11 Walakkad: Palaquium-Poeciloneuron

00-20 cm Dark brown, sandy loam, granular, friable, moderately gravelly, abundant coarse and medium roots, forming surface mat, very strongly acid.

20-40 " Strong brown, loam, blocky, moderately gravelly, many medium roots, strongly acid.

40-60 " Dark brown, clay loam, massive, slightly firm, moderately gravelly, few faunal channels of termites, few medium roots, very strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	284	230	354	289
Sand "	575	527	373	492
Silt "	59	109	104	91
Clay "	82	134	169	128
Soil pH	5.0	5.1	5.0	5.0
Org. carbon g/kg	34.1	14.9	14.8	21.3
Exch. acidity mg/kg	46	46	75	56
Exch. bases "	130	150	180	153
Total N g/kg	1.99	1.26	0.71	1.32
Extr. P mg/kg	4	4	3	4
Extr. K "	100	63	39	67
Extr. Ca "	68	32	8	36
Extr. Mg. "	33	17	5	18
Humic acid g/kg	5.22			
Fulvic acid	5.00			
Org. carbon: Total N	17.17	11.79	20.77	16.58
Humic acid: Fulvic acid	1.04			

Table 6. 13. Soil pit No. 12 Walakkad: Palaquium-Poeciloneuron

00-20 cm Dark brown, loam, granular, friable, slightly gravelly, abundant coarse and medium roots, decaying leaves forming a mat on and closely below surface, very strongly acid.

20-40 " Yellowish red, loam, blocky, highly gravelly, many coarse roots, strongly acid.

40-60 " Yellowish red, loam, massive, slightly firm, moderately gravelly, abundant fine roots, many medium and coarse distinct locally prominent multicoloured mottles, very strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	94	400	368	287
Sand "	652	374	398	475
Silt "	120	101	91	104
Clay "	134	125	143	134
Soil pH	4.7	5.1	4.9	4.9
Org. carbon g/kg	29.1	19.3	12.0	20.1
Exch. acidity mg/kg	63	29	59	50
Exch. bases "	140	140	180	153
Total N g/kg	1.70	1.05	0.60	1.12
Extr. P mg/kg	6	6	4	5
Extr. K "	163	151	100	138
Extr. Ca "	18	10	9	12
Extr. Mg. "	11	6	4	7
Humic acid g/kg	3.33			
Fulvic acid	3.17			
Org. carbon: Total N	17.14	18.43	19.88	18.48
Humic acid: Fulvic acid	1.05			

Table 6. 14. Soil pit No. 13 Walakkad: Palaquium-Poociloneuron

00-20 cm Reddish brown, loam, granular, very friable, slightly gravelly, abundant coarse roots, common medium and larger voids of roots, very strongly acid.

20-40 " **Reddish brown, loam, moderately gravelly, many medium roots, very strongly acid.**

40-60 " Dark reddish brown, loam, massive, slightly firm, moderately gravelly, many medium roots, very strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	178	220	397	265
Sand "	601	565	401	522
Silt "	102	91	100	97
Clay "	119	124	102	116
Soil pH	4.9	4.7	4.9	4.8
Org. carbon g/kg	30.4	19.5	15.1	21.7
Exch. acidity mg/kg	44	37	69	50
Exch. bases "	110	140	180	143
Total N g/kg	1.76	1.21	0.76	1.24
Extr. P mg/kg	11	8	4	8
Extr. K "	102	75	62	80
Extr. Ca "	34	20	6	20
Extr. Mg. "	20	12	4	12
Humic acid g/kg	4.10			
Fulvic acid	3.97			
Org. carbon: Total N	17.31	16.13	19.92	17.79
Humic acid: Fulvic acid	1.03			

Table 6. 15. Soil pit No. 14 Walakkad: Palaquium-Poeciloneuron

00-20 cm Very dark brown, sandy loam, granular, moderately gravelly, abundant coarse and medium roots, common faunal voids 1-3 cm across including termite nests, strongly acid.

20-40 " Yellowish brown, sandy loam, blocky, slightly gravelly, abundant medium roots, medium acid.

40-60 " Dark brown, clay loam, massive, slightly firm, moderately gravelly, many medium and fine roots.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	394	180	365	313
Sand "	460	608	414	494
Silt "	77	80	72	76
Clay "	69	132	149	117
Soil pH	5.3	5.7	5.7	5.6
Org. carbon g/kg	27.8	24.7	18.3	23.6
Exch. acidity mg/kg	70	33	30	44
Exch. bases "	310	210	210	243
Total N g/kg	1.88	1.60	1.65	1.71
Extr. P mg/kg	16	6	4	9
Extr. K "	113	88	38	80
Extr. Ca "	42	38	18	33
Extr. Mg. "	27	19	11	19
Humic acid g/kg	3.22			
Fulvic acid	3.01			
Org. carbon: Total N	14.75	15.39	11.39	13.75
Humic acid: Fulvic acid	1.07			

Table 6. 16. Soil pit No. 15 **Valakkad: Palaquium-Poeciloneuron**

00-20 cm Dark reddish brown, loam, granular, very friable, slightly gravelly, abundant coarse and medium roots, much decomposing organic litter and many roots, medium acid.

20-40 " Reddish brown, sandy loam, blocky, moderately gravelly, many medium and fine roots, fine faunal voids, medium acid.

40-60 " Yellowish red, clay loam, massive, slightly firm, slightly gravelly, many fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	102	239	123	155
Sand "	615	597	489	567
Silt "	129	71	160	120
Clay "	154	93	228	158
Soil pH	5.7	5.8	5.4	5.6
Org. carbon g/kg	36.7	18.5	15.1	23.4
Exch. acidity mg/kg	40	30	33	34
Exch. bases "	290	170	170	210
Total N g/kg	2.78	1.27	0.75	1.60
Extr. P mg/kg	13	6	4	8
Extr. K "	139	87	52	93
Extr. Ca "	38	32	12	27
Extr. Mg. "	20	13	8	14
Humic acid g/kg	5.58			
Fulvic acid	5.06			
Org. carbon: Total N	13.18	14.56	20.23	15.99
Humic acid: Fulvic acid	1.10			

Table 6. 17. Soil pit No. 16 Kattimudi: Mesua-Calophyllum

00-20 cm Strong brown, sandy loam, granular, very friable, moderately gravelly, abundant coarse and medium roots forming surface mat, strongly acid.

20-40 " Strong brown, sandy loam, blocky, moderately gravelly, many medium roots, distinct in decayed root channels, very strongly acid.

40-60 " Dark brown, loam, blocky, moderately gravelly, abundant fine roots, few faunal channels of termites.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	297	317	293	302
Sand "	538	511	494	514
Silt "	71	70	89	77
Clay "	94	102	124	107
Soil pH	5.2	4.9	4.9	5.0
Org. carbon g/kg	28.6	13.3	8.1	16.7
Exch. acidity mg/kg	30	21	24	25
Exch. bases "	250	200	200	217
Total N g/kg	1.38	0.72	0.46	0.85
Extr. P mg/kg	11	4	2	6
Extr. K "	226	163	75	155
Extr. Ca "	38	20	9	22
Extr. Mg. "	20	11	5	12
Humic acid g/kg	2.83			
Fulvic acid	3.00			
Org. carbon: Total N	20.78	18.46	17.64	18.97
Humic acid: Fulvic acid	0.94			

Table 6. 18. Soil pit No. 17 Kattimudi: Mesua-Calophyllum

00-20 cm Dark brown, loam, granular, very friable, highly gravelly, abundant coarse and medium roots, root mat and disintegrating organic debris, strongly acid.

20-40 " Strong brown, sandy loam, blocky, moderately gravelly, abundant medium and fine roots, strongly acid.

40-60 " Dark reddish brown, loam, blocky slightly firm, moderately gravelly, many fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	571	326	238	378
Sand "	298	513	547	453
Silt "	58	67	81	69
Clay "	73	94	134	100
Soil pH	5.4	5.2	5.3	5.3
Org. carbon g/kg	36.2	19.0	17.2	24.1
Exch. acidity mg/kg	30	26	35	30
Exch. bases "	320	200	180	233
Total N g/kg	2.76	0.99	1.14	1.63
Extr. P mg/kg	13	2	2	6
Extr. K "	238	88	63	130
Extr. Ca "	21	13	6	13
Extr. Mg. "	14	9	3	9
Humic acid g/kg	2.85			
Fulvic acid	3.06			
Org. carbon: Total N	13.12	19.18	15.15	15.82
Humic acid: Fulvic acid	0.93			

Table 6. 19. Soil pit No. 18 Kattimudi: Mesua-Calophyllum

00-20 cm Reddish brown, loam, granular, very friable, moderately gravelly, abundant coarse and medium roots, organic debris at the surface, strongly acid.

20-40 " Light reddish brown, loam, blocky, moderately gravelly, infiltration of humiferous materials from upper layer, abundant medium roots, strongly acid.

40-60 " Dark yellowish brown, loam, massive, slightly firm, moderately gravelly, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	359	345	241	315
Sand "	414	437	455	435
Silt "	108	87	132	109
Clay "	119	131	172	141
Soil pH	5.2	5.1	5.2	5.2
Org. carbon g/kg	37.2	22.2	18.2	25.9
Exch. acidity mg/kg	23	21	30	25
Exch. bases "	230	190	190	203
Total N g/kg	2.51	1.29	1.54	1.78
Extr. P mg/kg	9	4	3	5
Extr. K "	251	202	72	175
Extr. Ca "	21	14	4	13
Extr. Mg. "	13	8	3	8
Humic acid g/kg	2.85			
Fulvic acid	2.91			
Org. carbon: Total N	14.83	17.23	11.78	14.61
Humic acid: Fulvic acid	0.98			

Table 6. 20. Soil pit No. 19 Punnamala: Mesua-Calophyllum

00-20 cm Dark yellowish brown, sandy loam, granular, very friable, moderately gravelly, abundant coarse and medium roots, decaying leaves and roots forming a mat on and closely below surface, strongly acid.

20-40 " Strong brown, sandy loam, blocky, moderately gravelly, abundant medium and fine roots, strongly acid.

40-60 " Yellowish red, loam, massive, moderately gravelly, abundant fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	364	288	232	295
Sand "	513	545	537	532
Silt "	50	79	100	76
Clay "	73	88	131	97
Soil pH	5.5	5.2	5.3	5.3
Org. carbon g/kg	32.5	17.5	14.1	21.4
Exch. acidity mg/kg	24	17	31	25
Exch. bases "	250	170	180	200
Total N g/kg	3.18	1.22	0.78	1.73
Extr. P mg/kg	9	4	3	5
Extr. K "	317	183	82	194
Extr. Ca "	28	14	6	16
Extr. Mg. "	15	9	4	9
Humic acid g/kg	2.65			
Fulvic acid	2.61			
Org. carbon: Total N	10.22	14.33	18.15	14.25
Humic acid: Fulvic acid	1.02			

Table 6. 21. Soil pit No. 20 Punnamala: Mesua-Calophyllum

00-20 cm Very dark grayish brown, sandy loam, granular, very friable, moderately gravelly, abundant coarse and medium roots, common medium and larger voids of roots, strongly acid.

20-40 " Reddish brown, loam, blocky, slightly gravelly, abundant medium and fine roots, distinct in decayed root channels, strongly acid.

40-60 " Dark yellowish brown, loam, massive, slightly firm, moderately gravelly, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	203	136	247	195
Sand "	613	539	517	557
Silt "	82	150	78	103
Clay "	102	175	158	145
Soil pH	5.3	5.2	5.4	5.3
Org. carbon g/kg	25.3	23.9	15.3	21.5
Exch. acidity mg/kg	30	13	30	24
Exch. bases "	230	180	210	207
Total N g/kg	1.37	1.25	1.48	1.37
Extr. P mg/kg	6	5	2	4
Extr. K "	163	150	38	117
Extr. Ca "	18	12	6	12
Extr. Mg. "	10	7	4	7
Humic acid g/kg	2.97			
Fulvic acid	3.14			
Org. carbon: Total N	18.43	19.13	10.37	15.98
Humic acid: Fulvic acid	0.95			

Table 6. 22. Soil pit No. 21 Kattuvaramudi: Mesua-Cullenia

00-20 cm Brown, loam, granular, very friable, moderately gravelly, plentiful medium roots, disintegrating organic debris, medium acid.

20-40 " **Grayish brown, loam, blocky, slightly gravelly, many fine roots, few faunal voids, strongly acid.**

40-60 " Dark yellowish brown, sandy loam, massive, moderately gravelly, slightly firm, many medium roots, few faunal channels of termites, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	284	123	211	206
Sand "	503	619	593	572
Silt "	95	119	54	89
Clay "	118	139	142	133
Soil pH	5.7	5.3	5.4	5.5
Org. carbon g/kg	34.9	31.2	25.2	30.4
Exch. acidity mg/kg	31	30	34	32
Exch. bases "	180	160	150	163
Total N g/kg	2.07	1.53	1.47	1.69
Extr. P mg/kg	14	7	3	8
Extr. K "	188	131	63	127
Extr. Ca "	20	12	8	13
Extr. Mg. "	13	7	5	8
Humic acid g/kg	2.94			
Fulvic acid	3.11			
Org. carbon: Total N	16.84	20.41	17.17	18.14
Humic acid: Fulvic acid	0.95			

Table 6. 23. Soil pit No. 22 Kattuvaramudi: Mesua-Cullenia

00-20 cm Yellowish brown, loam, granular, very friable, highly gravelly, abundant coarse and medium roots, root mat, strongly acid.

20-40 " Brownish yellow, loam, blocky, moderately gravelly, abundant fine roots, infiltraion of humiferous materials from upper layer, strongly acid.

40-60 " Brownish yellow, loam, massive, slightly firm, moderately gravelly, many fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	432	267	215	305
Sand "	408	534	587	510
Silt "	70	98	74	80
Clay "	90	101	124	105
Soil pH	5.2	5.5	5.4	5.4
Org. carbon g/kg	21.4	20.5	20.1	20.7
Exch. acidity mg/kg	41	40	30	37
Exch. bases "	360	190	180	243
Total N g/kg	1.13	0.99	1.17	1.10
Extr. P mg/kg	13	8	6	9
Extr. K "	163	117	87	122
Extr. Ca "	29	18	9	19
Extr. Mg. "	15	9	4	9
Humic acid g/kg	3.27			
Fulvic acid	3.39			
Org. carbon: Total N	18.86	20.64	17.20	18.90
Humic acid: Fulvic acid	0.96			

Table 6. 24. Soil pit No. 23 Kattuvaramudi: Mesua-Cullenia

00-20 cm Dark yellowish brown, loam, granular, friable, moderately gravelly, abundant coarse and medium roots, much decomposing organic matter, medium acid.

20-40 " **Yellowish brown, loam, blocky, moderately gravelly, abundant medium and fine roots, fine faunal voids, medium acid.**

40-60 " Brown, loam, blocky, slightly firm, slightly gravelly, many fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	395	333	123	284
Sand "	412	481	467	453
Silt "	91	76	180	119
Clay "	102	110	220	144
Soil pH	5.9	5.9	5.2	5.7
Org. carbon g/kg	34.7	26.0	20.1	26.9
Exch. acidity mg/kg	37	31	27	32
Exch. bases "	320	125	220	222
Total N g/kg	2.81	1.65	1.51	1.99
Extr. P mg/kg	8	5	2	5
Extr. K "	238	142	59	146
Extr. Ca "	28	17	10	18
Extr. Mg. "	16	9	7	11
Humic acid g/kg	3.10			
Fulvic acid	3.19			
Org. carbon: Total N	12.37	15.77	13.31	13.82
Humic acid: Fulvic acid	0.97			

Table 6. 25. Soil pit No. 24 Kattuvaramudi: Mesua-Cullenia

00-20 cm Dark reddish brown, sandy loam, granular, friable, slightly gravelly, abundant coarse and medium roots, decaying leaves forming a mat on and closely below surface, medium acid.

20-40 " Dark reddish brown, loam, blocky, slightly gravelly, many medium and fine roots, scattered faunal voids, mainly termite channels and chambers, medium acid.

40-60 " Reddish yellow, loam, massive, moderately gravelly, slightly firm, many fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	200	137	358	232
Sand "	603	593	473	556
Silt "	96	129	80	102
Clay "	101	141	89	110
Soil pH	5.8	5.1	5.2	5.4
Org. carbon g/kg	26.6	16.4	14.3	19.1
Exch. acidity mg/kg	43	34	21	33
Exch. bases "	170	200	310	227
Total N g/kg	1.55	0.99	0.94	1.16
Extr. P mg/kg	8	6	3	6
Extr. K "	301	152	82	178
Extr. Ca "	17	13	9	13
Extr. Mg. "	11	10	6	9
Humic acid g/kg	2.76			
Fulvic acid	3.14			
Org. carbon: Total N	17.19	16.61	15.26	16.35
Humic acid: Fulvic acid	0.88			

Table 6. 26. Soil pit No. 25 Kattuvaramudi: *Mesua-Cullenia*

00-20 cm Very dark grayish brown, sandy loam, granular, very friable, abundant coarse and medium roots, common medium and larger voids of roots, very strongly acid.

20-40 " Dark brown, sandy loam, blocky, moderately gravelly, clay humus infiltration along old root and termite channels, many medium and fine roots, strongly acid.

40-60 " Dark brown, sandy loam, blocky, slightly firm, moderately gravelly, many fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	511	236	325	357
Sand "	401	597	519	506
Silt "	32	82	66	60
Clay "	56	85	90	77
Soil pH	4.8	5.1	5.2	5.0
Org. carbon g/kg	30.4	16.1	13.6	20.0
Exch. acidity mg/kg	27	19	29	25
Exch. bases "	400	330	350	360
Total N g/kg	1.58	0.79	0.89	1.09
Extr. P mg/kg	7	6	4	6
Extr. K. "	293	142	61	165
Extr. Ca "	18	12	7	12
Extr. Mg. "	12	10	5	9
Humic acid g/kg	2.86			
Fulvic acid	3.01			
Org. carbon: Total N	19.24	20.48	15.29	18.34
Humic acid: Fulvic acid	0.95			

Table 6. 27 . Soil pit No. 26 Poovanchola: Reed-Calophyllum

00-20 cm Dark reddish brown, loam, granular, very friable, slightly gravelly, abundant coarse roots, very strongly acid.

20-40 " Reddish brown, loam, blocky, slightly firm, slightly gravelly, many medium roots, distinct in decayed root channels very strongly acid.

40-60 " Yellowish red, loam, massive, slightly gravelly, many fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	87	89	191	122
Sand "	645	638	593	626
Silt "	120	123	100	114
Clay "	148	150	116	138
Soil pH	4.8	5.0	5.2	5.0
Org. carbon g/kg	18.2	14.3	18.3	16.9
Exch. acidity mg/kg	24	23	24	24
Exch. bases "	110	110	120	113
Total N g/kg	1.56	0.97	1.33	1.29
Extr. P mg/kg	14	10	7	10
Extr. K "	113	38	13	55
Extr. Ca "	19	17	9	15
Extr. Mg. "	12	11	5	9
Humic acid g/kg	5.57			
Fulvic acid	6.01			
Org. carbon: Total N	11.66	14.67	13.81	13.38
Humic acid: Fulvic acid	0.93			

Table 6. 28. Soil pit No. 27 Poovanchola: Reed-Calophyllum

00-20 cm Dark reddish brown, loam, granular, friable, slightly gravelly, abundant coarse roots, organic debris at surface, very strongly acid.

20-40 " Yellowish red, loam, blocky, slightly firm, slightly gravelly, many medium and fine roots, faunal voids, strongly acid.

40-60 " Yellowish red, loam, blocky, slightly gravelly, few fine roots, very strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	145	119	251	96
Sand "	634	609	602	615
Silt "	99	129	180	136
Clay "	122	143	193	153
Soil pH	5.0	5.1	4.9	5.0
Org. carbon g/kg	12.5	8.8	17.9	13.1
Exch. acidity mg/kg	22	11	25	19
Exch. bases "	110	110	140	120
Total N g/kg	0.68	0.50	1.18	0.79
Extr. P mg/kg	13	14	8	12
Extr. K "	175	138	79	131
Extr. Ca "	24	16	12	17
Extr. Mg. "	18	10	8	12
Humic acid g/kg	3.86			
Fulvic acid	4.17			
Org. carbon: Total N	18.37	17.71	15.18	17.09
Humic acid: Fulvic acid	0.93			

Table 6. 29. Soil pit No. 28 Poovanchola: Reed-Calophyllum

00-20 cm Dark reddish brown, sandy loam, graular, very friable, slightly gravelly, abundant coarse roots, common voids, very strongly cid.

20-40 " Yellowish red, loam, blocky, slightly firm, slightly gravelly, many medium roots, strongly acid.

40-60 " Reddish brown, loam, massive, slightly firm, slightly gravelly, few fine roots, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	187	124	110	140
Sand "	633	612	583	609
Silt "	79	120	133	111
Clay "	101	144	174	140
Soil pH	5.0	5.2	5.3	5.2
Org. carbon g/kg	13.8	9.7	19.9	14.5
Exch. acidity mg/kg	52	33	37	41
Exch. bases "	110	120	110	113
Total N g/kg	1.04	0.79	1.01	0.95
Extr. P mg/kg	14	6	9	10
Extr. K "	250	131	60	147
Extr. Ca "	31	13	12	19
Extr. Mg. "	16	9	5	10
Humic acid g/kg	3.99			
Fulvic acid	4.14			
Org. carbon: Total N	13.21	12.23	19.62	15.02
Humic acid: Fulvic acid	0.96			

Table 6. 30. Soil pit No. 29 Katisundan: Reed-Calophyllum

00-20 cm Dark reddish brown, sandy loam, granular, friable, moderately gravelly, abundant coarse roots, plentiful decomposing organic litter and many roots, strongly acid.

20-40 " Very dark gray, loam, blocky, moderately gravelly, many medium roots strongly acid.

40-60 ". Yellowish red, loam, massive, slightly gravelly, few fine roots, medium acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	240	222	191	218
Sand "	593	574	565	577
Silt "	70	94	110	91
Clay "	97	110	134	114
Soil pH	5.1	5.2	5.6	5.3
Org. carbon g/kg	30.0	17.7	13.1	20.3
Exch. acidity mg/kg	24	20	19	21
Exch. bases "	250	240	130	207
Total N g/kg	1.75	0.86	0.81	1.14
Extr. P mg/kg	9	6	2	6
Extr. K "	122	117	53	97
Extr. Ca "	29	16	7	17
Extr. Mg. "	16	9	4	10
Humic acid g/kg	2.01			
Fulvic acid	3.65			
Org. carbon: Total N	17.16	20.66	16.13	17.98
Humic acid: Fulvic acid	0.55			

Table 6. 31. Soil pit No. 30 Katisundan: Reed-Calophyllum

00-20 cm. Dark reddish brown, loam, granular, very friable, slightly gravelly, abundant coarse and medium roots, faunal voids including termite nests, strongly acid.

20-40 " Yellowish brown, sandy loam, blocky, slightly gravelly, many medium roots, very strongly acid.

40-60 " Strong brown, sandy loam, massive, moderately gravelly, few fine roots, medium acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	113	186	290	190
Sand "	634	602	573	603
Silt "	92	72	50	71
Clay "	161	140	87	130
Soil pH	5.2	5.0	5.7	5.3
Org. carbon g/kg	21.3	13.1	8.8	14.4
Exch. acidity mg/kg	24	31	23	26
Exch. bases "	210	230	230	223
Total N g/kg	1.47	0.80	0.45	0.91
Extr. P mg/kg	16	14	8	13
Extr. K "	359	217	97	224
Extr. Ca "	38	18	11	22
Extr. Mg. "	21	12	6	13
Humic acid g/kg	1.85			
Fulvic acid	2.17			
Org. carbon: Total N	14.50	16.42	19.68	16.87
Humic acid: Fulvic acid	0.85			

Table 6. 32. Soil pit No. 31 Walakkad: Reed-Poeciloneuron

00-20 cm Brown, sandy loam, granular, very friable, slightly gravelly, decaying leaves forming a mat on and closely below surface, abundant coarse roots, very strongly acid.

20-40 " Strong brown loam, blocky, slightly gravelly, many coarse and medium roots, very strongly acid.

40-60 " Yellowish red, loam, massive, slightly gravelly, abundant fine roots, very strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	159	150	581	297
Sand "	654	603	302	520
Silt "	90	110	50	83
Clay "	97	137	67	100
Soil pH	4.7	4.8	4.7	4.7
Org. carbon g/kg	21.6	16.6	36.9	25.0
Exch. acidity mg/kg	56	49	24	43
Exch. bases "	130	170	200	167
Total N g/kg	1.06	0.97	1.85	1.29
Extr. P mg/kg	12	9	6	9
Extr. K "	193	112	94	133
Extr. Ca "	24	19	8	17
Extr. Mg. "	14	11	5	10
Humic acid g/kg	1.89			
Fulvic acid	1.07			
Org. carbon: Total N	20.37	17.19	19.91	19.16
Humic acid: Fulvic acid	1.77			

Table 6. 33. Soil pit No. 32 Valakkad: Reed-Poeciloneuron

00-20 cm Dark reddish brown, sandy loam, granular, very friable, moderately gravelly, abundant coarse roots, strongly acid.

20-40 " Reddish brown, loam, blocky, slightly gravelly, many coarse and medium roots, distinct in decayed root channels, very strongly acid.

40-60 " Strong brown, clay loam, massive, slightly firm, slightly gravelly, abundant fine roots, very strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	350	197	34	194
Sand "	503	500	497	499
Silt "	60	140	199	133
Clay "	89	163	270	174
Soil pH	5.1	4.7	4.7	4.8
Org. carbon g/kg	15.3	16.9	24.0	18.7
Exch. acidity mg/kg	30	41	41	37
Exch. bases "	170	110	80	120
Total N g/kg	1.08	0.91	1.26	1.08
Extr. P mg/kg	9	8	6	8
Extr. K "	275	165	89	176
Extr. Ca "	32	18	11	20
Extr. Mg. "	17	11	5	11
Humic acid g/kg	2.07			
Fulvic acid	2.01			
Org. carbon: Total N	14.15	18.50	19.08	17.24
Humic acid: Fulvic acid	1.03			

Table 6. 34. Soil pit No. 33 Valakkad: Reed-Poeciloneuron

00-20 cm Dark reddish brown, loam, granular, very friabe, slightly gravelly, abundant coarse and medium roots, ooganic debris at surface, very strongly acid.

20-40 " Dark reddish brown, loam, blocky, slightly gravelly, many medium and fine roots, scattered faunal voids, very strongly acid.

40-60 " Yellowish red, loam, massive, slightly firm, slightly gravely, abundant fine roots, very strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	16	53	42	37
Sand "	694	639	599	644
Silt "	130	131	170	144
Clay "	160	177	189	175
Soil pH	4.7	5.0	4.8	4.8
Org. carbon g/kg	19.5	17.9	20.1	19.2
Exch. acidity mg/kg	33	32	28	31
Exch. bases "	120	130	340	197
Total N g/kg	1.08	1.36	1.30	1.25
Extr. P mg/kg	14	10	8	11
Extr. K "	263	149	63	158
Extr. Ca "	30	19	8	19
Extr. Mg. "	17	11	5	11
Humic acid g/kg	2.91			
Fulvic acid	2.87			
Org. carbon: Total N	18.01	13.14	15.43	15.53
Humic acid: Fulvic acid	1.01			

Table 6. 35. Soil pit No. 34 Walakkad: Reed-Poeciloneuron

00-20 cm Dark reddish brown, sandy loam, granular, very friable, moderately gravelly, abundant coarse roots, common medium and larger voids of roots, strongly acid.

20-40 " Reddish brown, sandy loam, blocky, moderately gravelly, many medium roots, strongly acid.

40-60 " Yellowish red, sandy clay loam, massive, slightly firm, highly gravelly, few fine roots, few faunal channels of termites, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	213	271	458	314
Sand "	603	568	378	516
Silt "	81	50	46	59
Clay "	103	111	118	111
Soil pH	5.4	5.3	5.3	5.3
Org. carbon g/kg	33.4	20.1	14.1	22.5
Exch. acidity mg/kg	43	27	27	32
Exch. bases "	150	210	240	200
Total N g/kg	1.85	0.99	0.96	1.27
Extr. P mg/kg	17	10	4	10
Extr. K "	299	168	103	190
Extr. Ca "	34	16	12	21
Extr. Mg. "	19	9	5	11
Humic acid g/kg	2.62			
Fulvic acid	2.16			
Org. carbon: Total N	18.06	20.28	14.63	17.66
Humic acid: Fulvic acid	1.21			

Table 6. 34. Soil pit No. 33 Valakkad: Reed-Poeciloneuron

00-20 cm Dark reddish brown. loam, granular, very friabe, slightly gravelly, abundant coarse and medium roots, ooganic debris at surface, very strongly acid.

20-40 " Dark reddish brown, loam, blocky, slightly gravelly, many medium and fine roots, scattered faunal voids, very strongly acid.

40-60 " Yellowish red, loam, massive, slightly firm, slightly gravely, abundant fine roots, very strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	16	53	42	37
Sand "	694	639	599	644
Silt "	130	131	170	144
Clay "	160	177	189	175
Soil pH	4.7	5.0	4.8	4.8
Org. carbon g/kg	19.5	17.9	20.1	19.2
Exch. acidity mg/kg	33	32	28	31
Exch. bases "	120	130	340	197
Total N g/kg	1.08	1.36	1.30	1.25
Extr. P mg/kg	14	10	8	11
Extr. K "	263	149	63	158
Extr. Ca "	30	19	8	19
Extr. Mg. "	17	11	5	11
Humic acid g/kg	2.91			
Fulvic acid	2.87			
Org. carbon: Total N	18.01	13.14	15.43	15.53
Humic acid: Fulvic acid	1.01			

Table 6. 35. Soil pit No. 34 Walakkad: Reed-Poeciloneuron

00-20 cm Dark reddish brown, sandy loam, granular, very friable, moderately gravelly, abundant coarse roots, common medium and larger voids of roots, strongly acid.

20-40 " **Reddish brown, sandy loam, blocky, moderately gravelly, many medium roots, strongly acid.**

40-60 " Yellowish red, sandy clay loam, massive, slightly firm, highly gravelly, few fine roots, few faunal channels of termites, strongly acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	213	271	458	314
Sand "	603	568	378	516
Silt "	81	50	46	59
Clay "	103	111	118	111
Soil pH	5.4	5.3	5.3	5.3
Org. carbon g/kg	33.4	20.1	14.1	22.5
Exch. acidity mg/kg	43	27	27	32
Exch. bases "	150	210	240	200
Total N g/kg	1.85	0.99	0.96	1.27
Extr. P mg/kg	17	[illegible]	4	[illegible]
Extr. K "	299	168	103	190
[illegible] "	34	16	12	21
Extr. M "	[illegible]	9	5	11
Humic acid g/kg	2.62			
Fulvic acid	2.16			
Org. carbon: Total N	18.06	20.28	14.63	17.66
Humic acid: Fulvic acid	1.21			

Table 6. 36. Soil pit No. 35 Valakkad: Reed-Poeciloneuron

00-20 cm Dark brown, clay loam, granular, friable, highly gravelly abundant coarse roots, root mat, medium acid.

20-40 " **Dark yellowish brown, loam, blocky, moderately gravelly, many medium roots, infiltration of humiferous materials from upper layer, medium acid.**

40-60 " Yellowish red, loam, massive, moderately gravelly, abundant fine roots, medium acid.

Properties	Depth (cm)			
	00-20	20-40	40-60	00-60
Gravel g/kg	658	255	201	371
Sand "	199	514	507	407
Silt "	50	90	130	90
Clay "	93	141	162	132
Soil pH	5.8	5.6	5.9	5.8
Org. carbon g/kg	31.3	17.0	11.9	20.1
Exch. acidity mg/kg	32	30	27	30
Exch. bases "	200	150	110	153
Total N g/kg	1.59	0.91	0.59	1.03
Extr. P mg/kg	17	12	8	12
Extr. K "	319	202	69	197
Extr. Ca "	32	18	13	21
Extr. Mg. "	21	12	7	13
Humic acid g/kg	2.74			
Fulvic acid	2.15			
Org. carbon: Total N	19.67	18.72	20.28	19.56
Humic acid: Fulvic acid	1.27			

Table 6. 37. Mean values of soil properties in different layers in Palaquium - Cullenia community

Properties	Depth (cm) 0-20	20-40	40-60
Gravel g/kg	136	143	152
Sand "	604	548	493
Silt "	107	126	130
Clay "	153	183	225
Soil pH	5.4	5.2	5.1
Org.carbon g/kg	27.2	19.4	15.3
Exch. activity mg/kg	55	45	39
Exch. bases "	218	178	220
Total N g/kg	1.9	1.3	1.1
Extr. P mg/kg	16	10	5
Extr. k "	87	94	69
Extr. Ca "	44	24	14
Extr. Mg "	21	11	7
Humic acid g/kg	2.76		
Fulvic acid "	2.39		
Org. carbon: Total N	14.64	16.50	15.20
Humic acid: Fulvic acid	1.17		

Table 6.38. Mean values of soil properties in different layers in Mesua - Palaquium community (n=5)

Properties	Depth (cm)		
	0-20	20-40	40-60
Gravel g/kg.	112	164	157
Sand "	643	588	584
Silt "	106	103	108
Clay "	139	145	151
Soil pH	5.3	5.5	5.6
Org. carbon g/kg.	30.8	22.7	12.6
Exch. acidity mg/kg.	50	44	48
Exch. bases "	237	176	164
Total N g/kg.	2.10	1.69	1.18
Extr. P "	16	8	4
Extr. K "	130	110	75
Extr. Ca "	60	19	19
Extr. Mg "	30	10	9
Humic acid g/kg.	4.87		
Fulvic acid "	5.17		
Org. carbon: Total N	14.90	15.77	15.93
Humic acid: Fulvic acid	0.92		

Table 6.39. Mean values of soil properties in different layers in Palaquium-Poeciloneuron community. (n=5)

Properties	Depth (cm)		
	0-20	20-40	40-60
Gavel g/kg	210	254	321
Sand "	581	534	415
Silt "	97	90	105
Clay "	112	122	159
Soil pH	5.1	5.3	5.2
Org. carbon g/kg	31.6	19.4	15.1
Exch. acidity mg/kg	53	35	53
Exch. bases "	196	162	184
Total N g/kg	2.02	1.28	0.89
Extr. P mg/kg	10	6	4
Extr. K "	123	93	58
Extr. Ca "	40	26	11
Extr. Mg "	22	13	6
Humic acid g/kg	4.29		
Fulvic acid "	4.04		
Org. carbon: Total N	15.91	15.26	18.38
Humic acid: Fulvic acid	1.06		

Table 6.40. Mean values of soil properties in different layers in Mesua - Calophyllum (n=5)

Properties	Depth (cm)		
	0-20	20-40	40-60
Gravel g/kg	154	148	161
Sand "	628	607	583
Silt "	92	108	115
Clay "	126	137	141
Soil pH	5.0	5.1	5.3
Org. carbon g/kg	19.2	12.3	15.6
Exch. acidity mg/kg	29	24	26
Exch. bases "	158	162	146
Total N g/kg	1.30	0.78	0.96
Extr. P mg/kg	13	10	7
Extr. K "	204	128	60
Extr. Ca "	28	16	10
Extr. Mg "	17	10	6
Humic acid g/kg	3.46		
Fulvic acid "	4.03		
Org. carbon: Total N	14.98	16.34	16.88
Humic acid: Fulvic acid	0.84		

Table 6.41. Mean values of soil properties in different layers in Mesua - Cullenia (n=5)

Properties	Depth (cm)		
	0-20	20-40	40-60
Gravel g/kg	279	185	263
Sand "	530	565	457
Silt "	82	104	119
Clay "	109	146	161
Soil pH	5.1	5.1	5.1
Org. carbon g/kg	24.2	17.7	21.4
Exch. acidity mg/kg	39	36	29
Exch. bases "	154	152	194
Total N g/kg	1.33	1.03	1.19
Extr. P mg/kg	14	10	6
Extr. K "	270	159	84
Extr. Ca "	30	18	10
Extr. Mg "	18	11	5
Humic acid g/kg	2.45		
Fulvic acid "	2.05		
Org. carbon: Total N	18.05	17.57	17.87
Humic acid: Fulvic acid	1.26		

Table 6.42. Mean values of soil properties in different layers in Reed-Calophyllum community (n=5)

Properties	Depth (cm)		
	0-20	20-40	40-60
Gavel g/kg	364	219	246
Sand "	465	565	528
Silt "	77	101	93
Clay "	94	115	133
Soil pH	5.5	5.4	5.3
Org. carbon g/kg	29.6	22.0	18.7
Exch. acidity mg/kg	36	31	28
Exch. bases "	286	201	242
Total N g/kg	1.83	1.19	1.20
Extr. P mg/kg	10	6	4
Extr. K "	237	137	70
Extr. Ca "	22	14	9
Extr. Mg "	13	9	7
Humic acid g/kg	2.99		
Fulvic acid "	3.17		
Org. carbon: Total N	16.90	18.78	15.65
Humic acid: Fulvic acid	0.94		

Table 6.43. Mean values of soil properties in different layers in Reed-Poeciloneuron community (n=5)

Properties	Depth (cm)		
	0-20	20-40	40-60
Gavel g/kg	359	282	250
Sand "	475	509	510
Silt "	74	91	96
Clay "	92	118	144
Soil pH	5.3	5.1	5.2
Org. carbon g/kg	32.0	19.2	14.6
Exch. acidity mg/kg	27	20	30
Exch. bases "	256	188	192
Total N g/kg	2.24	1.09	1.08
Extr. P mg/kg	10	4	2
Extr. K "	239	157	66
Extr. Ca "	25	15	6
Extr. Mg "	14	9	4
Humic acid g/kg	2.83		
Fulvic acid "	2.94		
Org. carbon: Total N	15.48	17.67	14.63
Humic acid: Fulvic acid	0.96		

Table 6. 44. Mean values of soil propprties in the 0-60 cm layer in the seven plant communities

	Plant Communities*						
Properties	I	II	III	IV	V	VI	VII
Gravel g/kg	144	144	262	297	277	154	243
Sand "	638	707	689	710	722	720	684
Silt "	143	122	133	123	122	122	131
Clay "	219	174	178	167	156	158	185
Soil pH	5.2	5.5	5.2	5.2	5.4	5.2	5.1
Org. carbon g/kg	20.64	22.02	22.02	21.92	23.42	15.84	21.10
Exchange acidity mg/kg	46	48	47	26	32	26	35
Exchangeable " bases	205	192	180	212	243	155	167
Total N g/kg	1.39	1.46	1.40	1.47	1.41	1.02	1.18
Extr. P mg/kg	10	10	7	5	7	10	10
Extr. K "	83	103	92	154	148	131	171
Extr. Ca "	27	33	26	15	15	18	20
Extr. Mg "	13	16	14	9	9	11	11

* I = Palaquium-Cullenia; II = Palaquium-Mesua; III = Palaquium-Poeciloneuron; IV = Mesua-Calophyllum; V = Mesua-Cullenia; VI = Reed-Calophyllum; VII = Reed-Poeciloneuron

Table 6.45. Mean values of humic and fulvic acids in the 0 - 20 cm layer in different plant communities

Properties	Plant Communities*						
	I	II	III	IV	V	VI	VII
Humic acid (g/kg)	2.76	4.87	4.29	3.46	2.45	2.99	2.83
Fulvic acid (g/kg)	2.39	5.17	4.04	4.03	2.05	3.17	2.94

I = Palaquium-Cullenia; II = Palaquium-Mesua; III = Palaquium-Poeciloneuron; IV = Mesua-Calophyllum; V = Mesua-Cullenia; VI = Reed-Calophyllum; VII = Reed-Poeciloneuron

n=5

Table 6.46. Analysis of variance of soil properties in the 0-60 cm layer in different plant communities

Source	Sum of squares	Degrees of Freedom	Mean squares	V-ratio
Gravel				
Total SS	316759.6	34		
Treatment SS	136661.0	6	22776.8	3.54*
Error SS	180098.6	28	6432.1	
Clay				
Total SS	32316.7	34		
Treatment SS	13476.5	6	2246.1	3.34*
Error SS	18840.2	28	672.9	
Exchange acidity				
Total SS	4453.5	34		
Treatment SS	2927.1	6	487.8	8.95
Error SS	1526.4	28	54.5	
Extractable P				
Total SS	378.5	34		
Treatment SS	132.9	6	22.1	2.53*
Error SS	245.6	28	8.77	
Extractable K				
Total SS	67219.9	34		
Treatment SS	34089.1	6	5681.5	4.80**
Error SS	33130.9	28	1183.2	
Extractable Ca				
Total SS	2854.7	34		
Treatment SS	1367.9	6	227.9	4.29**
Error SS	1486.8	28	53.1	
Extractable Mg				
Total SS	508.9	34		
Treatment SS	218.5	6	36.4	3.51*
Error SS	290.4	28	10.3	

*, ** significant at P = 0.05 and 0.01, respectively

Table 6.47. **Analysis of variance of humic and fulvic acids in the 0-20 cm layer in the different plant communities**

Source	Sum of squares	Degrees of Freedom	Mean squares	V-ratio
Humic acid				
Total SS	63.4	34		
Treatment SS	23.8	6	3.97	2.81*
Error SS	39.5	28	1.41	
Fulvic acid				
Total SS	69.7	34		
Treatment SS	35.1	6	5.86	4.75**
Error SS	34.5	28	1.23	

*, ** significant at P=0.05 and 0.01, respectively.

Table 6.48. Correlation between soil properties in the 0-60 cm layer in Palaquium - Cullenia plant community.

Properties	Clay	Exch. acidity	Exch. bases	Total N	Extr. P	Extr. Ca	Extr. Mg.
Sand	-0.92						-0.95
Silt			0.92			0.99	0.97
Clay					0.91		
Org. carbon		0.97		0.97			
Exch. acidity				0.93			
Exch. bases							0.92
Extr. Ca							0.97

n=5

Table 6.49. Correlation between soil properties in the 0-60 cm layer in Palaquium - Mesua plant community.

Properties	Clay	Exch. acidity	Exch. bases	Total N	Extr. Ca	Extr. Mg.
Sand	-0.97					
Org. carbon		0.95	0.92	0.96	0.95	0.93
Exch. acidity				0.99		
Exch. bases					0.97	0.93
Total N					0.95	
Extr. Ca						0.96

n=5

Table 6.50. Correlation between soil properties in the 0-60 cm layer in Palaquium-Poeciloneuron plant community

Properties	Exch. bases	Total N	Extr. Mg.
Silt			-0.90
Soil pH	0.96	0.95	
Org. carbon		0.96	
Exch. bases		0.95	
Extr. Ca			0.98

n=5

Table 6.51. Correlation between soil properties in the 0-60 cm layer in Mesua - Calophyllum plant community

Properties	Silt	Clay	Total N	Extr. Mg.
Sand	-0.99	-0.99		
Silt		0.96		
Org. carbon			0.90	
Extr. Ca				0.95

n=5

Table 6.52. Correlation between soil properties in the 0-60 cm layer in Mesua - Cullenia plant community

Properties	Silt	Clay	pH	Exch. bases	Total N
Gravel				0.91	
Sand	-0.95	-0.96	-0.96		
Clay			0.95		0.91
Org. carbon					0.91

n=5

Table 6.53. Correlation between of soil properties in the 0-60 cm layer in Reed-Calophyllum plant community

Properties	Sand	Silt	pH	Org. carbon	Exch. bases	Extr. P	Extr. Ca
Gravel	-0.92		0.93		0.90		
Sand		-0.96					
Clay				0.97			
Org. carbon						-0.90	
Extr. K							0.98

n=5

Table 6.54. Correlation between soil properties in the 0-60 cm layer in Reed-Poeciloneuron plant community

Properties	Silt	Clay	Total N	Extr. Ca
Sand	-0.90	-0.91		
Clay			-0.94	
Extr. K				0.99

n=5

7. ESTABLISHMENT OF PERMANENT SAMPLE PLOTS FOR LONGTERM MONITORING OF ECOLOGICAL PROCESSES

K. Balasubramanyan

Division of Ecology

Contents

7.1 Abstract

Twelve plots of 50 X 50 m size have been laid out in four localities viz., Panthanthodu, (with the dominants of *cullenia exarillata* and *Palaquium ellipticum*) Aruvampara, (with *Litsea* sp. and *Pterocarpus marsupium*) Punnamala (with *Cullenia exarillata* amd *Palaquium ellipticum*) and Chembotti (with *Cullenia exarillata, Palaquium ellipticum* and *Mesua ferrea*). 5483 trees spread over these twelve plots have been nailed with aluminium number plates at breast height. The basal area of all the individuals have been calculated. It varies from 48 to 80 m^2 per hectare. The individuals were also classified according to their girth classes. Although all the four areas had been worked in the past, at Panthanthodu and Chembotti individuals above 180 cm are still available. Aruvampara and Punnamala have been heavily worked in the past.

7.2 Introduction

In the context of conservation oriented forestry, establishment of permanent sample plots assumes significance as they serve as "controls" for evaluating the ecological changes over a period of time. These changes can be on different lines like, annual increment put forth by various species, the status of regeneration, succession of plant communities, microclimatic changes etc. With this in view twelve permanent sample plots were laid out in and around the core area of Silent Valley which is not likely to be under threat of any major biotic or anthropic changes.

FRI (1975) has brought out a compilation on the status of 158 preservation plots (163 in natural forests and 23 in plantations) scattered in various parts of India and covering an area of 8422 ha. As can be seen from this report there is no rigidity as far as the size of the plots are concerned. They vary from 0.01 ha to 400 ha Subsequently, a Tree Increment Plot of *Ougenia oojeinensis* (Singh 1980) in Palamau Plateau, Bihar and another permanent sample plot of mixed species in Maharashtra were also established (Singh & Sharma (1983).

7.3 Methodology:

Initially, the study area viz, Silent Valley was extensively perambulated for getting an idea of the different types of vegetation. Based on this reconnaissance twelve plots of 50 X50 m size were laid out at four localities depending upon the species composition and the degree of disturbance. In each locality three plots were laid out. The location of these plots with elevation are shown in Fig. 7.1. All the individuals above 10 cm gbh were numbered with aluminium labels nailed at breast height and over 90% them identified. A total of 5483 individuals were nailed and initial measurements were taken.

7.4 Results and Disucssion

Basal Area:

Table 7.1. to 7.12 summarises the salient features of these plots. The basal area of the most dominant speices in each plot were worked out and all the secondary and a few unidentified ones were grouped under the category "Miscellaneous".

At Panthanthodu, the basal area of two speices *Cullenia exarillata* and *Palaquium ellipticum* along with *Myristica dactyloides* are found to be more in comparison with others including the miscellaneous ones.On the other hand, these species have been almost totally extracted from Aruvampara. The miscellaneous ones occupy roughly 75% of the basal area.

Punnamala is another area where the dominant ones are *Cullenia exarillata* and *Palaquium ellipticum*. *Myristica dactyloides* and *Agrostistachys meeboldii* are fairly represented in all the three plots.

Chembotti presents a clear picture where one should encounter a community dominated by *Cullenia exarillata, Palaquium ellipticum* and *Mesua ferrea*. Besides these three species *Myristica dactyloides* and *Aglaia anamallayana* are also uniformaly distributed.

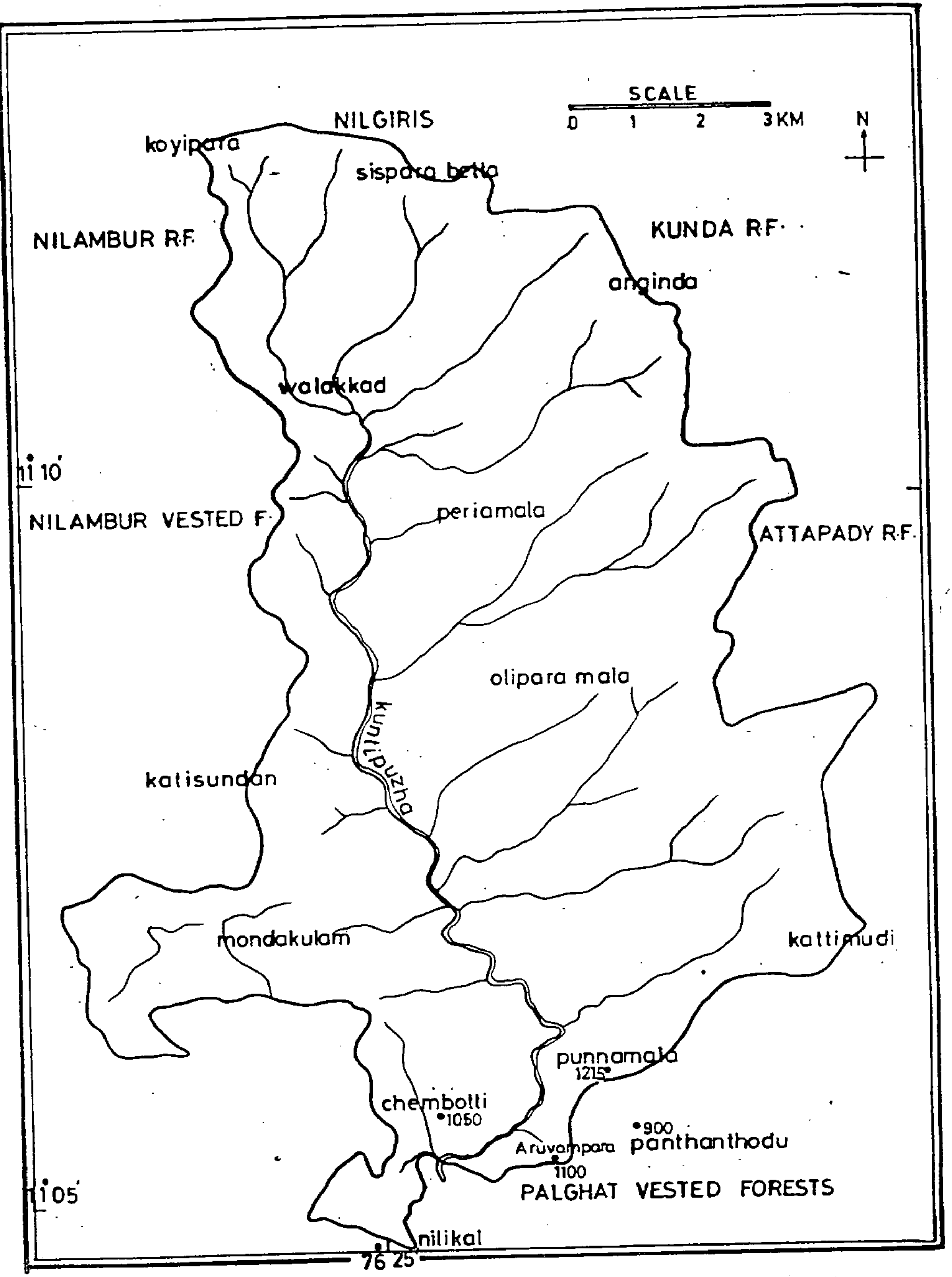

Fig.7.1. LOCATION OF PERMANENT SAMPLE PLOTS

Table 7.I.

Panthanthodu I

Total No. of individuals 332

	Species	Basal area (in m^2)	% Basal area
1.	Palaquium ellipticum	2.41	17.2
2.	Dysoxylum malabaricum	2.22	15.9
3.	Cullenia exarillata	2.13	15.2
4.	Mesua ferrea	1.28	9.2
5.	Myristica dactyloides	0.87	6.2
6.	Calophyllum tomentosum	0.47	3.4
7.	Agrostistachys meeboldii	0.39	2.8
8.	Miscellaneous	4.20	30.0
	Total	13.97	99.9

Table 7.2.

Panthanthodu II

Total No. of individuals 348

Species	Basal area (in m^2)	% Basal area
1. Cullenia exarillata	12.54	45.0
2. Palaquium ellipticum	4.08	14.6
3. Aglaia anamallayana	0.96	3.4
4. Gomphandra polymorpha	0.60	2.2
5. Litsea sp.	0.39	1.4
6. Syzygium cuminii	0.32	1.1
7. Garcinia morella	0.21	0.7
8. Calophyllum tomentosum	0.09	0.3
9. Miscellaneous	8.69	31.2
Total	27.88	99.9

Table 7.3

Panthanthodu III

Total No. of individuals 334

	Species	Basal area (in m^2)	% Basal area
1.	Cullenia exarillata	10.17	59.1
2.	Palaquium ellipticum	2.06	12.0
3.	Myristica dactyloides	1.41	8.2
4.	Agrostistachys meeboldii	0.13	0.8
5.	Mesua ferrea	0.09	0.5
6.	Miscellaneous	3.34	19.4
	Total	17.20	100.0

Table 7.4

Aruvampara I

Total No. of individuals 237

Species	Basal area (in m^2)	% Basal area
1. Litsea sp.	1.78	18.9
2. Syzygium cuminii	1.26	13.4
3. Elaeocarpus tuberculatus	0.46	4.9
4. Aglaia anamallayana	0.29	3.1
5. Cullenia exarillata	0.28	3.0
6. Myristica dactyloides	0.23	2.4
7. Schleichera oleosa	0.19	2.1
8. Antidesma menasu	0.17	1.8
9. Miscellaneous	4.77	50.6
Total	9.43	100.1

Table 7.5

Aruvampara II

Total No. of individuals 794

Species	Basal area (in m^2)	% Basal area
1. Pterocarpus marsupium	1.47	9.2
2. Persea macrantha	1.11	7.0
3. Clerodendrum infortunatum	0.97	6.1
4. Macaranga peltata	0.73	4.6
5. Spondias mangifera	0.17	1.1
6. Mallotus philippensis	0.13	0.9
7. Miscellaneous	11.35	71.2
Total	15.93	100.1

Table 7.6.

Aruvampara III

Total No. of indfviduals 349

Species	Basal area (in m^2)	% Basal area
1. Cullenia exarillata	0.88	7.5
2. Aglaia anamallayana	0.46	3.9
3. Polyalthia fragrans	0.24	2.1
4. Cleidion javanicum	0.19	1.6
5. Schleichera oleosa	0.16	1.4
6. Dysoxylum malabaricum	0.14	1.2
7. Miscellaneous	9.60	82.2
Total	11.67	99.9

Table 7.7

Punnamala I

Total No. of individuals 626

Species	Basal area (in m^2)	% Basal area
1. Cullenia exarillata	2.62	26.9
2. Palaquium ellipticum	1.61	16.5
3. Agrostistachys meeboldii	0.72	7.4
4. Schleichera oleosa	0.56	5.6
5. Dysoxylum malabaricum	0.51	5.2
6. Aglaia anamallayana	0.37	3.8
7. Myristica dactyloides	0.31	3.3
8. Garcinia morella	0.14	1.4
9. Miscellaneous	2.93	30.0
Total	9.77	100.1

Table 7.8

Punnamala II

Total No. of individuals 625

Species	Basal area (in m^2)	% Basal area
1. Cullenia exarillata	4.63	31.8
2. Palaquium ellipticum	1.64	11.3
3. Myristica dactyloides	0.99	6.8
4. Dysoxylum malabaricum	0.68	4.7
5. Schleichera oleosa	0.65	4.5
6. Aglaia anamallayana	0.64	4.4
7. Agrostistachys meeboldii	0.44	3.0
8. Elaeocarpus tuberculatus	0.38	2.6
9. Miscellaneous	4.51	31.0
Total	14.56	100.1

Table 7.9

Punnamala III

Total No. of individuals 738

Species	Basal area (in m^2)	% Basal area
1. Cullenia exarillata	4.83	36.5
2. Myristica dactyloides	1.32	9.9
3. Palaquium ellipticum	1.08	8.1
4. Dysoxylum malabaricum	0.55	4.1
5. Aglaia anamallayana	0.47	3.5
6. Schleichera oleosa	0.36	2.7
7. Mesua ferrea	0.33	2.5
8. Agrostistachys meeboldii	0.26	2.0
9. Miscellaneous	4.06	30.6
Total	13.26	99.9

Table 7. 10

Chembotti I

Total No. of individuals 525

Species	Basal area (in m^2)	%Basal area
1. Cullenia exarillata	3.25	27.7
2. Palaquium ellipticum	3.09	26.3
3. Myristica dactyloides	1.00	8.5
4. Aglaia anamallayana	0.38	3.3
5. Agrostistachys meeboldii	0.32	2.7
6. Dysoxylum malabaricum	0.13	1.1
7. Miscellaneous	3.55	30.3
Total	11.72	99.9

Table 7.11

Chembotti II

Total No. of individuals 436

Species	Basal area (in m^2)	%Basal area
1. Cullenia exarillata	3.10	32.7
2. Palaquium ellipticum	1.55	16.3
3. Mesua ferrea	1.08	11.4
4. Aglaia anamallayana	0.71	7.5
5. Myristica dactyloides	0.66	6.9
6. Dysoxylum malabaricum	0.32	3.4
7. Garcinia morella	0.06	0.6
8. Miscellaneous	2.01	21.2
Total	9.49	100.0

Table 7.12

Chembotti III

Total No. of individuals 139

Species	Basal area (in m^2)	% Basal area
1. Cullenia exarillata	5.36	34.5
2. Mesua ferrea	2.30	14.8
3. Palaquium ellipticum	1.98	12.8
4. Myristica dactyloides	0.47	3.0
5. Clerodendrum infortunatum	0.03	0.2
6. Miscellaneous	5.38	34.7
Total	15.52	100.0

Girth class:

Distribution of species by girth classes has been provided in Figs. 7.2 to 7.13.

As can be seen from Figs. 7.2. to 7.4. at Panthanthodu although the area has been worked in the past there still remains a good fraction of individuals above 180 cm.

Aruvampara appears to have been heavily worked in the past. Species with girth classes above 210 cm are relatively few and far between especially in Aruvampara I. As regards Aruvampara II species with girth class below 30 cm are quite high covering roughly 84%. Stray individuals of over 210 cm are also encountered. At Aruvampara III both the girth classes 10-30 and 31-60 cm are more or less proportionately represented.

Punnamala is another area where heavy extraction has taken place in the past. Species above 210 cm girth class are almost negligible. Even those in the intermediate class (60 to 210 cm) are poorly represented. There is a heavy preponderance of individuals less than 60 cm girth occupying over 90%.

Chembotti in general appears to have been not heavily worked. Individuals of higher girth classes are still available and the intermediate ones are also fairly represented.

7.5Conclusions:

Twelve permanent sample plots have been established in and around Silent Valley National Park and initial girth measurements for 5,483 trees were taken. To achieve the other objectives envisaged in the project proposal it is desired that this project is extended for another five years with adequate financial support.

7.6 Acknowledgement

I am grateful to Shri P.N. Unnikrishnan, IFS, Wildlife Warden and Shri T. Sabu, Assistant Wildlife Warden, Silent Valley National Park for their generous assistance in the field and logistics. Shri P.K. Chandrasekhara Pillai, Division of Ecology is thanked for analysis of data.

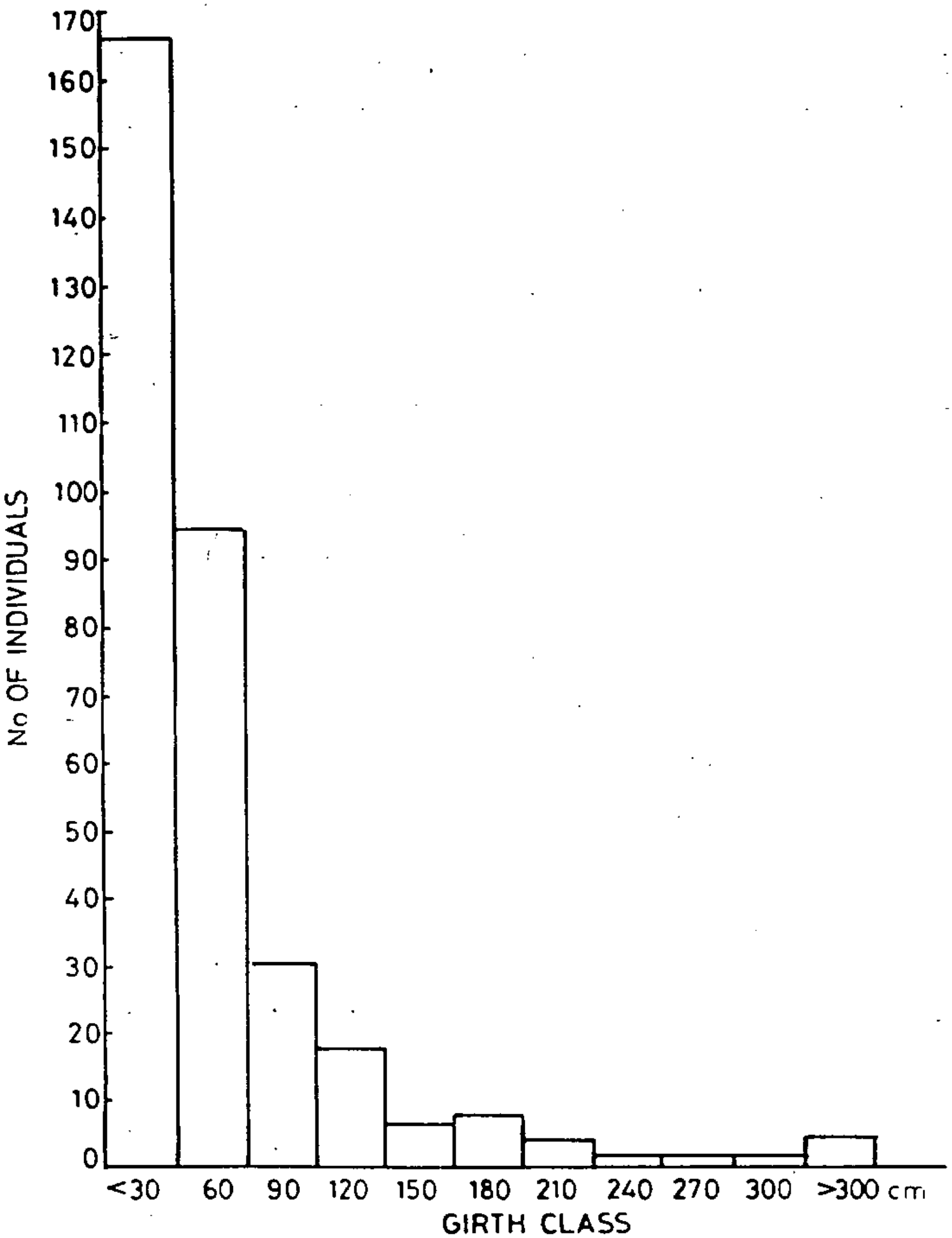

Fig. 7.2. Analysis of vegetation by girth class (Panthanthodu I)

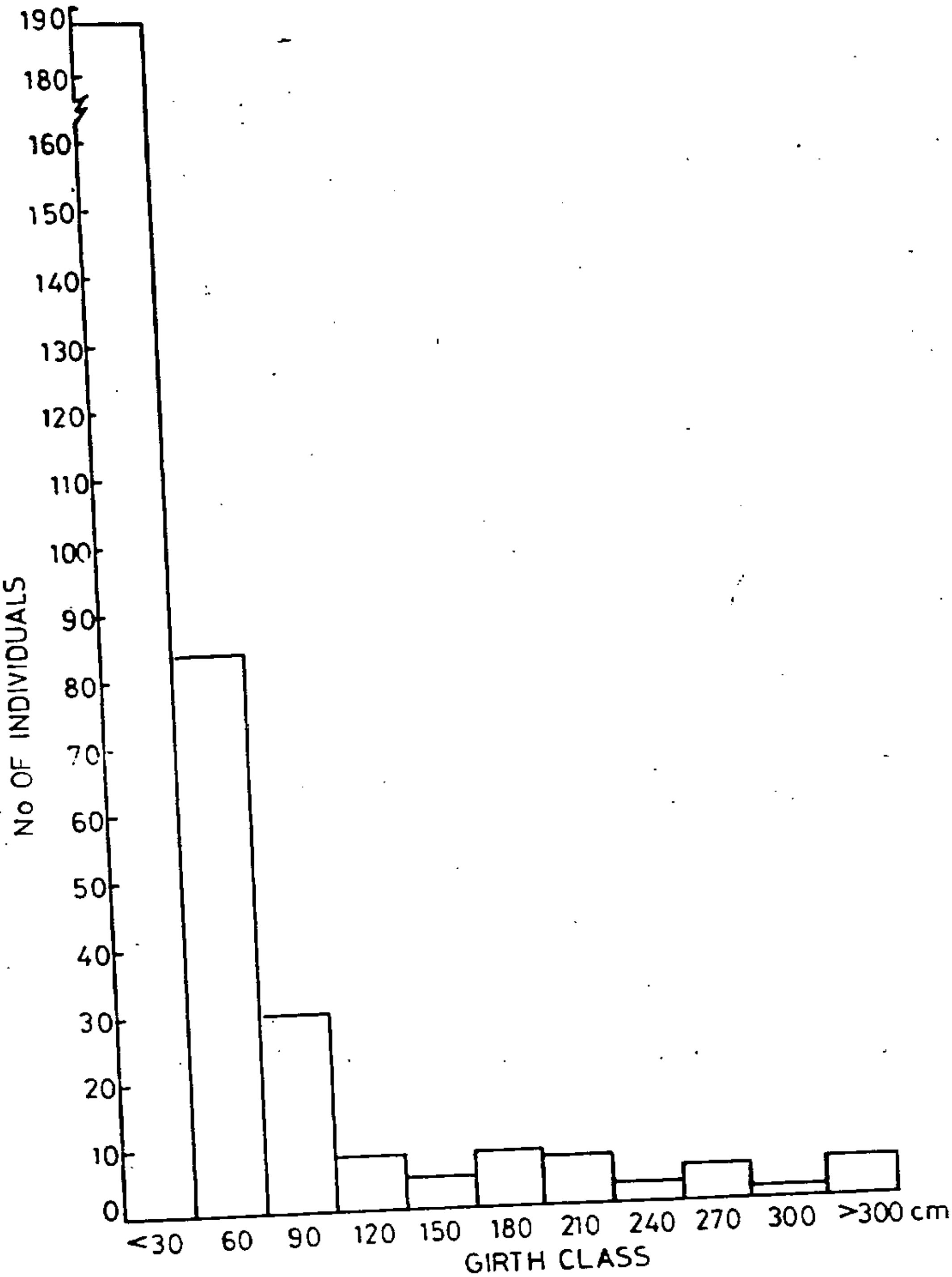

Fig.7.3. Analysis of vegetation by girth class (Panthanthodu II)

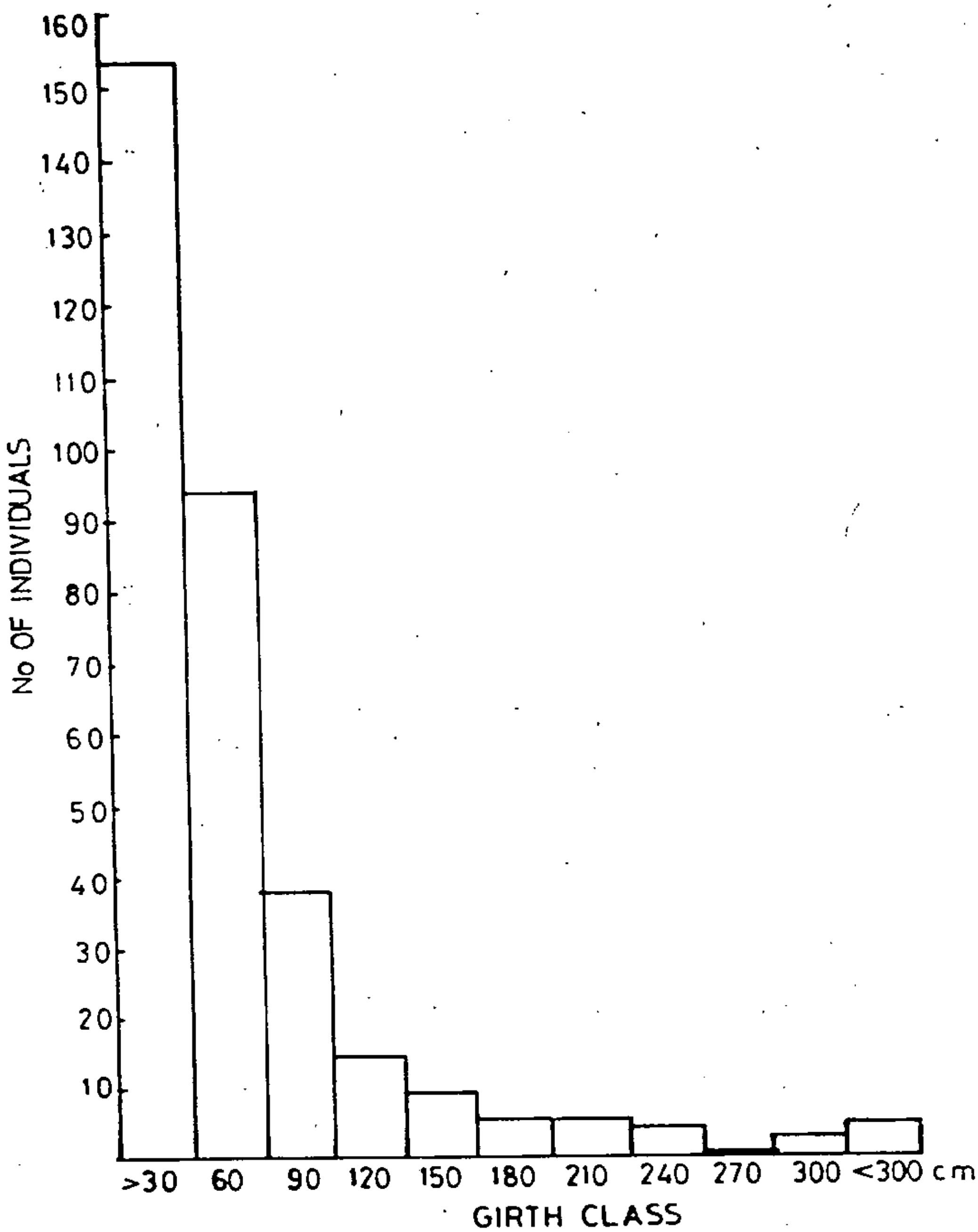

Fig.7.4 Analysis of vegetation by girth class (Panthanthodu III)

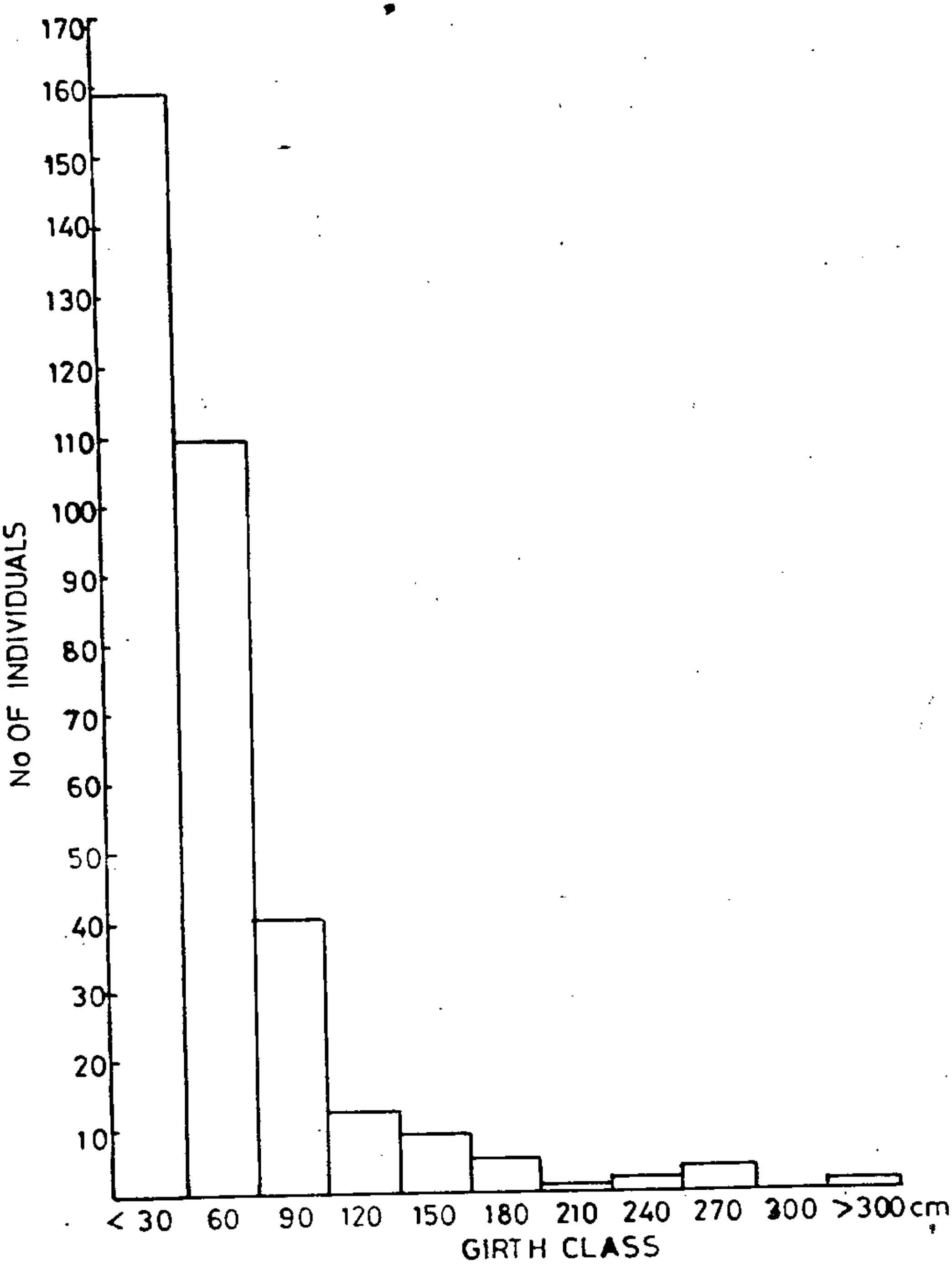

Fig.7.7. Analysis of vegetation by girth class (Aruvampara III)

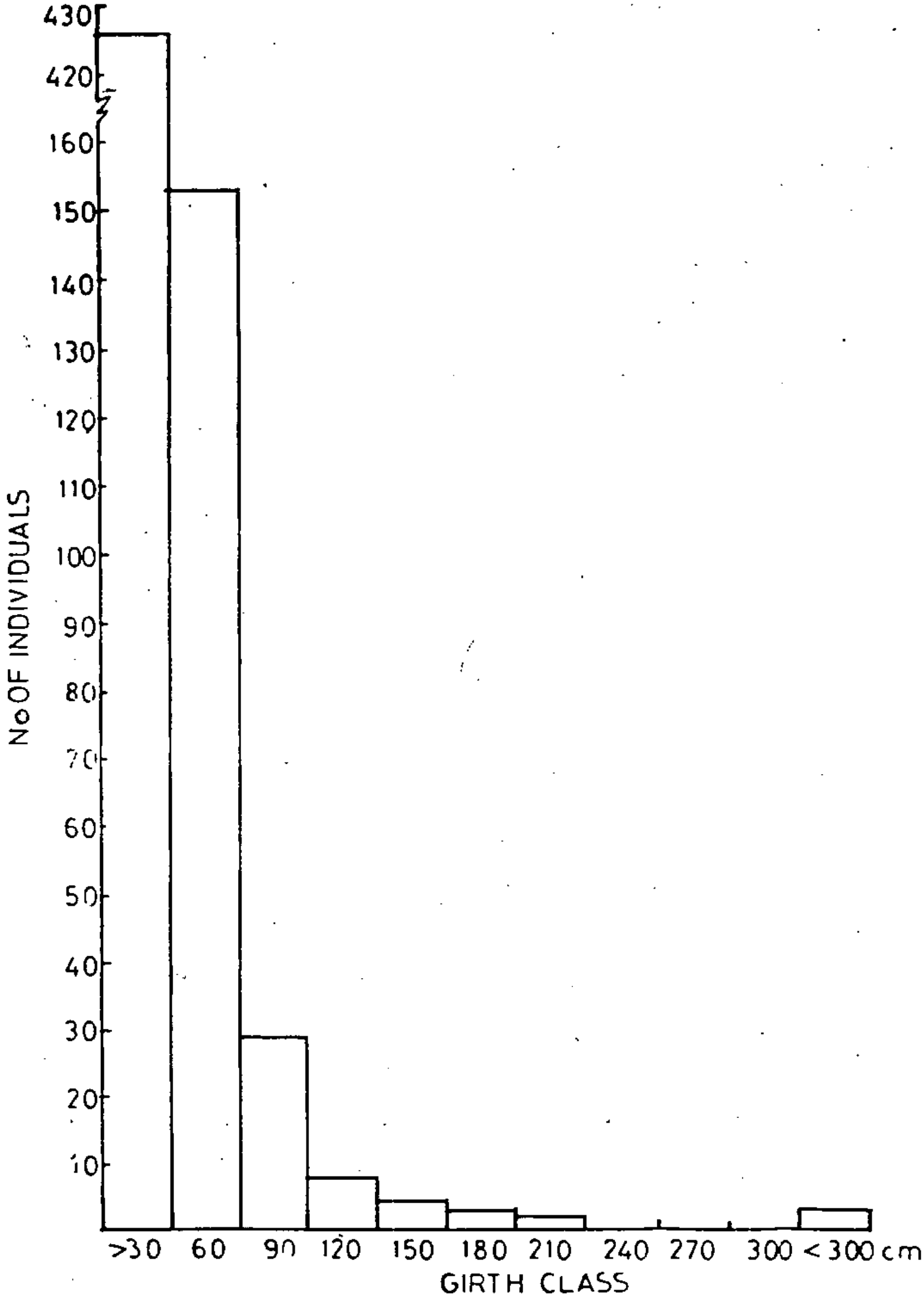

Fig.7.8. Analysis of vegetation by girth class (Punnamala I)

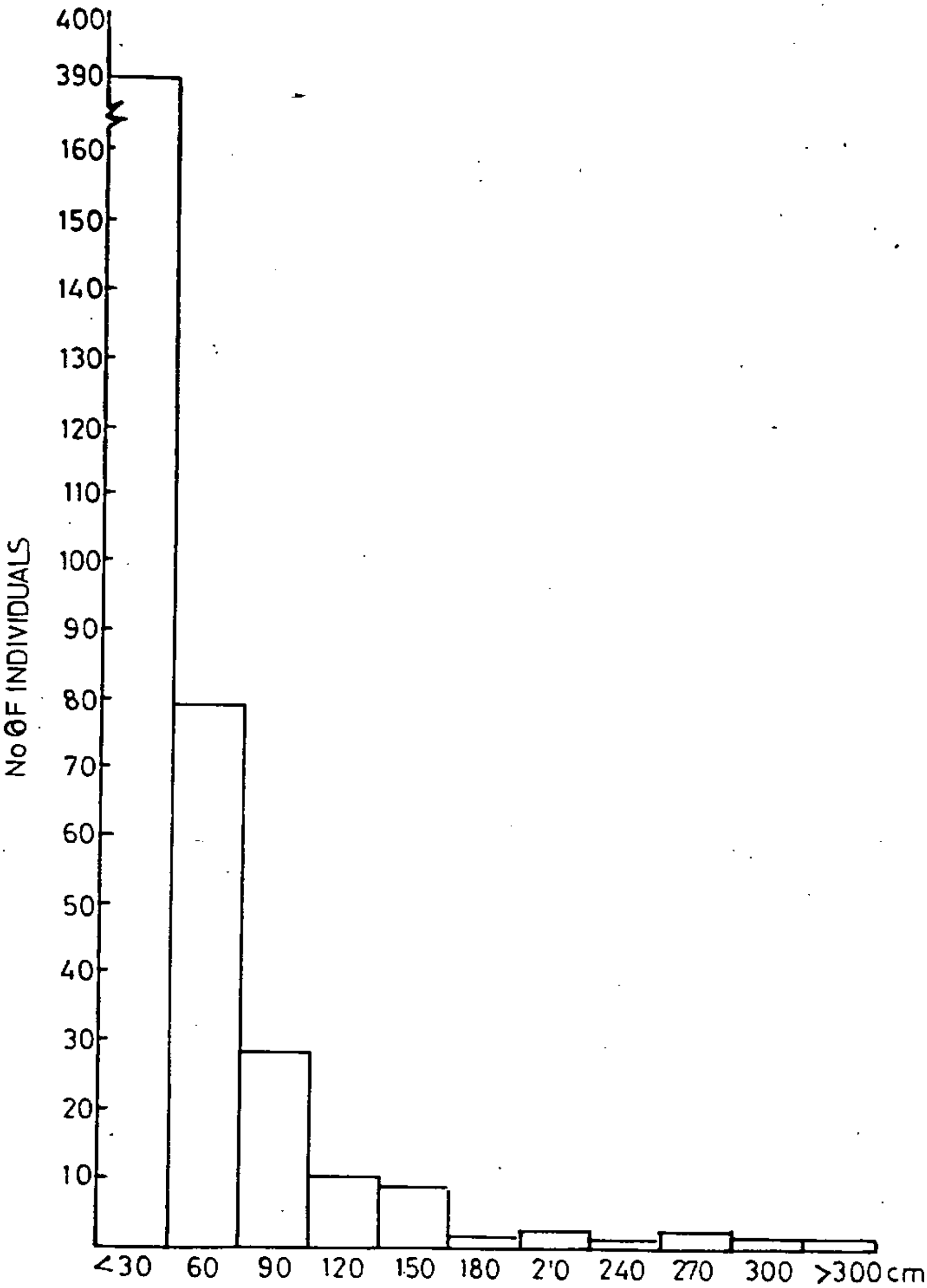

Fig.7.11.Analysis of vegetation by girth class (Chembotti I)

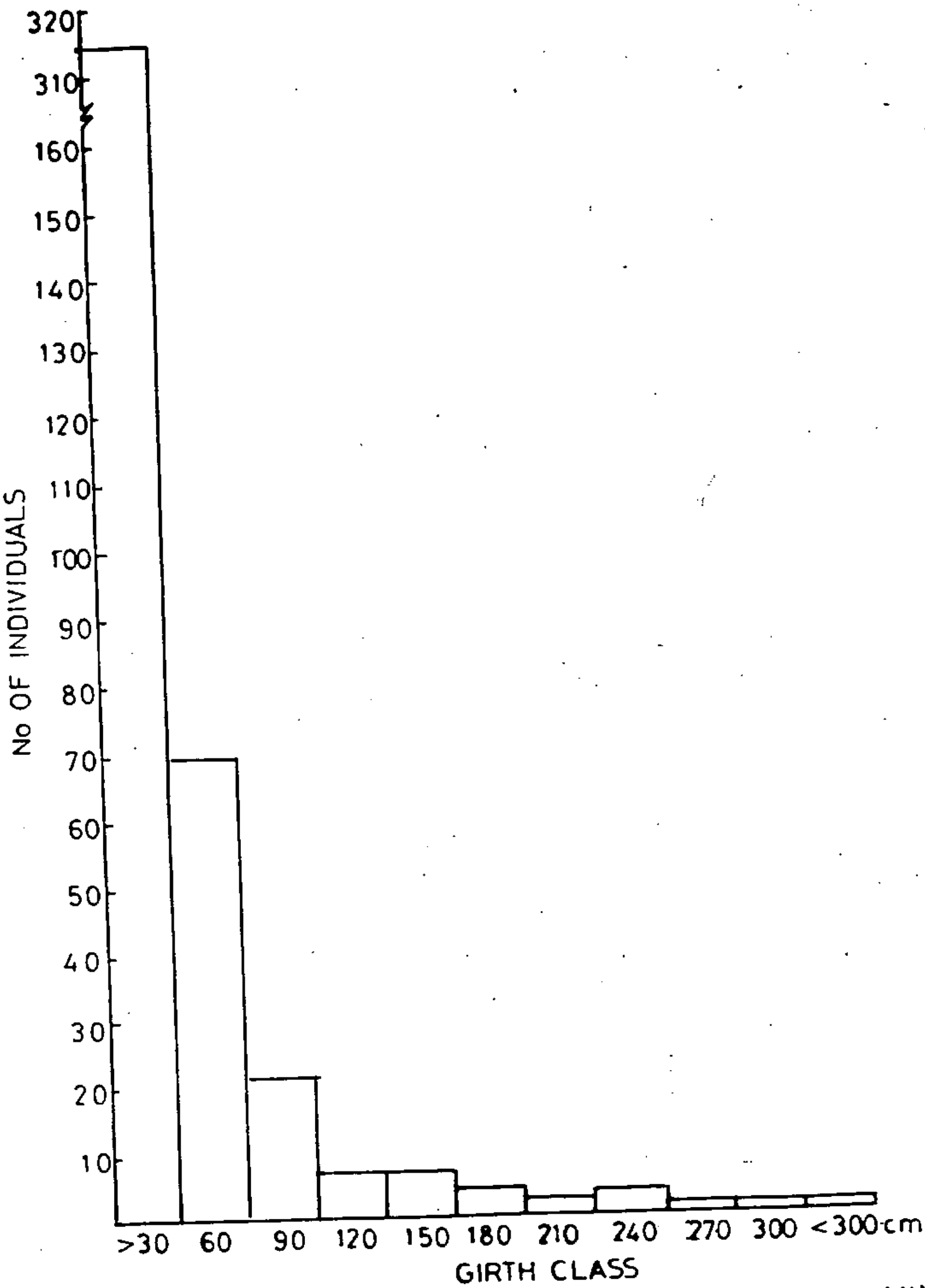

Fig.7.12. Analysis of vegetation by girth class (Chembotti II)

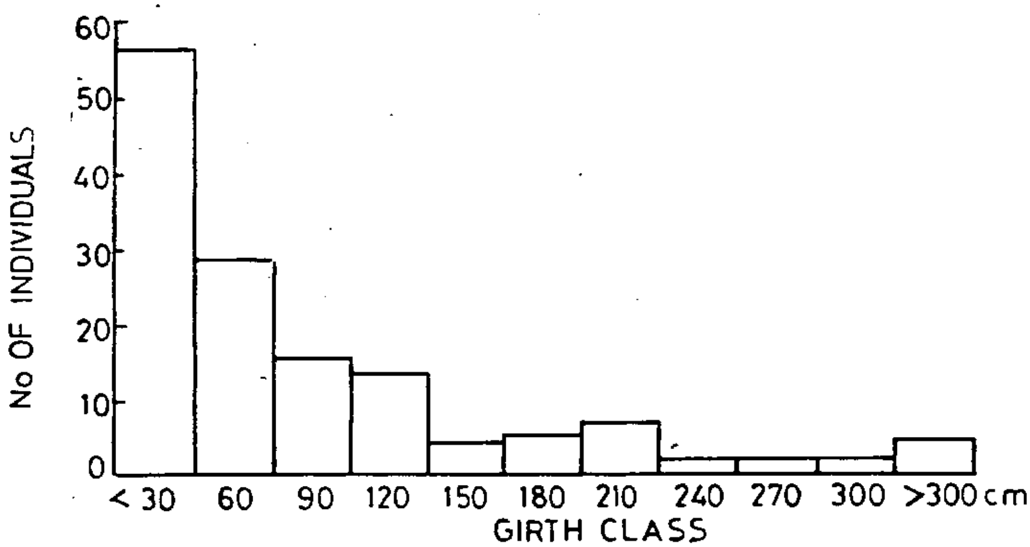

Fig.7.13. Analysis of vegetation by girth class (Chembotti III)

7.7 Literature cited

1. FRI (1975) Pressrvation Plots in India. *Indian For. Bull.* No.271. 42 p.

2. Singh, S.P(1980) Tree Increment Plots (*Ougenia oojeinensis*) *Indian For.* 106(8); 555-557.

3. Singh,S.P & Sharma, P.S. (1983) Permanent sample plots in stands of mixed species. *Indian For.* 109 (7); 449-457.