HABITAT UTILIZATION BY MALABAR GREY HORNBILL AT MUDUMALAI WILDLIFE SANCTUARY, WESTERN GHATS

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BOTANY

By

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Coimbatore

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CERTIFICATE

This is to certify that the thesis, entitled "Habitat Utilization by Malabar Grey Hornbill at Mudumalai Wildlife Sanctuary, Western Ghats", submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Botany is a record of original and independent research work done by Mr. B. Maheswaran during the period April 2000 to December 2002 of his study in Division of Terrestrial Ecology at Salim Ali Centre for Ornithology and Natural History, Coimbatore, under my supervision and guidance and the thesis has not formed the basis for the award of any Degree/Diploma/Associateship/Fellowship or other similar title to any candidate of any University.

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DECLARATION

I, B. Maheswaran hereby declare that the thesis, entitled "Habitat Utilization by Malabar Grey Hornbill at Mudumalai Wildlife Sanctuary, Western Ghats", submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Botany in Division of Terrestrial Ecology at Salim Ali Centre for Ornithology and Natural History, Coimbatore, is a record of original and independent research work done by me during the period April 2000 to December 2002 under the supervision and guidance of Dr. P. Balasubramanian, Division of Terrestrial Ecology and it has not formed the basis for the award of any Degree/Diploma/Associateship/Fellowship or other similar title to any candidate in any University.

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SUMMARY

Utilization of habitat resources, particularly fruit and nest trees, by an endemic bird species, Malabar Grey Hornbill (*Ocyceros griseus*) was studied in a tropical semi-evergreen forest and the adjoining tea/coffee plantations at Mudumalai Wildlife Sanctuary, Western Ghats. This bird species is mainly distributed in the moist forests of southern Western Ghats. Though some aspects of Malabar Grey Hornbill in an evergreen forest at Anamalai Hills have been studied during the breeding season, fruit utilization during the non-breeding season is not known. Also, the preference of this endemic hornbill for food and nest tree species is unknown. This study aimed to assess the food preferences of Malabar Grey Hornbill during breeding and non-breeding seasons, nest-tree preferences and to identify the keystone resources for the Malabar Grey Hornbill in the semi-evergreen forest

A total of 1643 individuals of fleshy fruited trees belonging to 27 species were marked and monitored once in a month for fruit availability in three belt transects totaling 6 ha of sample. The 27 species included 4 figs and 23 non-figs. Availability of fleshy fruits in the tea/coffee plantations was also assessed by monitoring 149 individuals belonging to 17 species (10 Families) from 6 ha once a month.

Fruit Utilization during breeding season in the Sanctuary was assessed by continuous monitoring of two nests and periodic collection of the seed

middens from 12 nests. Fruit Utilization during non-breeding seasons in the Sanctuary and plantations were assessed by scanning trees for foraging birds along marked transects. Role of Malabar grey hornbills in forest regeneration was assessed by observing seedling growth under nest trees. Square plot each of 5-sq. m. was demarcated at the base of the nest tree facing the nest hole and behind the same tree. These sites were visited every week during the post-breeding season to study regeneration of seedlings.

Intensive surveys were conducted during every breeding season, to document the use of nest trees, nest fidelity and the effect of human disturbances on nesting. Nest site and tree characteristics of 40 nest trees were measured. Variables were selected based on factors that were considered to have potential effect on nest-site selection.

Diversity and distribution of food and nest trees used by hornbills were assessed by conducting a phytosociological analysis of the habitat. A total of 3 ha was sampled.. All trees ($\supseteq$ 30 cm girth at breast height) were enumerated. Anthropocentric activities that could influence food and nest plants of the hornbill were documented.

Assessment of fruit availability revealed that twenty-six tree species belonging to 12 families fruited in the Sanctuary, including four species of figs. April was the peak fruiting month for non-figs during 2000-2001 and

2001-2002, when 101 individuals (7 species) and 144 individuals (8 species) were recorded in fruits respectively.Two fruiting peaks were observed for figs. Both the peaks of fig fruiting synchronized with a decline in fruiting activity of non-fig species.

Twenty-seven fruit species belonging to 17 families were consumed by Malabar Grey Hornbill. Fruit utilization during breeding season was assessed by monitoring two nests. Seventeen species of 13 families were delivered by the male hornbill to the nest inmates. Two species namely *Actinodaphne malabarica* (30 %) and *Olea dioica* (24 %) contributed for about 55% of the fruits delivered at the nests. The analysis of seeds collected from middens revealed the presence of 16 species (9 families). Majority of the seeds found in the middens belonged to two species namely, *Olea dioica* (45 %) and *Persea macrantha* (26 %).

During the two non-breeding seasons, sixteen species belonging to 10 families were consumed by the Malabar Grey Hornbill. Two species of figs, *Ficus drupacea* and *Ficus tsjahela,* both of Moraceae accounted for 58. % of feeding.

Ivlev's Index of Selectivity was used to determine preference index (P.I.) for the diet species utilized during breeding and non-breeding season at the Sanctuary. *Actinodaphne malabarica* (Lauraceae), a lipid-rich species

(P.I.= 0.91) and *Ficus drupacea* (P.I. = 0.93) were the preferred fruit species during breeding and non-breeding season respectively.

Studies on regeneration at the midden site showed that while 13 species consisting of 280 regenerated seedlings were recorded behind the nest, 18 species consisting of 761 seedlings regenerated opposite to the nest site. All the nest sites, barring one, showed a significantly greater number of regenerated seedlings opposite to the nest site compared to behind the nest.

Role of plantations as supplementary habitat for Malabar Grey Hornbill was investigated. Analysis of the fruiting pattern during the two-year study period revealed a major fruiting peak in January. Malabar grey hornbills utilized fruits of nine species in plantations during the two non-breeding seasons. Four species (*Ficus drupacea, F. tsjahela, F. virens* and *Streblus asper*) of the family Moraceae and *Maesopsis emenii* (Rhamnaceae) together accounted for 80.6% of feeding in the plantations.

Malabar Grey Hornbill utilized eighty-one nest trees belonging to 19 species (14 families) for nesting.Maximum number of nesting trees belonged to *Lagerstroemia microcarpa* (26 nest-trees; 32 %), followed by *Terminalia bellirica* (21 nest trees; 25.93%) and *Terminalia crenulata* (9 nest trees; 11 %). Ivlev's index of selectivity estimated for various nest trees revealed that Malabar Grey Hornbill preferred *Lagerstroemia* *microcarpa* (P.I = 0.92) most followed by *Terminalia bellirica* (P.I = 0.91) and *Terminalia crenulata* (P.I = 0.76). Nest site and tree characteristics of 40 nest trees were studied. Thirty-five (67.30 %; n = 52) nests were re-used in 2001 while 21 (40.3 %; n = 52) were re-used in 2002.

Figs (*Ficus tsjahela* and *F. drupacea*) formed the keystone resources for Malabar grey hornbills. Apart from the Malabar grey hornbills, numerous other birds and mammals were recorded consuming fig fruits. In addition to figs, fruits of *Aphanamixis polystachya* supported hornbill population during the lean seasonand hence considered as a 'pivotal' species.

A total of 36 species belonging to 23 families were used by Malabar Grey Hornbill for food and nesting. While 24 species were food plants belonging to 15 families, sixteen species belonging to 14 families were nest trees. The phytosociological analysis of the study sites revealed that greater number of species, 53 and 49 were recorded from the relatively undisturbed site and moderately disturbed site respectively, while the highly disturbed site had a species richness of 37 only, an average reduction of 33%. Shannon-Weiner richness, Simpson's index and Evenness index decreased with increasing disturbance.

A total of 68 individuals belonging to 17 species were affected by cutting.All the cut-signs were documented in the highly disturbed site, which was located close to the forest settlements. Fourteen of the 17 species (82 %) affected by cutting were utilized by Malabar grey hornbills either for food or nesting.

Thus, the present study infers that fruit and nest trees are lifeline for Malabar Grey Hornbill in Mudumalai Wildlife Sanctuary. While figs are keystone fruit resources in the habitat, tall trees with large girth, namely, *Lagestroemia microcarpa* and *Terminalia* spp. are indispensable for the hornbills here.Plantations adjacent to the Sanctuary also supplement fruit resources for Malabar Grey Hornbill.Restraining human activities in the study site would be the key for the conservation of the habitat as diversity and species richness decreased with increasing human incursions.

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CHAPTER I - INTRODUCTION

1.1. Concept of Habitat

According to "The New Encyclopaedia Britannica", habitat is a place where an organism or a community of organisms live, including all biotic and abiotic factors or conditions of the surrounding environment (McHenry 1992). First used in the 18th century in order to describe to natural place of growth or occurrence of a species while studying flora and fauna, the word 'habitat', adopted from Latin, literally means 'it inhabits' or 'it dwells'. According to Odum (1971), a habitat is simply where an organism can be found in nature. Habitats can be described in terms of geography, geology and climate as well as by other species commonly found within the same habitat. The scale of the habitat when larger is termed biome while narrow definitions denote the same as microhabitat.

Habitat concept, originally applied to single species, is used when the major focus is an organism. But since many species share a single habitat, some general descriptions are necessary. Habitat descriptions used in such fashion often incorporate the dominant species commonly found in that habitat. In nature demarcation between two habitats is often not distinct giving way to a zone of transition usually called ecotone.

1.2. Habitats as Units of Conservation

Tropical forests are richest terrestrial ecosystems on the planet (WCMC 1992, Heywood 1995). Tropical forest, though cover only 6-7% of earth's geographical area, contain 50% of world's biodiversity (WRI 1990). Various factors such as introduction of cash crops (Saunders & Hobbs 1991) and timber trade (Whitmore 1986) were all responsible for rapid decline of original tropical forests around the world. Habitat loss and modifications are considered the primary threats to species through out the world (Heywood 1995). Habitat fragmentation has different implications for different species. Habitat fragmentation result in large populations getting sub-divided into smaller discrete entities (Soule 1986, 1987, Pimm *et al.* 1988), alterations in the species composition (Johns 1987, Ferreira & Laurance 1997, Ganeshaiah *et al.* 1997) and changes in predation rates (Johns 1985, Wilcove *et al.* 1986, Andren 1992) In general, after isolation existing species richness declines overall in the resulting fragment (Willis 1979, Whitcomb *et al.* 1981, Lovejoy *et al.* 1986, Wilcove *et al.* 1986, Pahl *et al.* 1988, Terborgh 1989, Laurance 1990, 1991, Newmark 1991 and Chiarello 1999).

Habitats embody interacting communities of organisms. Adequate description of habitat is necessary for conservation management as there is insufficient time to study all aspects of an organism's ecology before an action can be taken. To preserve a species, one must also preserve its habitat. Thus, by preserving a habitat one is more likely to preserve communities with all niche interconnections intact. This ultimately will result in the preservation and restoration of biodiversity in general. Determination of habitat associations of species or groups of species is fundamental to the maintenance of biodiversity and provides baseline data vital to management and conservation (Krusic *et al.* 1996).

1.3. Vegetation as Defining Units of Habitat

The vegetation of that particular locality which provides shelter and food for the organism usually defines the habitat studied (Barnes *et al.* 1998). Vegetation is universally recognized as an integral component of major importance in site evaluation and classification. It integrates the effects of many interacting factors and key species may indicate specific conditions (Coile 1938, Rowe 1969, Daubenmire 1976). In general vegetation provides animals with their food, directly or indirectly and also to a large extent, the physical environment in which their activities take place. Studies that have explored the importance of habitats include (McCoy & Bell 1991, Doak 1992).

Different species of trees are best suited to different habitats, where they are competitively dominant and relatively more abundant (Hubbell & Foster 1983, Tilman & Pacala 1993). A growing body of experimental evidence supports the hypothesis that ecosystem properties are strongly influenced by the characteristics of dominant plants (Hooper & Vitousek 1997, Wardle *et al* 1997, Grime 1998). Even in species rich vegetation most of the plant biomass reside in a small number of dominant species (Grime 1973, Whittaker 1975, McNaughton 1978).

The habitat or site in a forest is definable as it is a concrete entity and usually forms a realizable basis for describing forest ecosystems. The onus of distinguishing a collective area of a given plant association into 'habitat type' goes to Daubenmire (1952 & 1968) and Pfister & Arno (1980). The habitat type approach has been widely used in forest management on public lands in timber, forest protection, wildlife, range and watershed management (Arno 1976, Layser 1974, Ferguson *et al.* 1989).

1.4. Habitat Approach in Ornithology

Use of the term "habitat" has been multifaceted in ornithological perspective. Habitat use is defined as the manner in which a species uses a collection of components to meet its life requisites and can be considered as specific acts or needs such as foraging, nesting or roosting (Block & Brennan 1993). Habitat utilization by birds has a long-standing history that dates back to the time of Darwin (1859, 1897). Based on his observations on two species of geese on the Falkland Islands, Darwin categorized one of the two species, *Anas magellanica* as an upland species and *Anas antartica* as a rocky-shore species. The concept of habitats gained significant ornithological perspective from the efforts of Grinnell (1904, 1917), who put forward the theory that congeneric bird species usually utilize different habitats based on field observations of chickadees (*Parus* spp.) and thrashers (*Taxostoma* spp.). Lack (1933), observed that woodland birds exhibited strong preferences for habitats with particular features such as conifers, broadleaf forests, abundance of nest holes, tall trees etc. Svardson (1949) observed that interspecific competition limited habitat use. Hutchinson (1957) introduced the method of quantitative description of habitat features leading to the understanding of the synergistic role played by suite of biotic and abiotic features. MacArthur (1958), based on his study on eastern wood warblers successfully elucidated the variety of habitat-use patterns using quantitative methods. Hilden (1965) identified the factors determining habitat choice. He inferred that the evolution of habitat preference determined by and determines the bird's morphological structure and behavioural functions, its ability to obtain food and shelter successfully in the habitat. Studies abound on the significance of specific habitat requirements for particular birds (Houston 1975, van de Weghe & Monfort-Braham 1975, Terborgh 1976, Wakeley 1978, Davis 1982, Higuchi & Hirano 1983).

1.5. Keystone Species - Resources of Sustenance in Tropics

A keystone species is defined as a species whose impacts on its community or ecosystem is much larger than its abundance. The concept places emphasis on species that has a small biomass and yet plays critical roles in their communities or ecosystems and which therefore should be included in conservation priorities. This concept also emphasizes the non-trophic interactions between organisms in a community. Certain species are important not because they feed upon others or are fed by others, but because they provide the physical environment for many other organisms to thrive and provide them with diverse benefits such as protection and dispersal.

Keystone species as a concept evolved on account of the attempts by Paine (1966) to address the consequences arising out of similarity in species in community or ecosystem processes. The central core of the keystone concept is that only one or a few species have uniquely important effects on the community or ecosystem by virtue of unique traits or attributes. Analogous to the removal of a keystone from the arch, removal of keystone species results in dramatic changes in the functional properties of the ecological systems. Paine initially restricted the concept of keystone species to predators of competitive dominants in a community.

Paine (1966) found that after removing the top carnivore, a starfish, from its ecosystem, the number of prey species collapsed from 15 to 8, and a single mussel covered almost the whole experimental site. The top predator played the role of the keystone, maintaining the arch formed by the entire community, hence the name of "keystone species" to designate such organisms.

Building on a series of investigations in a wide range of ecosystems, a recent review by Power *et al.* (1996) expands this concept to include any species with an impact on its community or ecosystem that is disproportionately large relative to the abundance of the species. They conclude that (a) keystone species have been demonstrated in a wide variety of ecosystems, (b) based on indirect evidence, keystones may be more prevalent than has been demonstrated, and (c) the concept can apply to individual species or groups of species, but that *a priori* prediction of a keystone species remains elusive.

With increasing examples of species with apparent keystone importance, comprehensive review warranted the extension of this concept to include "keystone herbivores", "keystone prey", "keystone mutualist", "keystone host", "keystone resources", "keystone guilds and "keystone modifiers". Most communities have only one keystone species. Several distinct communities belonging to a single ecosystem might have more than one keystone species. Consensus prevails among conservation biologists around the world that no community has more than a single keystone species.

1.6. Western Ghats – A Unique Biogeographic Region

Western Ghats (WG), is a contiguous chain of mountains, broken only briefly by the Palghat Gap. Rich biodiversity, high endemism and an increased threat perception all together have resulted in these mountainous region being recognized as one of the hotspots of biodiversity along with the forests of neighbouring Sri Lanka (Myers, 1988, 1990; Mittermeier *et al.* 1999). A vibrant montane forest ecosystem that runs parallel to the west coast, Western Ghats virtually encompasses an estimated area of 160,000 km^2, in peninsular India and extends from southern tip of the peninsula (8° N) northwards about 1600 km to the mouth of the river Tapti (21° N). More than 14 peaks have their highest points above 2000 m while at least 60 westward flowing rivers and three eastward flowing rivers originate from this antique biogeographic montane formations, a permanent entity since the aurora of the Tertiary era.

Tropical rainforests are the chief centers of diversity and endemism within Western Ghats. Four thousand flowering plants are known from this region of which 1400 (35%) are endemic. A very high generic endemism is a characteristic feature of this biome. Fifty-eight plant genera are endemic of which 42 are monotypic. Examples of many genera and families abound, which although themselves not endemic, are represented by rich endemism at species level. For example, of the 86 species of *Impatiens* 76 (88%) are endemic; 12 (92%) of the 13 *Dipterocarpus*; 23 (92%) of the 25 *Calamus* are endemic and in the family Ebenaceae 12 (60%) of the 20 species are endemic. Of the 490 tree species (over 10 cm dbh) recorded from low and medium elevation forests, 308 (63%) are endemic (Kumar *et al.* 1999).

Western Ghats is recognized as an Endemic Bird Area by BirdLife International (Stattersfield *et al.* 1998). Seventeen species of birds, 90 amphibians, 89 reptiles, 37 butterflies and 12 species of mammals are endemic to the Western Ghats (Kumar *et al.* 1999).

Bounteous richness in biological vicissitude characterizes the region on account of the striking alteration in rainfall regimes. The hill ranges of Western Ghats block the monsoon winds and so the regions east of the Western Ghats are rain shadow. The average annual rainfall ranges from 400 mm in the rain-shadow region to 3000 mm in the Westward slopes. The variety in climate and topography has resulted in the formation of multifarious habitats that support versatile group of plants and animals (Champion & Seth 1968; Rodgers & Panwar 1988). Habitats encountered in Western Ghats include the scrub jungle, shola formations, grasslands, dry and moist deciduous forests, semi-evergreen and evergreen forests.

Culturally this region is highly diverse and is abode to a variety of tribal communities. Indigenous people with a historical continuity of resource-use practice often possess a broad knowledge base of the complex ecological systems in their own localities and they do develop a stake in conserving.

Western Ghats, on account of its hyper diverse habitat and species, is one of the extensively studied region for its vegetation. Phytosociological studies in tropical forests of Western Ghats are abounding: Sukumar *et al.* (1992) in moist deciduous forests of Mudumalai; Elouard *et al.* (1997) in evergreen forests of Karnataka; Parthasarathy and Karthikeyan (1997) in a tropical evergreen forest of Courtallum; Singh *et al.* (1981) in Silent valley; Chandrashekara and Ramakrishnan (1994) in wet evergreen forests of Nelliampathy; Ganesh *et al.*(1996) in tropical evergreen forests of Kakachi; Parthasarathy (1999) in high elevation evergreen forests at Kalakad; Ayyappan and Parthasarathy (1999) in tropical evergreen forest of Anamalais.

Originally covered by tropical wet evergreen, moist deciduous and dry deciduous forests, the vegetation of Western Ghats has been profoundly modified through human interventions, so that now only an intricate mosaic of various degradation stages of the natural forest types along with plantations of rubber, eucalyptus, wattle, casuarina, betelnut, fields of paddy and gardens associated with habitation (Chattopadyay 1985). The standing forests of this region provide livelihood for more than 3 million people. Of the estimated 160, 000 km^2 area, only 25% (40, 000 km^2) is forest including extensive monocultures of teak, eucalyptus, tea and coffee plantation.

Unfortunately, exploitation of resources borne out of forests, encroachment of forest habitat and an alarming increase in population, have all resulted in the forest patches of this region, put to enormous anthropogenic pressures (Tamart Bekele 1994). A study on deforestation rates in Western Ghats using Geographic Information System covering a total geographical area of 81,870 sq km, in states of Kerala, Karnataka and Tamil Nadu showed 40% decline of natural vegetation between 1920 and 1990 (Menon and Bawa 1997). The loss of forest habitat was attributed to one of the following landuse types: open/cultivated lands, coffee and tea plantations, and hydroelectric reservoirs. Deforestation has also resulted in extensive landscape fragmentation in the Western Ghats. The number of forest patches increased four-fold (179-769) with a simultaneous 83% reduction in average forest patch size. Investigations on forest loss and land-use changes in the study area between 2 time periods, 1960 and 1990 showed that deforestation rates were high in the study region. Between 1920 and 1960, 0.07% of the forest area was lost annually. Between 1960 and 1990, annual forest loss was 33% even though the entire area had been under some form of protection. Tilman *et al.* (1994) showed that more the habitat is fragmented, greater is the probability of extinction caused by further habitat destruction Thus, the biotic community of the Western Ghats complex are being subjected to constant changes.

Significant proportions of forest habitats have been deforested and converted to plantations, settlements and for hydrolectric reservoirs (Menon and Bawa 1997). Added to this, constant summer fires have resulted in a change in the species composition, favouring certain species such as *Bambusa arundinacea*, *Acacia catechu*, *Careya arborea*, *Dalbergia latifolia*, *Dillenia pentagyna*, *Schleichera oleosa*, *Tectona grandis*, *Terminalia* spp., and *Xylia xylocarpa*. Thus, the biotic community of the Western Ghats complex are being subjected to constant changes. In order to understand the dynamics of disturbance in various habitats of Western Ghats, it is imperative that regular, systematic phytosociological analysis are carried out.

1.7. Hornbills: General Habits

Hornbills (Family: Bucerotidae) are frugivorous birds exclusive to Old World tropics. The name "hornbill" is derived on account of the conspicuously decurved bill and the proteinaceous casque that projects above their bill. Fifty-four species of hornbills are known from sub-Saharan Africa, through India, Southeast Asia and Australasia (Kemp 1995). Most of the hornbill species depend on trees for fruit resources and nesting requirements (Kemp 1995). A characteristic feature of breeding behaviour of hornbills is nest fidelity exhibited by them, returning every year to their traditionally used nest cavities (Kemp 1978). Hornbills are mostly forest species, but species inhabiting savannahs, forest edges and even semi-desert conditions are also known (Kemp 1995).

Researchers and naturalists studying hornbills all over the world have been attracted by the peculiar behaviour of the female sealing herself in the nest throughout the breeding period. Hornbills are unique among the birds as the female seals the entrance of the nest hole leaving a narrow slit for the male to supply food during the process of egg laying, hatching and raising the hatchlings. All species of hornbills, except two species of *Bucorvus*, seal their nest. All hornbills are secondary hole-nesters and prefer natural cavities in trees or rock crevices.

1.7.1. Hornbills Species in India

In India, nine species of hornbills are known (Ali & Ripley 1987), of which four are safe, three are near threatened and two are vulnerable. Most species of hornbills in India are facing severe survival pressures due to fragmentation of the wet-evergreen habitats (Chatopadhyay 1985), poaching of adults as well as nestling (Ali and Ripley 1987). Of the nine species found in India four species, the Bar-pouched Wreathed Hornbill *Aceros undulatus*, Oriental Pied Hornbill *Anthracoceros albirostris*, Indian

Grey Hornbill *Ocyceros birostris* and Malabar Grey Hornbill *O. griseus* are known to be safe. While the Narcondam Hornbill *Aceros narcondami* and Rufous-necked Hornbill *Aceros nipalensis* have been recognized as vulnerable, Tickell's Brown Hornbill *Anorrhinus tickelli*, Malabar Pied Hornbill *Anthracoceros coronatus* and Great Pied Hornbill *Buceros bicornis* are catergorized as near threatened (BirdLife International 2001). Four of the nine hornbills found in India, the Indian Grey Hornbill, Malabar Grey Hornbill, Malabar Pied Hornbill and Great Pied Hornbill occur in Western Ghats.

1.7.2. Fruit Utilization by Hornbills

Poonswad *et al.* (1987), while studying the breeding biology of four sympatric hornbills in Thailand observed that about 57% of food items delivered by the hornbills were figs. Suryadi *et al.*, 1994 determined food preferences of the Sulawesi Red-knobbed Hornbill during the non-breeding season. The study showed that fig species were the most important component of the diet. Of the 24 diet species recorded, 20 were figs. Kinnaird *et al.*, (1996) demonstrated the role of figs in determining the spatial patterns in hornbill densities. The study also brought to light the importance of primary forests for hornbills.

Kannan and James (1997) recorded 19 fruit species delivered to the nest inmates. 72.9% of the fruits delivered at nests were figs. Kinnaird (1998) showed that the Sulawesi Red-knobbed Hornbill, used ripe fruits of 33 species as its diet species. The five most common diet species included four tree species namely, *Horsfieldia brachiata, Cananga odorata, Syzygium spp., Polyalthia grandifolia* and one liana, *Gnetum latifolium.* Fruits of all these species were single-seeded and the size of the seeds ranged from 10-47 mm (length of longest axis). The seeds were regurgitated undamaged after processing.

Whitney *et al.*, (1998) studied three species of *Ceratogymna* in Dja Reserve, Cameroon. Their observations reveal that each of the three hornbill species consumed fruits from 25-49 species of trees and lianas. Together the three hornbill species consumed fruits from 59 species in at least 20 plant families. Favoured plant families included Annonaceae, Moraceae, Euphorbiaceae, Meliaceae, Olacaceae and Myristicaceae.

1.7.3. Hornbills and seed dispersal

Frugivorous birds play a pivotal role in dispersal of seeds of tropical forest plants (Mckey 1975, Howe and Eastabrook 1977, Howe and Vande Kerchkhove 1981, Howe 1986, 1990, Herrera 1995), by selectively dispersing seeds, destroying seeds or failing to disperse seeds. Hornbills, being primary frugivores of tropical forests, play very important role in seed dispersal and germination (Kemp 1995). This is made possible by their ability to swallow large fruits followed by regurgitation of the same undamaged (Leighton and Leighton 1983, Kalina 1988, Kemp 1995). Taxonomic diversity of hornbill dispersed plants is comparable to that dispersed by the most important mammalian species (Whitney *et al.* 1998). Kinnaird (1998) showed that the Sulawesi Red-knobbed Hornbill moved fruits of at least 33 species away from the fruiting trees during the breeding season to nest sites. Seedling abundance, species richness, diversity and dominance was measured in plots placed below and immediately behind 20 active nest sites to evaluate the role of Red-knobbed hornbills as agents of seed dispersal. Significantly greater number of diet seedlings germinated below nests and the diversity of diet species was greater than that of non-diet species. Also few seedlings were dominant among the diet seeds germinated below, thus consistent with the hypothesis that hornbills effectively disperse seeds of some but not all of their diet species.

Whitney *et al.* (1998), studied seed dispersal effected by three hornbill species (*Ceratogymna atrata, C. cylindricus* and *C. fistulator*) in Dja Reserve, Cameroon. Together the three hornbill dispersed 56 of the 59 species consumed. *C. atrata* dispersed about 42 tree species (18% of the tree flora), while *C. cylindricus* and *C. fistulator* dispersed seeds of 20% and 10% of tree flora respectively. Apart from dispersing tree species, the *Ceratogymna* spp. also dispersed five species of lianas. The tree species usually dispersed by the hornbills have also been community dominants and economically important to humans (Whitney *et al.* 1998). The Malay Black Hornbill (*Anthracoceros malaynus*) is known to be a effective seed disperser of large seeded *Aglaia* species in Asia (Becker and Wong 1985).

Silvery-cheeked Hornbill (*Ceratogymna brevis*) disperses the seeds of exotic timber *Maesopsis eminii* in African tropical forests (Bingelli 1989).

Estimations of time taken for regurgitation by Bornean hornbills revealed that, about 80% of the seeds were regurgitated after 80 minutes from the time of feeding. By this time the birds would have moved far enough from the site of breeding and thus qualify as effective dispersers of seeds in rainforests (Leighton 1982). Poonswad and Tsuji (1994) studied the ranges of males of the Great Hornbill, Brown Hornbill and Wreathed Hornbill using radio telemetry during the breeding and non-breeding seasons in Khao Yai National Park, Thailand. The home range of the Great Hornbill and Brown Hornbill was very similar (3.7 km^2 and 4.3 km^2) respectively while the Wreathed Hornbill occupied the largest home range (10.0 km^2). Suryadi *et al.*, (1996), while studying the Red-knobbed hornbill in the Tangkoko-Duasaudara Nature Reserve in North Sulawesi, showed that their home ranges varied from 39.8 - 55.8 km^2. While the mean daily travel length was 10.49 km, some individuals traveled a maximum of 30 km a day. As discussed above, since hornbills cover large tracts of forests for purposes of foraging their role in the function of seed dispersal is of utmost importance.

1.7.4. Nest Tree Utilization

Nest site characteristics of very few Asian hornbills have been determined till date. Based on studies made on Narcondam Hornbill, Hussain (1984) made a rough estimate of heights of the nests. According to him heights of the nests varied between 2.4 m and 15.2 m. The outer rim of the hole measured 30 cm breadthwise. Depth from the entrance to inner wall measured about 180 cm and tapered inwards gradually.

Poonswad (1995) studied the nest site characteristics of four sympatric species of hornbills at Khao Yai National Park, Thailand and found that hornbills mostly preferred tall trees with large girth. Majority of the nests (79% of the total of 80) were located between 700 and 800 meters above sea level. Among 73 nest trees, 14 were at 25 m or higher. This included 13 trees of *Dipterocarpus* and one individual of *Eugenia* sp. While the Diameter at Breast Height (DBH) of nesting trees varied between 54 cm and 109 cm, DBH at nest height varied between 7 cm to 45 cm. Nests were located between 2m to 45 m.

Marsden and Jones (1997) determined the characteristics of nest holes for the Sumba hornbills and parrots. Of the 132 nests located, about 95% were located in cavities of trees. While 50% of the nests were located on trunks, the rest were located on side branches. The nest trees were large with mean girths of between 3.1 m ± 1.0 m. The hole length and hole width were determined as 28 cm ± 7 cm and 24 cm ± 9 cm.

Mudappa and Kannan (1997) determined nest site characteristics for Malabar Grey Hornbill. It was found that, most of the nests were in open, tall, evergreen forest with dense undergrowth. While the average height of the nest trees was 24 m, mean DBH was 75 cm. Nest cavities were located at an average height of 16.5 m and average diameter of the nest entrance was 8 cm.

1.7.5. Habitat Preferences by Hornbills

The most suitable habitat for hornbills is primary forest containing both large canopy fruit trees and shrubby regenerating riverine patches. According to Johns (1987), most Southeast Asian hornbills are primarily adapted to exploit resources that are widespread. A large undisturbed patch is thus imperative for foraging and breeding activity. Greatest abundance and diversity of hornbills is found in undisturbed tropical forests. But most species do persist in selectively logged forest, despite the high proportion of food resources lost during the removal of timber trees. Figs have been considered one of the most preferred fruit for most hornbills. Most fig trees grow as stranglers on other canopy timber trees. Loss of the timber trees in turn reflects on deficient food resources for hornbills. The loss of high canopy trees also seems to affect availability of animal prey for the hornbills. Thus, on a long run hornbill population could be drastically modified negatively, ultimately becoming a threatened entity. Kinnaird *et al.*, (1996) based on her study of the Sulawesi Red-knobbed Hornbill proved that primary forests were much preferred than secondary habitats. This trend has been previously demonstrated by Kalina (1988) who showed that the Black-and-white-casqued Hornbills were present in significantly higher densities in primary forest than in logged areas of East Africa.

1.7.6 Research on Hornbills in India

Research on hornbills of India has been a recent initiative (Hussain 1984, Vijayan *et al.* 2000 [*Aceros narcondami*]; Reddy *et al.* 1990, Balasubramanian and Saravanan 2001 [*Anthracoceros coronatus*]; Kannan, 1994 [*Buceros bicornis*]; and Mudappa & Kannan 1997, Balasubramanian & Maheswaran 2001, 2002 [*Ocyceros griseus*]; Datta 1998, 2001, Datta & Rawat 2000 [Hornbills of Arunachal Pradesh]). Except Datta & Rawat (2001), all the above mentioned studies confined themselves to documenting breeding ecology.

1.8. Justification for the Present Study

Malabar Grey Hornbill (Plates 1 & 2) is an endemic frugivore of restricted range in the moist forests of Western Ghats, South India (Kemp 1995, Mudappa 2000). According to Ali & Ripley (1970), Malabar grey hornbills inhabit the high rainfall regions, and are distributed from Bombay through southern Maharashtra, Karnataka, Kerala and western Tamil Nadu. Confining themselves to evergreen and semi-evergreen, they are resident

Plate 1. Malabar Grey Hornbill in semi-evergreen forest

Plate 2. Malabar Grey Hornbill in tea plantation

from plains to 1600 m altitude. They are also known to frequent plantations flanking semi-evergreen forests.

The population is now fragmented on account of habitat loss (Grimmet *et al.* 1998). The population of this species is on the decline in the northern regions of the Western Ghats (del Hoyo *et al.* 2001). Malabar Grey Hornbill, like most other hornbills do not excavate their own nests and use available cavities that are suitable (Poonswad 1995; Poonswad *et al.* 1988). As a consequence of their specific breeding requirements and an essentially fruit based diet, the Malabar Grey Hornbill have evolved an intimate relationship with tree species. A major seed disperser in Western Ghats region, Malabar Grey Hornbill is considered one of the indicators of primary moist forest habitat.

Studies on food habits of hornbills in India are restricted to breeding season only. There is no documented information on fruit utilization by Malabar Grey Hornbill during the non-breeding season. Until the initiation of this study, no attempts have been made to understand the tree species preference of this endemic hornbill for feeding and nesting. Though the breeding biology of Malabar Grey Hornbill has been studied in an evergreen forest habitat of Western Ghats, ecological information on this species is lacking from the semi-evergreen forests and man-modified habitats such as plantations.

Habitats in the Nilgiri region of Western Ghats where Malabar Grey Hornbill are reported, have undergone ecological transformations due to various developmental processes such as hydro-electric projects, construction of dams, reservoirs, canals, tunnels. This is further compounded by encroachment of prime low elevation montane forests for human settlement, and plantation cropping and have resulted in fragmentation of habitats (Chattopadhyay 1985). Realizing the current pace of deforestation and the resultant habitat loss, holistic research on the ecology of this specialized frugivore was found very essential. Hence, the present study was undertaken.

1.9. Objectives

1. To understand the utilization pattern of habitat resources, mainly the trees for food and nesting by the endemic Malabar Grey Hornbill in Mudumalai Wildlife Sanctuary
2. To document fruit availability and find out preferred food tree species.
3. To understand nest-tree utilization and determine the nest-tree characteristics.

CHAPTER II - STUDY AREA

2.1. Mudumalai Wildlife Sanctuary

2.2. Plantations

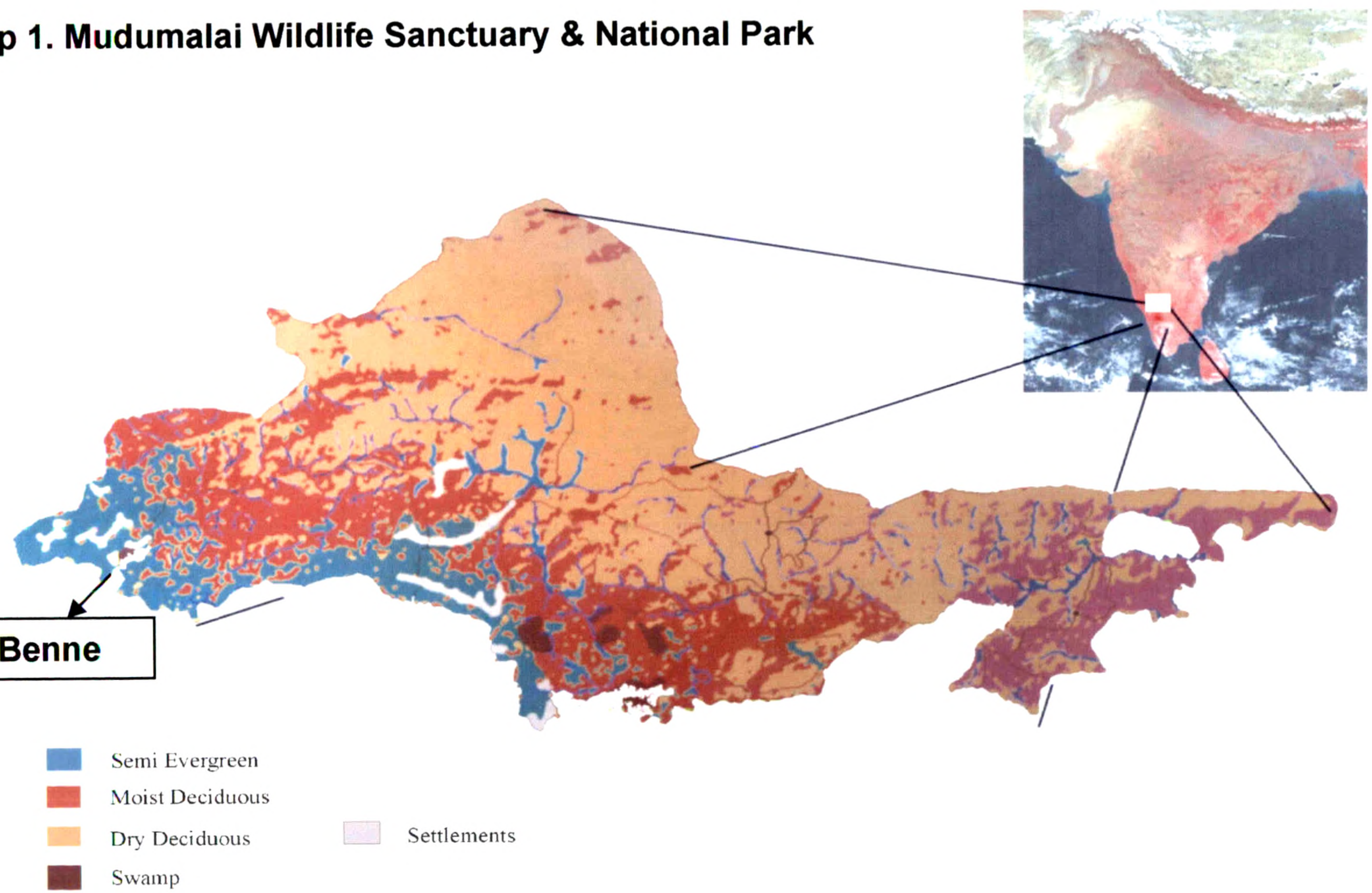
2.1. Mudumalai Wildlife Sanctuary

Mudumalai Wildlife Sanctuary is located on the foothills of the Nilgiri Mountain Ranges, in the south Indian state of Tamil Nadu (between 11° 30' and 11° 39' N and 76° 27' to 76° 43' E; Map 1). Mudumalai is one of the oldest sanctuaries of India and along with Bandipur National Park to the north in Karnataka and the Wynaad Wildlife Sanctuary to the west, cover a contiguous forest of about 2000 sq. km. To the east and south of the Sanctuary are revenue lands that include private agriculture, and estate, privately owned forests and forested land under the control of revenue department. Mudumalai Wildlife Sanctuary was integrated with Nilgiri Biosphere Reserve under the Man and Biosphere Programme in 1986.

2.1.1. A Brief History

Originally the wealth of Nilambur Kovilagam, Mudumalai was leased out to a timber merchant in the first half of 19th century. Mudumalai forests were notified as "reserved land" under Section 26 of the Forest Act of 1889 and 1892. In 1927 the area was declared as reserved forest. The Madras Government declared an area of 23 sq. km as a sanctuary in 1940. By 1958 the area of the sanctuary was expanded to 318.7 sq. km. The present extent of 321.5 sq. km was notified as a sanctuary in the year 1974.

Map 1. Mudumalai Wildlife Sanctuary & National Park



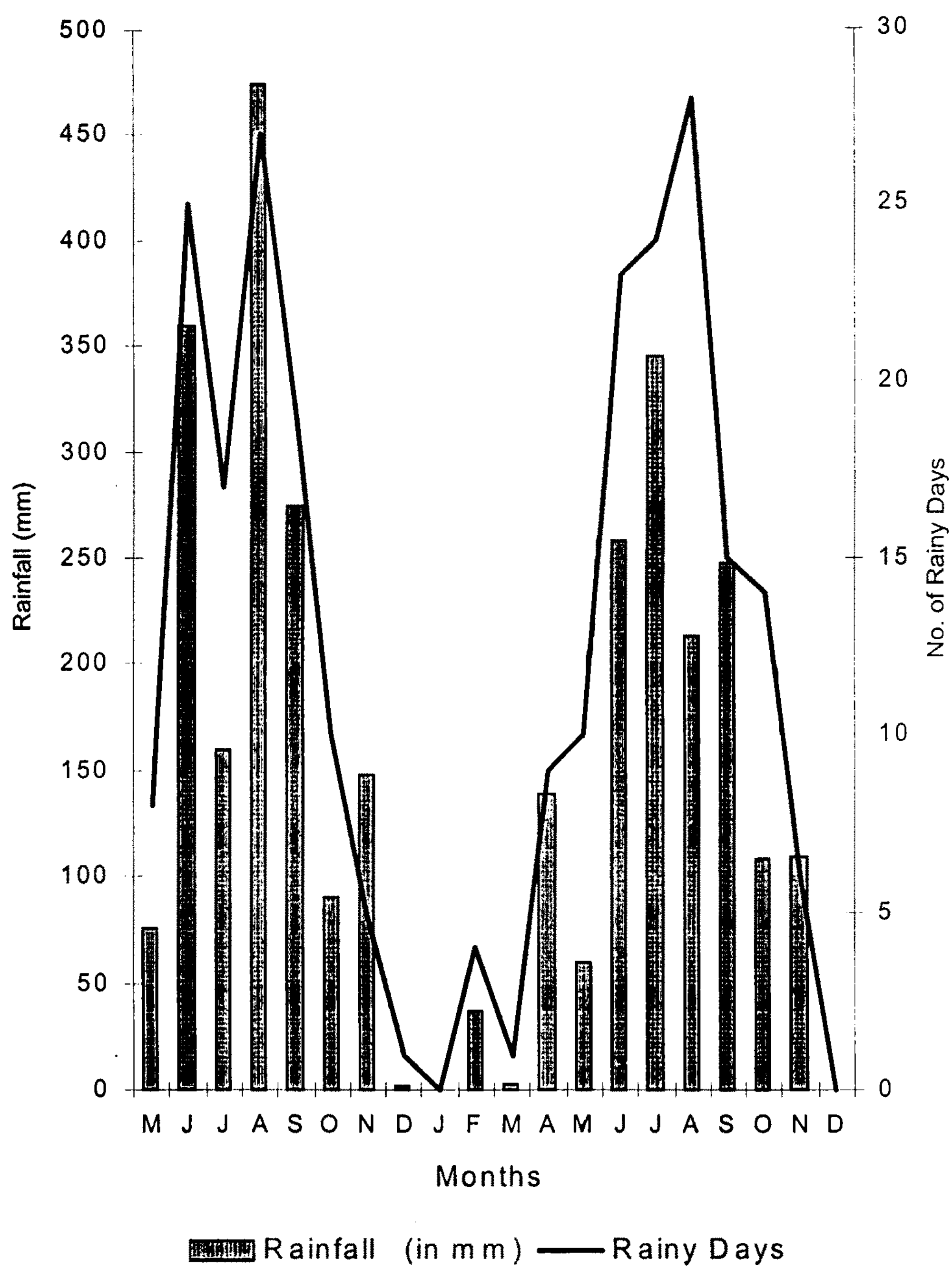
2.1.2. Climate and Topography

Average elevation of the Sanctuary is 1000 m, with the peak of Morganbetta reaching a maximum height of 1258 m. The climate usually is moderate with temperatures varying from 14°-17° C during the winter and 29° – 33° C in summer (March-May). Marked transition in annual rainfall is observed as one move from the eastern parts (600-mm) of the Sanctuary to the western region (2000-mm). Gradient of rainfall during the study period is given in Fig 1. Two peaks of rainfall were observed at the Sanctuary during the study period. Maximum rainfall occurs during southwest monsoon (June–August) followed by a second peak during northeast monsoon (September–November). A dry spell prevails between December to March.

2.1.3. Flora

Endowed with a variety of flora, this Sanctuary encompasses a spectrum of habitats. Habitats of the sanctuary are determined principally by rainfall and classified into (a). Southern tropical thorn forest, (b). Tropical dry deciduous forest, (c). Tropical moist deciduous forest and (d). Tropical semi-evergreen forest (Champion & Seth 1968, Tyagi 1995). While the thorn forest and dry deciduous forests occur in the low rainfall zone, moist deciduous forest and semi-evergreen forest are characterized in high rainfall regions of the Sanctuary. Marshy swamps locally known as "vayal" also dot the Sanctuary in regions where drainage is poor.

Fig. 1 Rainfall Pattern in the Study Site



Southern Tropical Thorn Forest characterizes the foothills of the Nilgiris flanking the eastern side of the Sanctuary. The annual rainfall in this zone ranges between 600 mm and 900 mm. Dominant plants of this habitat include *Acacia* spp., *Anogeissus latifolia, Ziziphus* spp., *Phyllanthus emblica, Cassia fistula, Capparis* spp. etc.

The Tropical Dry Deciduous Forest characterizes most part of the Sanctuary. The annual rainfall in this zone ranges between 900-1500 mm. *Tectona-Anogeissus-Terminalia* community is dominant in this forest type. Trees like *Kydia calycina*, *Cassia fistula* and *Ziziphus xylopyrus* are characteristic of the understorey strata of the forest.

The Western and Southern areas within the Sanctuary, that receive annual rainfall above 1500 mm is characterized by the Tropical Moist Deciduous Forest. *Lagerstroemia microcarpa, Tectona grandis, Terminalia tomentosa, T. bellirica, Anogeissus latifolia* and *Kydia calycina* occur in this habitat.

The heavy rainfall zone in the western part of the sanctuary is characterized by Tropical Semi-evergreen forest. Tree species common to this vegetation type are *Olea dioica Actinodaphne malabarica*, *Persea macrantha*, *Cinnamomum verum*, *Lagerstroemia microcarpa*, and *Terminalia* spp.

2.1.4. Fauna

The Asian Elephant (*Elephas maximas*) is the largest mammal of the Sanctuary. The sanctuary with the neighbouring protected areas together supported 1800-2300 elephants (Desai 1991). Other mammals such as Gaur (*Bos gaurus*), Leopard (*Panthera pardus*), Sambar (*Cervus unicolor*), Tiger (*Panthera tigris*), Sloth Bear (*Melurus ursinus*), Chital or Spotted Deer (*Axis axis)*, Barking Deer (*Muntiacus muntjak*), Mouse Deer (*Tragulus memminna*), Four-horned Antelope (*Tetracerus quadricornis*), Wild Dog (*Cuon alpinus*), Hyaena (*Hyaena hyaena*) and Wild boar (*Sus scrofa*) are of common occurrence.

Avifaunal richness encompasses 265 species in Mudumalai Wildlife Sanctuary while nine of the 16 bird species endemic to Western Ghats are known from this sanctuary (Gokula & Vijayan 1996).

2.1.5. Earlier Research Works

Research studies abound in Mudumalai, ever since these forests were notified as a sanctuary in late 70s. In a major initiative Sukumar *et al.* (1992) began a long-term study of a large plot (50 ha) to monitor the vegetation of the tropical deciduous forest at Mudumalai Wildlife Sanctuary. Murali & Sukumar (1994) documented the phenology of the deciduous forest. Taxonomic study on the flora of Mudumalai Wildlife Sanctuary (Stephen 1994) revealed the occurrence of 1015 species belonging to 539 genera and 118 families. Five major families include Poaceae (65 genera), Fabaceae (34 genera), Asteraceae (31 genera), Rubiaceae (22 genera) and Acanthaceae (20 genera). Eighty-nine species endemic to Western Ghats and Peninsular India were recorded in the sanctuary.

Among mammals, the charismatic Asian Elephant is well studied (Sivaganesan 1991, Baskaran *et al.* 1995, Baskaran and Desai 1996, Desai & Baskaran 1996). Other mammals studied include Sloth Bear (Baskaran *et al.* 1997), Wild Dog (Venkatraman *et al.* 1995), and small carnivores (Swaminathan 2002).

Avifaunal studies, though scanty till late 1990s, received impetus by virtue of studies initiated from the Salim Ali Centre of Ornithology and Natural History, Coimbatore, India. Gokula and Vijayan (1996) documented the avifauna of the sanctuary. Gokula (1998) studied the bird communities of the thorn and dry deciduous forests in the Sanctuary. Amongst hornbills, though Great Pied Hornbill and Malabar Grey Hornbill are known to occur, only the Malabar Grey Hornbill was a confirmed resident at the Sanctuary (Balasubramanian & Maheswaran 2001).

2.1.6. Tribal Communities

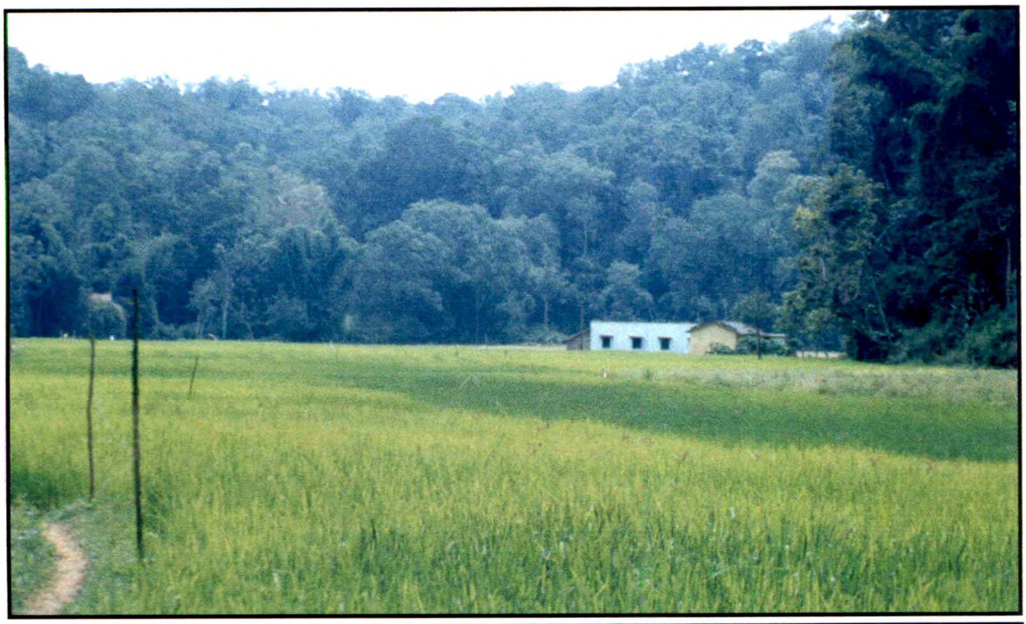
Tribal communities who live within the sanctuary include 'Kurumbas', 'Kattunaickans' and 'Paniyas'. Two non-tribal communities – 'Wynaad' and 'Mondodu Chetties' also inhabit the sanctuary. The human inhabitants of the study site have converted large tracts of the marshy swamps to rice fields (Plate 3). About one third of the population settled within the Sanctuary are dependent on the forest resources such as firewood, timber and honey.

Intense biotic pressure, rapid development of tourism in and around the Sanctuary, electroplating industries in Masinagudi, hydroelectric projects and increasing encroachment have done irreversible damage to the wildlife of the sanctuary (Baskaran *et al.* 1997, Desai & Baskaran 1996, Tyagi 1995).

2.2. Plantations

The rainforests of Western Ghats in general have undergone rapid transformations resulting in the formation of extensive tea, coffee, eucalyptus, and cardamom plantations. Thus, today we find that most of the protected areas in Western Ghats such as Mudumalai Wildlife Sanctuary, Bandipur National Park, Nagarhole National Park, Wynaad Wildlife Sanctuary, Silent Valley National Park, Mukurthi National Park, Indira Gandhi National Park, Kalakkad Mundanthurai Tiger Reserve,

Plate 3. Swampy habitats converted into agricultural plots for rice cultivation, semi-evergreen forest at the backdrop



Eravikulam National Park etc are immediately flanked by vast stretches of plantations that include, tea, coffee, eucalyptus, wattle and casuarina.

Numerous trees that have been planted as shade trees in the plantations produce fruits that are adapted for frugivory. As a result, lot of avian and mammalian frugivores from the neighbouring forests are known to visit these trees in order to fulfil their foraging needs. In the present scenario, where more and more pristine habitats are being fragmented, man-made agroforestry ecosystems can be considered as supplementary habitats for the fauna and should be explored for biotic interactions and their conservation.

The present study was conducted in Benne, a tropical semi-evergreen habitat, located in the western portion of the Mudumalai Wildlife Sanctuary (Map 1.) and the coffee/tea plantations flanking the Sanctuary (Plate 4).

Plate 4. Tea plantation at the study site

a. Tea plantation with shade trees of *Grevillea robusta*

b. & c. Plantations merging with the Sanctuary, separated only by a narrow path

CHAPTER III - METHODS

3.1. Fruit Availability

3.2. Fruit Utilization during Breeding Season

3.3. Fruit Utilization during Non-breeding Seasons

3.4. Assessment of Regeneration Under Nest Trees

3.5. Nest Tree Utilization

3.6. Nest Tree, Hole and Site Characteristics

3.7. Random Tree and Site Characteristics

3.8. Distribution and Density of Hornbill's Food and Nesting Trees

3.9. Statistical Analysis

3.1. Fruit Availability at the Study Site

3.1.1. Semi-evergreen forests

Fruits are lifelines for hornbills. Availability of fruits in the semi-evergreen forests at Benne was assessed by monitoring fleshy fruited plants in three belt transects of dimensions 2000 m x 10 m (totally 6 ha). All fleshy-fruited plants within the transects were marked with aluminium tags and numbered with paint. Provisional identification of the plant taxa was done in the field. Fruit bearing plant specimens were collected and identified at the Botanical Survey of India, Southern Circle, Coimbatore. A total of 1569 individuals belonging to 23 non-fig tree species were marked. Plants were monitored once in a month for fruit availability. The canopies of trees bearing fruits were scanned with binoculars. We used a percentage scale of 0-4 to assess fruit availability in the canopy, where, 0 = no fruits, 1 = 1-25%, 2 = 26-50%, 3 = 51-75% and 4= 76-100%. Fruits were classified as ripe and unripe. The same percentage scale was used to estimate ripe and unripe fruits in the canopy. Since the 6 ha area in which fruiting trees were marked to study phenology contained very few fig trees, we augmented the sample by marking additional trails of 12 km, tagging all fig trees within a width of 5 m on both sides of the trail. A total of 74 individuals belonging to 4 species were obtained in this manner. The fig trails were also visited once in a month for recording fruiting activity.

3.1.2. Tea/Coffee Plantations

Malabar Grey Hornbills also visited the plantations flanking the semi-evergreen forests of Benne. Numerous trees, native as well as planted, that produce fleshy fruits, occurred in the plantation. Availability of fleshy fruits in the plantations were assessed by demarcating three belt transects, each of dimension 2000 m x 10 m. A total of 149 individuals belonging to 17 species (10 Families) were tagged and monitored for fruiting activity every month.

3.2. Fruit Utilization during Breeding Season

3.2.1. Nest Monitoring

During the breeding season, the male hornbills carry a large load of fruits to the nesting site to feed the incarcerated female and chicks. Therefore, continuous monitoring the nest and regular collection of the seeds squirted below the nest helped in determining the diet of hornbills. An intensive nest search was conducted in the study site for nesting activity of the Malabar Grey Hornbill. Cavities in trees used by Malabar Grey Hornbill for nesting were located by following breeding pairs prior to breeding season. Local tribals also assisted in locating nest holes. Two nests were selected for intensive monitoring of fruit deliveries by breeding males to the nest inmates. Observations were carried out between 6 am and 6 pm. Details such as number of visits made by the male, fruit species and number of fruits delivered per visit were recorded.

3.2.2. Seed Midden Collection

Seeds of fruits consumed by the nest inmates were squirted out through the nest slit and got embedded in the litter-strewn forest floor. These seed deposits are usually termed as midden. Therefore, monitoring the midden depositions and analyzing the seeds therein during breeding season helped in determining the variety of fruit species consumed and dispersed by Malabar Grey Hornbill. Seven nests in the first breeding season and twelve nests in the second breeding season were visited and the seeds squirted out by the nest occupants were collected and identified.

3.3. Fruit Utilization during Non-breeding Seasons

3.3.1. Semi-evergreen Forest

Fruit utilization by hornbills during non-breeding season was quantified by scanning trees for feeding birds along three marked transects, each of two kilometers in length. The feeding observations were recorded in units of bouts. Each bout comprised of 5 minutes. The method involved walking along marked trails, and whenever a single bird or flock was observed feeding, the flock size and number of individuals feeding on fruits were recorded for five minutes. Focal animal sampling method was used to quantify the number of fruits ingested by an individual per minute. Feeding observations were recorded between 0600-1200h of the day. Fruits eaten were classified as figs, non-fig sugar- rich fruits and lipid-rich fruits.

3.3.2. Tea/Coffee Plantations

Three transects in plantations, each 2 km in length, were walked regularly for documenting frugivory by the Malabar Grey Hornbill. The methods used was the same as the one used during non-breeding season in the semi evergreen forest (please refer to Section 3.3.1. of this chapter).

3.4. Assessment of Regeneration Under Nest Trees

Twelve nests were selected for studying regeneration in the midden. A square plot of 5-sq. m. was demarcated at the base of the tree facing the nest hole. Similarly another plot of 5-sq. m. was demarcated at the base of the tree behind the same tree. During the post-breeding season (May - January), these sites were visited every week to study regeneration from the midden deposits.

3.5 Nest Tree Utilization

An intensive search for active nest cavities was done within the Sanctuary during the breeding season. Active nesting were confirmed by following breeding pairs and breeding male carrying fruit load as well as from deposits of seeds under the nest tree. Intensive surveys were conducted during every breeding season, to document the use of nest trees, nest fidelity and the effect of human disturbances on nesting.

3.6. Nest Tree, Hole and Site Characteristics

Nest site and tree characteristics of 40 nest trees were measured. Variables were selected based on factors that were considered to have potential effect on nest-site selection. Results of previous studies were also taken into consideration for assessing nest tree, hole and site characteristics. Variables recorded during the course of the study are listed in Table 1.

3.7. Random Tree and Site Characteristics

All parameters of nest hole, site and tree were compared with measurements obtained from random trees in order to determine the factors facilitating nesting. A tree with nest cavity ideal for housing a female hornbill is termed as a potential nesting tree. The potential tree sighted at about 100 m radius from the active nest tree (focal nest tree) was considered to be random. All variables measured for the nest trees were recorded for the random tree also.

Table 1. List of variables collected for assessing Nest tree, nest hole and nest site characteristics at the study site

S. No.	Variables
	Nest Tree Characteristics
1	Girth at breast height (cm)
2	Tree height (m)
	Nest Hole Characteristics
3	Nest height (m)
4	Girth at nest height (cm)
5	Inner depth (cm)
6	Nest entrance length (cm)
7	Nest entrance breadth (cm)
8	Orientation of the nest (o)
9.	Position of the nest (Main trunk, secondary or tertiary branch
	Nest site characteristics
10	Altitude (m)
11	Aspect (o)
12	Distance from nearest hamlet (m)
13	Distance from nearest nest (m)
14	Distance from nearest water source (m)

3.8 Distribution and Density of Hornbill's Food and Nesting Trees

Phytosociological analysis was undertaken to understand the diversity and distribution of trees utilized by hornbills for food and nesting purposes. The study was carried out in three patches of semi-evergreen forests with differential human activity. The three patches studied were located at Jodipalam (RD), Kalladi (MD) and Nelliankunni (HD). Site RD wass relatively undisturbed and 5 km from nearest human habitation. Site MD had a history of selective logging. Selective logging was undertaken in this site about 20 years ago. Site HD ran parallel to human settlements and is separated by 100 – 200 m. These study sites were 1 km to 5 km apart. In each of these study sites, a plot of 1-hectare (1000 x 10 m) was demarcated and all trees (⊇ 30-cm girth at breast height) were enumerated. This demarcated area was further divided into 10-m x 10-m sub plots for data collection. Girth at breast height (1.3-m) and heights of all trees were measured. Trees were identified using regional floras (Gamble & Fischer 1915-1935, Mathews 1991, Pascal & Ramesh 1987). The sampling also included documentation of anthropocentric activities prevailing in the habitat that could influence food and nest plants of the hornbill. Disturbance parameters studied in the vegetation plots included number of cutting and lopping signs, potential nest cavities, active nest cavities, illegal tree felling and signs of animal traps and bird traps.

3.9. Statistical Analysis

3.9.1. Phytosociological Analysis

Diversity of tree species was calculated using Shannon-Weiner index (1949) H' = $-p_i \log p_i$ (where H' = diversity and p_i = the proportion of observation in subset i)

3.9.2. Food and Nest Tree Preference

Ivlev's index of selectivity (Ivlev 1961) was used to determine fruit and nest tree preference by Malabar Grey Hornbill. Ivlev's Index of Selectivity = U – A / U+ A Where 'U' denotes percent utilization of species and 'A' denotes percent availability of corresponding species. Selectivity values of Ivlev's range between –1 and +1, where –1 indicates avoidance while +1 indicates highest preference.

3.9.3. Other Statistical Tests

Univariate analysis of variance (ANOVA), Chi square test, Spearman's rank correlation, Wilcoxon's signed rank test and other simple statistics (Mean and SD) was used for various attributes of fruit availability, fruit utilization, nest tree utilization and nest-site regeneration. Statistical analysis was performed using the statistical program SPSS Version 7.5. Results are reported as significant if they are associated with a value of $P < 0.05$.

Chapter IV - Results

4.1. Fruit Availability

4.2. Fruit Utilization

4.3. Plantations: Supplementary habitat for Malabar Grey Hornbill

4.4. Keystone Resources for Malabar Grey Hornbill

4.5. Nest Tree Utilization

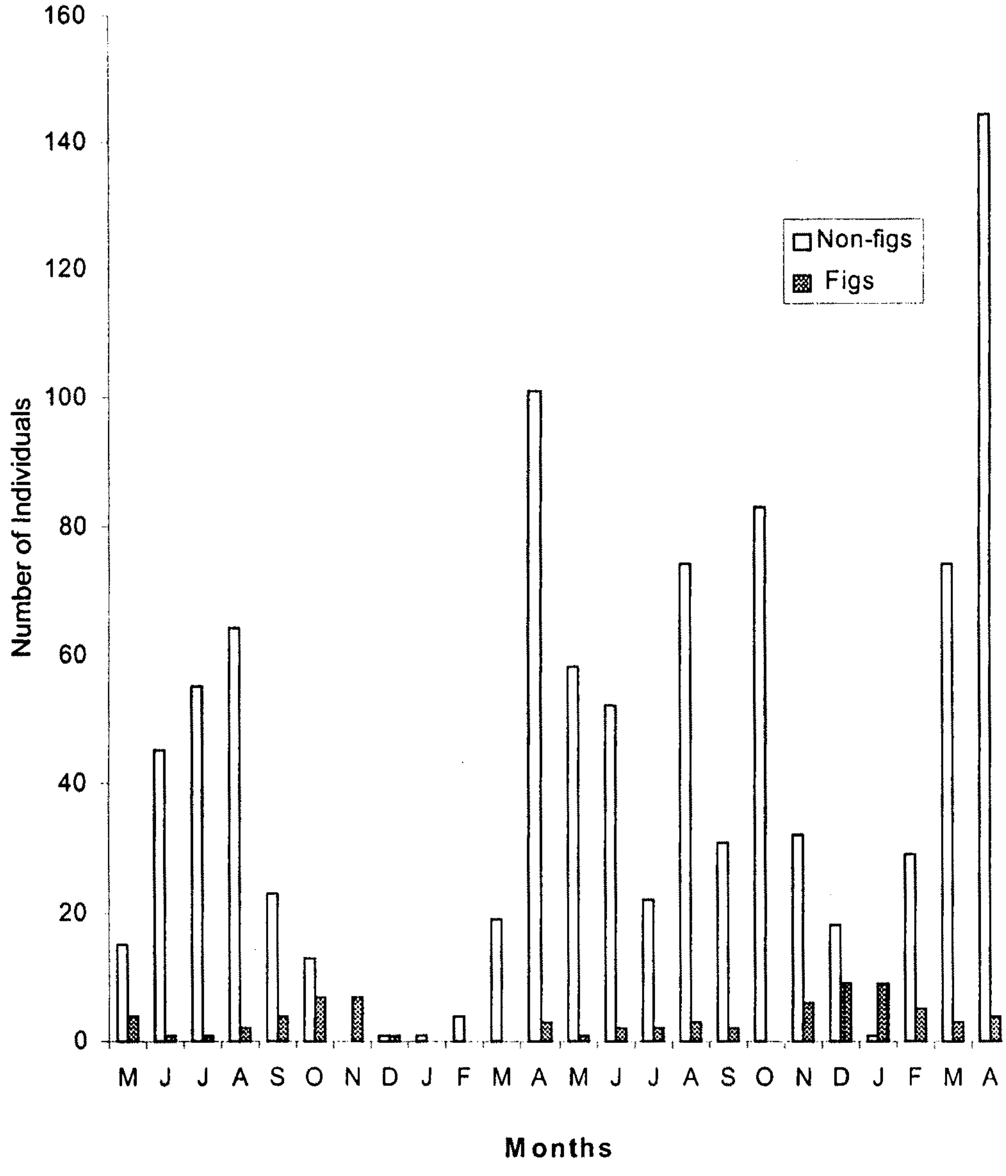
4.6. Vegetation Features of Hornbill Habitat

4.1. Fruit Availability in Semi-evergreen Forest

Phenological monitoring showed that 26 tree species belonging to 12 families fruited during the study period. This included four species of figs and twenty-two species of non-figs. During 24 months phenological observations starting from May 2000, one major peak and a minor peak were observed for non-fig fruit species (Fig. 2). Fruiting peak for 2001 was observed in April, when 7 species and 101 individuals were recorded in fruits. The fruiting peak for 2002 was observed during April when 8 species and 144 individuals were recorded in fruits. The highest number of species was in fruits during May 2001 when 9 species were recorded in fruits. During October 2001, 83 individuals were recorded with fruits. This was mainly due to a spurt in fruiting of *Viburnum punctatum,* which contributed to 93.9% of fruiting individuals.

Fruit species selected for the study were classified broadly into three types: figs, non-fig sugar-rich and lipid rich fruits (Table 2). While four *Ficus* species (Family: Moraceae) formed figs, species of families Apocynaceae, Flacourtiaceae, Lauraceae, and Meliaceae produced lipid-rich fruits. Members of family Caprifoliaceae, Flacourtiaceae, Myrtaceae, Oleaceae, Rutaceae, Tiliaceae and Verbenaceae accounted for non-fig sugar-rich fruits.

Fig. 2. Fruit Availability of Fig and Non-fig Trees (May 2000-April 2002)



With regard to the fig fruiting in the study area, two fruiting peaks were observed. A major peak occurred in December 2001, when 9 individuals produced ripe fruits (Fig. 2). Both the peaks of fig fruiting synchronized with a decline in fruiting activity of non-fig species. September – December 2000 and November – January 2001 were periods of decline in fruiting activity of non-fig species (Fig. 2). Hence, this period could be called as the lean period in the study site. This lull in fruiting by non-fig species was compensated by the fruiting of fig species (Fig.3).

Fig. 3. Fruiting pattern of figs

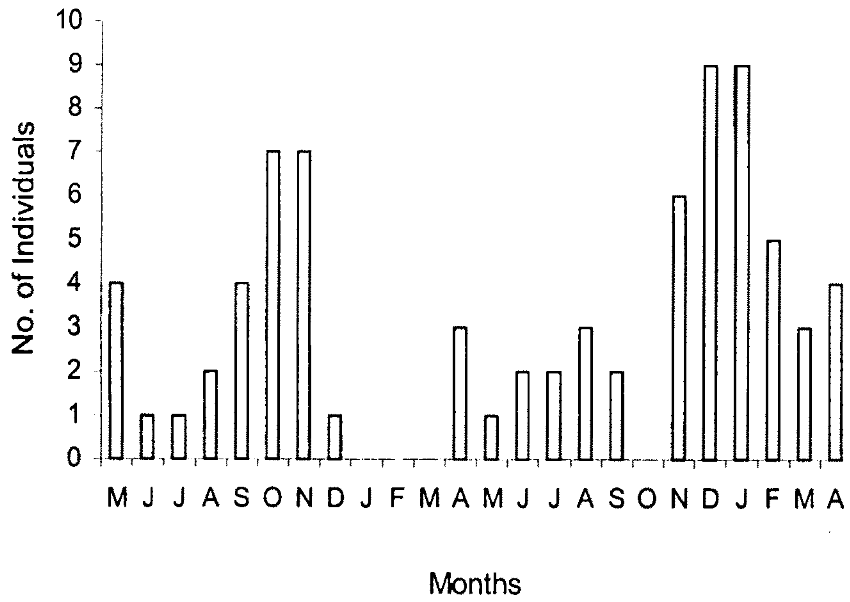


Fig and non-fig fruit availability was correlated with rainfall and number of rainy days for every month. Correlation between non-fig fruiting individuals and number of rainy days (r_s = 0.6468, N =20, P = 0.002) and monthly rainfall (r_s = 0.4887, N = 20, P = 0.029) were significantly positive.

Figures 4 and 5 illustrate the fruiting pattern of select fruit tree species at the study site. The pattern indicated that lipid-rich fruits such as *Actinodaphne malabarica* (Fig. 4a), *Cinnamomum verum* (Fig.4b) and *Persea macrantha* (Fig. 4c) (Lauraceae) timed their peak fruiting activity in the dry season (February to May). On the other hand another lipid-rich fruit species, *Aphanamixis polystachya* (Fig. 4d) (Meliaceae), fruited actively between December and January and extending upto February. December-February happens to be the transition period in terms of fruiting at the study site. The figs have just completed their peak fruiting activity (Fig 3), while the sugar-rich fruit tree species such as *Olea dioica* began their fruiting activity (Fig 5). Thus, fruits of *Apahanamixis polystachya* thus bridged the gap in fruiting during the transition period.

Fig. 4 Fruiting pattern of select lipid-rich fruit tree species

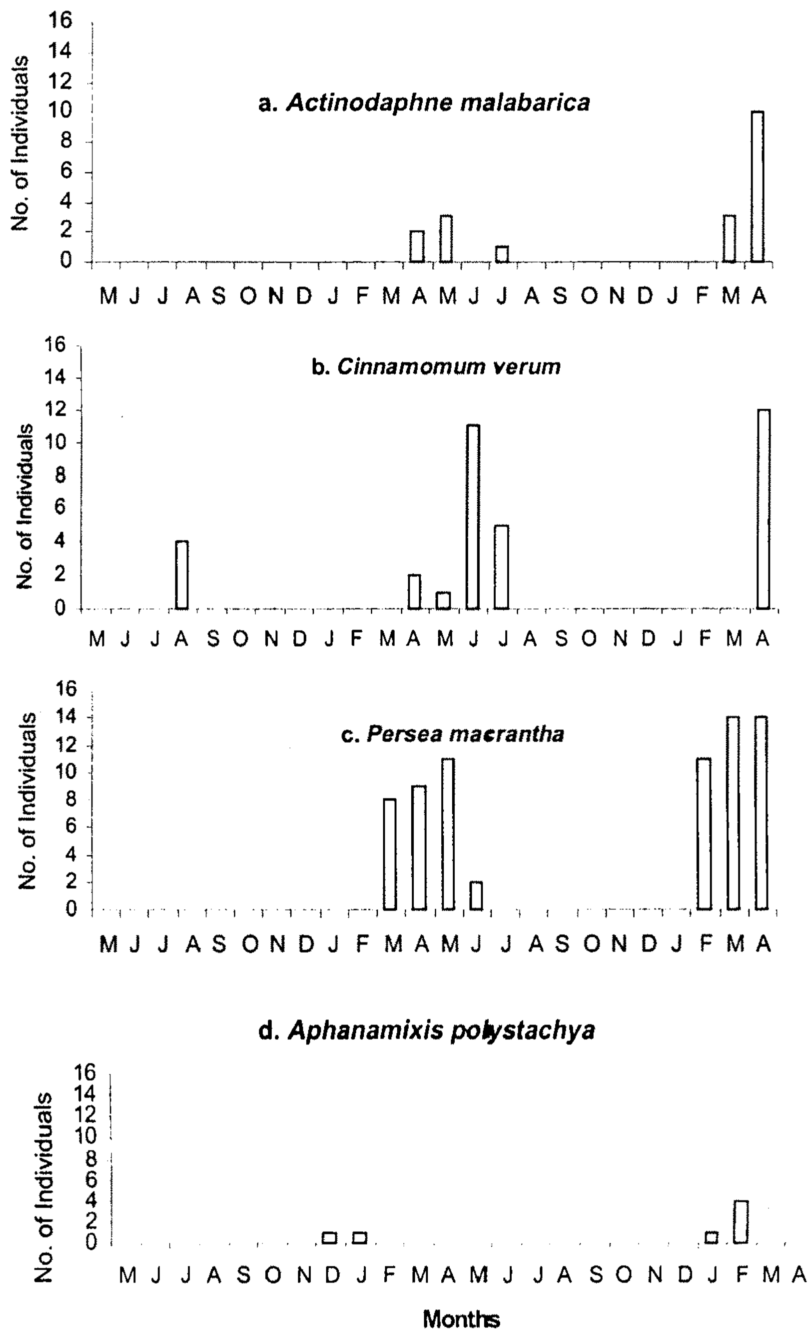
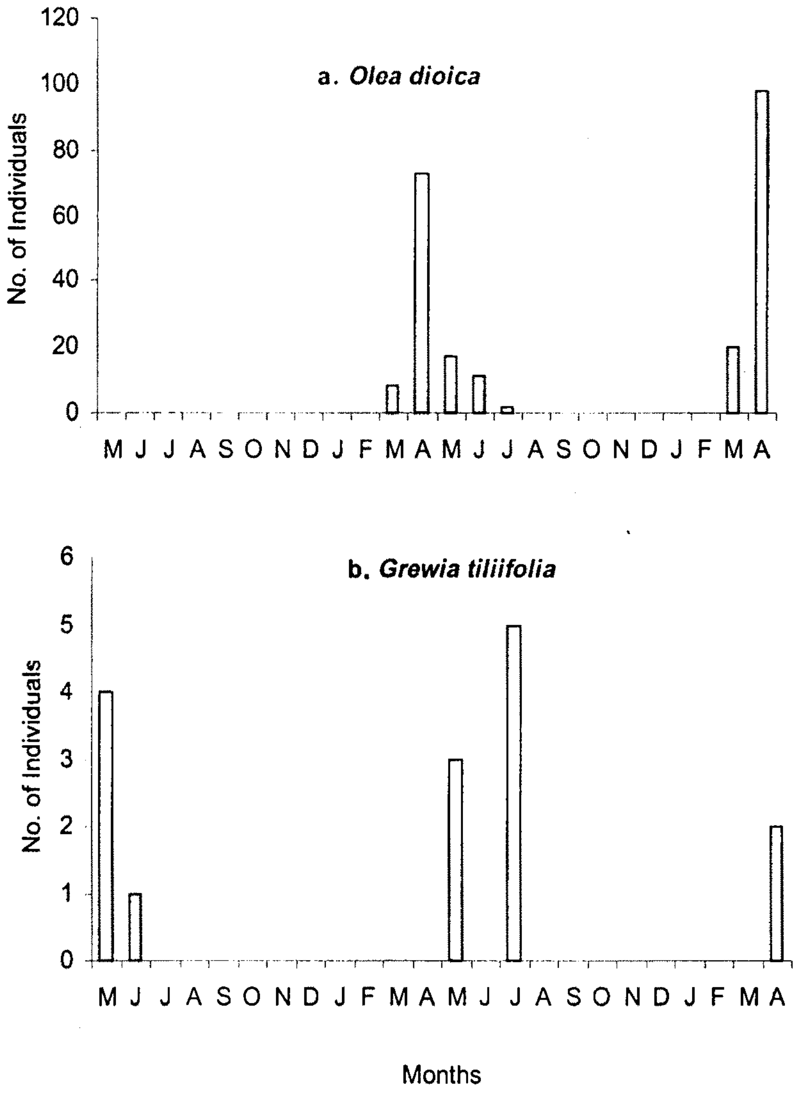


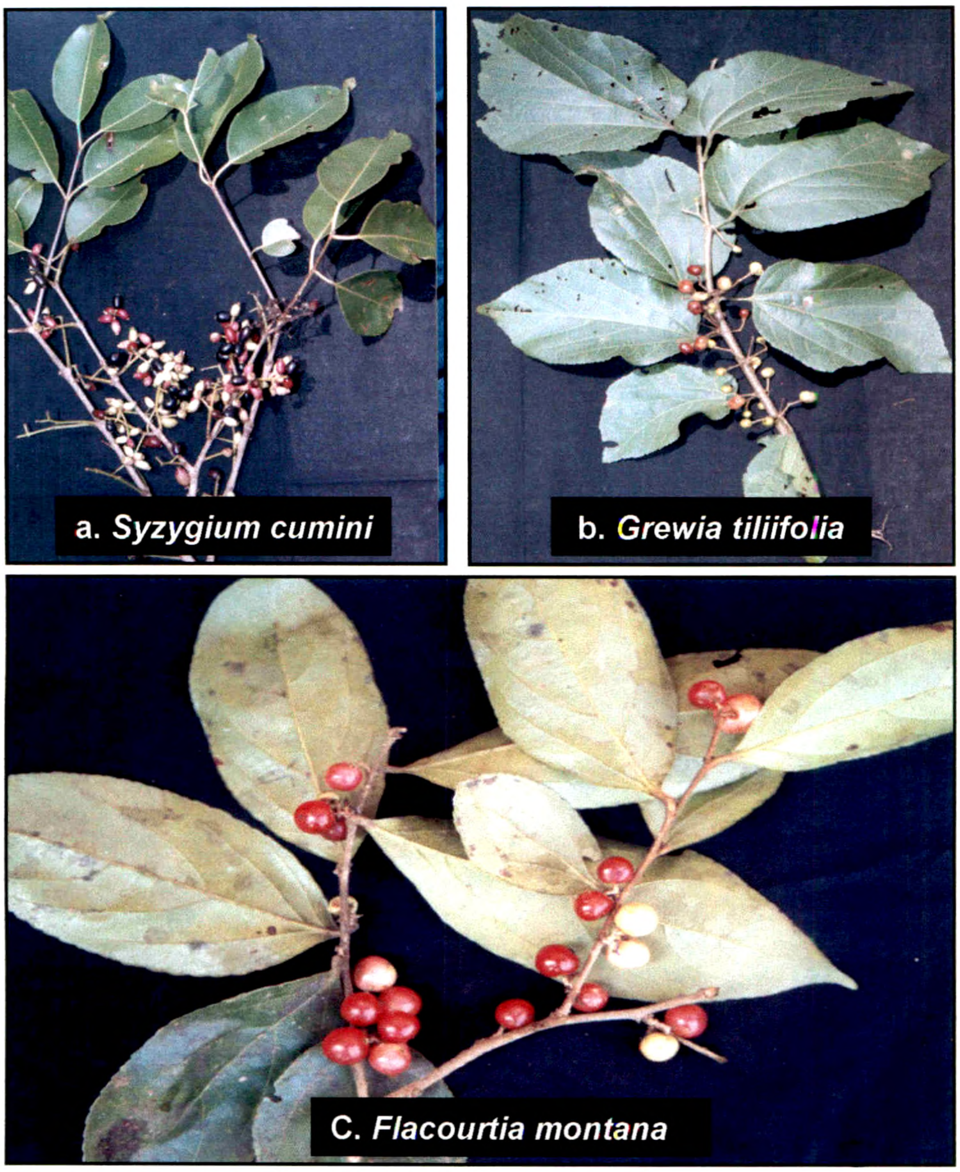
Fig. 5. Fruiting pattern of sugar rich fruit tree species



4.2. Fruit Utilization in Semi-evergreen Forest

Twenty-seven species belonging to 17 plant families were identified as food plants for Malabar Grey Hornbill (Table 2.). This number has been arrived at by taking into account the species recorded during nest monitoring, midden analysis and those utilized during the non-breeding season. Of these 27 species, two species could not be identified and have been classified as unidentified. Members of Families Lauraceae (4 species), Moraceae (3 species) and Flacourtiaceae (3 species) were the predominant food plants of Malabar grey hornbills in this habitat. The different fruit types utilized included (i). 16 species of non-fig sugar-rich fruits (Plate 5), (ii). 8 species of lipid-rich fruits (Plates 6-8) and (iii). 3 species of figs (Plate 9). Five different morphological types within the fruits were recognized of which drupes and berries contributed 70% (19 species) of the fruit species. Fruits eaten by the Malabar Grey Hornbill belonged to four colour types: purple (13 species), yellow (9), red (4) and white (1). Species bearing purple and yellow colour fruits, together contributed 81% of the fruit species. Fruits were classified into three classes based on Balasubramanian (1996): diameter < 10 mm (10 species), 11-20 mm (11 species) and >20 mm (3 species). Fruit sizes of three species could not be recorded.

Plate 5. Sugar-rich Fruits



a. *Syzygium cumini*

b. *Grewia tiliifolia*

C. *Flacourtia montana*

Plate 6. Lipid rich fruits, Lauraceae

a. *Persea macrantha* b. *Actinodaphne malabarica*

Table 2. Characteristics of fruits utilized by Malabar Grey Hornbill

Species	Family	Season of Diet	Nutritional Type	Mean Fruit Length (cm)	Morphological Type	Fruit Colour
Actinodaphne malabarica	Lauraceae	B[a] / NB[b]	Lipid-rich	0.99	Berry	Purple
Aphanamixis polystachya	Meliaceae	B/NB	Lipid-rich	1.21	Capsule	Red
Casearia ovata	Flacourtiaceae	B/NB	Lipid-rich	1.08	Capsule	Red
Cinnamomum verum	Lauraceae	B/NB	Lipid-rich	1.46	Berry	Purple
Coffea arabica	Rubiaceae	B	Sugar-rich	0.74	Drupe	Purple
Diospyros sp.1	Ebenaceae	B	Sugar-rich	1.5	Drupe	Yellow
Ficus drupacea	Moraceae	B/NB	Figs	2.5	Syconium	Yellow
Ficus tsjahela	Moraceae	NB	Figs	0.69	Syconium	Yellow
Ficus virens	Moraceae	B/NB	Figs	1.02	Syconium	Yellow
Flacourtia montana	Flacourtiaceae	B	Sugar-rich	1.71	Berry	Purple
Glochidion velutinum	Euphorbiaceae	B/NB	Sugar-rich	0.68	Capsule	Red
Gmelina arborea	Verbenaceae	B	Sugar-rich	Not recorded	Drupe	Yellow
Gnetum ula	Gnetaceae	NB	Sugar-rich	2.02	Drupe	Yellow
Grewia tiliifolia	Tiliaceae	B/NB	Sugar-rich	0.63	Drupe	Purple

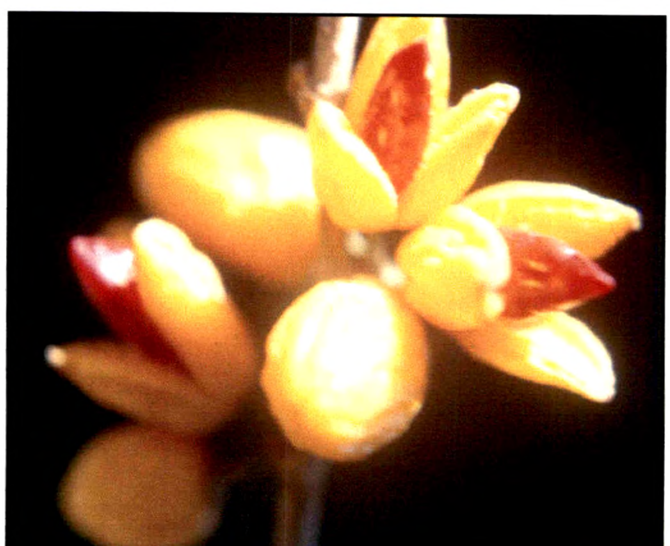
....

Table 2 Continued..........

Species	Family	Season of Diet	Nutritional Type	Mean Fruit Length (cm)	Morphological Type	Fruit Colour
Litsea stocksii	Lauraceae	B/NB	Lipid-rich	1.4	Berry	Purple
Melia dubia	Meliaceae	B	Sugar-rich	2.19	Drupe	Yellow
Meliosma simplicifolia	Meliosmaceae	B	Sugar-rich	0.6	Drupe	Yellow
Olea dioica	Oleaceae	B	Sugar-rich	1.15	Drupe	Purple
Olea paniculata	Oleaceae	B	Sugar-rich	1.27	Drupe	Purple
Persea macrantha	Lauraceae	B/NB	Lipid-rich	0.91	Berry	Purple
Syzygium cumini	Myrtaceae	B/NB	Sugar-rich	1.14	Berry	Purple
Tabernaemontana heyneana	Apocynaceae	NB	Lipid-rich	0.66	Capsule	Red
Toddalia asiatica	Rutaceae	NB	Sugar-rich	0.86	Berry	Orange
Trichilia connarroides	Meliaceae	NB	Lipid-rich	1.26	Capsule	White
Xylosma latifolium	Flacourtiaceae	B	Sugar-rich	0.84	Berry	Purple
Angali (Unidentified 1)	Unidentified 1	B	Sugar-rich	Not recorded	Drupe	Purple
Thuvalai (Unidentified 2)	Unidentified 2	B	Sugar-rich	Not recorded	Drupe	Purple

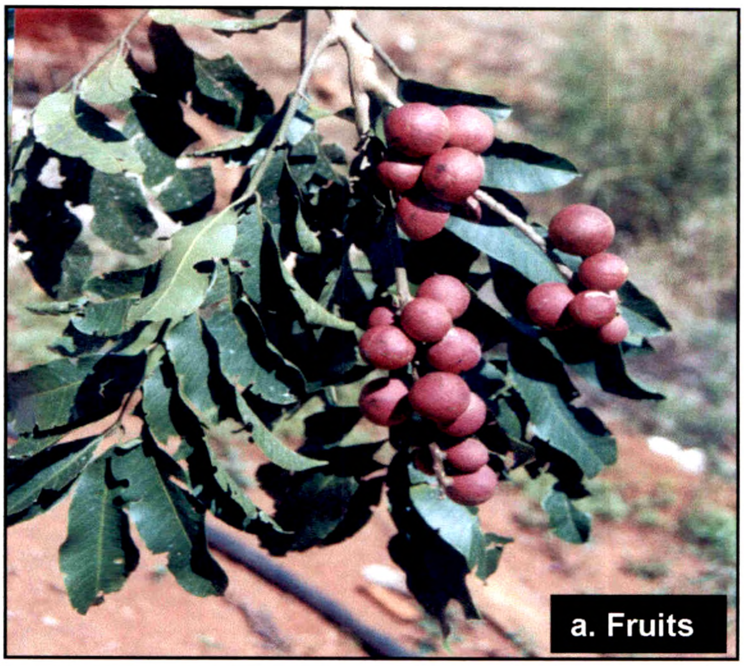
[a] Breeding season; [b] Non-breeding season

Plate 7. *Casearia ovata*



Capsules split open to expose red arillate seeds

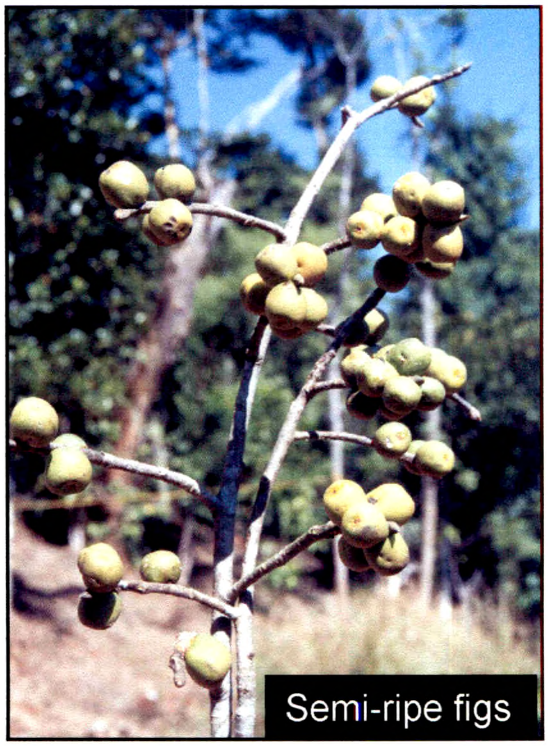
Plate 8. *Aphanamixis polystachya*



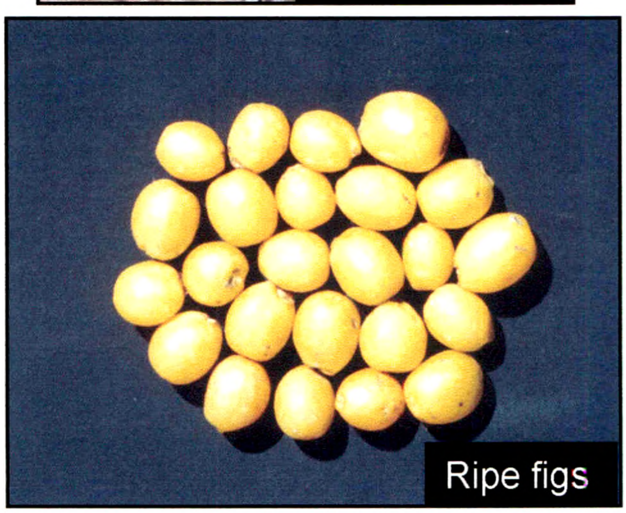
a. Fruits

b. Seeds

Plate 9. *Ficus drupacea,* a preferred fig for Malabar Grey Hornbill



Semi-ripe figs



Ripe figs

4.2.1. Breeding Season Food

4.2.1.a. Nest Monitoring

The breeding season is defined as the duration between the day of complete nest sealing and the day on which female and hatchlings break out of the nest. Non-breeding season is the intervening period between two successive breeding seasons (June to January). In the Sanctuary, Malabar grey hornbills began their nesting activity at the earliest on February 20, 2001 and ended latest by May 25, 2001 when the female and hatchlings broke out of the nest together. Two hatchlings were recorded from each of the two focal nests observed. The mean duration of nesting was 90 days. Two nest trees were selected for monitoring. These two nests were monitored during two successive breeding seasons for a total of 791 hours. The two males made 486 visits to the nests when 8754 fruits belonging to 17 species and 13 families were delivered to the nest inmates. Bulk of the fruits delivered (69.73%) belonged to two families, Oleaceae and Lauraceae. Two species namely *Actinodaphne malabarica* (30.31%) and *Olea dioica* (24.99%) contributed for about 55% of the fruits delivered to the nest inmates while the remaining 15 species together accounted for 45% of the food. Two food plant species are endemic to the Western Ghats, viz., *Actinodaphne malabarica* and *Litsea stocksii.*

Non-fig sugar-rich fruits formed 47.59% of all fruits delivered closely followed by lipid-rich fruits (47.16%). Two species of figs, *Ficus virens* and *Ficus drupacea* together accounted for only 5.25% during the breeding season (Fig. 6a). It was also found that 94.43% of the fruits delivered were purple, 3.82% of fruits were red and 1.74% of fruits were yellow.

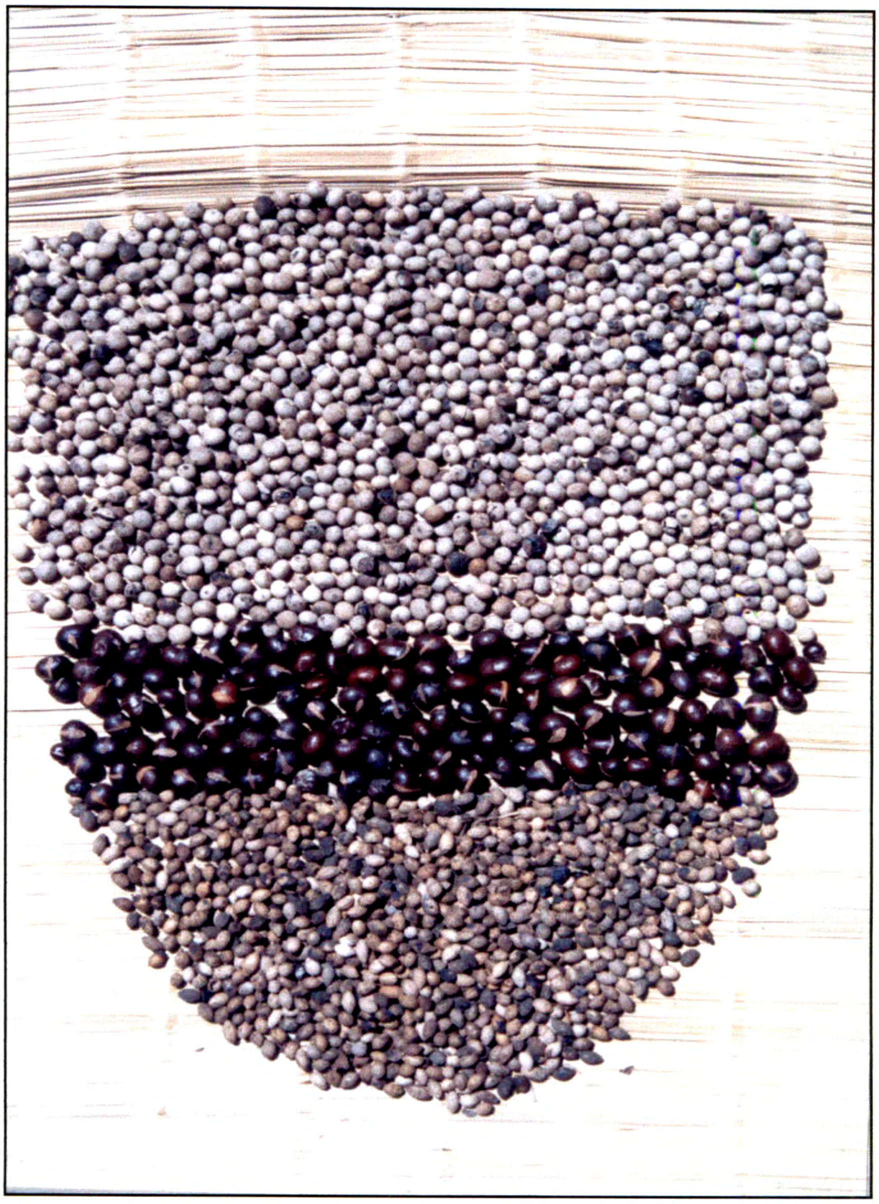
4.2.1.b. Midden Analysis

The analysis of seeds collected from seven nests (middens) in the first breeding season (calendar year 2000) and twelve nests in the second breeding season (calendar year 2001) showed the occurrence of 15,220 seeds belonging to 16 species. Of these 16 species (9 families), 11 fruit species were also recorded during direct observations at the nests. Seeds of two species could not be identified. Majority (71.66%) of the seeds found at the midden belonged to two species namely *Olea dioica* (45.24%) and *Persea macrantha* (26.42%) (Plate 10).

4.2.2. Non-Breeding Season Food

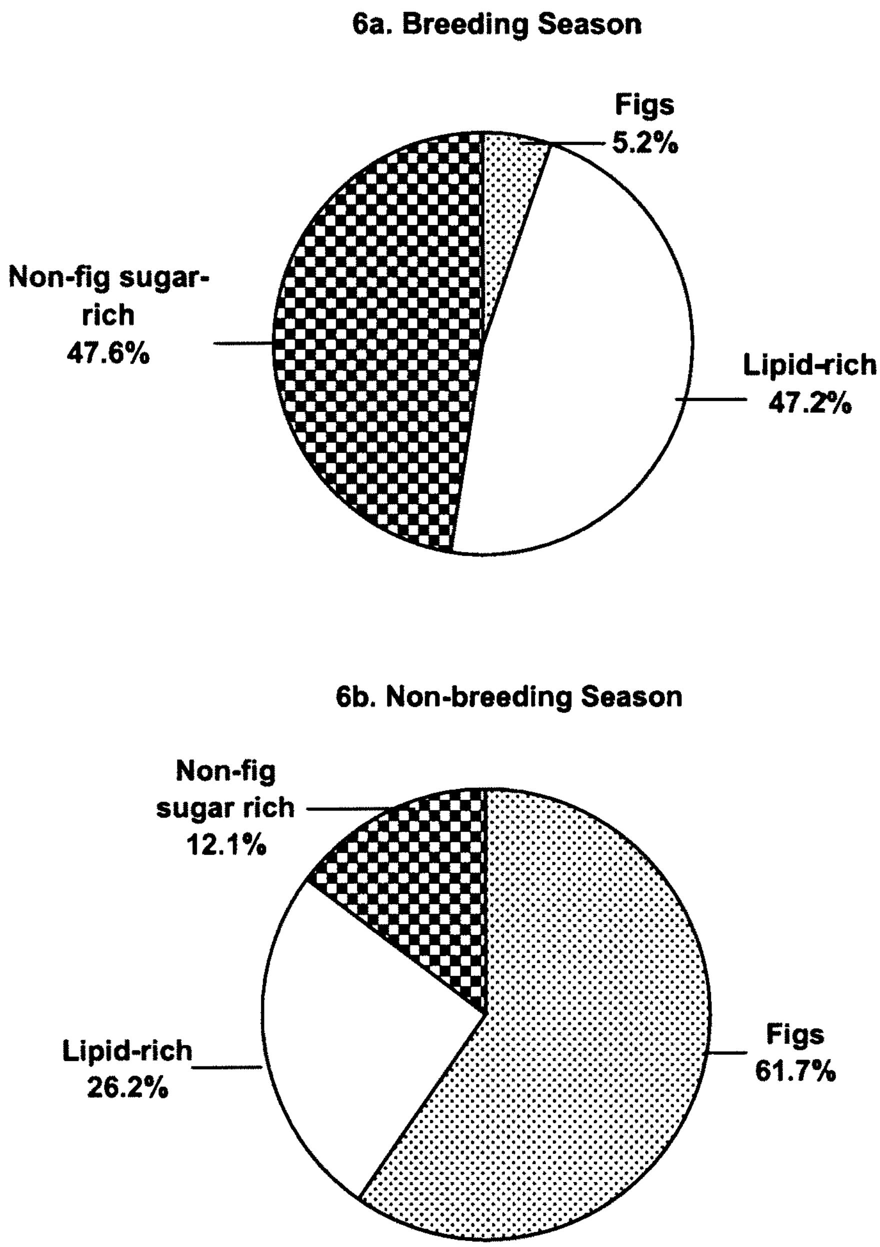
June to January was the non-breeding season for Malabar Grey Hornbill at this study site. During the two non-breeding seasons, a total of 222 walks were made along three transects. Sixteen species belonging to 10 families

Plate 10. Seeds collected from nest sites



Top to bottom: *Persea macrantha*, *Aphanamixis polystachya* and *Olea dioica*

Fig. 6. Contribution of differrent fruit types based on nutritive values of fruits utilized by Malabar Grey Hornbill during a) breeding and b) non-breeding season



were consumed by the Malabar Grey Hornbill during the non-breeding season. Of the 727 observations, 58.01% were on two species of figs, *Ficus drupacea* and *Ficus tsjahela*, while 26.2% were on lipid rich arillate fruits of *Aphanamixis polystachya, Tabernaemontana heyneana* and *Trichilia connaroides*. Non-fig sugar-rich fruits formed only 12.1% of observations (Fig. 6b). A majority of the feeding observations were on yellow coloured fruits (67.23%), followed by red (16.6%) and purple (6.81%).

4.2.3. Fruit Preference in Breeding and Non-breeding Season

Ivlev's Index of Selectivity (Ivlev 1961) was used to determine preference index (P.I.) for the different diet species delivered to the nest inmates during the breeding season. *Actinodaphne malabarica* (Lauraceae), a species bearing lipid-rich fruits with a P.I. of '0.91' was the most preferred species followed by *Olea dioica* (Oleaceae) and *Persea macrantha* (Lauraceae) which had preference indices of 0.84 and 0.81 respectively (Table 3). Fruit lengths of diet species were negatively correlated with number of fruits delivered to the nest inmates. In the non-breeding season. *Ficus drupacea* (P.I. = 0.93) and *Ficus tsjahela* (P.I. = 0.92) were the two most preferred species (Table 3). Among the non-fig species *Aphanamixis polystachya* (P.I. = 0.72) was preferred.

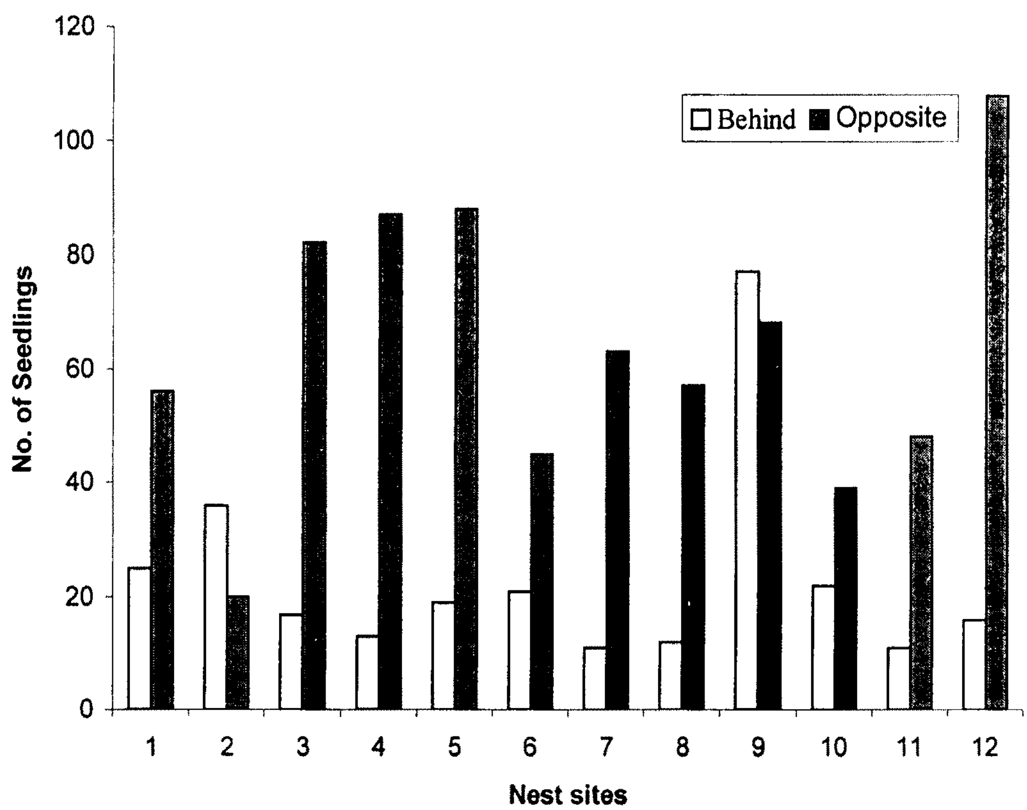
Table 3. Preference index (P.I.) for food plant species utilized by Malabar Grey Hornbill during breeding and non-breeding season

Species	Family	Breeding Season P.I.	Non-breeding Season P.I.
Actinodaphne malabarica	Lauraceae	0.91	0.15
Aphanamixis polystachya	Meliaceae	-0.39	0.72
Casearia ovata	Flacourtiaceae	-1	-0.05
Cinnamomum verum	Lauraceae	-0.46	0.44
Diospyros sp 1	Ebenaceae	-0.84	-1
Ficus drupacea	Moraceae	0.37	0.93
Ficus tsjahela	Moraceae	-1	0.92
Ficus virens	Moraceae	0.41	0.54
Glochidion velutinum	Euphorbiaceae	0.1	-0.21
Gmelina arborea	Verbenaceae	0.12	-1
Gnetum ula	Gnetaceae	-1	0.66
Grewia tiliifolia	Tiliaceae	0.83	-0.21
Litsea stocksii	Lauraceae	0.38	-0.78
Meliosma simplicifolia	Meliosmaceae	0.58	-1
Olea dioica	Oleaceae	0.84	-1
Persea macrantha	Lauraceae	0.81	-0.9
Syzygium cumini	Myrtaceae	-0.25	-0.79
Tabernaemontana heyneana	Apocynaceae	-1	0.62
Toddalia asiatica	Rutaceae	-1	0.62
Trichilia connaroides	Meliaceae	-1	0.54
Xylosma latifolium	Flacourtiaceae	-0.56	-1
Angali (Unidentified 1)	Unidentified 1	-0.97	-1

4.2.4. Role of Malabar Grey Hornbills in Forest Regeneration

A total of 19 species belonging to 13 families were enumerated from the square plots in the midden sites. *Olea dioica*, one of the favoured fruit of MGH was recorded in all the 12 midden sites, while *Cinnamomum verum* was recorded from 11 midden sites. Lauraceae and Flacourtiaceae (3 species each) were the most represented family among the regenerated seedlings. While 13 species consisting of 280 regenerated seedlings were recorded behind the nest, 18 species consisting of 761 seedlings regenerated opposite to the nest site. All the nest sites (except one) showed a greater number of regenerated seedlings opposite to the nest site compared to behind the nest (Fig. 7). The number of seedlings regenerated opposite the nest site were significantly higher than those behind the nest (t= -4.220; DF =11; P = 0.01).

Fig. 7. Regeneration of seeds opposite and behind the nest at the study site



4.3. Plantations: Supplementary Habitat for Malabar Grey Hornbill

4.3.1. Tree Flora of Plantations

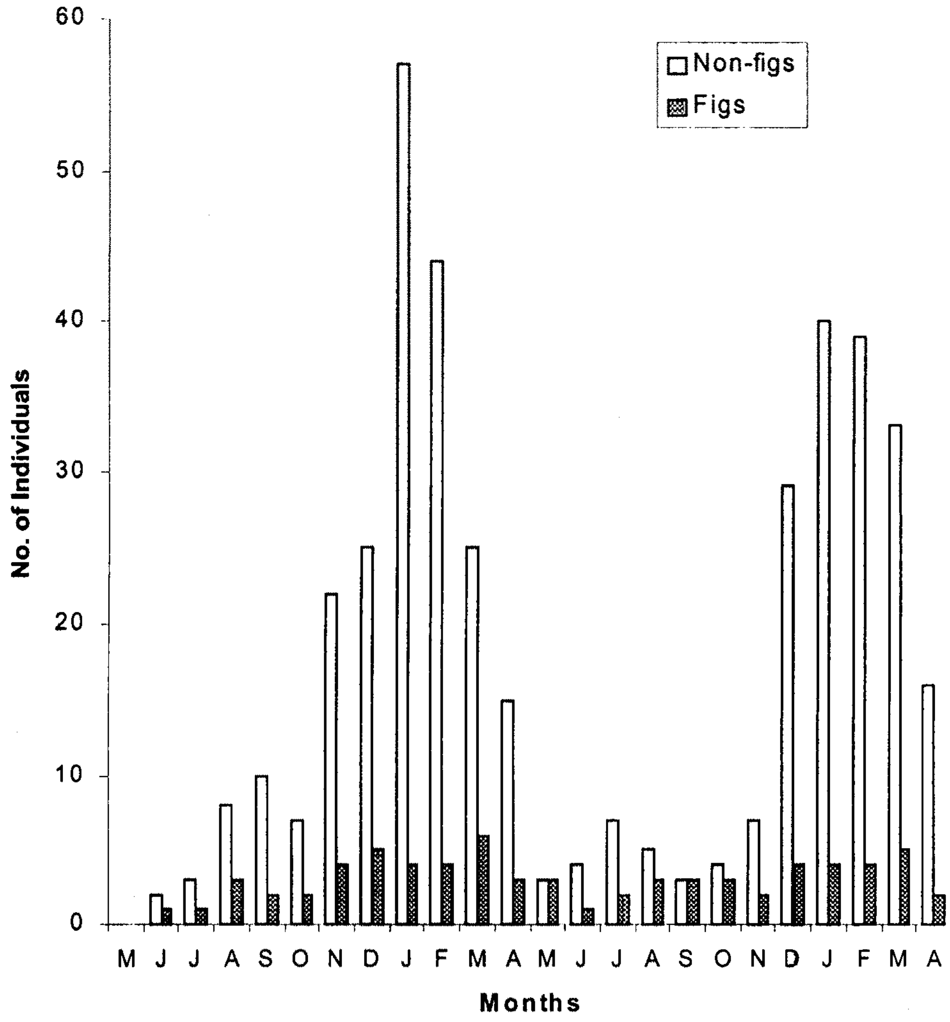
Tea plantations are vibrant habitats for the frugivorous fauna of this region. The tea plants (*Camellia sinensis*) essentially dominate the species composition of the plantations. *Grivellia robusta*, an Australian tree of 10-15 m height, commonly called as Silver Oak, is planted every 20m distance to provide shade to the tea plants. The stems of silver oak also act as a support to the climbing pepper plants, which is a very important cash crop of the Nilgiris District. Plantations are also home to an umpteen number of forest tree species that are adapted for dispersal by birds. Tree species that occur in the plantations include *Caryota urens* (Palmae); *Ficus drupacea, F. racemosa, F. virens, F. tsjahela* and *Streblus asper* (Moraceae); *Melia dubia* and *Trichilia connarroides* (Meliaceae); *Grewia tiliifolia* (Tiliaceae); *Trewia nudiflora* (Euphorbiaceae); and *Syzygium cumini* (Myrtaceae). *Maesopsis emenii* (Rhamnaceae), a tree of African origin is a major attractant for the frugivores of the region. The birds of this region voraciously consume the fruits of the principal plantation crops namely, coffee and pepper. The semi-evergreen habitat of Mudumalai Wildlife Sanctuary abruptly merges with the tea/coffee plantations on one side. Since these plantations were dotted with a fair number of fleshy-fruited species adapted for attracting a variety of birds, hornbills invariably used this man-modified habitat for feeding.

4.3.2. Fruit Availability in Plantations

A total of 149 individuals belonging to 17 plant species (11 Families) were tagged and monitored every month for fruiting activity. Analysis of the fruiting pattern during the two-year study period revealed a major fruiting peak in January 2001 when 60 individuals belonging to 6 species were in fruits followed by February 2001 when 45 individuals of 5 species were in fruits (Fig. 8.). For both the years, fruiting activity recorded an uptrend in November and peaked in January and thus declining gradually. While November to April could be termed as the active fruiting period, June to October was a period of decline in fruiting.

A characteristic feature of fruiting in the plantations was that, all months during the study period witnessed fruiting by some individuals, thus providing a reliable source of food for the frugivores in general, the Malabar grey hornbills in particular. Individuals of *Maesopsis emenii* produced ripe fruits for 20 of the 24 months monitored while four members of the Family Moraceae alternately produced ripe fruits over a period of 19 months. *Coffea* spp, *Piper nigrum* and *Caryota urens* produced ripe fruits over a period of eight, six and five months respectively. Thus, birds seem to enjoy a veritable fruit resource base in the plantations throughout the year.

Fig. 8. Fruiting individuals in the plantations (May 2000-April 2002)



Peak fruiting in plantations coincided with early breeding period or the period when Malabar grey hornbills were busy preparing for the upcoming prolonged breeding activity during January and February. Though this trend was consistent for both the years, it must be noted that the peak breeding months of March and April in both the years have 17 - 34 individuals in fruits, thus providing steady supply of fruits for the breeding hornbills.

4.3.3. Fruit Utilization in Plantations

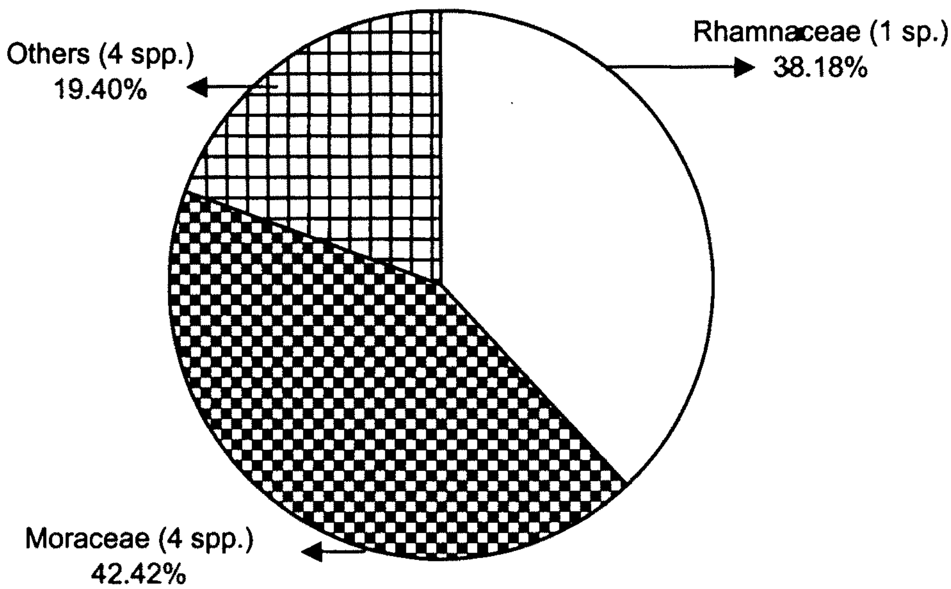
The three transects in plantations were also walked regularly for documenting frugivory by the Malabar grey hornbills. During the study period, 198 walks were conducted in the transects of the plantations to record feeding activity.

A total of 165 feeding records of Malabar Grey Hornbill were made on nine species of plants during the two non-breeding seasons in the plantations. Four species (*Ficus drupacea, F. tsjahela, F. virens* and *Streblus asper*) were members of the family Moraceae. *Caryota urens*, *Coffea* spp., *Maesopsis emenii*, *Melia dubia* and *Piper nigrum* were members of the families Palmae, Rubiaceae, Rhamnaceae, Meliaceae and Piperaceae respectively.

Maesopsis emenii (Rhamnaceae), on which 63 observations were recorded accounted for 38 . % of total feeding observations for the two-year study period (Fig. 9). Four species of Moraceae (*Ficus drupacea, F. tsjahela, F.virens* and *Streblus asper*) together accounted for 42 % of feeding observations. Thus, members of the families Moraceae and Rhamnaceae together accounted for 80.6% of feeding in the plantations.

Analysis of feeding observations for the period June 2000 to January 2001, revealed that the Family Moraceae consisting of four species contributed to 68% of the feeding observations with *Streblus asper* alone contributing 36 % of feeding observations. During the period June 2001 to January 2002, *Maesopsis emenii* contributed 46 % of the feeding. Thus, members of Moraceae and Rhamnaceae act as pivotal fruit resources to Malabar Grey Hornbill in the plantations.

Fig. 9. Fruits utilized by Malabar Grey Hornbills in plantations
(June 2000 - January 2002)



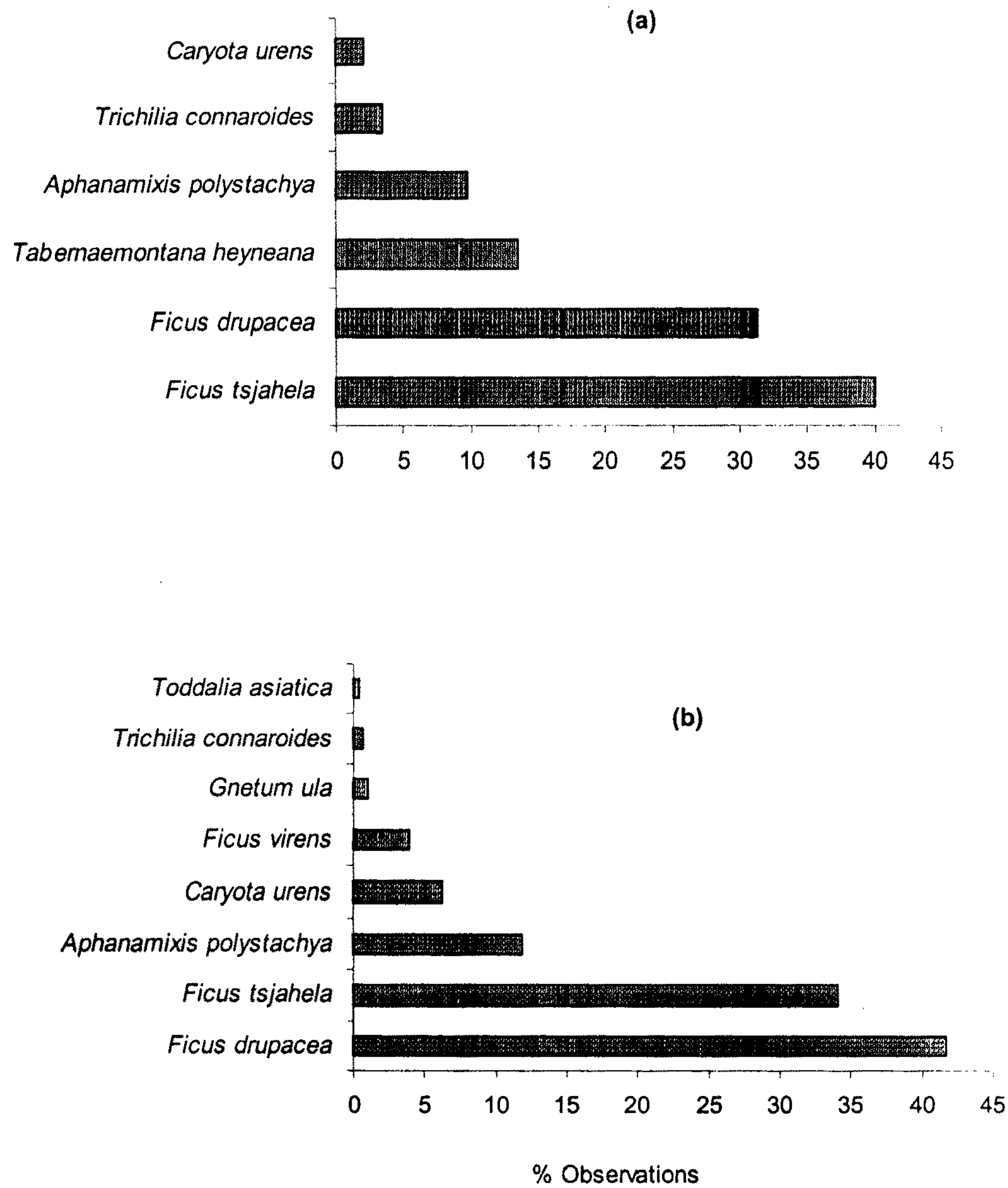
4.4. Keystone Resources and Conservation Implication

4.4.1. Plants of Keystone Importance for Malabar Grey Hornbill

There is a sharp decline in fruiting activity in the beginning of October and the dip in fruiting activity extends till January of the following year (Fig. 2). This period can be characterized as the period of scarcity in terms of fruit production at the study site. Although a peak in fruiting was recorded in October, the fruiting activity was dominated by a single species, *Viburnum punctatum* (Caprifoliaceae). Malabar Grey Hornbill throughout the study period did not consume the fleshy drupes of *Viburnum punctatum.* Thus, in the context of fruit utilization by the Malabar Grey Hornbill, it can be said that the lean season begins in October and extends upto January.

Figures 10a. & 11a. illustrate feeding observations during the lean seasons in the first year of the study. During the lean season (October-January), Malabar Grey Hornbill depended overwhelmingly on figs. Two species of figs: *Ficus tsjahela* (40.08%) and *Ficus drupacea* (31.22%) together accounted for 71.31% feeding by Malabar grey hornbills (Fig. 11a). The contribution of four non-fig species during the same time was only 28.69%. Of the four species, *Aphanamixis polystachya* and *Trichilia connarroides* belongs to the family Meliaceae, *Tabernaemontana heyneana* belongs to the family Apocynaceae while *Caryota urens* is a monocot of family Palmae.

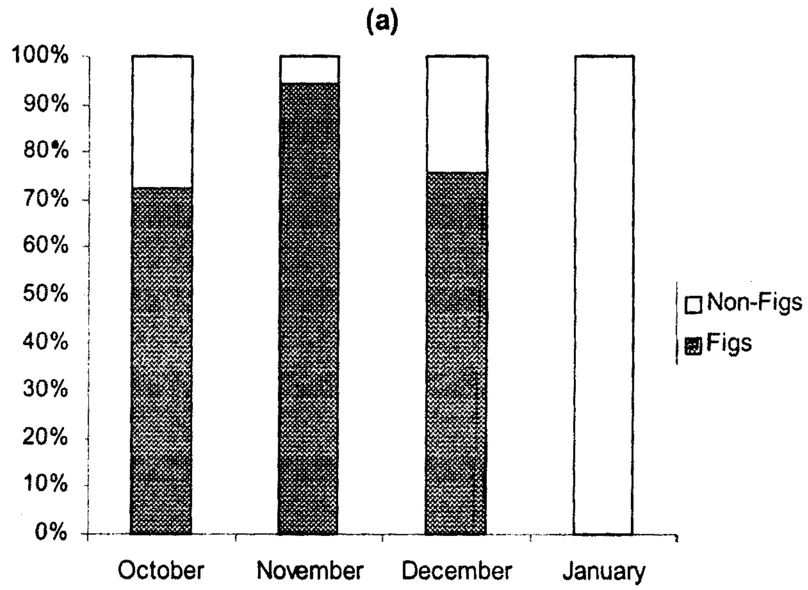
Fig. 10. Percentage feeding by Malabar Grey Hornbill on fruit species in the semi-evergreen forests a) October 2000 - January 2001 and b) October 2001 - January 2002

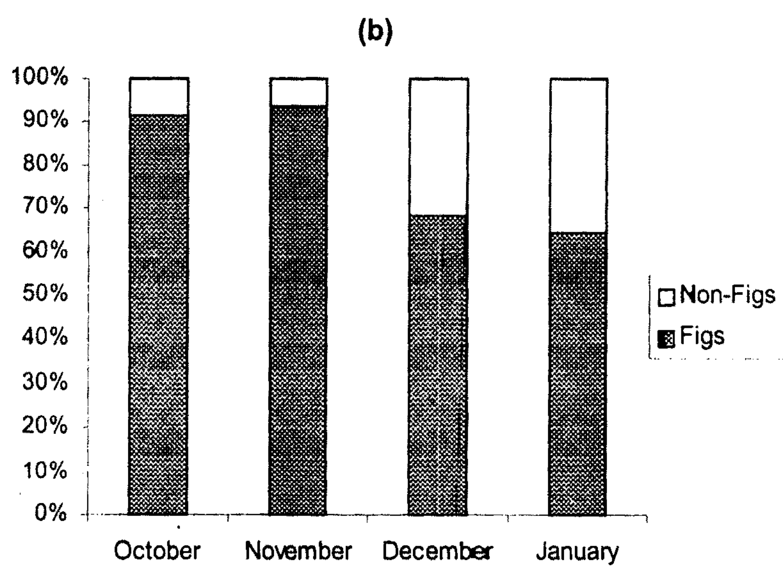


Peak feeding for *Ficus drupacea* was in October, while for *F. tsjahela* and *Aphanamixis polystachya* peak feeding was observed during November and December respectively. Percentage of feeding observations on figs was 72.98%, 94.34% and 75.68% for the months October, November and December respectively (Fig 11a.). Only in the last month of the lean season i.e., January 2001, do the Malabar Grey Hornbill shift to the crimson-coloured, arillate fruits of *Aphanamixis polystachya*, a member of the family Meliaceae. The shift was forced due to the absence of ripe figs during the period.

Figures 10b. & 11b. illustrate feeding during the lean months in the second year. Feeding observations in the lean season of the second year revealed that 75.79% of 285 observations were on two figs, *Ficus tsjahela* and *F. drupacea* (Fig 10b). Figs accounted for 91.66%, 93.81%, 68.42% and 64.10% for the months October, November, December and January respectively (Fig. 11b). The reduction in the dependence of figs in the last two months of the lean season indicates the supportive role played by the fruits of *Aphanamixis polystachya* in sustaining hornbill populations. The other species that accounted for 6.32% of feeding observations was *Caryota urens* (Family Palmae). Thus, in both the years, the lean seasons were predominantly sustained by two species of figs and sparsely supported by non-fig fruit species of the family Rhamnaceae, Palmae and Apocynaceae (Fig.10). This trend wherein, dependence of Malabar Grey Hornbill on figs as the primary source of food in the lean season both the years has confirmed the keystone role of figs in the semi-evergreen forests. In addition to figs, fruits of *Aphanamixis polystachya* supplements hornbill population during the lean season.

Fig. 11. Percent feeding by Malabar Grey Hornbill on fig and non-fig fruit species during the lean season a) October 2000 - January 2001 and b) October 2001 - January 2002





Ficus tsjahela and *Ficus drupacea* are distributed in low densities of 1.3 ha^{-1} and 0.67 ha^{-1} These two species sustain hornbill populations inspite of their low density. The fact that these species reached peak fruiting in the lean season makes them a reliable source of food for the frugivores. Thus, these three species based on their low densities, ability to produce fruits during the lean season form a better example of "keystone resources" in the study site.

Apart from the Malabar grey hornbills, numerous other birds and mammals were recorded consuming fig fruits. They included Malabar Giant Squirrel (*Ratufa indica*), Common Langur (*Presbytis entellus*), Bonnet Macaque (*Macaca radiata*) and Large Flying Squirrel (*Petaurista philippensis*) and several birds, Southern Maroonbacked Imperial Pigeon (*Ducula badia*), Small Green Barbet (*Megalaima viridis*), Large Green Barbet (*Megalaima zeylanica*), Jungle Myna (*Acridotheres fuscus*), Hill Myna (*Gracula religiosa*), Redvented Bulbul (*Pycnonotus cafer*) and Redwhiskered Bulbul (*Pycnonotus jocosus*). Thus, figs are indispensable for the sustenance of the entire frugivore community of the semi-evergreen forest and can be called as "keystone resource" in the semi-evergreen forest of Mudumalai Wildlife Sanctuary.

4.5. NEST TREE UTILIZATION

4.5.1. Tree Species Use

Eighty-one nest trees belonging to 19 species (14 families) were utilized for nesting by Malabar Grey Hornbill during the study period (Table 4). Of these 81 trees, while 79 were live, two were dead. The two dead trees were *Cedrella toona* and *Aphanamixis polystachya* (both of family Meliaceae). The number of species used for nesting was 14, 13 and 12 for 2000, 2001 and 2002 respectively. Three species, *Lagerstroemia microcarpa* (Family: Lythraceae), *Terminalia bellirica* and *T. crenulata* (Family: Combretaceae) together contributed for 69% of nest trees. Maximum number of nesting trees belonged to *Lagerstroemia microcarpa* (26 nest-trees; 32%) followed by *Terminalia bellirica* (21 nest trees; 26%), and *Terminalia crenulata* (9 nest trees; 11%). Sixteen other species together contributed for 31% of nest trees. The percent contribution of *Lagerstroemia microcarpa, Terminalia bellirica* and *T. crenulata* together in 2000, 2001 and 2002 were 71.1 %, 73% and 69.7% respectively. All the results summarized in the following sections are discussed in relation to *Lagerstroemia microcarpa*, *Terminalia bellirica*, *Terminalia crenulata* and others (16 species clumped together).

Table 4. Nest tree species utilized at Mudumalai Wildlife Sanctuary (2000-2002)

S. No.	Species	Family	No. Nest Trees	% Contribution	Preference Index (P.I.)
1	*Lagerstroemia microcarpa*	Lythraceae	26	32.10	0.92
2	*Terminalia bellirica*	Combretaceae	21	25.93	0.91
3	*Terminalia crenulata*	Combretaceae	9	11.11	0.76
4	*Grewia tiliifolia*	Tiliaceae	3	3.7	0.49
5	*Albizia lebbeck*	Mimosaceae	3	3.7	0.48
6	*Alstonia scholaris*	Apocynaceae	2	2.47	0.38
7	*Toona ciliata*	Meliaceae	2	2.47	0.38
8	*Elaeocarpus serratus*	Elaeocarpaceae	3	3.7	0.36
9	*Syzygium cumini*	Myrtaceae	2	2.47	0.36
10	*Pterocarpus marsupium*	Fabaceae	1	1.23	0.05
11	*Ficus tsjahela*	Moraceae	1	1.23	0.05
12	*Schleichera oleosa*	Sapindaceae	1	1.23	0.05
13	*Aphanamixis polystachya*	Meliaceae	1	1.23	-0.01
14	*Cinnamomum verum*	Lauraceae	1	1.23	-0.01
15	*Olea dioica*	Oleaceae	1	1.23	-0.25
16	*Kydia calycina*	Tiliaceae	1	1.23	-0.31
17	*Antiaris toxicaria*	Moraceae	1	1.23	Not determined
18	*Melia dubia*	Meliaceae	1	1.23	Not determined
19	*Mitragyna parvifolia*	Rubiaceae	1	1.23	Not determined
	Total		81		

4.5.2. Nest Tree Species Preference

Though 19 tree species were used for nesting, Malabar Grey Hornbill exhibited preference towards certain tree species. Ivlev's index of selectivity was used to estimate species preference for various nest trees. Preference index was calculated for 16 of the 19 species. Malabar Grey Hornbill preferred *Lagerstroemia microcarpa* (P.I = 0.92) most followed by *Terminalia bellirica* (P.I = 0.91) and *Terminalia crenulata* (P.I = 0.76). These three species were the most preferred in all three years. *Lagerstroemia microcarpa* was preferred most in years 2000 (P.I.: 0.93) and 2001 (P.I = 0.91). The details of preference indices for other nest tree species are summarized in Table 4.

In 2000 and 2001, the number of nest-holes occupied by Malabar Grey Hornbills was 52. In 2002, 33 nests were recorded to be active, a decline of 36.5 % compared to the active nest-holes of the previous year. Thirty-five (67.3 %) nest holes were re-used in 2001 while 21 (40.3 %) nest holes were re-used in 2002.

4.5.3. Nest Tree and Site Characteristics

Nest site and tree characteristics of 40 nest trees were studied. The mean height of the nest trees, mean girth at breast height and mean nest height were 35.9 m $\pm$ 6.2 m, 2.83 m $\pm$ 1.06 m and 17.2 m $\pm$ 5.9 m respectively. All the 40 nests were distributed between 890 and 1050 m above sea level. Twenty-two (55 %) nest trees belonged to the height class of 30 - 40 m while girth at breast heights of 23 nest trees (57.5 %) was distributed between girths 2.0 and 3.2 m. Twenty nests (50 %) were located at heights of 13 to 20 m from the ground level. Girth at nest height of twenty-one (52.5 %) nest trees falls in the class 151 -210 cm. Nest entrance length of 28 (70 %) cavities was between lengths 14 - 17 cm. Twenty-five nests (62.5 %) were oriented towards east. None of the nest cavities studied was typically round in shape. Summary of nest tree and site characteristics is given in Table 5.

Height of the nest trees positively correlated with girth at breast height ($r_s = 0.3190$, n=40, P = 0.045) and girth at nest height ($r_s = 0.4039$, n=40, p = 0.01) of nest trees. Heights at which nest cavities were located on the trees showed a positive correlation with girth at breast height ($r_s = 0.5462$, n=40, $p < 0.001$), tree heights ($r_s = 0.6245$, n=40, $P < 0.001$) and girth at nest height ($r_s = 0.4078$, n=40, p = 0.009).

Differences between nest trees and random trees were tested with Wilcoxon Signed Ranks Test. The statistical test revealed that nest tree characteristics such as GBH and tree height, hole characteristics such as nest height, girth at nest height, inner depth, length and breadth of the nest entrance significantly differed between nest trees and random trees. Among the site characteristics distance from hamlet and water sources for nest trees differed significantly with that of random trees (Table 6).

Table 5. Summary of nest tree, nest hole and nest site characteristics (n=40)

Variables	Mean	SD	Range
Nest Tree Characteristics			
Girth at Breast Height (cm)	283.13	101.06	160-727
Tree Height (m)	35.91	6.27	22-45
Nest Hole Characteristics			
Nest Height (m)	17.27	5.92	4.7-3.2
Girth at Nest Height (cm)	176.69	49.74	90-295
Inner Depth (cm)	33.85	8.12	15.5-56.5
Nest Entrance Length (cm)	15.11	1.30	12.6-18.3
Nest Entrance Width (cm)	13.6	2.15	16.5.
Nest Site Characteristics			
Altitude (msl)	931.38	40.11	890-1040
Distance from Hamlet (m)	985.75	1429.84	20-5000
Distance from Water (m)	90.875	76.509	5-300
Distance from Nearest Nest (m)	134.37	170.847	25-1000

Table 6. Comparison of parameters in nest tree, hole and site characteristics for nesting trees and random trees at Mudumalai Wildlife Sanctuary

Variables	N	Nesting Tree*	Random Tree*	Z	P
Nest Tree Characteristics					
Girth at breast height (cm)	21	278.71 (70.19)	150.18 (19.88)	-4.58	**0.000**
Tree height (m)	21	35.59 (6.51)	30.0 (2.73)	-3.28	**0.001**
Nest Hole Characteristics					
Nest height	21	15.99 (4.99)	13.93 (1.94)	-2.27	0.023
Girth at nest height	21	181.25 (97.59)	93.3 (26.1)	-3.91	**0.000**
Inner depth	21	32.35 (9.51)	21.85 (9.51)	-4.583	**0.000**
Nest entrance length	21	15.15 (1.29)	12.95 (1.51)	-4.491	**0.000**
Nest entrance breadth	21	14.16 (1.9)	11.86 (1.9)	-4.583	**0.000**
Orientation	21	139.28° (69.77°)	119.28° (69.77°)	-4.583	**0.000**
Nest site characteristics					
Altitude	21	928.80 (34.34)	923.8 (30.69)	-1.449	0.147
Aspect	21	6.80° (9.96°)	7.14° (6.03°)	-0.172	0.864
Distance from nearest hamlet	21	1083.5 (1427.87)	1244.04 (1629.45)	-1.224	0.221
Distance from nearest nest	21	182.14 (221.80)	165.47 (208.93)	-0.080	0.936
Distance from nearest water source	21	93.08 (83.64)	197.61 (80.58)	-3.189	**0.01**

Differences between nested tree and random tree were tested with Wilcoxon Signed 2-Sample Test for 2-tailed significance at $P<0.1$ (underlined and $P<0.01$ (bold and underlined)
*Mean (SE); N = Number of sample trees

4.5.4. Nest Fidelity

Fidelity for nesting trees was documented for each year from 2000 to 2002 (Table 7). A total of 12 nests belonging to six species were used in all the three years repeatedly. Of the 52 nests recorded during 2000, 35 (67.3 %) were re-used in 2001. It was observed that *Terminalia crenulata* had a 100% re-use record followed by *Terminalia bellirica* (72.7%) in 2001. Of the 52 nests used in 2001, twenty one (40.%) was re-used in 2002. *Terminalia crenulata* had maximum re-use (6 of 9 nest-trees; 66.6%) followed by *Lagerstroemia microcarpa* (7 of 17 nest-trees; 41%)

4.5.5. New Nest Occupancy

Seventeen (32.7%) nest-holes unoccupied in the previous year were used in 2001. Maximum number of new nest-trees in 2001 was recorded for *Lagerstroemia microcarpa* (6 of 17 nest-trees; 35.2%) followed by *Terminalia bellirica* (4 of 12 nest-trees; 33.3%). In 2002, 12 (36.3%) of 33 nest trees were new. *Terminalia bellirica* (6 of 9 nest-trees; 66.6%) was recorded to house maximum number of new nests in 2002. Details of new nest occupancy have been summarized in Table 8.

The observations on cavity use revealed that nest holes used by Malabar Grey Hornbill were also used by Large-brown Flying Squirrel (LFS) and Honeybee (HB) and *vice versa*. Flying squirrels and honeybees occupied seventeen nest holes in 2001 and 11 nest holes in 2002, which were used by hornbills during the previous years. In 2001, nine nest holes were occupied by flying squirrels and eight by honeybees. In 2002, while nine nest holes were occupied by flying squirrels, two were used by honeybees. In 2000 and 2001 number of nest-holes occupied by hornbills were 52. In 2002, 33 nests were recorded to be active, a decline of 36.5 % compared to the active nest-holes of the previous year.

Table 7. Nest re-use pattern at Mudumalai Wildlife Sanctuary from 2000 to 2002

Year	No. Nests Used	No. Nests Re-used	Percentage Re-used
2000	52	-	-
2001	52	35	67.3
2002	33	21	40.38

Table 8. New nest holes occupied at Mudumalai Wildlife Sanctuary in 2001 and 2002

Year	No. of Nests Used	No. of New Nests	Percentage New Nests
2000	52	-	-
2001	52	17	32.7
2002	33	12	36.6

4.5.6. Influence of Fire on Nesting Activity

Though fire was not encountered in the study site in the first two years of the study, vast stretches within the study site were gutted by summer fire in February 2002, the third year of the study. This seemed to influence nest cavity usage by Malabar Grey Hornbill. A total of 31 nest cavities were unoccupied during 2002 in the study site. Of these 31 nests, 23 (74.2%) were located in the fire affected region. This preliminary observation needs further research before arriving at some conclusions on the impact of fire on nesting activity.

4.6. PHYTOSOCIOLOGICAL FEATURES OF HORNBILL HABITAT

4.6.1. Species Diversity and Richness

Phytosociological studies were undertaken in three sites of semi-evergreen forests with differential human activity and were called as RD (the relatively undisturbed site), MD (the moderately disturbed site) and HD (the highly disturbed site located very near to human habitation). A sample plot of 1 ha. each was enumerated in the above mentioned sites. A total of 70 species belonging to 38 families were enumerated from three hectare of vegetation sample (Appendix 1). Greater number of species, 53 and 49 were recorded from the relatively undisturbed site RD and moderately disturbed site respectively (Table 10). The highly disturbed study site had a species richness of 37 only, an average reduction of 33%. The familial richness for site HD also showed an average reduction of 23.8%, compared to the mean of sites RD and MD. Shannon-Weiner richness, Simpson's index and Evenness index also were relatively lower for site HD compared to sites RD and MD (Table.9)

4.6.2. Tree Diversity and Basal Area

A total of 1430 tree stumps were enumerated from all the three sites together. Stand density showed a wide variation from 278 trees ha^{-1} in site MD to 620 trees ha^{-1} in site RD (Appendix 1). The mean stand density for three sites together was 466.66 trees ha^{-1}. and the mean basal area was 80.22 cm^2. Individual species that dominated in each 1 ha site was:

Elaeocarpus serratus of Elaeocarpaceae (936.89 cm^2, 3.39%) in RD; *Terminalia crenulata* of Combretaceae (651.72 cm^2, 9.71%) for MD and *Terminalia crenulata* (1575.45 cm^2, 13.91%) for HD.

Table 9. Consolidated details of Phytosociological analysis of trees in three 1 ha. study sites, Relatively Undisturbed (RD), Moderately Disturbed (MD) and Highly Disturbed (HD) in the tropical semi-evergreen forest of Mudumalai Wildlife Sanctuary

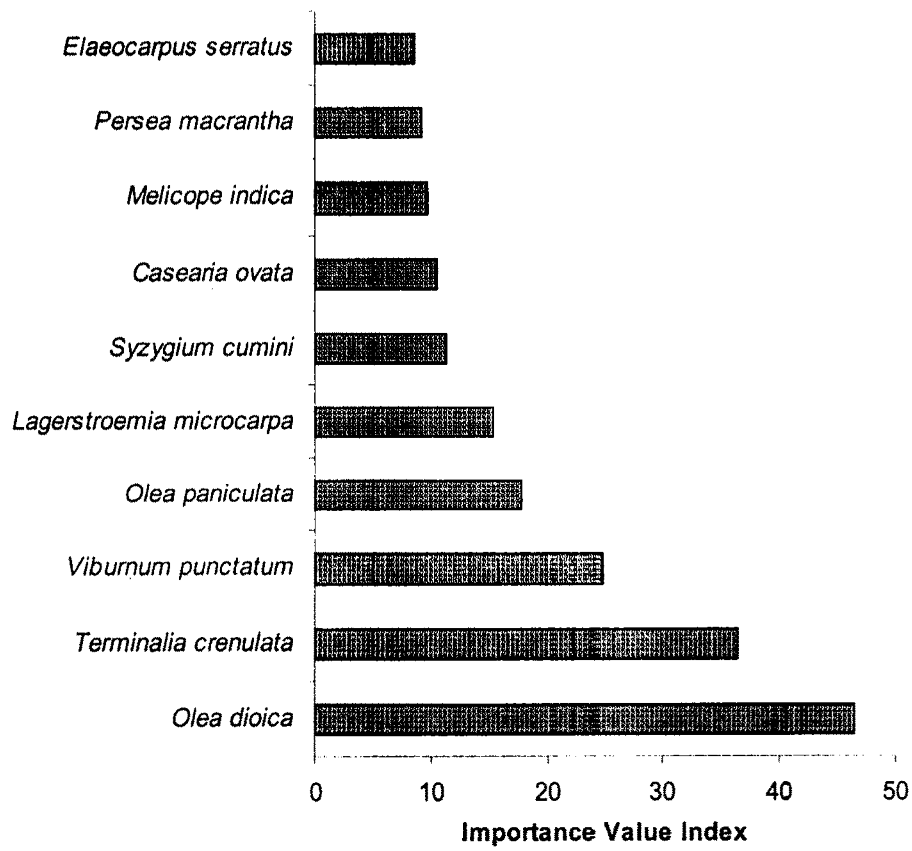
Variables	**SITES**			
	RD	**MD**	**HD**	**Total**
Species Richness	53	49	37	70
Family Richness	32	31	24	38
Diversity Indices				
Shannon (H')	3.14	3.19	2.33	3.17
Simpson's (D)	0.92	0.93	0.84	0.92
Evenness Index (E)	.79	.82	.65	.75
Tree Density	620	278	532	1430
Number of Trees with Cut Signs	0	0	68	68
Number of Trees Logged	0	0	11	11
Number of Trees Debarked	1	4	-	5

4.6.3. Dominance and Rarity

All three sites were dominated by a single species. In site RD, *Olea paniculata* formed 21.13% of the stand. There was an almost 11-13% difference from the nearest dense species namely *Olea dioica* (9.35%) and *Viburnum punctatum* (7.74%). In site MD *Olea dioica* formed 19.78% of the stand density followed by *Viburnum punctatum* (10.79% and *Terminalia crenulata* (9.71%). In site HD *Olea dioica* was domineering consisting of 31.39% of the stand density followed by *Viburnum punctatum* (15.98%) and *Terminalia crenulata* (13.91%). For all the three sites together, *Olea dioica* (19.58%) followed by *Viburnum punctatum* (11.40%) and *Olea paniculata* (10.07%) were three densest species. Family Oleaceae was densest in all the three sites contributing 30.49%, 23.02% and 32.14% in sites RD, MD and HD respectively.

The role of a species in its totality in the community is depicted by IVI. The top ten species in terms of IVI for the 3 ha. sample are illustrated in Fig. 12. For all the three sites together, *Olea dioica* showed maximum IVI (46.4) followed by *Terminalia crenulata* (36.3) and *Viburnum punctatum* (24.8). In site RD, *Olea paniculata* (IVI: 35.34) ranked highest while in sites MD and HD, *Olea dioica* ranked first with an IVI of 50.3 and 74.13 respectively.

Fig.12. Importance Value Index (IVI) of top ten species in three hectares



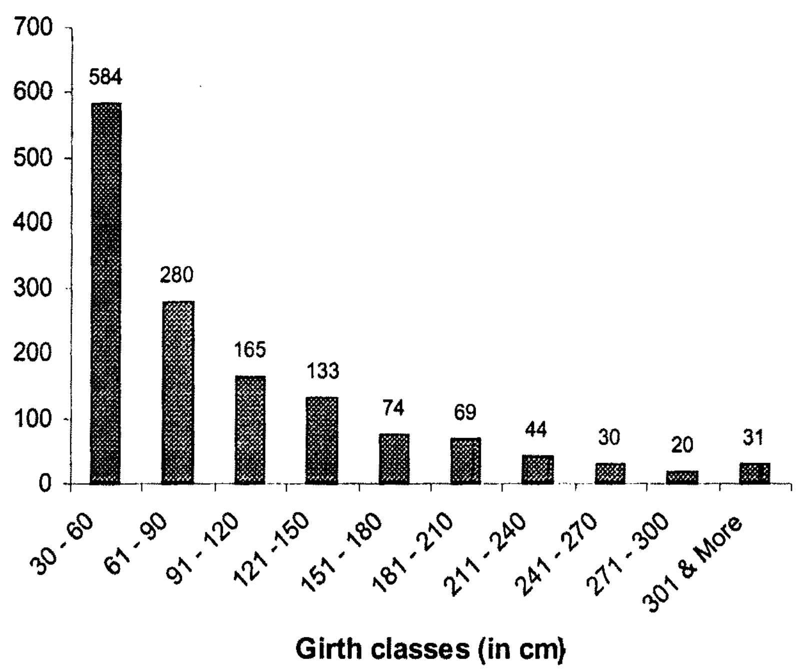
4.6.4. Familial diversity

Thirty-eight families were encountered in the 3 ha of vegetation sampled. Euphorbiaceae, Lauraceaee and Meliaceae were each represented with 4 species. Oleaceae was the densest family (29.65 %) followed by Caprifoliaceae (12.59%) and Combretaceae (9.79%). Oleaceae was the densest family in all the three sites with their contribution being 30.48%, 23.02% and 32.14% respectively for sites RD, MD and HD. The relatively undisturbed site and moderately disturbed site had a familial richness of 32 and 31 respectively. The highly undisturbed site had a familial diversity of 24 only, an average reduction of 23.8%.

4.6.5. Girth Class Distribution

Tree density decreased with increasing girth class, (Fig. 13). In all the three sites, the lower girth class (30-60 cm gbh) had maximum number of trees. The distribution of trees in lower size class (30-60 cm gbh) ranged from 29.5% in site MD to 48.06% in site RD. The stepwise decline in frequency of individuals with increasing girth classes is evident in all the three sites.

Fig 13. Girth class distribution of trees in the study site



4.6.6. Distribution of Hornbill Food and Nesting Plants

A total of 36 species belonging to 23 families were recorded to be used by MGH as food and nest trees. Of these 24 were food plants belonging to 15 families. A total of 991 individuals out of 1430 trees (69.3%) were were used for feeding and nesting. Family Laruaceae with four species contributed maximum to the food plants followed by Flacourtiaceae, Meliaceae and Moraceae, each of which constituted 3 species. The sum of IVI of food and nest plants was 215.58, which was 71.93% of IVI of all the trees in the study site.

Family Lauraceae, with 4 species, was one of the well-represented families in food plants, followed by Flacourtiaceae and Moraceae, which contributed to three species each. The sum of IVI of food plants was 136.53, which was 45.51% of the total IVI recorded for all plants in the 3 ha. Sixteen species belonging to 15 genera and 14 families were known nest tree species. A total of 599 individuals (41.89%) contributed to IVI of 141.81 (47.27%) of all the plants enumerated in the three plots. Combretaceae and Fabaceae, each with two species contributed maximum to nest tree species. .

4.6.7. Tree Species Used by Local People

A total of 68 individuals belonging to 17 species were affected by cutting. All the cut-signs were documented in site HD, which was located close to the forest settlements. In site HD, 45.95% of the 37 species and 12.78% of

532 individuals were affected by cutting. For the entire 3 ha sample, this would account to 24.29% species (17 of 70) species and 4.76% individuals (68 of 1430). Maximum number of individuals affected belonged to *Olea dioica*, (23; 33.82%), followed by *Viburnum punctatum* (16; 23.53%) and *Terminalia crenulata* (9; 13.24%).

Fourteen of the 17 species (82.35%) affected by cutting were utilized by Malabar grey hornbills either for food or nesting. Twelve species out of the 14 cut species (70.59%) in site HD were food species while 6 (35.29%) were nest tree species. *Ficus tsjahela*, *Olea dioica*, *Actinodaphne malabarica*, and *Persea macrantha* were preferred food species while *Terminalia crenulata and T. bellirica* are preferred nest tree species.

Six trees belonging to six species fell naturally during the torrential rains in 2001. These were *Albizia lebbeck*, *Grewia tiliifolia*, *Lagerstroemia* microcarpa, *Olea dioica*, *Terminalia bellirica* and *Cedrella toona* and happened to be the nest trees. *Olea dioica* and *Grewia tiliifolia* also formed food species. All signs of human centered disturbance were recorded only in the site located near human settlements. Though no trees were recorded with debarking signs in the sampling locations, outside the sites, 34 trees of *Cinnamomum verum* (Lauraceae) were debarked totally. As a consequence the trees are drying and are on the verge of dying. The dried bark of *Cinnamomum* is a most valued spice and is a popular ingredient in Indian cuisine.

CHAPTER V – Discussion

DISCUSSION

5.1. Fruits: Lifeline for Malabar Grey Hornbill

Malabar Grey Hornbill is a fruit specialist. The fact that during breeding season 22 species of fruits were utilized while during non-breeding season only 16 species were recorded indicates a higher diversity of diet species during breeding season. Ten species were exclusive to the breeding season, while 5 species were exclusive to the non-breeding season. Eleven species were found to be used both in breeding and non-breeding season.

The Breeding season at the Sanctuary coincided with peak fruiting in lipid-rich and non-fig sugar-rich fruit species. Lipid-rich fruits (47.16%) and non-fig sugar-rich fruits (47.59%) together account for 95% of fruits while the figs formed only 5.25% of fruits during the same period. The dependence of Malabar grey hornbills on fig fruits at the study site is very low compared to other hornbill species (Tsuji 1996, Kannan & James 1997). The low fig utilization during breeding season is a direct effect of relatively low fruiting abundance of *Ficus* species at the study site. On the other hand fruiting abundance of lipid-rich fruiting individuals and non-fig sugar-rich individuals was higher than fig producing individuals and this is reflected in the proportions of fruits fed to the nest inmates.

During the breeding season, the only overriding consideration of a breeding male is to satiate the dietary needs of the nest inmates as frequent as possible. The very high dietary requirements put enormous strain on the bird's ability to carry large load of fruits. Malabar grey hornbills seemed to use the immediate and surest fruit resources available in the vicinity discounting the criteria of preference. Size also influenced fruit delivery as 58% of fruits delivered were < 10 mm in length while 32% were in the range of 10 – 20 mm and only 2.5% were >20 mm.

5.2. Dependence on Lipid-rich Fruits

Fruiting activity of lipid-rich fruits is predominant during the dry season, January to May. This period incidentally is the breeding season for the Malabar grey hornbills, thus highlighting the significance of lipid-rich fruits for these birds.

Lipid-rich fruits are usually metabolized much slower than carbohydrate-based diet (Karasov & Hume 1997). As a result, birds predominantly dependent on lipid-based diet, have relatively long gut-retention times. The dependence on lipid-rich diet is also governed by the physiological ability of the bird to absorb and metabolize lipids. The opposite is true for birds dependent on carbohydrate-based diet, where metabolism is quick and gut retention time are comparatively lower (Bosque & de Parra 1992, Place & Stiles 1992, Zurovchak *et al.* 1999). This difference in processing and retention capability has resulted in specialization of dietary preferences among birds (McDiarmid *et al.* 1977, Stiles 1980, 1993, Herrera 1984, Loiselle & Blake 1990, Fuentes 1994). Experiments in captivity have shown that preference for fruits is directly correlated to the ability to process and defecate or regurgitate seeds rapidly (Levey & Grajal 1991, Murray *et al.* 1993). Short retention times on the other hand signify low assimilation efficiency (Karasov 1990, Martinez del Rio & Karasov 1991). Birds specializing on traditional diet resource will rarely switch over to another diet type unless forced. This transition usually is influenced either by scarcity or abundance of a particular resource type. The Malabar Grey Hornbill seems to have evolved an efficient mechanism to use available fruit resources, by processing lipid-rich fruit resources as well as non-fig sugar-rich fruits, simultaneously during the breeding season.

5.3. Colour as a Factor in Preference

It seems colour had no influence on fruit selection by hornbills. In the breeding season, 91% of the fruits consumed were purple, 8% yellow and 1% of fruits red. This shows a strong preference for purple fruits during the breeding season. In the non-breeding season 67% of the feeding observations were recorded on trees bearing yellow fruits. Fruit selection appears to depend on fruit availability.

The favoured fruits during non-breeding season, the figs, produced yellow fruits, and that is why major proportion of fruits eaten was yellow.

Malabar Grey Hornbill feed on figs, as other non-fig resources were scarce. Studies on fruit-fugivore interactions at Point Calimere, South India, have highlighted the importance of red and black coloured fruits (Balasubramanian 1996). This feature was also associated with small size of the fruits where 16 out of 17 black and 14 out of 25 red fruits measured < 10-mm in diameter. The conspicuous colour combined with their small sizes enabled frugivorous community to access the fruit resources easily (Balasubramanian 1996). This trend is consistent with findings from the neo-tropics (Janson 1983, Howe 1986) Africa (Knight & Siegfried 1983, Gautier-Hion *et al.* 1985), Australasia (Beehler 1983) and Indonesia (Suryadi *et al.* 1994). In conclusion, it can be said that the non-availability of non-fig fruiting resources has forced the Malabar Grey Hornbill to shift from a combination of high-energy lipid based and non-fig sugar-rich fruit resource to figs as the birds proceed from breeding to non-breeding season. This shift also coincided with a shift from preference for purple coloured fruits in breeding season to yellow coloured fruits in the non-breeding season.

5.4. Figs as Keystone Resources

This study brings to fore, the fact that *Ficus* spp. are keystone resources for hornbills. While overall density of figs in this site was 3.4 trees ha^{-1} densities of individual species varied from 0.6 trees/ ha. for *Ficus drupacea* to 1.6 trees/ ha^{-1} for *Ficus virens.* Though, fruiting of figs had been recorded for nine months in a year, their fruiting increased from October and reached a maximum in November extending up to December. The bird's non-breeding season, September to December, was the lean period in terms of number and diversity of fruiting. Observations during non-breeding season showed that 58.01% of feeding were on two species of figs, which indicates the prominence of figs in the diet during the non-breeding season. Figs are indispensable for the sustenance of the entire frugivore community of the semi-evergreen forest. Thus, figs can be called a "keystone resource" in the semi-evergreen forest of Mudumalai Wildlife Sanctuary.

In the present study site, the role of fig fruits in supplementing the diet during breeding season is low compared to other studies in India and other southeast Asian countries for different species of hornbills. Balasubramanian and Saravanan (2001) observed that *Ficus benghalensis* was the major food species for Malabar Pied Hornbill during both breeding and non-breeding seasons in a lowland forest of Western Ghats. Poonswad *et al.* (1987), while studying the breeding biology of four sympatric hornbills in Thailand observed that about 57% of food items delivered by the hornbills were figs. In a study made on the same species by Suryadi *et al.* (1994), 24 food species were recorded of which 20 species were figs. O' Brien (1997), who studied the Northern Sulawesi Tarictic Hornbill, observed that one third of all fruits delivered at the nests were figs. Kannan and James (1997), who studied the Great Pied Hornbill in south India, observed that 72.9% of the fruits delivered were figs. Anggrainy *et al.* (2000) while studying the Helmetted and Rhinoceros hornbills observed that, figs formed 90% and 70% of their feeding records respectively. In a study conducted by Mudappa (2000) on the breeding biology of Malabar grey hornbills in the Indira Gandhi National Park, South India, figs formed 30% of the fruits delivered to the nest inmates while lipid-rich and non-fig sugar- rich fruits formed 42.7% and 27.3% respectively. In most of the above-mentioned studies, figs are the sustaining resources for hornbills in breeding and non-breeding seasons.

This study is the first attempt to document the fruits utilized the Malabar grey hornbill during non-breeding season in India. The comparison of diet between breeding and non-breeding season clearly indicates a shift from lipid and non-fig sugar-rich fruits to figs. In the study site, figs form the keystone fruit resource for the Malabar Grey Hornbill during the non-breeding season. Their role in the non-breeding season is indisputable. But in the breeding season the lipid rich fruits and other non-fig sugar-rich fruits seem to sustain birds. *Ficus* species at the study site produce ripe fruits through out the year, irrespective of fluctuations in climatic parameters such as rainfall. This continuity in fruiting outside community fruiting peaks sustains the frugivores, especially the Malabar grey hornbills. Plant taxa of this kind which fruit outside community peaks are considered pivotal in maintaining populations of resident frugivores (Terborgh 1986, Lambert & Marshall 1991).

In the study site, figs were also utilized by a host of other frugivores such as the Common Langur, Bonnet Macaque, Malabar Giant Squirrel, barbets and Imperial Green pigeon during periods of scarcity. Studies on Sulawesi red-knobbed hornbills have established that hornbill densities fluctuated with the distribution and abundance of fruiting figs (Kinnaird *et al.* 1996). Other studies corroborating this trend have been reported from Asia (Fogden 1972, Leighton & Leighton 1983, Wong 1985, Leighton 1986, Anggrainy *et al.* 2000), and Neotropics (Medway 1972).

Documented evidence on keystone resources for vertebrates from paleotropics are very few. Only one site, namely Kutai Reserve of West Kalimantan, Indonesia, has been documented for keystone resources at the community level (Leighton & Leighton 1983). Fruiting was highly episodic and periods of super-abundance interspersed with intervals of relative scarcity. It was observed that, during the periods of scarcity, frugivores subsisted on a select sub-set of plant species, of which figs were most pivotal. The plants of the family Annonaceae, Myristicaceae and Meliaceae were the other fruit resources. These fruit resources were of critical importance to large avian frugivores especially hornbills. Numerous researchers have named figs as a major food source for a variety of vertebrates (Africa: Waser 1977, Strusaker 1978, Gautier-Hion 1980, Waser & Case 1981; Asia: McClure 1966, Terborgh & Diamond 1970, Fogden 1972, Raemaekers *et al.* 1980).

Neotropics has a fair history of research in documenting keystone plant resources for the frugivore community. It has been observed that fruit resources such as palm nuts, figs and nectar are reliable resources for diverse frugivores during scarcity in Cocha Cashu, Peru (Terborgh 1986). Other sites in Neotropics where palm nuts have been consistently regarded as keystone resources are Barro Colorado, particularly for rodents (Smythe 1970; Smythe *et al.* 1982) and squirrels (Glanz *et al.* 1982). Figs have been 'pivotal' in sustaining frugivorous communities in nearly every type of forest vegetation of Neotropics. Figs ensure a reliable source of ripe fruit resource throughout the year on account of the non-synchronous fruiting habit (Leck 1972, Croat 1978, Morrison 1978, Milton 1980, Foster 1982).

Regardless of the quality of nutrition provided by the keystone resources, they are critical, as they sustain frugivores during times of scarcity. They are thus of great ecological significance for the availability of resources in the period of scarcity, directly influences the carrying capacity of the ecosystem. Therefore, an understanding of keystone plant resources is an absolute necessity for they have direct implications for the forest management in the context of sustainable utilization of forest resources.

5.5. Role of Hornbills in Seed Dispersal and Regeneration

Hornbills are one of the dominant frugivores and seed dispersers of the paleo-tropical region. Hornbills in the Asian tropical forests have been well studied for frugivory, especially in the breeding season and are known to disperse the seeds undamaged (Leighton 1981). Hornbill for most part of the year are scatter dispersers, while during the nesting season large number of seeds are deposited under the nests creating conspicuous middens.

Effects of hornbills on seeds have been documented for 34 species in Dja Reserve, Cameroon (Whitney *et al.* 1998). They found that seeds of most species passed without much physical damage. Germination trials on 24 species showed that 23 species germinated after passage by two hornbills - *Ceratogymna atrata* and *C. cylindricus* and major proportion of these species did not exhibit any drop in the germination rate.

Frugivores affect germination success of seeds which they either defecate or regurgitate as the gastrointestinal enzymes and acids within the gut of the birds soften the hard seed coat thus breaking dormancy in seeds (Fleming and Heithaus 1981). Balasubramanian *et al.* (1998) have established clearly the role played by birds in enhancement of seed germination in dry mixed deciduous forests of Western Ghats. *Ficus benghalensis*, *F. racemosa*, *Celtis philippensis*, *Cassine glauca* and *Strychnos potatorum* showed significant enhancement in germination after passing through the gut of birds. Similar results have been reported for *Ficus benghalensis* (58% germination of bird dispersed seeds against 34% control) by Midya and Bhramachary (1991) and *Azadirachta indica*, (76% germination of bird-dispersed seeds against 42% for control seeds (Mishra *et al* 1987). In south Australia, Yan (1993) observed more than 90% germination of Misletoe (*Amyema preissii* and *Lysiama excocarpi*) seeds dispersed by birds.

5.6. Nesting Tree Abundance: Key to Hornbill Conservation

Three deciduous tree species *viz.*, *Lagerstroemia microcarpa*, *Terminalia bellirica* and *T. crenulata* were most preferred in the study site. In all the three years, about 70 - 75 % of nesting trees was contributed by these three species. A study on three sympatric hornbills at Pakhui Wildlife Sanctuary, Arunachal Pradesh in North-east India showed that *Tetrameles nudiflora* (Datiscaceae), a deciduous tree was the most favoured nesting trees, comprising of 83% of the nest trees (Datta 2001). Hornbills and parrots, in the Island of Sumba, Indonesia, preferred deciduous trees of the family Datiscaceae (Marsden & Jones 1997). Two species of the genus *Tetrameles* housed 55 % of nests belonging to parrots and hornbills, though *Tetrameles* accounted for only 8.4% of the total 920 trees sampled in the habitat. In Sulawesi, Red-knobbed hornbills preferred *Palaquium amboinense* which was common and prone to heart-rot enabling frequent nest hole formation. Ali & Ripley (1987) reported the use of *Calophyllum* and *Cullenia* by Great Indian Hornbill in the Western Ghats, while Baker (1927) reported the use of *Bombax*, *Lagerstroemia* and *Dipterocarpus* in Burma. *Dipterocarpus* and *Eugenia* sp. were most preferred in Khao Yai National Park, Thailand (Poonswad 1995). The endemic Narcondam Hornbill was known to predominantly use *Sideroxylon* and *Sterculia* (Hussain 1984). Malabar Grey Hornbill used *Alseodaphne semecarpifolia*, *Hopea parviflora* and *Aglaia roxburghiana* in another site at Western Ghats (Mudappa & Kannan 1997).

Malabar Grey Hornbill prefers live trees compared to dead stumps. In the study site, of the 81 nest holes, 79 were on live trees while only two were on dead stumps. This is similar to the observations at Khao Yai National Park, Thailand where hornbills used 80 cavities of live trees and only one cavity on a dead stump of *Dipterocarpus* (Poonswad *et al* 1987). Other studies that reinforce preference by hornbills for living trees are Madge 1969; Kemp 1976; and Hussain 1984. According to Mudappa & Kannan (1997) 26 of the 27 nest trees located in another habitat at Western Ghats were on live trees.

Malabar grey hornbills preferred tall trees with large girth. The mean height of nest trees, height at which nest cavities were located and the mean girth at breast height were 35.9 m, 17.2 m and 2.83 m respectively. In Sumba, most hornbill and parrot nests were located on large and aged trees (Marsden and Jones, 1997). Other studies that confirm this trend include Baker (1927), Johns (1982), Poonswad (1995) and Mudappa & Kannan (1997).

The mean nest entrance length and mean nest entrance width for Malabar Grey Hornbill were 15.11 cm $\pm$ 1.30 cm and 13.6 cm $\pm$ 1.59 cm respectively. In a study on nest site characteristics and nesting success of Malabar Grey Hornbill at Anamalais, southern Western Ghats, the mean diameter of nest entrance was determined as 8 cm (Mudappa & Kannan 1997). The cavity dimensions determined from the present study are small compared to similar studies on larger hornbill species in Thailand (Poonswad 1995). The smaller cavity dimension is in tune with the size of Malabar Grey Hornbill, which is a comparatively smaller hornbill species.

In most tropical forests where hole nesters are dependent on forest cover, there is enormous pressure on the habitats due to rapidly declining forest cover. Asian hornbills are forest specialists and their density and distribution are known to be influenced by forest area and habitat structure (Poonswad & Kemp 1993; Kinnaird *et al.* 1996). Island of Sumba, which is home for the endemic Sumba Hornbill, has undergone more than 60%

decline in forest cover since 1927. This accounts for 10% of the total land area of that island (Jones *et al.* 1994). Species nesting in cavities are sensitive to habitat degradation (Forshaw 1989, Poonswad 1995, Christian *et al.* 1996). Great Indian hornbill densities were significantly higher in unlogged forest than in logged forests, semi-disturbed forest and old logged forests (Datta 1998). Studies on Sulawesi Red-knobbed Hornbill show that they prefer primary habitat over secondary habitat, burned forests, or regenerating agricultural lands irrespective of habitat type (Kinnaird *et al.* 1996). Black-and-white casqued hornbills were recorded in significantly higher densities in the primary forests than selectively logged areas in east Africa (Kalina 1988). This kind of a decrease in hornbill numbers on selectively logged areas and secondary forests have also been reported from other south-east Asian islands (Wilson & Johns 1982, Johns 1987). Breeding densities of Red-knobbed hornbills are high in Sulawesi, due to fruiting activity of figs in the breeding season and the availability of numerous tree cavities (Suryadi *et al.* 1994).

Species of *Lagerstroemia microcarpa*, *Terminalia bellirica*, *T. crenulata* are hard wooded trees susceptible to heart rot disease caused by fungi. Also these three species are also tall and vulnerable to breaking of branches during stormy and windy conditions. These two factors increase frequency of occurrence of nest cavities in the study site. Chalermponse (1987), reported that *Dipterocarpus* was susceptible to *Ganoderma* sp. and *Cryptoderma* sp. which cause heart and butt rot.

No nest predation was observed during the study period. This could be a direct reflection of the protection provided by nest sealing process as well as the height at which nest cavities were located. It has been reported that nests at higher positions of trees suffer lower amounts of predation in both primary and secondary cavity nesters (Li & Martin 1991). Mudappa & Kannan (1997) observed that only one of the 27 nests was abandoned during the breeding season.

5.7. Impact of Fire on Nesting

Summer fires are major cause of disturbance in the dry forests of the Sanctuary. Extensive patches of forests were burnt during the summer fires of 2002, which affected the forests in the moist zone also. The time of advent of fire coincided with the early breeding period of the Malabar Grey Hornbill

i.e., February 2002. During this period, hornbills are usually busy selecting and sealing the nest hole. Abnormally fiery fires in the moist forest might have disrupted the nest selection and sealing activity of the hornbills in the study site. This is revealed by the fact that, of the 52 nest holes used in the previous year, thirty-one were unoccupied during 2002. Percentage of nests unoccupied in 2001 was 34.6% while in 2002 it was much higher (59.6%). Also the fact that 74% of the 31 nests unoccupied were located in the fire-affected area might have influenced the hornbills to abandon the fire-affected area temporarily.

There are only a few published information specifically on the role of fire on nesting frequency and success in hornbills (Leighton & Wirawan 1986, Anggrainy *et al.* 2000, Cahill & Walker 2000). Leighton & Wirawan (1986) observed that hornbill numbers declined drastically after fire. In a study on an assemblage of Sumatran hornbills, it was observed that all species deserted burnt areas during and after fire, and densities of at least three species declined throughout the study area (Anggraini *et al.* 2000). Cahill & Walker (2000) reported a significant decline in nesting success of the Sulawesi Red-knobbed Hornbill after forest fires.

5.8. Species Richness and Density - Indicator for Habitat Health

Quantitative inventorying of the three sites (3 ha) in the present study, together yielded a total of 70 species belonging to 38 families, while species richness for individual sites ranged from 37 per hectare in the highly disturbed site (HD) to 53 species per hectare in the relatively undisturbed site (RD). The reduced tree diversity in site HD and low density in site MD are indicators of deleterious effect of human disturbances such as exploitation of minor forest products and selective logging. In Uppangala, Kodagu District, Western Ghats, It was observed that the part of the compartment which experienced fire after felling is still far from having recovered from the combined effect of exploitation and fire; the canopy cover is open and dominated by few remaining large trees and the stand was colonized by *Macaranga peltata*. In the part of the compartment, the selective exploitation did deeply alter the forest structure and diversity (Elouard *et al.* 1997).

The mean density of trees was 476.66 ha^{-1} for all the three sites together while within sites density ranged from a minimum of 278 for the moderately disturbed site to a maximum of 620 for the undisturbed site. The moderately disturbed site has a long history of logging, practiced here as recent as twelve years ago, which resulted in huge openings in the canopy. The opened areas have been subsequently colonized by the pervasive weed species *Lantana camara*. The tree stand structure is sparse and have not completely recovered from the practice of selective logging.

5.9. Plantations as Supplementary Habitat for Hornbills

Habitat fragmentation and transformation of pristine tropical forest ecosystems have resulted in a mosaic of agricultural ecosystem, human settlements and forest ecosystems. Though this kind of transformations mean local disappearances of species and isolation of natural habitats, certain plantation ecosystems, especially the coffee plantations are known to play important role for biodiversity conservation (Tejeda-Cruz and

Sutherland 2002). This has resulted in the promotion of "biodiversity friendly" coffee in the Neo-tropics. In a study conducted across five habitats including cloud forests and coffee plantations, the shaded coffee plantations showed high richness and abundance of migratory bird species. Thus, shaded coffee systems were found to be important for migratory species. The authors also inferred that these systems may play important role in maintaining local biodiversity but may be detrimental for forest specialist.

Plantations are the last refuge for forest-adapted organisms in many countries. In the regions most heavily used by migratory birds - the Caribbean islands, and Colombia--coffee plantation "forests" cover 2.7 million hectares, or almost half of the permanent cropland. In southern Mexico, coffee plantations cover an area over half the size of all of the major moist tropical forest reserves, providing critical woodland habitat in mid-elevation areas where virtually no large reserves are found.

Birds are only one indicator of the role that plantations play in protecting biological diversity. Ongoing studies of insects, canopy trees, orchids, and amphibians show that coffee plantations are often critical refuges protecting forest species where there is no longer any forest. Plantations in the present context have to be visualized as modified forest habitats. Even where a single species of tree is planted as cover, the trees often produce flower and fruit crops used by variety of birds. Apart from the Malabar grey hornbills, the Great pied Hornbill was also recorded on a few occasions. Other birds using this habitat include barbets, mynas and bulbuls. Thus, plantations could be a significant part of future biodiversity conservation initiatives in Western Ghats.

5.10. Implications for the Management

An uphill task for conservationist and forest planners will be restraining human incursions in the vicinity of protected areas. All signs of human centered disturbance were recorded only in the site located near human settlements. Though selective logging was abolished 15 years ago, illegal logging is still persistent in the study site. This sanctuary is located in a trijunction embracing two sanctuaries of neighboring states of Kerala and Karnataka in South India, and hence easily accessible to poachers. During the study period some large trees of *Lagerstroemia microcarpa*, *Terminalia bellirica* and *T. crenulata* were felled by wood cutters. These three species are the most preferred of 19 species used by hornbills for nesting. The loss of nesting tree may lead to the emigration of hornbills to other localities. The reduced tree diversity in disturbed sites are indicators of deleterious effect of human disturbances such as exploitation of minor forest products and selective logging. Those negative experiences should be borne in mind while implementing conservation measures.

Conservation needs for every habitat must be addressed in the local perspective. Species such as *Lagerstroemia microcarpa*, *T. bellirica* and *T. crenulata* are key to hole nester abundance. Apart from hole nesters, a host of other arboreal mammals such as Malabar Giant Squirrel, Bonnet Macaque, Common Langur, Nilgiri Langur also use these tree species for breeding and resting purposes. Though this study was directed exclusively on Malabar grey hornbills, cavity use pattern by other hole nesters such as flying squirrels and honeybees were also observed. A host of cavity nesters are resident to this sanctuary. Six different species of barbets, five species of parakeets, lorikeet, nine species of owls and at least five different species of wood peckers are resident to this region (Gokula & Vijayan 1996). Such a diversity of hole nesters implies competition for suitable nest cavities and tree species. It is only logical that conservation efforts may be directed towards identification and preservation of such species. In an earlier study on nesting cavity success and nest site requirements of Malabar Grey Hornbill in the Anamalai hills (about 235 km from MWLS) *Alseodaphne semecarpifolia*, *Hopea parviflora* and *Aglaia roxburghiana* three most frequently used species. This clearly illustrates the variability in species preference and utilization with changing localities and thus the need to devise management plan in tune with the local needs.

The tropical forests of Mudumalai Wildlife Sanctuary, in spite of being disturbed constantly, has been able to maintain its integrity. A strategic advantage for this site is that it is part of a large protected network of sanctuaries embracing the Bandipur National Park on one side and Wyanad Wildlife Sanctuary on the other side. This area is also unique due to the fact that it is located in an transition zone where temperature, rainfall and related climatological factors show characteristic gradient. These factors has lead to the evolution of a variety of habitats within the sanctuary. Also the numerous tribal communities dwelling in the sanctuary allow us to understand better, the utilization pattern of biological resources by them. This will enable us to understand and accordingly respond to the conservation needs of the region.

CONCLUSIONS

A brief highlight of the important findings and conclusions regarding habitat utilization by Malabar Grey Hornbill in the semi-evergreen forest at Mudumalai Wildlife Sanctuary are summarized below.

1. Phenology of fleshy fruited species consumed by Malabar Grey Hornbill was determined. Twenty-six plant species belonging to 12 families produced fruits. Major fruiting peak occurred during April in both the years for non-fig species while peak fig fruiting occurred in December. April and May, the peak fruiting activity coincided with the breeding season for Malabar Grey Hornbill.
2. Fruit utilization and preference by Malabar Grey Hornbill differed distinctly between breeding and non-breeding seasons. While non-fig fruit species were the preferred diet during breeding season, figs were the most preferred food during non-breeding season.
3. Malabar Grey Hornbill enhanced the regeneration of fleshy-fruited species. Regeneration study culminated in the enumeration of seedlings of nineteen species belonging to 13 families, at the midden sites.
4. The role of coffee and tea plantations as a supplementary habitat for Malabar Grey Hornbill were realized through the present study. Nine species of fleshy-fruited species were utilized by Malabar Grey Hornbill from the plantations. Members of the families Moraceae and

Rhamnaceae together accounted for majority of the feeding observations in the plantations.

5. Nest tree utilization, preference, nest fidelity and nest tree characteristics were assessed. A total of 81 nest trees belonging to 19 species of 14 families were used for nesting by Malabar Grey Hornbill. Trees of two families, Lythraceae and Combretaceae, together accounted for 80% of the nest trees at the study site.
6. Study on nest fidelity by Malabar Grey Hornbill also revealed that Large brown flying squirrels and honeybees competed for tree cavities thus affecting fidelity.
7. Nest site and tree characteristics of 40 nest trees were studied. The mean girth at breast height and tree height were 283.13 cm $\pm$ 106.06 cm and 35.9 m $\pm$ 6.2 m respectively.
8. Vegetation structure of three 1-hectare plots in semi-evergreen forest with varying degrees of human disturbance was studied to document the human impacts on the hornbill habitat. A total of 1430 trees belonging to 70 species from 38 families were enumerated from three hectares of vegetation sample. Shannon-Weiner, Simpson and Evenness index showed a decrease in diversity with increase in disturbance.
9. Malabar Grey Hornbill used a variety of tree species (36 species belonging to 23 families) for food and nesting. While 24 were used for food, 16 were used for nesting.

10. 'Keystone resources' for Malabar Grey Hornbill was determined. During the lean season of October-January, Malabar Grey Hornbill depends overwhelmingly on figs. The fact that the peak fruiting of figs during the lean season makes them a reliable source of food for this frugivorous bird.

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Appendix 1. Population density of tree species enumerated in 1 ha plot of sites RD, MD, HD and in total 3 ha of tropical semi-evergreen forest in the Mudumalai Wildlife Sanctuary, Western Ghats, South India

		Density			
Species	**Family**	**RD**	**MD**	**HD**	**Total**
Actinodaphne malabarica	Lauraceae	2	2	8	12
Aglaia elaegnoidea	Meliaceae	7	8	1	16
Albizia lebbeck	Mimosaceae	1	5	-	6
Alstonia scholaris	Apocynaceae	-	1	-	1
Aphanamixis polystachya	Meliaceae	2	1	5	8
Aporusa lindleyana	Euphorbiaceae	-	-	3	3
Bischofia javanica	Bischofiaceae	17	-	-	17
Bombax malabaricum	Bombacaceae	1	-	-	1
Bridelia retusa	Euphorbiaceae	1	2	-	3
Careya arboreya	Lecythidaceae	-	2	1	3
Casearia ovata	Flacourtiaceae	37	10	16	63
Cassia fistula	Caesalpiniaceae	-	6	-	6
Cinnamomum verum	Lauraceae	4	4	7	15
Cordia obliqua	Boraginaceae	2	2	-	4
Dalbergia latifolia	Fabaceae	3	3	5	11
Diospyros sp 1	Ebenaceae	4	1	-	5
Diospyros sp 2	Ebenaceae	-	1	-	1
Elaeocarpus serratus	Elaeocarpaceae	21	1	-	22
Entada pursathea	Mimosaceae	6	-	-	6
Erythrina indica	Fabaceae	2	-	-	2
Ficus drupacea	Moraceae	-	1	1	2
Ficus tsjahela	Moraceae	-	-	4	4
Ficus virens	Moraceae	1	-	3	4
Flacourtia montana	Flacourtiaceae	5	1	-	6

Appendix 1 Contd.....

Species	Family	Density			
		RD	MD	HD	Total
Gardenia sp.	Rubiaceae	2	-	-	2
Garuga pinnata	Bursearaceae	-	6	1	7
Glochidion velutinum	Euphorbiaceae	12	1	-	13
Gmelina arborea	Verbenaceae	1	1	2	4
Gnetum ula	Gnetaceae	-	3	-	3
Grewia tiliifolia	Tiliaceae	9	5	2	16
Hibiscus tiliaceus	Malvaceae	3	-	-	3
Hydnocarpus sp.	Bixaceae	14	1	-	15
Kydia calycina	Malvaceae	17	-	-	17
Lagerstroemia microcarpa	Lythraceae	34	14	7	55
Litsea stocksii	Lauraceae	-	1	2	3
Mangifera indica	Anacardiaceae	-	1	1	2
Melicope indica	Rutaceae	-	-	69	69
Meliosma simplicifolia	Sabiaceae	30	1	1	32
Naringi crenulata	Rutaceae	2	-	-	2
Olea dioica	Oleaceae	58	55	167	280
Olea paniculata	Oleaceae	131	9	4	144
Orophaea indica	Annonaceae	2	1	-	3
Persea macrantha	Lauraceae	15	6	11	32
Phyllanthus emblica	Euphorbiaceae	5	4	-	9
Unidentified 3	Unidentified 3	-	-	1	1
Pterocarpus marsupium	Fabaceae	-	3	-	3
Pterospermum sp.	Sterculiaceae	1	1	-	2
Radermachera indica	Bignoniaceae	4	5	1	10
Randia dumetorum	Rubiaceae	17	5	6	28
Salix tetrasperma	Salicaceae	3	-	-	3
Schleichera oleosa	Sapindaceae	7	4	-	11

Appendix 1 Contd.....

Species	Family	Density			
		RD	MD	HD	Total
Semecarpus anacardium	Anacardiaceae	3	-	-	3
Sterculia urens	Sterculiaceae	1	-	-	1
Stereospermum personatum	Bignoniaceae	7	5	1	13
Syzygium cumini	Myrtaceae	17	7	11	35
Tabernaemontana heyneana	Apocynaceae	1	9	20	30
Tamilnadia ulginosa	Rubiaceae	2	-	-	2
Tectona grandis	Verbenaceae	-	7	-	7
Terminalia bellirica	Combretaceae	5	6	4	15
Terminalia crenulata	Combretaceae	24	27	74	125
Toddalia asiatica	Rutaceae	5	1	2	8
Toona ciliata	Meliaceae	2	1	1	4
Trichilia connaroides	Meliaceae	2	-	-	2
Acacia sp.	Mimosaceae	-	-	2	2
Unidentified 1	Unidentified 1	-	-	1	1
Unidentified 2	Unidentified 2	2	-	-	2
Viburnum punctatum	Caprifoliaceae	48	30	85	163
Viburnum sp.	Caprifoliaceae	13	4	-	17
Vitex altissima	Verbenaceae	3	2	1	6
Xylosma latifolium	Flacourtiaceae	2	1	1	4
Total		**620**	**278**	**532**	**1430**