Study on Avian frugivory in Tropical Mixed Dry Deciduous and Scrub Forest in Southern India

Thesis submitted to the

Bharathiar University, Coimbatore

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Doctor of Philosophy

in

BOTANY

By

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JUNE 2012

CERTIFICATE

This is to certify that the thesis entitled, **"Study on Avian frugivory in Tropical Mixed Dry Deciduous and Scrub Forest in Southern India"** 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 research work done by **Ms. R. Aruna** during the period from 2007 to 2012 of her research in the Division of Landscape Ecology at Sálim 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 of any candidate of any university.

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DECLARATION

I, **R. Aruna** hereby declare that the thesis, entitled, **"Study on Avian frugivory in Tropical Mixed Dry Deciduous and Scrub Forest in Southern India"** 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 research work done by me during the period 2007 to 2012 under the supervision and guidance of Dr.P.Balasubramanian, Division of Landscape Ecology, Sálim Ali Centre for Ornithology and Natural History, Coimbatore and the thesis has not formed the basis for the award of any Degree/diploma/Associateship/Fellowship or other similar title of any candidate of any university.

Aruna.R

Signature of the Candidate

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R.Aruna

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INTRODUCTION

Biodiversity

Biodiversity or its physical manifestation- the biological resources are the basis of life on earth. It is an ecological imperative that we depend on them for our basic existence. The floral diversity of the world supports human life in many practical ways such as for food, clothing and shelter. One of the most fundamental contributions of the plant diversity for human survival is in the supply of food.

Deforestation is a global threat to biodiversity and ecosystem services (Mooney *et al.* 2005). While considerable areas of cleared land have reverted to secondary forest, and there have been increasing efforts to reforest degraded land, the rate of deforestation still greatly exceeds the rate of reforestation (Young, 2000). Large-scale reforestation is considered necessary to offset ecological degradation in extensively-cleared tropical and subtropical landscapes (Chazdon, 2003) The barriers to regeneration are seed and seedling predation, changes to the physical, chemical and biological properties of soils, and ongoing disturbances, particularly fire (Duncan and Chapman, 2002). Consequently, much abandoned land in former tropical forest landscapes is covered by grassland or scrub (Ashton *et al.* 2001). Furthermore, many of the regrowth (secondary) forests that do occur in these landscapes are dominated by invasive exotic plants, since these are often the earliest colonizers of highly disturbed areas in the tropics (Lugo, 2004). The conservation of existing biodiversity will not only improve the productivity and tree cover of the study area, but also the overall species composition of the region. Birds form an important component of the diverse fauna of any region and are considered as the best indicators of the environment (Cody, 1985) and hence, widely used for ecological studies and in conservation planning.

Plant-bird interactions

The study of interactions between avian frugivores and plant species is important for identifying the roles that individual disperser species play in plant recruitment dynamics, thus having implications for both theoretical understanding of mutualisms, species

interactions, and modeling vegetation change, and for applied work, including conservation and restoration (Loiselle and Blake 1999). The interactions between frugivores and plant species within communities have been represented as networks, where each species (of plant or frugivore) can interact with one or more other species, the analysis of network structure can advance our understanding of complex ecosystems and allow predictions of the consequences of avian species extinctions for the process of seed dispersal, and hence the plant community.

Avian frugivores are considered the most important seed dispersers in most ecosystems, as assessed by the numbers of successful propagules disseminated (Herrera 1995; Stiles 2000). Fruit-eating birds play a critical role in the functioning of tropical ecosystems and may assist in the natural regeneration of rain forests by dispersing seeds into cleared areas (Da Silva *et al.* 1996, Nepstad *et al.* 1996, Holl *et al.* 2000).

Biotic seed dispersal is frequent among woody species from rainforests in the South American tropics (70-94%), Australia (82-88%), Africa (80%) and temperate Chile (70%) (Howe & Smallwood 1982; Armesto & Rozzi 1989; Willson *et al.* 1989; Jordano 2000). In Mediterranean-type shrublands, the frequency is lower but varies between 22 and 56%; with means of 56.1% of fleshy-fruited species in Spain; 41.9% in Chile; 34.4% in California, and 22.5% in Australia (Milewski 1982; Herrera 1984; Jordano 1984; Hoffmann & Armesto 1995; Jordano 2000).

Frugivory is the last step of the predispersal reproductive phase and because these species interactions determine the location and environmental conditions in which seeds are deposited, they can also influence plant germination, survival, and forest regeneration (Jordano 2000, Chazdon 2003). Increasing research efforts (Levey *et al.* 2002, Wang and Smith 2002) are aimed at understanding how plant-frugivore dynamics influence the maintenance of forest biodiversity. Seed dispersal is characterized by diffuse mutualisms between suites of disperser and plant species, in contrast to the more specific coevolutionary relationships seen in some pollination systems (Wheelwright and Orians 1982).

Mutualistic plant-animal interactions exist in a wide variety with one of the most important being seed dispersal or the transport of seeds away from a parent plant by animals (Howe & Westley 1988). Not only plants depend on animals for the dispersal of their seeds, animals, too, rely on plants for fruit as a food resource. Seed dispersal by animals and frugivory have reached their pinnacle in tropical forests, where a percentage of up to 90% of tree and shrub species produce fleshy fruits adapted to animal dispersal and eaten by a large number of vertebrates (Frankie *et al.* 1974, Howe 1986). Complementing the diversity of fruits suitable for consumption by animals is an equivalent diversity of frugivores, i.e. fruit-eating birds and mammals that depend mainly on fleshy fruit.

Frugivores can shape plant populations in varied ways that involve interactions between foraging decisions and the spatial configuration of fruiting plants – decisions that could ultimately affect plant spatial configuration itself (Hampe *et al.* 2008). For example, frugivores can direct seeds towards other fruiting plants and habitats (Russo *et al.* 2006). Frugivores also behave predictably with respect to fruit crop sizes (Saracco *et al.* 2005), fruiting neighbourhoods (Von Zeipel & Eriksson 2007), and the location of fruit resources in space and time (Saracco *et al.* 2004)

In tropical forests, frugivorous animals are the dominant group of vertebrates. The challenge of frugivores is to find, eat and subsist partly or entirely on fruits that are mostly deficient in protein, but rich in carbohydrates or lipids (Howe & Westley 1988). Fruit availability is one crucial factor influencing the frugivore community (Howe & Estabrook 1977). It appears to be highly variable also in the tropics and marked by periods of scarcity and abundance (Terborgh 1986a). Most phenological studies report seasonality with fruit being more limiting in some seasons than in others for most tropical ecosystems (Frankie *et al.* 1974, Foster 1982). Consequently, frugivorous animals are facing seasonal irregularities in their food resources. The percentage of animal-dispersed tree species can be as high as 90% in the tropics (Howe & Smallwood 1982). In spite of the widespread occurrence of animal-dispersed plants, it is not known, whether plants depend on particular animal species for the dispersal of their seeds. At one end of the interaction continuum, plant species can be dispersed by a multitude of fruit eating

animal species (Pizo 1997). Thus, the extirpation of one or a small number of animal species might not have consequences for seed dispersal because animal species are redundant and other species would fill the gap (Herrera 1985).

Declines in frugivore diversity due to habitat fragmentation have been reported by Pizo (1997) and Santos & Telleria (1997). Disrupted seed dispersal might reduce seedling establishment as it is reported to be lower under the parent tree as compared to greater distances from the tree (Schupp 1988). Consequently, frugivore reduction could affect the abundance and extinction probability of trees (Bond 1995). Furthermore, changes in the spatial pattern of seedling establishment might have consequences for the spatial distribution of trees (Hubbell 1979). Thus, frugivore diversity might have severe consequences for the regeneration potential, the dynamics and the floristic composition of forests. It is therefore important for the conservation of forest ecosystems to investigate whether frugivore diversity indeed has an influence on plant populations. As deforestation and fragmentation increase and as global warming alters regional weather patterns, many species will have to migrate to survive. In these circumstances, dispersal limitation of plant distributions will become an increasingly serious problem (Primack & Miao, 1992).

These "keystone resources" have been identified for several forests with figs being of importance (Leighton & Leighton 1983, Terborgh 1986a) as well as a variety of lipid-rich arillate species (Gautier-Hion & Michaloud 1989). Increasing fragmentation and destruction of tropical ecosystems is known to not only affect biodiversity but also are crucial for the maintenance of these ecosystem processes such as seed dispersal and frugivory. Loss of dispersal agents might lead to a break-down in seed dispersal (Pizo 1997) and reduce seedling establishment and recruitment of fruiting trees. Consequently, disrupted seed dispersal has consequences for the regenerative potential of ecosystems and probably leads to changes in the abundance and spatial distribution of trees (Hubbell 1979).

Seed dispersal

Biotic seed dispersal consists of the removal of plant propagules by animal frugivores and the deposition of germinable seeds away from the source plant. Seed deposition

patterns may range from seed fall in the vicinity of the mother plant to very long distances from the source (Willson & Traveset 2000). Avian frugivore-plant interactions, as opposed to herbivore-plant interactions, can have positive, negative or neutral effects on the reproductive potential of a plant, depending on the survival of seeds and seedlings during and after fruit consumption (Cipollini 2000).

Seed dispersal research that considers different aspects of avian activity (e.g. fruit removal, seed ingestion and post-feeding microhabitat use), together with seed deposition and germination, from the perspective of the disperser effectiveness is a powerful tool for understanding the ecological consequences of bird-plant interactions for the regeneration patterns of plant species (Jordano & Schupp 2000) The effectiveness of frugivores as seed dispersers is the contribution a frugivore makes to plant fitness, defined as the proportion of seedlings in a population that result from the activity of the dispersal agent (Schupp 1993). Fruit is a primary resource for many birds and provides a key ecological function, seed dispersal, for much of the world's flora (Sekercioglu 2006).

Seed dispersal processes are essential for the persistence of plant populations, and are fundamental mechanisms for the organization and maintenance of species richness in plant communities (Bascompte & Jordano 2007). Despite the importance of frugivores as agents of seed dispersal, the general mechanisms by which animals potentially shape plant populations and influence community organization are still absent from the theoretical core of community ecology (Carlo *et al.* 2007).

Seed dispersal offers at least three ecological benefits to a plant. It provides an opportunity to seeds to escape themselves from the excessive crowding and mortality that invariably occurs under the crown of the parent tree on account of competition. Dispersal may also allow a seed to spread its species into new habitats. Finally, some types of dispersal may position a seed in the precise site required for successful germination and seedling establishment. Vertebrate animals are important dispersal agents and among them birds are perhaps most commonly associated with seed dispersal (Van der Pijl 1972).

Much of the work on fruit frugivore interactions have come from the low land rainforests of the Neotropics (Foster 1982. Terborgh 1983) and a few from the forests of Africa (Gautier-Hion 1990, Chapman *et al.*. 1994). South East Asia (Leighton and Leighton 1983). Australia (Willson *et al.*. 1989) and India (Ganesh and Davidar 2001). Comparisons between the Neotropics and the Paleotropics show significant differences not only in fruit abundances but also in the diversity, abundances, sizes and the species compositions of frugivores and folivores (Terborgh 1986a). Only some studies on phenology in dry tropical forests, India (Prasad and Hegde 1986, Singh and Singh 1992, Murali 1992 Balasubramanian and Bole 1993) are under taken.

In India most of the studies on frugivory have focused on a single plant or animal species (Kannan and James 1999, Datta and Rawat 2003, Prasad *et al.*. 2004, Mishra and Gupta 2005) with very few community level studies (Hegde 1991, Balasubramanian and Bole 1993, Balasubramanian 1996, Ganesh and Davidar 2001). In dry deciduous forest, knowledge on the relative attractiveness of native plants to frugivorous birds is useful in planning afforestation because fruiting trees will attract birds which dispersed the seeds, thus increasing the diversity of the forest (Corlett 1992). With this background and understanding, a community level study on fruit-frugivore interactions was undertaken in two forest types namely dry deciduous forest, Western Ghats and scrub forest, Eastern Ghats. Avian frugivory studies on tropical dry deciduous forests of India are only a few, (Balasubramanian *et al.*. 1998) Study on the relationship between fruit characters (fruit colour, fruit size) which attract the birds are studied very less. The fruting seasonality of the bird-dispersed trees is also least known in the tropical dry deciduous forest, India and hence the present study was undertaken. The result shortlists the major fleshy fruited species, whose conservation is crucial for the survival of frugivores, and to the overall health of the forest ecosystem.

The objectives of the study are as follows

- Study fruit-frugivore interactions in two tropical forests namely tropical mixed dry deciduous and scrub forest in Southern India.
- Assess fruit characteristics such as size and colour of fleshy fruited species and relate with the fruit preferences of birds.
- Study the fruiting phenology of fleshy-fruited species,consumed by birds.

Plate 1. Study area - Tropical Mixed Dry Deciduous Forest, Anaikatty, Western Ghats

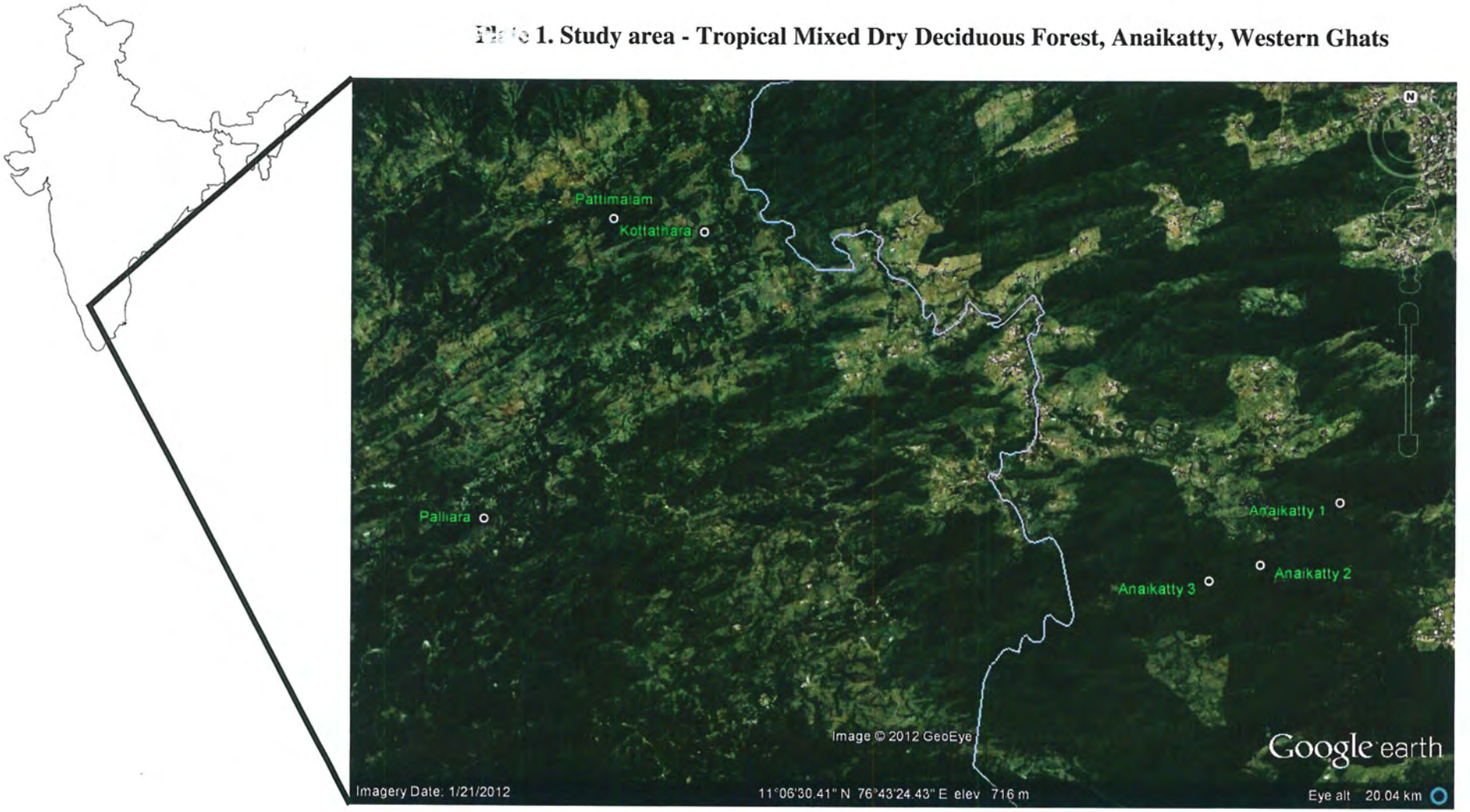
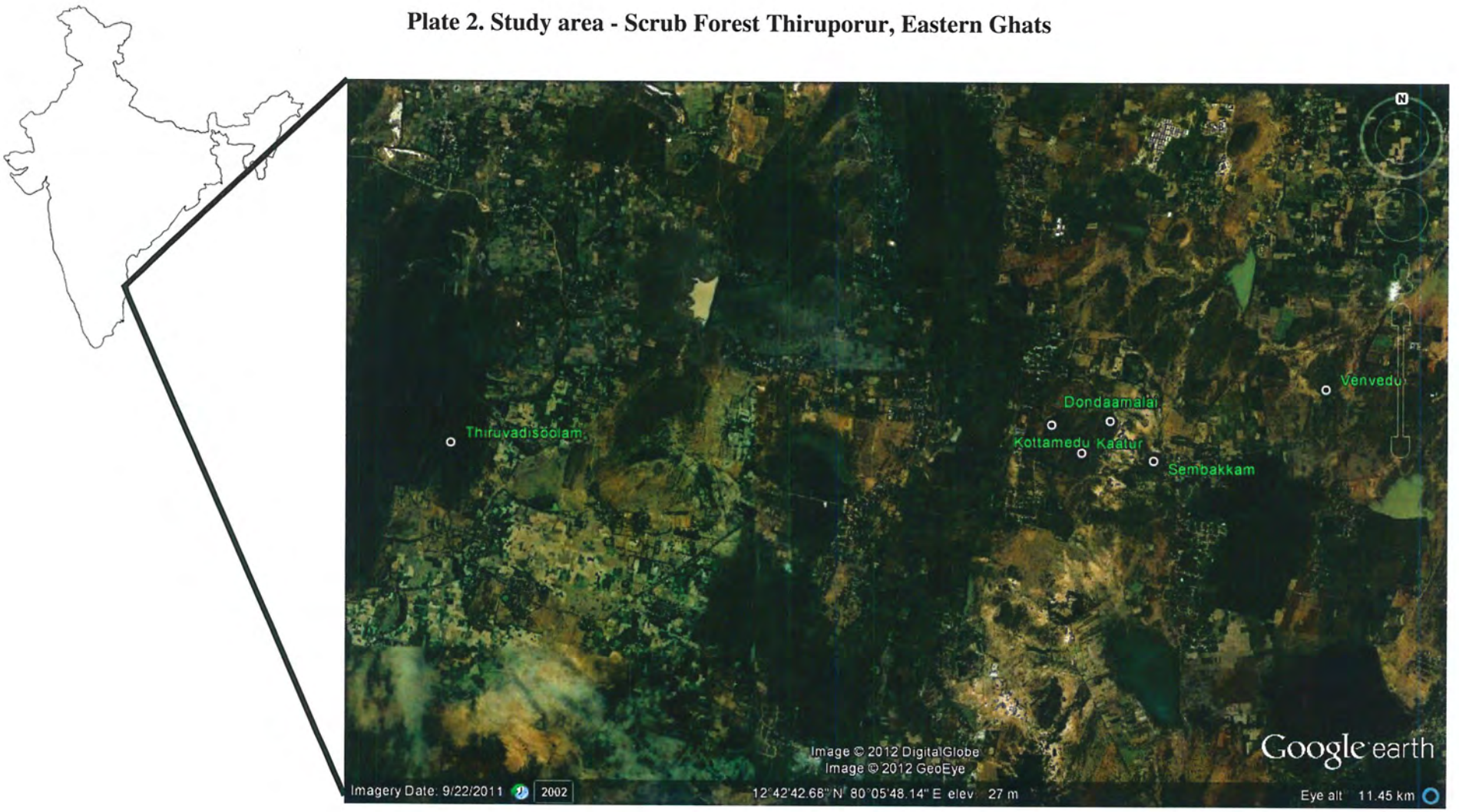


Plate 2. Study area - Scrub Forest Thiruporur, Eastern Ghats



STUDY AREA

The Western Ghats is considered as one of the three biodiversity hotspots in the country; the other being the Eastern Himalayas and the Western Himalayas. The Western Ghats, extending along the West Coast of India, covers an area of 180,000 km^2. Later in a revision when 34 biodiversity hotspots were recognized around the world, the Western Ghats along with Sri Lanka and the Indo–Burma region covering the Eastern Himalayas, the Western Himalayas were considered as three hotspots (Mittermeier *et al.* 2005). The region also has gained international attention, as a globally important eco region (Olson & Dinerstein 1998).

The Western Ghats is extraordinarily rich in biodiversity. Although the total area is less than 6% of the land area of India, it contains more than 30% of all plant, bird, and mammal species found in India. Like any other hotspots, the Western Ghats has a high proportion of endemic species. The region also has a spectacular assemblage of large mammals and is home to several nationally significant wildlife sanctuaries, tiger reserves, and national parks. The Western Ghats harbours medicinal plants and other important genetic resources such as the wild relatives of grains (rice, finger millet), fruits (mango, banana, jack fruit), and spices (black pepper, cinnamon, cardamom, nutmeg etc).

The loss of biodiversity is due to the introduction of exotics, causing havoc to native biodiversity, habitat destruction and conversion by shifting cultivation, rapid industrialization and excessive exploitation of raw materials are some of the reasons for the disappearance of many plants and animals. Developmental projects like dam constructions and other anthropogenic activities tend to the shrinkage of the habitat. Elimination of even a single species is disastrous to the entire ecological system. The introduction of exotic species in the system may prove equally harmful. It may not be able to integrate itself in the newly altered ecosystem. We have several examples of harmless insects turning into pests and exotic weeds spoiling the native habitats. Forest land is a multiple-use ecosystem that performs a number of protective, productive and economic functions, to sustain the ecological and livelihood securities of indigenous communities.

Such luxuriant vegetation compositions evolved over geologic time scales, have witnessed various land use practices depending upon the resource demand and ingress of human dimension. This has induced considerable alteration in the Western Ghats biogeographically, bringing commercial agriculture, commercial forestry, hydropower, mining and biotic pressures inside the forest ecosystems in the country. The tropical forests harbour a large number of plant and animal species in addition to various microorganisms. Each species has a specified role to play, which is in turn integrated in the ecological system.

Profile of Attappady

Attappady is one of the important tribal tracts of Kerala. It is one of the two extensive east sloping plateaus in the Western Ghats, which stretches from Mukkali to Anaikatty and Thazhemully to Muthikulam. The forests of these areas are controlled and managed by Attappady and Agali forest ranges, which are under the jurisdiction of Mannarkkad Division, Kerala.

Location:

Attappady is located at the Middle East portion of Kerala State between 10^{o} 55' 10" and 11^{o} 14' 19" North latitude and between 76^{o} 27' 11" and 76^{o} 48' 8" East longitude stretching over an area of 745 sq. km. in the Mannarkkad Taluk of Palakkad Revenue District touching the Nilgiri and Coimbatore district of Tamil Nadu as its Northern and Eastern boundaries respectively.

Attappady is part of the Nilgiri Biosphere Reserve in South India which forms a complex topography isolated from other high ranges. The terrain of Attappady is quite undulating, holding a large number of hillocks of varying elevation ranging from 450 meters to 2300 meters above the sea level. Majority of the area falls within the category of land above 35% slope. Rainfall varies considerably in Attappady block, being higher with an annual rainfall of about 3000 mm in the western slopes whereas rain fall in eastern Attappady is less than 1000 mm. Due to deforestation, low depth of soil and barren hills, the rainwater on the land has a high run- off speed. The extent of soil erosion in Attappady is one of the

highest in the state. The Attappady region is drained by two major rivers, Bhavani and Bharathapuzha. Bhavani basin has three district major sub – basins and Bharathapuzha has two basins.

The Eco-system of Attappady is highly fragile due to its physiographical and meteorological characteristics. Excessive fragmentation of the land holdings, unscientific agricultural practices followed in the area made the soil and vegetation in a poor state. Indiscriminate and excessive felling of the trees in forest area dwindled the forest vegetation in extent and in quality and uncontrolled grazing and frequent annual fires caused in weakening the quality of the forest in extent.

Locality factors

Soil

Soil survey organization, Kerala published a report on the soils of vested forests of Palakkad district. They classified the soil into three series viz, Anaikatty, Kallamala and Karuvara Chindakki series. Anaikatty series from deep to very deep and yellowish red to reddish brown loamy soils derived from genesis parent material. These soils have a compact gravelly texture in the second layer, while in the third layer few types of gravel are seen. These soils are found in sloppy areas. Kallamala series consist of very deep, moderately fine textured loamy soils having reddish brown to dark reddish brown surface soil and clay loam to silty clay loam texture. The clay content increases with depth of sand pockets are seen in the profile in most cases. The soils are developed over alluvium eroded from adjoining hill slopes. They occur in the low-lying regions of Attappady Valley. Karuvara Chindakki series represent the very deep soils having dark reddish brown to dirty red coloured surface soil. These soils are developed over gneissic parent material, mottling is absent under the layer of gravel in upper horizon. Clay content is increasing with depth. These soils are found occurring in the midland region of Attappady and in the slopes of the undulating hills.

Rainfall and climate

Attappady region has got two distinct climatic patterns. The eastern portion of Attappady is a rain shadow region with an average rainfall of 900 mm /year and the western side of Attappady is a rain fed area with an average rainfall of 3000 mm/year. Aralikkonam, Kinnakkara and Thoova are in the rain shadow region where the main source of rain is from Northeast monsoon and all other areas receive major precipitation from South-west monsoon.

Terrain

The terrain of this tract is quite undulating to very steep carrying a very large number of hillocks of varying altitude ranging from 750 m to 2,237 m above MSL. The highest peak in Malladmala in Aralikkonam block. Topography is rugged and descending in a South westerly direction.

Wind

Prevailing winds are from the west and southwest during April, September and from North and Northeast from October to March. From November to March, strong easterly winds blowing from early morning till past noon causes faster rate of evapo-transpiration. The mean wind velocity is 5 to 20 Km /hour.

Temperature

Temperature varies widely between the plains and hills. The temperature in the plains fluctuates between 21°C and 40°C and in hills it varies from 10°C to 30°C.

The Perennial Rivers

The main rivers passing through Attappady are Bhavani and Kundipuzha (Tributary of Bharathapuzha). Bhavani is east flowing with three tributaries viz. Siruvani, Kodungarapallam and Varagar.

Vegetation

Forests in Attappady, even within the limited geographical area, exhibit considerable variation in floristic composition, structure and physiognomy due to climatic,

physiographic and edaphic influences. As per the classification of Champion and Seth (1968) nine forest types can be recognized in the entire Attappady plateau.

1. West coast tropical evergreen forest
2. West coast semi-evergreen forest
3. South Indian moist deciduous forest
4. South Indian moist mixed deciduous forests
5. Southern tropical dry deciduous forests
6. Southern tropical dry deciduous scrub/Pioneer euphorbiaceous scrub
7. Southern subtropical broad leafed hill forest
8. Southern montane wet temperature forest
9. Southern montane wet grassland

Forest Types

Based on the revised system of classification of the Forests of India by Champion and Seth (1963), the following are the forest types occurring in Mannarkkad Forest Division. It is to be mentioned that Attappady Block represents almost all forest types discussed in the revised system of classification.

1. West Coast Tropical Evergreen Forests

This Forest Type is seen in Muthikulam of Agali Range (Attappady Block VI) and Attappady blocks I to V of Attappady range covering an area of more than 10,000 ha. The annual rainfall is above 3,000 mm and mean annual temperature is below 27° C. Very brief dry spell, characterized by occasional precipitation has supported climatic climax vegetation. Lofty evergreen tree species like *Cullenia exarillata, Calophyllum polyanthum, Mesua ferrea, Palaquium ellipticum,* and *Dysoxylum malabaricum* are present.

The top canopy consists of *Cullenia exarillata, Calophyllum polyanthum, Toona ciliata, Canarium strictum, Hopea parviflora, Dysoxylum malabaricum, Dipterocarpus indicus, Mesua ferrea, Palaquium ellipticum, Bischofia javanica, Vateria indica, Dipterocarpus bourdillonii, Persea macrantha and Poeciloneuron indicum.*

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Middle canopy consists of *Schleichera oleosa, Cinnamomum zeylanicum, Myristica malabarica, Elaeocarpus serratus, Hydnocarpus pentandra Evodia lunu-ankenda, Holigarna arnottiana, Syzygium cumini, Garcinia gummi-gutta, Macaranga peltata, Mallotus philippensis, Ochlandra beddomei,* and *Calamus* spp The shrub flora mainly consists of *Strobilanthes sp, Clerodendron viscosum* and *Glycosmis pentaphylla.*

2. West Coast Semi Evergreen Forests

This type of forest is seen in Attappady Block I Thudukki, Ummanarimala, Mukkali Venga malavaram, near Panthenthodu of this division between an elevation of 250 and 600 above MSL.

The top canopy consists of *Dipterocarpus indicus, Bombax ceiba, Polyalthia fragrans, Terminalia bellerica, Ficus* spp, *Stereospermum chelonoides, Tetrameles nudiflora, Alstonia scholaris, Lagerstroemia microcarpa, Spondias pinnata, Albizzia odoratissima, Vitex altissima,* and *Dysoxylum ficiforme.*

Middle canopy consists of *Mallotus phillippensis, Bauhinia malabarica, Miliusa tomentosa, Bridelia crenulata, Hydnocarpus pentandra, and Wrightia tinctoria,* other prominent flora include *Acacia intsia, Olea dioica, Dioscorea* spp and *Calamus* spp.

3. Southern Moist Mixed Deciduous Forests

This type is seen in Attappady valley, Kottanikunnu and Panakkadan RF and in the vested forests of Thathengalam, Paruthimala, Murukkanpara, Vetilachola, Kalaloor, Pothopadam and Karapadam. It also occurs in Compartment No.1 of Aralikkonam block on both banks of east Varahapallam and west Varahapallam Rivers.

The component species are *Dillenia pentagyna, Xylia xylocarpa, Dalbergia latifolia, Syzygium cumini, Tectona grandis, Lagerstroemia microcarpa, Grewia tiliifolia, Terminalia paniculata, Anogeissus latifolia, Bridelia crenulata, Albizzia lebbeck, Haldina cordifolia, Strychnos nux-vomica, Bambusa arundinacea, Ochlandra rheedi, Ochlandra travancorica* etc.

4. Southern Tropical Dry Deciduous Forests

This type of forest is confined to rain shadow regions like Aralikkonam, Mulli and Thoova. The major species are *Bauhinia malabarica, Bridelia airy-shawii, Strychnos nux-vomica, Albizia amara, Tamarindus indica, Careya arborea, Tamilnadia uliginosa* etc.

5. Southern Montane Wet Temperate Forests

Characterized by stunted branch of natural trees, this type is found in Attappady reserve block I to V where rainfall is above 3000 mm per annum.

6. Southern Euphorbia Scrub

This type of forest is found in the higher reaches of southern tropical dry deciduous forest in the Aralikkonam vested forests especially in the eastern portion around Mulli and in Thoova forests. This vegetation is predominated by *Euphorbia antiquorum.*

Wildlife

Asian Elephant (*Elephas maximus*), Sambar (*Cervus unicolor*), Wild Dog (*Cuon alpinus*) and Wild Boar (*Sus scrofa*) are some of the fauna found in Attappady.

Land, Forest and Tribals

The relationship between tribals, forest and land in this region changed over a period of time. Till the beginning of the second quarter of the 20th century, the only inhabitants of the regions were the three hill tribes, namely, Irula, Muduga and Kurumba. Settlements in the area were likely to have started from about the beginning of the century and the early settlers were mostly from Tamil Nadu who occupied the eastern plains. After the Second World War, and especially after independence, more settlers moved from the plains of Tamil Nadu and Kerala. While the further increase in population of tribals is due to natural growth only, that of settlers is mostly due to large scale influx in the area.

The Kurumbas were perhaps the earliest tribal inhabitants of Attappady. When the Badagas started colonizing the Nilgiris, these people have moved down to the Attappady valley. They are the smallest among the three tribal groups of Attappady. Mudugas are the second largest tribal community in Attappady. It is believed that they were the original inhabitants of Coimbatore and later moved westward due to persecution and

exploitation by more dominant communities. Their settlements are distributed in the vested forests distributed in between Karara and Mukkali area. Irulas are the numerically dominant and are relatively advanced among the three tribal groups in Attappady. They have probably been occupied this area after the Kurumbas and Mudugas. They mostly inhabit the eastern half of the valley and found residing in more than 95 settlements, which are distributed in all the three panchayats of Attappady. These tribals practice agriculture, they plough the land and sow a mixture of seed grains which include Finger millet (*Eleusine coracana*), Little millet (*Panicum miliaceum*) and Amaranth (*Amaranthus gangeticum*) along with pigeon pea (*Cajanus cajan*). Recently cash crops like sugar cane, cotton, ground nut and tapioca have been introduced to these tribals by farmers who have migrated here

Present status of landscapes of Attappady

The process of deforestation in Attappady is closely linked with the large scale immigration of the plainsmen; deforestation which began in the early 1950s has by seventies, assumed alarming proportions. Forest area constituted 82 per cent of the total geographical area of Attappady in 1959. It reduced to 28 per cent in 1971. It is totally degraded, remnants of vegetation alone are found, patches of vegetation could be seen in some localities. The important tree species seen here are *Tectona grandis, Alstonia scholaris, Phyllanthus emblica, Grewia tiliifolia, Stereospermum colais, Schleichera oleosa, Wrightia tinctoria, Terminalia bellerica, Lagerstroemia microcarpa, Trewia nudiflora.* The obnoxious weeds, *Lantana camara, Chromolaena odorata* are fast spreading in this area. In addition to these weeds *Parthenium hysteropyrus* spreads faster to the cultivated areas.

Study sites were selected in Kottathara, Palliara and Pattimalam, which is primarily the dry belt, predominated by tropical mixed dry deciduous vegetation (Figure 1). In addition to these, three sites were selected in adjoining Anaikatty forests where the climax community of the mixed dry deciduous vegetation occurs.

Anaikatty

The major part of the research work was carried out in the tropical mixed dry deciduous forest of the Anaikatty hills of Nilgiri Biosphere reserve, Western Ghats. This area is

situated between 76°39'and 76°47'E and from 11°5' to11°31'N. This area falls between Nilgiri south and Sathyamangalam forest divisions on the north, Erode division on the east and Palghat forest division of Kerala state on the south border of the Anaikatty reserve forest. This forest has an undulating terrain 610-750 m with seasonal waterways with hilltops and south rising upto 1600msl.

The Anaikatty forest ranges were working under permit system till 1905 for felling tree for local demands. Simple coppice system operated in this areatill 1983 whereby trees in a particular area were felled and the resultant coppice was allowed to grow for 20 years.This cycle was repeated. This was adopted for a particular area and was reapeated periodically in the other areas also. The Tamil Nadu forest department has implemented afforestaton in this forest since 1990, mostly filling gaps or the open areas.Now the existing forest is a secondary forest that was formed by the secondary succession (Soundarapandian 1992).

Soil

Anaikatty hill is comprised of various types of rocks largely Archean origin. In most parts, soil is hard gravel and in some places it is red loamy. The reddish brown soil and clay are mostly found in the plains. In general, most parts of the area have soil devoid of humus. (Soundarapandian 1992)

Rainfall

This area receives rainfall from both the monsoons but comparatively high during North-east monsoon.The monthly mean rainfall is about 75 cm in the plains and along the foot hills and increasing to about 120cm towards the higher elevations (Balasubramanian 1996) The North-east monsoon normally commences in the latter part of August or in early September and lasts till the beginning of December with occasional pauses. The South-west monsoon is during June to August.The area had an average annual rainfall of 688mm during the 10 year study from 1991-2000. The mean annual rainfall of the area was lower than that of the moist deciduous forest zone of the country but was comparable to that of the mixed dry deciduous forest zone (Champion and Seth 1968)

Climate

In general, climate of Anaikatty hills is moderate for most of the year except summer (March to May). The foothills are hot and dry while the upper regions of the hills enjoy a mild cool climate.This hill receives precipitation from both Soth-west (March to August) and North-east (Septeber to November) monsoons.The North-east monsoons contributes more than half of the total annual rainfall of the Anaikatty hills.

Seasons

Based on the climate, the seasons may be categorized into four namely South-west monsoon, North-east monsoon, winter, summer (Nirmala 2002).

South-west monsoon (June, July, August)

The study area receives 5% of the total annual rainfall during this season. The mean rainfall received was around 40mm.This season had a moderate temperature and next to the least of humidity among the seasons.

North-eastMonsoon (September, October and November)

This season receives more than half (69%) of the total annual rainfall. The mean rainfall received was around 500mm.This season had the lower temperature when compared to the south-west monsoon maximum relative humidity among the seasons.

Winter (December, Januray, February)

It was the least rainy period of the year with the annual rainfall of 34 mm. This season was the colder period with the minimum temperature falling to 18c and also with the lowest wind speed.

Summer (March, April, May)

This season receives 21% of the annual rainfall from the pre-monsoon showers. This was the period of maximum temperature, which leaped upto 37c with low relative humidity.

Wind speed

Windspeed was maximum during South-west monsoon. The monthly mean wind speed recorded showed fluctuation between 3 and 14 km/h. Very low wind speed was observed in December and highest wind speed in July.

Vegetation & Forest types

The vegetation of Anaikatty Reseve Forest comes under the Southern tropical mixed dry deciduous type (Champion and Seth 1968). The major forest types in Coimbatore Forest Division harbours tropical southern mixed dry deciduous forest (47%), southern thorn forest (29%), semi evergreen forest (8%) and wet evergreen forest (2%).

Mixed dry deciduous forest

Mixed dry deciduous forest species dominates this reserve forest. This area consists of trees, herbs and many shrubs. It consists of the combination of trees such as *Acacia leucophloea, Ziziphus mauritiana, Chloroxylon swietenia, Albizia amara, Tamarindus indca, Albizia lebbeck, Diospyros montana, Cassia fistula, Santalum album* and *Commiphora caudata.* Dominant shrubs found here are *Chromolaena odorata* and *Clausena indica. Cassine glauca, Flacourtia indica, Bauhinia racemosa, Ziziphus mauritiana, Premna tomentosa* are dominant woody species. Succulents such as *Opuntia dillenii* and *Euphorbia antiquorum* are also common. Bamboos (*Bambusa bamboos* and *Dendrocalamus strictus*) are common along the streams. The hilltops of the area harbour tropical semi evergreen forests. Major tree species on hilltops include *Neolitsea scrobiculata, Ziziphus xylopyrus, Syzygium cumini* and *Nothopegia racemosa.* Since many villagers are dwelling in and around this forest type, anthropogenic pressures are quiet common here. Cattle grazing were observed frequently. The degraded area is mostly private land and is partly allowed to regenerate naturally, also by plantations.

Wildlife

Mammals

Anaikatty hills harbours larger herbivores such as the Asian Elephant (*Elephas maximus*), Wild Gaur (*Bos gaurus*), Sambar (*Cervus unicolor*) and Chital (*Axis axis*). Carnivores such as Leopard (*Panthera pardus*), Wild Dog (*Cuon alpinus*); omnivores such as Sloth Bear (*Melurus ursinus*) and Wild Boar (*Sus scrofa*); primates such as Common Langur (*Presbytis/Semnopithecus entellus*) are present. Common Mangoose (*Herpestes edwardsi*) Indian Three-striped Palm Squirrel (*Funambulus palmarum*), Black-naped

Hare (*Lepus nigricollis*) and many species of field rats are the small mammals found in the Anaikatty hills. Man-animal conflict includes occasional reports of elephants attacking humans and raiding crops

Birds

A total of 187 species of birds were observed in this area (Nirmala 2002). Common bird species include Red-whiskered Bulbul (*Pycnonotus jocosus*), Red-vented Bulbul (*Pycnonotus cafer*), Indian Robin (*Saxicoloides fulicata*), Yellow-billed babbler (*Turdoides affinis*) and Indian peafowl (*Pavo cristatus*). Endemic bird species such as Malabar Parakeet (*Psittacula columboides*) is also recorded here.

Reptiles

Indian Rock Python (*Python molurus*), Brozebacked Tree Snake (*Dendrelaphis tristis*), Indian Rat Snake (*Ptyas mucosa*), Green Vine Snake (*Ahaetulla nastusa*) and Common Sand Boa (*Eryx conica*) are major reptiles in Anaikatty hills.

Amphibians

Common Asian Toad (*Bufo melanostictus*), Red narrow-mouthed Frog (*Microhyla rubra*) and Malabar Baloon Frog (*Uperodon systoma*) are the important species of amphibians observed here.

People and their livelihood

The tribals of the surrounding villages (Doomanur, Sembukkarai, Kondanur, Kondanurpudhur, Aalamaramedu and Moongilpallam) collect firewood and minor forest produces from this forest. Their main income comes from brick works and agriculture. Cultivation is done in their own land and cattle grazing in the forest.

Scrub Forest, Eastern Ghats

The Eastern Ghats are a series of discontinuous low ranges running generally northeast-southwest parallel to the coast of the Bay of Bengal. They cover an area of about 75,000 sq km in the Indian peninsula, with an average width of 220 km in the north and 100 km in the south. The Eastern Ghats are located between 11°3` and 22° N Latitude 76°50` and

86°30` E. Longitude in a North-East to South West strike. They extend over a length of 1750 km between the rivers of Mahanadi and Vaigai along the East Coast of India across the states of Orissa, Andhra Pradesh and Tamil Nadu. The largest single sector, the remnant of an old mountain range that eroded and subsequently rejuvenated is found in the Dandakaranya region between the Mahanadi and Godavari rivers. This narrow range has a central ridge, the highest peak of which is Arma Konda (1818 m) in Andhra Pradesh.

The hills become more subdued farther southwest, where they are traversed by the Godavari River through a gorge 40 miles long. Still farther southwest, beyond the Krishna River, the Eastern Ghats appear as a series of low ranges, including the Erramala, Nallamala, Velikonda, and Palkonda. Southwest of the city of Madras, the Eastern Ghats continue as the Javadi and Shevaroy hills, beyond which they merge with the Western Ghats (Legris and Meher-Homji, 1982). Eastern Ghats are a chain of broken hill ranges in South Eastern India. It is one of the nine floristic zones in India. The Eastern Ghats has rich floristic diversity, more than 2500 species of Angiosperms occur in this region which constitute about 13 percent of the flowering plants of India Flora of Orissa (Saxena and Brahmam 1994); Flora of Tamil Nadu, (Nair and Henry 1983, Henry *et al.* 1987, 1989).

The distribution pattern of the endemic plants of the Eastern Ghats is quite different from that of the Western Ghats. The species-rich zones are isolated mainly because the Eastern Ghats do not form a continuous range, but form rather broken hill ranges with plains in between. Thus the isolation and restricted distribution of the narrow endemic plants due to geographical, ecological, edaphic and climatic barriers is much more pronounced in Eastern Ghats, in comparison with the Western Ghats where there is a continuity of mountain system and an almost same humid climatic regime throughout, for which reason the endemic plants of Western Ghats have a relatively wider distribution range (Ahmedullah & Nayar, 1987).

Study on scrub forest observation was made in Thiruporur, Kancheepuram district in Eastern Ghats. Kancheepuram district is situated on the northern East Coast of Tamil Nadu and is adjacent by Bay of Bengal and Chennai city and is bounded in the west by

Vellore and Thiruvannamalai district, in the north by Thiruvallur district and Chennai district, in the south by Villuppuram district in the east by Bay of Bengal. It lies between 11° 00' to 12° 00' North latitudes and 77° 28' to 78° 50' East longitudes. The district has a total geographical area of 4, 43,210 hectares and coastline of 57 Kms. There are only a few hills of considerable elevation in the district. The southern part of Maduranthakam taluk contains small hills. The total forest area in the district is 23,586 hectares, it spread interior regions and around the district. In this forest area there are 366.675 hectares of Reserved Land.

Climate

Generally, the plateau enjoys a mild and equitable climate favourable to vegetation and in particular the sandal. The slopes and plains are subjected to hot and dry climate. The average minimum and maximum temperature are 21°C and 27°C in the plateau and the average minimum and maximum temperature are 26°C and 32°C in the plains.

Hills

There are only a few hills of considerable elevation in the district. The southern part of Maduranthakam taluk contains small hills.

Rainfall

The pre-monsoon rainfall is almost uniform throughout the district. The coastal regions receive more rainfall than the interior ones. This region is mainly dependent on the monsoon rains. Failure of monsoon leads to distress condition. Northeast and Southwest monsoon are the major donors, with 54% and 36% contribution each to the total annual rainfall. During normal monsoon, the district receives a rainfall of 1200 mm.The district is mainly dependent on seasonal rains, with the Northeast and Southwest monsoons contributing 54% and 36% respectively to the total annual rainfall.

Rivers

Palar and Moyar run through the division and water supply is good in the vicinity of these perennial rivers. Otherwise, in general, the water supply on the plateau is either unwholesome inadequate. The water table on the plateau is also low. The Palar and

Cheyyur Rivers are rainfed with rare surface flows. Rivers are polluted by the leather, dyeing and other industries as well as municipal sewage. Riverine acquifer is heavily tapped for urban and industrial use.

Scrub forest

The scrub forest consists of a combination of trees such as *Anogeissus latifolia* , *Albizia amara, Azadirachta indica, Acacia leucophloea Buchanania lanzan, Diospryos montana, Lannea coromendelica Pleurostylia opposita, Canthium dicoccum, Tamarindus indica, Terminalia arjuna, Pongamia pinnata, Manilkara hexandra, Dolichandrone atrovirens* and *Strychnos potatorum.* Dominant shrubs in this forest are *Carissa spinarum, Ziziphus oenoplia, Diospyros ferrea var buxifolia, Tarenna asiatica, Flueggea virosa, Carmona retusa, Glycosmis cymosa, Cleistanthus collinus, Morinda tinctoria, Catunaregam spinosa* and *Premna tomentosa.* Succulents such as *Euphorbia antiquorum, Agave sisalana* and *Sansevieria roxburghiana* are also common. Since many villagers are dwelling near this forest, anthropogenic pressures mostly affect it. Cattle grazing was observed frequently, in addition to of fire wood collection.

Wildlife

This scrub forest harbours Chital (*Axis axis*) and Bonnet Macaque (Macaca radiata). Common bird species include Common Myna, Red-vented Bulbul, White-headed Babbler, House Crow, Eurasian Golden Oriole, Crimson-throated Barbet, White-browed Bulbul, Small Green Bee-eater and Indian Peafowl. Study sites in Thiruporur include Dondamalai, Kaatur, Kottamedu, Sembakkam, Thiruvadisoolam and Venvedu. (Figure.2)

Plate 1. Study area, Tropical Mixed dry deciduous forest, Anaikatty; Western Ghats

Plate 2. Scrub forest, Thiruporur, Eastern Ghats

LITERATURE REVIEW

Phenology

Phenology is the study of relationship between climatic factors and periodic phenomena in organisms. Periodic behaviour of plants in tropical environments has received much attention in recent years. Tropical forests with their high level of species diversity, display phenological events such as leaf drop, leaf flushing, flowering and fruiting, etc. in relation to time and space (Singh and Singh, 1992). Study of such events is useful in evolving proper management strategy as well as better understanding of natural forest regeneration potential and community level interactions (Fox, 1976).

The tropical forests have a distinctive array of species different from temperate and rain forests. It supports different varieties of over storey and under-storey plant species, which are major food resources for a variety of biota (Bhat and Murali, 2001). In the Indian subcontinent many of the studies on phenology have come from dry tropical forests (Murali, 1992; Singh and Singh, 1992). Efforts have been made to discern the importance of general community patterns in leafing, flowering and fruiting for many species, of which particular forest types are composed (Frankie *et al.*, 1974).

The study of plant phenology provides knowledge about the pattern of plant growth and development as well as the effects of environment and selective pressures on flowering and fruiting behavior (Zhang *et al.*, 2006). Singh & Kushwaha (2005) suggested that climate change forced deviations in the length of growing period, and competition among species may change the resource use patterns in different species. Karmer (1997) concludes that differences in phenological responses to temperature changes can have long-term consequences on the geographic distribution of plants. He further suggests that phenology and climate relationship can also reveal the potential impacts of future climate changes.

Hamann (2004) suggested that climatic factors are not directly responsible for triggering and synchronization of phenological events. Progress made in the field of phenology of tropical tree species is encouraging (Frankie *et al.*, 1974). In India the phenology of tree species has been studied in the subtropical forests in north-eastern region

(Boojh & Ramakrishnan 1981; Kikim & Yadava 2001) and in western Himalayas (Sundriyal 1990). However, only a few attempts have been made to evaluate the phenology of tree species in the tropical dry deciduous forests (Khan 1999; Singh & Singh 1992).

Many studies were conducted to reveal the complexity of bird – vegetation association. Rice *et al.*. 1984 studied the importance of different habitat attributes such as density of vegetation, foliage height diversity, and patchiness to avian community organization. Phenology of the vegetation has considerable effect on the structure of avian community (Feisinger 1978); however in some cases food resources increase the bird diversity (Wolf 1975). The interactions of birds and animals with plants are expressed in the phenology, flower morphology and seed dispersal. The advantages of dispersal are not mutually exclusive; they can be assessed only if deposition sites and post-dispersal fates are known. Another possible benefit for vertebrate-dispersed seeds is enhanced germination after gut passage.

Extreme seasonality is the rule in forests with distinct wet and dry seasons (Foster, 1982), and substantial fruiting seasonality even occurs in very wet (annual precipitation of 4000 6000mm) neotropical forests with weak dry seasons (Frankie *et al.*. 1974). Fruiting seasonality is less pronounced, but noticeable, in wet forests showing virtually no monthly variation in rainfall, as has been reported in a Colombian forest (Hilty, 1980). Food may be far more limiting in some seasons than in others, and consequently trees bearing fruits during lean times will play a greater role in maintaining entire communities of fruit-eating animals than those bearing fruit during peak production of the entire forest (Howe, 1977).

Knowledge of fruiting phenology is of central importance for conservation management generally, but is of special value in tropical forests which support a diversity of fruit-dependent species (Fenner 1998). The phenology of tropical mixed dry deciduous forest forest species of Western Ghats, scrub forest in Eastern Ghats region is less understood. The present work aims to document the phenological diversity of fruiting of a tropical mixed dry deciduous forest, Western Ghats and scrub forest in Eastern Ghats.

Avian frugivory and Seed dispersal

The study of relationships between bird-dispersed plants and fruit-eating birds in the tropical region has received considerable attention (Ali, 1931; Howe and Estabrook, 1977, Frost, 1980, Beehler, 1983, Wheelwright *et al.*. 1984, Dowsett- Lemaire, 1988, Green, 1993, Balasubramanian, 1996, Kannan & James, 1999, Holbrook & Smith 2000; Wenny 2000, Ganesh and Davidar 2001, Sankamethawee *et al.*. 2011). The majority of plant species in tropical communities and many species in temperate regions produce fruits adapted for avian and mammalian consumption (Howe and Smallwood 1982; Herrera 1984).

Fleshy fruits, which are apparently adapted for consumption by vertebrate seed-dispersal agents are very common in most tropical forests (Willson *et al.*. 1989). The survival of a plant species is best ensured by the dispersal of fruits and seeds to as many different and far off localities as possible (Venkateswaralu, 1982). Among the regular methods of seed dispersal, birds play a vital role, because of their fruit eating habits and the long distances they travel (Ridley, 1930). A variety of birds and mammals depend predominantly on fruits to fulfill their nutritional requirements. Frugivores also help seed escape from the deleterious effects of seed and seedling predators (Janzen, 1970).

Frugivorous birds are of fundamental importance for the maintenance and expansion of plant populations as they act as agents of seed dispersal (Takahashi and Kamitani 2004). The architectures of bird–plant interactions are assumed to have great implications for the stability and robustness of both bird and plant populations (Silva *et al.*. 2007), and thus, understanding these interactions is crucial for conservation purposes (Moran and Catterall 2010). One characteristic of fruit–bird interactions is thought to be their diffused nature (Herrera 2002); one bird species typically utilizes various fruit species, and one fruit species is utilized by various bird species (Silva *et al.*. 2007).

Most plant-frugivore interactions involve many species of plants and animals or could not be separated from the influence of evolutionary and palaeontological events (Willson and Whelan 1990). It was suggested that plant-frugivore co-evolution was more diffuse than initially postulated, with a number of factors contributing to the noted interactions (Stiles

and Rosselli 1993) and that plants had evolved to attract as many species of disperser as possible, compatible with other ecological constraints affecting fruit quality (Snow and Snow 1988; Traveset 1994). Furthermore, utilising more than one disperser reduced the chance that losing a single 'specialist' disperser would result in the loss of dispersal capabilities, and consequent risk of extinction of the plant species (Snow and Snow 1988).

Karr *et al.*. (1982) stated that the relationship between the fruiting time of bird-dispersed plants and fruit-eating bird abundance is vital for understanding the tropical bird fruit dispersal syndromes. Temporal variation in tropical fruit-eating bird abundance is usually ascribed to changes in fruit abundance. In fleshy-fruited plants, fruit size helps and constrains seed dispersal by animals. In tropical communities, small fruits attract a wider array of dispersal agents than larger ones. Plant species with small fruits are often visited by more species of dispersal agents. (Howe & Westley, 1988 and Dowsett-Lemaire, 1988).

Fruit-frugivore interactions are widespread and are fundamental to the structure of terrestrial communities (Wang and Smith, 2002). Fruits support a winter population of bird species that is mainly insectivorous in summer (Sorensen 1981). Therefore, a sudden fluctuation in the interaction between fruiting plants and frugivores has a critical effect both on plant and animal populations (Loiselle & Blake 2002)

Seed dispersal by vertebrates is a key process in the dynamics of natural vegetation and in vegetation recovery after human impact (Corlett, 1995). As deforestation and fragmentation increase and as global warming alters regional weather patterns, many species will have to migrate to survive. In these circumstances, dispersal limitation of plant distributions will become an increasingly serious problem (Primack & Miao, 1992). Vertebrates which depend on fruit for a significant part of their diet may, in turn, be vulnerable to changes in fruit supply resulting from deforestation, logging (Leighton & Leighton, 1983), and the influence of climatic change on plant phenology (Corlett & LaFrankie, 1998).

From 50 to over 90% of tropical tree and shrub species produce fleshy fruits and rely on frugivorous vertebrates to disperse their seeds, by offering them energetic rewards, such as lipids, carbohydrates, and protein (Howe and Smallwood, 1982). Seed dispersal provides many advantages for plants, including occupancy of vacant sites (colonization), avoidance of sites occupied by relatives or other individuals of the same species (escape from distance or density-dependent mortality), and occupancy of specific microsites critical for establishment (directed dispersal) (Howe and Smallwood, 1982).

In fragmented landscapes, seed dispersal by frugivores may guarantee the possibility of gene flow among natural vegetation patches (Jordano and Godoy, 2002). With the defaunation of the frugivores, some plant species may suffer a decrease in seed dispersal and, consequently, in seedling recruitment and/or survival (Galetti *et al.*2003). However, the impact of frugivore defaunation could be reduced, if frugivorous species that are more resistant or even benefit from anthropogenic impacts are able to disperse seeds of a great variety of morphological fruit types, compensating, at least partially, for the decline of other frugivores.

Seasonality in fruit production in tropical forest ecosystem has brought to light the roles played by keystone or pivotal species during period of scarcity. Green (1993) has dealt on the role of birds in the restoration of tropical forests. Planting fleshy-fruited trees and shrubs of any kind will often attract frugivores. However, knowledge of local frugivores and their role in seed dispersal could be very useful for planning an effective and efficient regeneration programme. In tropical forests, 50 – 70 % of trees possess fleshy fruits adapted for animal consumption (Howe, 1984b). Fleshy fruited plants may not only serve as seed sources but also in the re-establishment of other species by attracting seed dispersing birds to the vicinity (Mc Donnell & Stiles, 1983) Birds by virtue of their greater mobility, can be more effective seed disseminators than other fruit eating animals.

Many plants have their seeds dispersed by frugivorous birds (Howe and Smallwood 1982). Fruits eaten by specialized frugivores are generally large, and have relatively large seeds and high nutritive quality. Of the plant families which have coevolved with frugivorous birds to produce fruits of this kind, families such as Lauraceae, Burseraceae, and Palmae

are of outstanding importance (Snow, 1981). In open country and human dominated landscapes, members of the family Corvidae and Sturnidae are important frugivores. In such areas, they are often amongst the largest birds, and thus, even these less frugivorous species may be significant as dispersers of fruits and seeds that are too large or smaller frugivores (Corlett 1998).

Forest fragmentation and the resulting anthropogenic edges may alter the abundance of fruiting plants and frugivorous birds, however, very few studies have evaluated how anthropogenic edges and habitat fragmentation affect the mutualistic process of frugivory and seed dispersal (Restrepo *et al.*, 1999). Frugivore assemblages may be altered through forest degradation and fragmentation (Babweteera and Brown 2009), through the introduction of exotic species (Foster and Robinson 2007) and through human-induced extinctions or near-extinctions (Meehan *et al.* 2002).

A large proportion of vascular plants in Neotropical rain forests is dispersed by birds or mammals (Howe and Westley, 1988,). Under-storey small fruits on the other hand, are consumed by wide variety of generalist birds, including manakins, and tanagers (Wheelwright *et al.* 1984; Loiselle and Blake, 1999), which are not as highly affected by fragmentation (Aleixo and Vielliard, 1995). Many bird-dispersed species are characterized by a diverse frugivore community (Jordano and Schupp 2000), yet the large majority of dispersal events is caused by a limited number of species of the overall frugivore community (Jordano and Schupp 2000).

Dispersal provides the opportunity to escape the neighbourhood of the parent plant, and allows seeds to colonize new and potentially more favourable micro sites for seedling establishment (Howe & Smallwood 1982). Balasubramanian (1996) studied the interactions between birds and plants in the Tropical dry evergreen forests of Point Calimere. In the wet forest of Kakachi in the Western Ghats, 50% of fruits produced by shrubs are zoochomus and mostly dispersed by buds (Krishnan 1994). Ganesh and Davidar (2001) have recorded information on the various dispersal modes associated with 82 tree species in a wet evergreen forest of Kakachi in Kalakad-Mundanthurai Tiger Reserve. Tropical forests have been the showcase for studies on the mutualistic

relationship between plants and their avian seed dispersers. Only in the tropics can one find such a bewildering diversity of fruit types, or birds that survive on nothing but fruits

Fruit colour

Fruit color is among the most remarkable traits expressed by endozoochorous plants, which usually show bright, saturated and varied colors, as opposed to the dull colors of dry fruits. Among these colors, red and black are the most common in the majority of systems studied to date, both in the tropics and in temperate latitudes (Schaefer & Schaefer 2007), whereas green fruits are commonly cited as the least frequent fruits (Willson & Whelan 1990). Fruit colours are traditionally viewed as an adaptation to increase the detectability of fruits for animals that disperse their seeds (Schmidt, Schaefer & Winkler 2004). Fleshy fruits consumed by avian frugivores are often coloured red or black, sometimes blue, purple, pink, or white, but rarely orange, yellow, green, or brown (Janson 1983, Willson *et al.* 1989). In bird dispersed plants, fruit colour is one of the factors determining the fruit choice by birds in the world (Burns & Dalen 2002).

Fruit colour displays may have two other functions, to be conspicuous and to attract. Bright colours are the "flag" (Ridley 1930; Stiles 1982) that catches birds' attention. If conspicuousness were the sole reason for colour displays in bird fruits, we would expect similar fruit displays under similar visibility conditions. In addition to signaling location, a fruit's colour may convey information about its quality that would influence a bird's choosing the fruit. Obvious examples of such information are the changes in nutritional value and digestibility that a bird can anticipate with the change in fruit colour during ripening (Biale 1975). Relevant morphological fruit traits that may influence an animal's choice of fruit include fruit type, fruit and seed size, and fruit colour (Gautier-Hion *et al.* 1985).

Ridley 1930, Forget *et al.* 2007 noted that fruit colours are a form of long distance advertisement to fruit foragers. He observed that bird-dispersed fruits are most often red or black. Darwin (1859) noted that fruits eaten by birds tend to be brightly coloured, at

least to human perception. Like Darwin, Ridley (1930) interpreted bright colours as serving three functions: to draw the attention of potential seed dispersers to a fruiting plant, to reveal the location of individual fruits, and to signal ripeness.

The importance of the many different colours of fruits is not completely clear, but the non-random use of certain fruit colours within animal guilds suggests the importance of at least certain colours as a signal to frugivores (Stiles 2000). Fruit colours can enhance conspicuousness of fruits and detection by frugivores and advertise far-ranging information on fruit maturity. Red and black fruits exhibit stronger contrasts against a background of foliage than other colours (Schmidt *et al.* 2004).

Fruits are small, red to black in color, and lack pulp protection (e.g., Gautier-Hion *et al.* 1985, Wheelwright and Janson 1985), The conservative nature of these characteristics may promote the formation of new plant disperser relationships when fleshy-fruited plants or frugivorous birds spread to new ranges. Second, plants with bright, bird-attracting fruits are often favored by horticulturalists and, thus, especially prone to introduction (Reichard *et al.* 2001).

Red is one of the most common colours of bird dispersed fruits (Ridley 1930). Surveys of regional floras, despite their taxonomic differences, support this generalization (Gautier-Hion *et al.* 1985, Willson *et al.* 1989). Willson and Whelan (1990) proposed a set of hypotheses to explain the evolution of fruit colour. Of these, perhaps the most intuitively appealing hypothesis is that certain colours are more attractive to frugivorous birds and promote seed dispersal. However, only a few experiments have examined whether birds discriminate among fruits on the basis of colour (Willson *et al.* 1990).

Collectively, these studies showed that individual birds differ in their initial colour preferences, and in the transitivity and temporal stability of these preferences. Often, however, inferences about the importance of colour in determining fruit preferences in aviary studies have been confounded by cross species comparisons of fruits that introduce other, uncontrolled variables such as their size, shape, taste and nutritional value (Moermond *et al.* 1987).

Plants bearing soft, fleshy fruits like berries, drupes or functionally analogous structures represent the most widespread and diverse vertebrate-plant dispersal system (Herrera 2002). Other fruit types can set string constraints to fruit and seed handling, e.g. when pulp and seeds are protected in hard, indehiscent capsules or pods that can only be opened with strong teeth, bills, fingers, or elaborated fruit handling techniques (Stiles 2000).

Fruit size

Recent studies highlight the importance of fruit traits associated with avian frugivore preferences, such as morphology (Gosper and Vivian-Smith 2009) and nutritional composition (Gosper and Vivian-Smith 2010). Small, single-seeded fruit or those with fewer seeds (Gosper and Vivian-Smith 2009), as well as soft, many-seeded fruits tend to be visited more often by frugivores (Green 1993). Fruit size is also one of the most important factors determining fruit choice (McConkey & Drake 2002).

Fruit size is a prime candidate for coevolution between plants and their dispersers, as it is correlated with disperser type (Jordano 1995). Fruit or seed size can differ among years, among populations, among plants within a population and among fruits within an individual plant (Parciak 2002). Although this variation in fruit size may shape the interaction between frugivores and their food plants, selection forces may be acting in opposing directions.

Fruit selection presumably depends on the behavior, morphology, and nutritional require ments of birds, the abundance of alternative food resources, and fruit characteristics such as temporal availability, habitat, taste, colour, abundance, and placement on a plant (Wheelwright and Janson 1985). Positive relationships between fruit size and the average size of fruit consumers have been previously documented in other geographic locales (Rey *et al.* 1997). Small fruit and large fruit with small seeds are generally consumed and dispersed by a greater number of frugivores than large fruit with large seeds (Jordano 2000).

Fruit size may be critical to selection, but it has been given surprisingly little consideration, despite the demonstration in many foraging studies that the sizes of predators and prey are often positively correlated (Wilson 1975). In general, both fruit and seed size of Angiosperms are correlated with the size of the frugivores that consume the fruits (Jordano 1995).

Keystone species: Ficus and Avian Frugivory

Studies of avian frugivory in the tropics have led to the concept of pivotal plant species (Howe 1977) and keystone plant resources (Terborgh 1986b). These plants perform a critical function in the forest ecosystem because they sustain frugivorous animal species and communities through periods of resource scarcity. For frugivores, keystone plant taxa are those that produce fruit during periods when other fruit resources are insufficient to meet frugivore nutritional requirements. Deletions of keystone plant species or species groups would potentially result in the extinction of frugivores which depend on them during periods of resource scarcity. Such extinctions could have further repercussions for the ecosystem, such as the eventual loss of other plants which were dependent on seed dispersal by these frugivorous species. Such a scenario obviously has serious implications for forest management and conservation.

Ficus is one of the largest genus with approximately 350 species in Southeast Asia (Corner 1965). It is widely considered as a keystone mutualist for many vertebrates in the tropical rain forest (Janzen 1979). Being abundant and always available throughout the year, figs constitute an important diet for many frugivorous animals when other food resources (e.g. insects) are scarce (Leighton and Leighton 1983). Globally, a staggering number of vertebrates over 1200 species feed on *Ficus* (Shanahan *et al.* 2001). Ficus have a disproportionately large influence over their ecosystem in relation to both their abundance and biomass. At the population level, figs exhibit fruiting asynchrony and are a critical year-round food source when other fruits are not available. Lambert and Marshall (1991) argued that figs play an important role in maintaining populations of frugivores such as Flowerpeckers (Dicaeidae) and Green Pigeons (*Treron* spp.) during periods of general fruit scarcity.

It comprises the most important class of plant resources as Terborgh (1986b) has shown that the species that feed on the figs constitute about 40% of the animal biomass at Cocha Cashu, Peru. Lambert and Marshall (1991) identified the characteristics, which make figs the most important keystone plant resources: their large crop sizes, relatively short fruiting intervals, intra-crown synchrony of fruit ripening and intra-population asynchrony. Although Ficus are perhaps best known for the intricate mutualism with their generally species-specific wasp pollinators (Janzen 1979), the ripe fruit that is one product of that interaction also provides an important food source for a wide range of frugivores that, in turn, usually disperse the viable fig seeds.

Tropical Ficus species, however, tend not to conform to either of these patterns. Rather, at the population level, figs are produced year-round and individuals are capable of producing more than one crop per year (Janzen, 1979). Classically, Ficus phenology entails individuals producing synchronously ripening crops but exhibiting asynchrony between individuals. However, many exceptions to the classical pattern are being described, particularly among dioecious Ficus species.

Ficus species constitute probably the most important group of keystone plant resources. This may also be true in Panama (Windsor *et al.* 1989), but in a Gabon rain forest, fruiting Ficus occur at such low densities that they do not act as keystone plant resources for the majority of frugivorous animals. Nevertheless, circumstantial evidence suggests that Ficus may play a more important role in sustaining frugivores in other African rain forests (Gautier-Hion & Michaloud 1989).

Fig trees have several attributes in addition to seasonality that make them a unique and extremely important of bird dispersed fruit resources (Lambert and Marshall, 1991). Balasubramanian and Bole (1993) states that the family Moraceae is the dominant bird-attracting family in the tropical dry evergreen forest of Point Calimere. Due to the fact that birds are generally more abundant than mammals, birds tend to remove large quantities of seeds, favouring specialization of dispersal syndromes towards their group. As fruit production fluctuates in many tropical forests, certain species fruiting during

periods of fruit scarcity may become "keystone species" (Terborgh, 1986b). Through out the tropics, fig fruiting occurs year-round making figs an indispensable resource for tropical frugivores (Kinnaird *et al.* 1996).

Ficus is heavily dependent on the frugivores to disperse their seeds (Lambert 1989a). Seed dispersal by animals ensures the long-term survival of many Ficus species. Such ecological processes provided by the frugivores may also determine the Ficus species and genetic composition in the disturbed landscapes (Corlett 1995). Thus, the patterns of visit by frugivores may influence the succession in disturbed areas such as the forest edge or gaps. On the other hand, the presence of fruiting trees in the disturbed landscapes may maintain the frugivorous faunal communities in these areas (Restrepo *et al.* 1999). Understanding such ecological processes is essential for the conservation of biodiversity and restoration of the disturbed landscapes.

Many fig species are pioneers and play a significant role in forest succession in the tropics (Harrison 2005). It has been suggested that the establishment of Ficus is a critical phase in the reassembly of forests (especially on islands), with plant colonization accelerating after the first figs begin to fruit and thereby to attract seed dispersers carrying the seeds of other species in their guts. They are thus an important resource for maintaining biodiversity outside protected areas, and their loss may result in undesirable ecological regime shifts.

Avian frugivores and invasive plant species

Invasive alien plants are non-native, naturalized species that have successfully spread outside of their native range (Richardson *et al.* 2000). Invasive plant species that have the greatest impact on natural habitats are often trees or shrubs that are shade tolerant, grow rapidly, reproduce early, produce numerous seeds, and have fleshy fruits associated with bird-dispersal (Cronk and Fuller 1995). Birds are recognized as the main dispersal agent of several invasive plant species (Renne *et al.* 2002). Despite this, our understanding of how birds contribute to the success of invasive alien plants is limited, leading to ineffective management of invasive plant spread.

Invasive plant dispersal by birds can be via generalized mutualistic or non-mutualistic relationships. Mutualistic spread occurs through intentional fruit consumption and subsequent seed dispersal. In this review, we consider bird-dispersed invasive plants within the framework of mutualistic spread of fleshy-fruited plants (the term 'fleshyfruited' includes berries, drupes, synconiums and arillate seeds and seeds with elaiosomes that are attractive to vertebrate dispersers).

Invasive plant species that have the greatest impact on natural habitats are often trees or shrubs that are shade tolerant, grow rapidly, reproduce early, produce numerous seeds, and have fleshy fruits associated with bird-dispersal (Cronk and Fuller 1995). Many highly invasive plants are fleshy-fruited and owe their invasiveness largely to mutualisms formed with local dispersers. The energetic benefits gained by frugivores from ingestion of fruits of invasive alien plants remain poorly documented. Complex dispersal patterns of fleshy-fruited invasive plants should be expected, as studies in systems without invasive plants emphasize a variety of frugivorous species consuming fruits from a single plant species (Kitamura *et al.* 2002).

The loss of indigenous fruiting species allows invasive alien species to penetrate ecosystems (Lafleur *et al.* 2007). Invasive species are sometimes preferred by frugivores and may therefore compete with native plant species for dispersal agents (Lafleur *et al.* 2007). Many habitats now support both introduced fleshy fruited plants and introduced frugivores creating the potential for non-native species to promote each other's populations (Richardson *et al.* 2000). There are several reasons to be particularly concerned about the addition of non-native species to avian-mediated seed-dispersal systems. Successful plant invasions have been attributed to particular fruit traits that enhance effective seed dispersal, and alien plants that have fruits that are preferred by frugivores are expected to be more invasive (Buckley *et al.* 2006).

Lantana camara L. (Verbenaceae), a native of tropical America is found in 47 countries and has been described as one of the world's ten worst weeds (Cronk & Fuller 1995. *Lantana* was introduced to India in 1807 as an ornamental plant at the National Botanical Garden of Calcutta (Thakur *et al.* 1992). It soon escaped into the wild and has established

itself all over the Indian subcontinent, stretching from the submontane regions of the outer Himalayas to the southernmost part of India. *Lantana* berries attract frugivorous birds and mammals that help to disperse its seeds widely.

Bird species feed on *Lantana* fruits and, in some locations, seed dispersal has been facilitated by the introduction of exotic bird species. By feeding on exotic species, such as Lantana, birds might increase the density and distribution of the species at the expense of native vegetation and might displace other bird species (Loyn & French 1991). *Lantana camara* produce fruits that are purple black drupes (Parsons and Cuthbertson 2001), measuring 5–7 mm in diameter (Sharma *et al.* 2005). These drupes have a thin, wax exocarp and pulpy mesocarp surrounding a single, oval seed, 2–4 mm long (Parsons and Cuthbertson 2001), containing 1–2 embryos (Sharma *et al.* 2005).

The successful spread and establishment of fleshy fruited alien plants is greatly enhanced by the rapid formation of loose mutualisms with resident dispersers (particularly birds and mammals) (Richardson *et al.* 2000). It has been shown that plant invasiveness increases when avian frugivore communities are more diverse (Gosper and Vivian-Smith 2009). Of further concern is the possibility that alien vegetation may compete with indigenous plant species for the attention of dispersal agents (Lafleur *et al.* 2007).

METHODOLOGY

Phenology

A total of 150 individuals of woody species belonging to 30 species (24 tree species and 6 shrubs) were marked with aluminum tags and observed for phenology (Table 1). The phenology of fruit production was observed twice in a month to assess the periodicity of fruiting. During the observation, percentage fruiting was noted for each tagged individual. Phenological observations were carried out for a continuous period of 1 year (November 2006 – October 2007) in the mixed dry deciduous forest, Anaikatty.

In the scrub forest, a total of 110 individuals belonging to 22 species were marked and observed for phenology (Table 2). Phenological observations were carried out 1 year (December 2008 – December 2009) in the scrub forest.

Table 1. Woody species tagged for phenology studies in tropical mixed dry deciduous forest, Anaikatty

S. No.	Name of the plant	Family
1.	*Azadirachta indica* A.Juss	Meliaceae
2.	*Breynia vitis-idaea* (Burm.f.) Fischer	Euphorbiaceae
3.	*Canthium dicoccum* (Gaertn.) Teijsm. & Binn.	Rubiaceae
4.	*Capparis grandis* L. f.	Capparaceae
5.	*Capparis sepiaria* L.	Capparaceae
6.	*Capparis grandiflora* Wall. ex Hook. f	Capparaceae
7.	*Carmona retusa* (Vahl.) Masamune	Cordiaceae
8.	*Canthium parviflorum* Lam.	Rubiaceae
9.	*Cassine glauca* (Rottb.) O. Ktze.	Celastraceae
10.	*Celtis philippensis* (Planch.) Soep.	Ulmaceae
11.	*Clausena dentata* (Willd.) Roem.	Rutaceae
12.	*Cordia monoica* Roxb.	Cordiaceae
13.	*Cordia obliqua* Willd.	Cordiaceae
14.	*Diospyros ferrea* (Willd.) Bakh *var buxifolia* (Rottb.) Bakh.	Ebenaceae
15.	*Diospyros montana* Roxb.	Ebenaceae
16.	*Ehretia ovalifolia* Wight	Cordiaceae
17.	*Ficus benghalensis* L.	Moraceae
18.	*Ficus racemosa* L.	Moraceae

S. No.	Name of the plant	Family
19.	*Glycosmis pentaphylla* (Retz.) DC.	Rutaceae
20.	*Ixora pavetta* Andr.	Rubiaceae
21.	*Lantana camara* L.	Verbenaceae
22	*Murraya paniculata* (L.) Jacq.	Rutaceae
23.	*Tarenna asiatica* (L.) O. Ktze. ex K. Schum.	Rubiaceae
24.	*Premna tomentosa* Willd.	Verbenaceae
25.	*Santalum album* L.	Santalaceae
26.	*Streblus asper* Lour.	Moraceae
27.	*Strychnos potatorum* L. f.	Loganiaceae
28.	*Syzygium cumini* (L.) Skeels	Myrtaceae
29.	*Ziziphus mauritiana* Lam.	Rhamnaceae
30	*Ziziphus oenoplia* (L.) Mill.	Rhamnaceae

Table 2. Woody species tagged for phenology studies in scrub forest, Thiruporur.

S.No.	Name of the plant	Family
1	*Azadirachta indica* A.Juss.	Meliaceae
2	*Benkara malabarica* (Lam.) Tirveng.	Rubiaceae
3	*Canthium dicoccum* (Gaertn.) Teijsm. & Binn.	Rubiaceae
4	*Carissa spinarum* L.	Apocynaceae
5	*Carissa spinarum* L. *var microphylla* Gamble	Apocynaceae
6	*Carmona retusa* (Vahl.) Masamune	Cordiaceae
7	*Diospyros ferrea* (Willd.) Bakh *var buxifolia* (Rottb.)Bakh.	Ebenaceae
8	*Diospyros ovalifolia* Wight.	Ebenaceae
9	*Ficus benghalensis* L.	Moraceae
10	*Ficus religiosa* L.	Moraceae
11	*Flueggea virosa* (Roxb. ex Willd.) Baill.	Euphorbiaceae
12	*Glycosmis cymosa* (Kurz.) Narayanaswamy.	Rutaceae
13	*Grewia hirsuta* Vahl.	Tiliaceae
14	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae
15	*Manilkara hexandra* (Roxb.) Dubard.	Meliaceae
16	*Melia azedarach* L.	Meliaceae
17	*Memecylon umbellatum* Burm. f.	Memecylaceae
18	*Phoenix pusilla* Gaertn.	Arecaceae
19	*Scutia myrtina* (Burm. f.) Kurz.	Rhamnaceae
20	*Strychnos potatorum* L. f.	Loganiaceae
21	*Syzygium cumini* (L.) Skeels	Myrtaceae
22	*Ziziphus oenoplia* (L.) Mill.	Rhamnaceae

Bird foraging observations

Foraging observation was made by extended bird feeding watches on fruit-bearing plants. Plants with good visibility were selected for extended feeding watches. Observations were made between 6.00 and 9.00 hours on the bird visitation to the focl tree, with the help of binoculars. The visit by each individual bird followed by pecking/swallowing of fruits were considered as a fruit-feeding visit by a bird Certain birds, particularly carnivores and insectivores simply perching on trees were not included in this observation as they are not frugivores. For each species of plant, three individuals were observed for 12 hours each. Thus a total of 36 hours of observations was made for each plant species. Plants selected for observation had drupes, berries or similar soft fruits having one or a few seeds or with composite fruits with many small seeds (Moraceae).

Fruit colour and Fruit size

Colours of ripe fruits for plant species were assigned to one of eight broad colour categories as used by Wheelwright and Janson (1985). Diameter of the fruits were measured using vernier calipers.

Vegetation sampling

Vegetation sampling was done by using quadrat method, since it is the most widely used technique for vegetation sampling. Six, 1 km transects were laid for sampling vegetation. In each transect, 10 quadrats of 10x10 mm were laid. In total 60 quadrats were laid. The woody species measuring more than 20 cms (GBH) were recorded. The plant specimens were identified with the help of Floras, The vegetation data were analysed to obtain quantitative structure and composition of plant communities. For understanding the synthetic characters of the forest vegetation, the species richness, diversity of species in the stands are to be analysed. The vegetational data were quantitatively analysed for density, relative density, following Curtis and MC Intosh (1950).

$$\text{Density} = \frac{\text{Total number of individuals}}{\text{Total number of quadrats examined}}$$

$$\text{Relative density} = \frac{\text{No. of individuals of the species in all quadrats}}{\text{No. of individuals of all species in all quadrats}} = \text{x100}$$

Density values are significant as they show the relative importance of each species in a stand, when they are in similar life form and size. This method is more accurate and allows direct comparison of different areas and is an absolute measure of the abundance of the plant (Kershaw, 1973)

Statistical Analysis

Mean values (± SE) for species richness, number of visits, bird diversity, evenness (Brillouin index); were compared among different plant species using ANOVA. To compare the Mean number of visits of birds Kruskal-Wallis test was used. All calculations were done using SPSS version 16.

TROPICAL MIXED DRY DECIDUOUS FOREST – WESTERN GHATS

RESULTS

Phenology

Phenological observations were made on 30 woody plant species belonging to 16 families during the study period. This included 2 species of figs and 28 species of non-figs. A fruiting peak was observed during June, July and September, with 10 species. Species fruited during June were *Premna tomentosa, Celtis philippensis, Ficus racemosa, Glycosmis pentaphylla, Lantana camara, Cordia obliqua, Syzygium cumini, Ehretia ovalifolia, Diospyros ferrea* var *buxifolia, Murraya paniculata.* Species that fruited during July included *Capparis grandis, Celtis philippensis, Glycosmis pentaphylla, Lantana camara, Breynia vitis-idaea, Cordia obliqua, Syzygium cumini, Ehretia ovalifolia, Diospyros ferrea var buxifolia and Murraya paniculata* (Figure 3). Species in fruits during September were *Lantana camara, Breynia vitis-idaea, Carmona retusa, Ehretia laevis, Diospyros ferrea* var *buxifolia, Santalum album, Diospyros montana, Tarenna asiatica, Capparis grandis and Capparis zeylanica.* A dip was observed during December where only 3 species had fruits, viz. *Breynia vitis-idaea, Ziziphus oenoplia* and *Ziziphus mauritiana* (Figure 3). *Lantana camara* and *Tarenna asiatica* fruits were available throughout the year.The fruiting peak was noticed during July where 49 individuals (31.5%) were fruiting and a dip was noticed in December with 14 individuals (9.3%) in fruiting. (Figure 4)

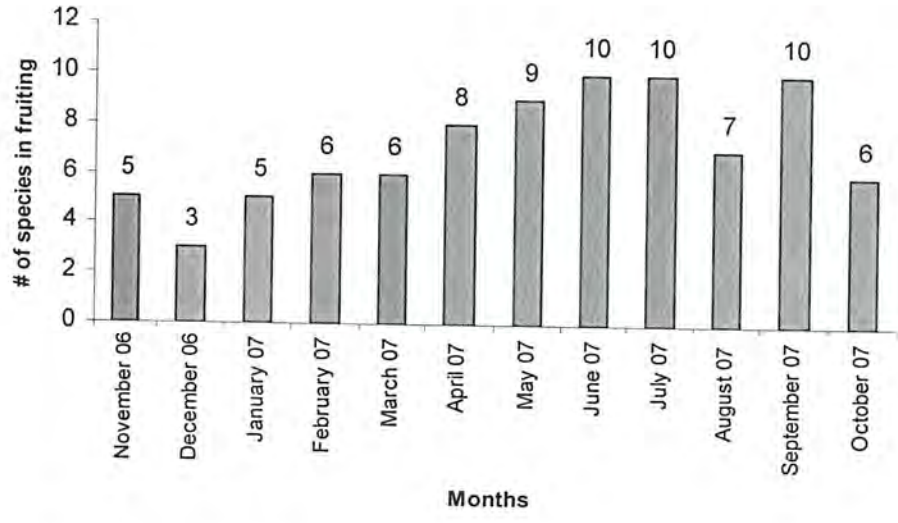


Figure 3. Phenology of fleshy fruited plants in the tropical mixed dry deciduous forest. (# of species in fruiting)

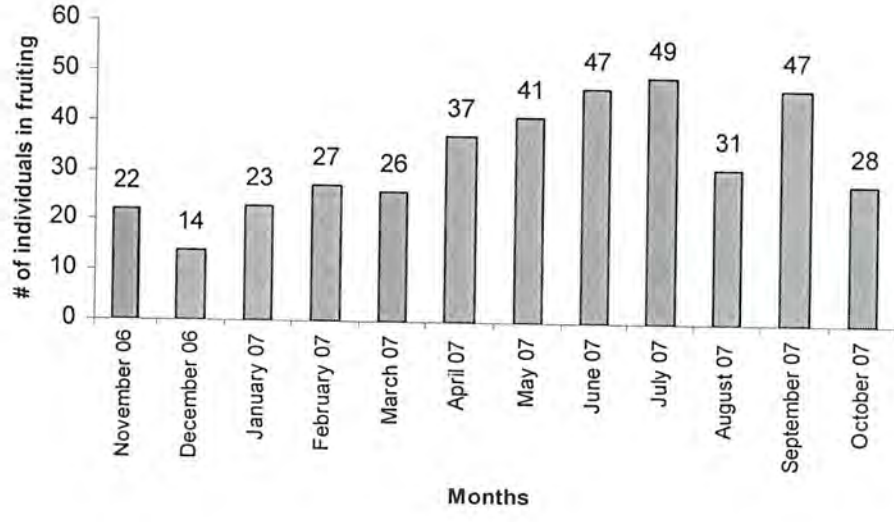


Figure 4. Phenology of fleshy fruited plants in the tropical mixed dry deciduous forest. (# of individuals in fruiting)

The fruiting phenology is discussed with regard to four seasons namely, Summer (March–May), South-west Monsoon (June–August), North-east Monsoon (September–November) and Post Monsoon (December–February). There was a peak in fruiting during the South-west monsoon (21 species) and a dip during Post monsoon (9 species). While summer had 13 fruiting species, north-east monsoon had 14 fruiting species. Fruiting schedule of woody species of the study area is shown in Table 3.

Table 3. Fruiting schedule of various fleshy fruited species in the dry deciduous forest, Western Ghats

S. No.	Botanical name	Summer	South- West Monsoon	North-East Monsoon	Post-Monsoon
1	*Azadirachta indica*		√		
2	*Breynia vitis-idaea*		√	√	
3	*Canthium dicoccum*	√			√
4	*Canthium parviflorum*				√
5	*Capparis sepiaria*		√	√	
6	*Capparis grandiflora*		√	√	
7	*Capparis grandis*		√	√	
8	*Carmona retusa*			√	
9	*Cassine glauca*			√	
10	*Celtis philippensis*	√	√		
11	*Clausena dentata*		√		
12	*Cordia monoica*		√		
13	*Cordia obliqua*		√		
14	*Diospyros ferrea* var *buxifolia*		√	√	
15	*Diospyros montana*		√	√	
16	*Ehretia ovalifolia*		√	√	√
17	*Ficus benghalensis*	√			√
18	*Ficus racemosa*	√	√		
19	*Glycosmis pentaphylla*	√	√		
20	*Ixora pavetta*	√	√		
21	*Lantana camara*	√	√	√	√
22	*Murraya paniculata*		√		
23	*Premna tomentosa*	√	√		
24	*Santalum album*	√		√	√
25	*Streblus asper*	√	√		
26	*Strychnos potatorum*	√			√
27	*Syzygium cumini*	√	√		
28	*Tarenna asiatica*	√	√	√	√
29	*Ziziphus mauritiana*			√	
30	*Ziziphus oenoplia*			√	√

Avian frugivory

Bird dispersed plants

Extended observations were made on 32 plant species belonging to 16 families (Table 4). Fruits of 32 species have been recorded to be dispersed by avian frugivores in the study area, among which Moraceae family constituted 6 plant species (figs and *Streblus asper* 20 %). The genus Ficus (figs) is known for their ability to produce asynchronously and support the avian frugivores during periods of scarcity. The favoured plant species for the avian frugivores were *Ficus benghalensis, Ficus microcarpa* and *Ficus mollis* belonging to the family Moraceae. Moraceae, Rutaceae, Euphorbiaceae, Rubiaceae and Rhamnaceae constituted about 50 % of the frugivore's diet. The least used families were Santalaceae, Meliaceae and Capparaceae. Cordiaceae and Rhamnaceae constituted 3 species (10%) each, while Celastraceae, Ebenaceae, Euphorbiaceae, Meliaceae, Rubiaceae, Rutaceae and Verbenaceae constituted 2 species (6%) each and Boraginaceae, Capparaceae, Flacourtiaceae, Myrtaceae, Santalaceae and Ulmaceae constituted 1 species (3%) each.

Other than figs and *Lantana camara* major bird attracting species *are Benkara malabarica, Cassine glauca, Canthium dicoccum, Flacourtia indica, Pleurostylia opposita, Ziziphus oenoplia, Cordia obliqua, Flueggea virosa, Ziziphus mauritiana, Diospyros montana, Streblus asper* and *Santalum album* (Figure 5).

Table 4. Observed frugivory by birds during extended watches on fleshy fruited trees

S.No	Plant Name	Family	Fruit colour	Fruit type	Fruit size (cm)	# of bird species visited
1	*Azadirachta indica*	Meliaceae	Yellow	Drupe	1.76	2
2	*Benkara malabarica*	Rubiaceae	Black	Drupe	1.76	17
3	*Breynia vitis-idaea*	Euphorbiaceae	Black	Capsule	1.17	9
4	*Canthium dicoccum*	Rubiaceae	Black	Drupe	1.76	15
5	*Capparis grandis*	Capparaceae	Red	Berry	2.34	1
6	*Carmona retusa*	Cordiaceae	Brown	Drupe	0.94	7
7	*Cassine glauca*	Celastraceae	Black	Capsule	1	17
8	*Cetis philippensis*	Ulmaceae	Red	Drupe	0.94	7
9	*Cipadessa baccifera*	Meliaceae	Red	Drupe	0.59	8
10	*Clausena dentata*	Rutaceae	Black	Berry	0.94	7
11	*Cordia monoica*	Cordiaceae	Orange	Drupe	0.6	1
12	*Cordia obliqua*	Cordiaceae	Yellow	Drupe	1.17	11
13	*Diospyros ferrea var buxifolia*	Ebenaceae	Orange	Berry	0.5	6
14	*Diospyros montana*	Ebenaceae	Orange	Berry	1.76	10
15	*Ehretia laevis*	Boraginaceae	Red	Drupe	0.4	6
16	*Ficus benghalensis*	Moraceae	Red	Syconium	1.17	21
17	*Ficus microcarpa*	Moraceae	Pink	Syconium	0.25	17
18	*Ficus mollis*	Moraceae	Yellow	Syconium	0.7	8
19	*Ficus racemosa*	Moraceae	Red	Syconium	2.5	10
20	*Ficus religiosa*	Moraceae	Pink	Syconium	1.17	6
21	*Flacourtia indica*	Flacourtiaceae	Black	Berry	1.76	15
22	*Flueggea virosa*	Euphorbiaceae	White	Capsule	0.5	11
23	*Lantana camara*	Verbenaceae	Black	Drupe	0.23	11
24	*Naringi crenulata*	Rutaceae	Black	Berry	0.7	5
25	*Pleurostylia opposita*	Celastraceae	White	Capsule	0.4	15
26	*Premna tomentosa*	Verbenaceae	Black	Drupe	0.5	6
27	*Santalum album*	Santalaceae	Black	Drupe	0.94	8
28	*Scutia myrtina*	Rhamnaceae	Blue	Drupe	1.17	7
29	*Streblus asper*	Moraceae	Yellow	Syconium	1.4	9
30	*Syzygium cumini*	Myrtaceae	Black	Berry	1.64	7
31	*Ziziphus mauritiana*	Rhamnaceae	Red	Drupe	1	11
32	*Ziziphus oenoplia*	Rhamnaceae	Black	Drupe	0.6	14

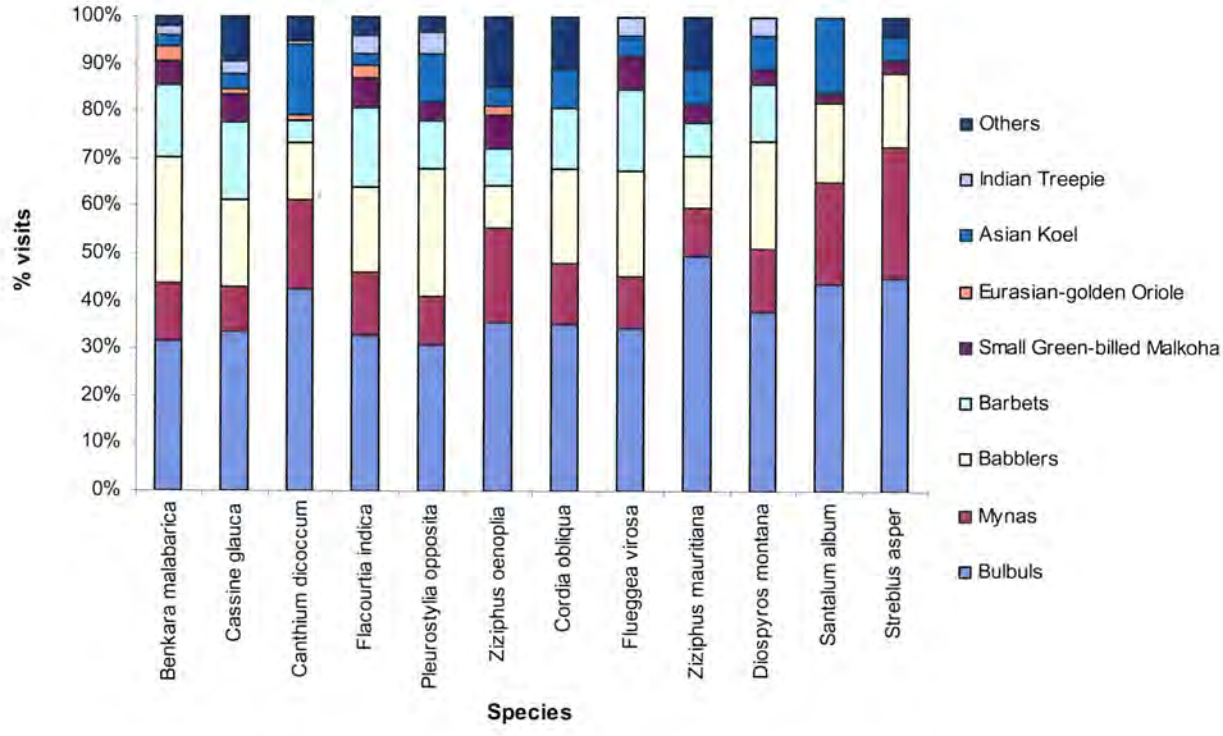


Figure 5. Percentage of visits by avian frugivores to important fleshy fruited plant species in the tropical mixed dry deciduous forest

Figs – Keystone species

A total of 24 bird species were feeding on figs (5 species). Highest number of bird species was observed on *F. benghalensis* (21 species) followed by 17 species on *F. microcarpa*, 10 on *F.racemosa*, 8 on *F.mollis* and 6 species on *F.religiosa*. Eighteen species of residents and 3 species of local migrants ate *F. benghalensis* fruits, while 15 species of residents and 2 species of local migrants fed on *F.microcarpa*. *F.racemosa* fruits were consumed by 8 species of residents and 2 local migrants. *F.mollis* and *F. religiosa* were consumed by residents only.

Ficus benghalensis

A total of 370 feeding visits were recorded on *F. benghalensis*. The most common species that fed on *F. benghalensis* was Red-vented Bulbul *Pycnonotus cafer* followed by Coppersmith Barbet *Megalaima haemacephala* and Common Myna *Acridotheres tristis*.

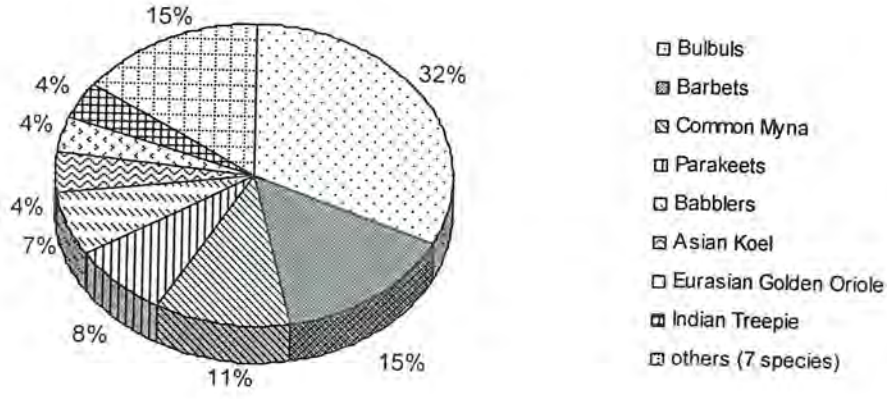


Figure 6. Avian frugivores of *Ficus benghalensis*

Bulbuls (4species; *Pycnonotus cafer, Pycnonotus jocosus, Pycnonotus luteolus and Hypsipetes madagascariensis*) contributed 32% of the visits, while barbets (2 species *Megalaima haemacephala* and *Megalaima zeylanica*) made 15% and Common Myna 11% (Figure 6). *Ficus benghalensis* attracted maximum number of avian frugivores in the study area, a total of 21 species of birds consumed these figs.

Ficus microcarpa

A total of 252 feeding visits were recorded on *F. microcarpa.* The most common visitor was Red-whiskered Bulbul *(Pycnonotus jocosus)* followed by White-browed Bulbul (*Pycnonotus luteolus)* and Red-vented Bulbul *(Pycnonotus cafer)* belonging to the family Pycnonotidae.

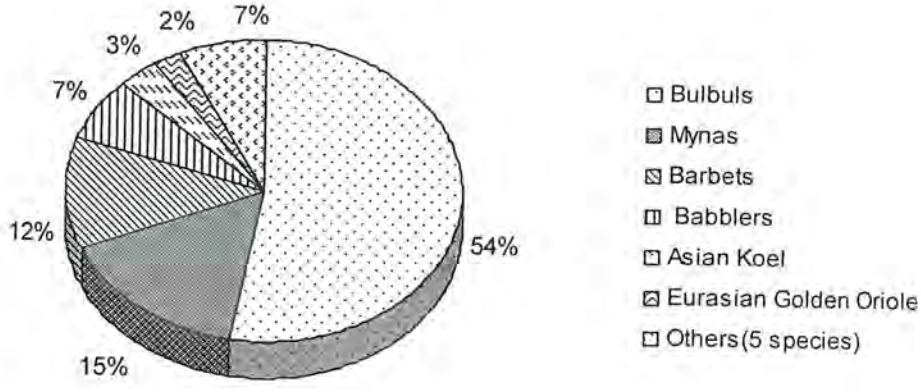


Figure 7. Avian frugivores of *Ficus microcarpa*

Bulbuls (4 species; *Pycnonotus cafer, Pycnonotus jocosus, Pycnonotus luteolus* and *Hypsipetes madagascariensis*) contributed (54%) majority of the visits, followed by mynas (2 species; *Acridotheres tristis* and *Sturnus pagodarum*) (15%) and barbets (2 species, *Megalaima haemacephala* and *Megalaima zeylanica*) (12%) (Figure 7). *F. microcarpa* was visited by 17 species of frugivorous birds.

Ficus racemosa

A total of 205 feeding visits were recorded on *F. racemosa.* The most frequent visitors include Red-whiskered Bulbul *(Pycnonotus jocosus)* followed by White-browed Bulbul (*Pycnonotus luteolus)* and Red-vented Bulbul *(Pycnonotus cafer)* of the family Pycnonotidae.

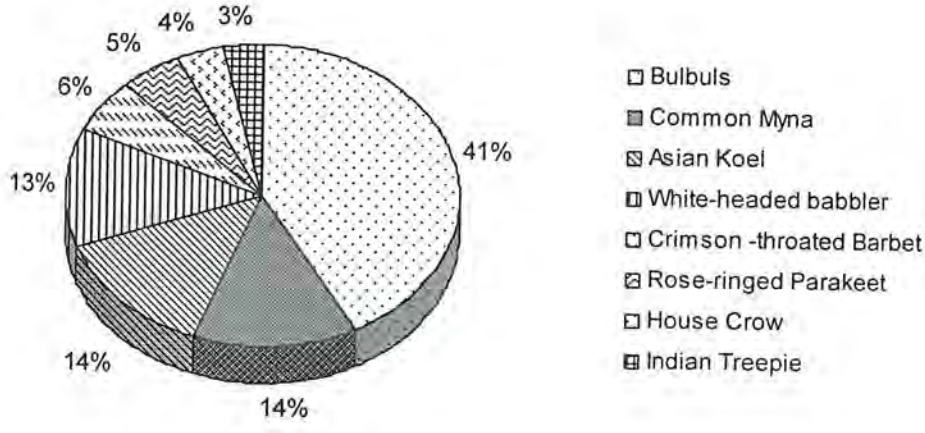


Figure 8. Avian frugivores of *Ficus racemosa*

Bulbuls (3 species; *Pycnonotus cafer, Pycnonotus jocosus,* and *Pycnonotus luteolus*) contributed 41% of the visits, while Common Myna and Asian Koel contributed 14% (Figure 8). *F. racemosa* attracted 10 species of birds.

Ficus mollis

A total of 152 feeding visits were made on *F. mollis*. The most common species that fed on *F. mollis* was White-headed Babbler (*Turdoides affinis)* of the family Muscicapidae followed by Common Myna *Acridotheres tristis* (Sturnidae) and White-browed Bulbul *Pycnonotus luteolus,* (Pycnonotidae).

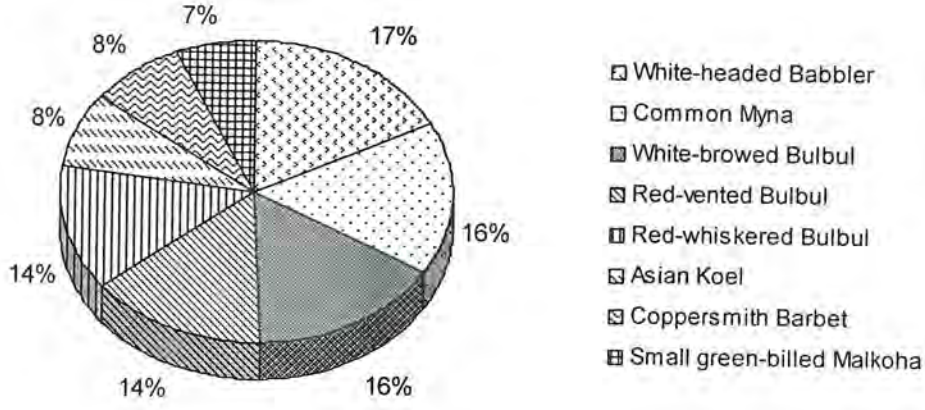


Figure 9. Avian frugivores of *Ficus mollis*

White-headed Babbler (*Turdoides affinis)* contributed 17 % visits, while Common Myna 16 % and White-browed Bulbul contributed 16 % (Figure 9). A total of eight species of birds consumed *F. mollis* fruits.

Ficus religiosa

A total of 172 feeding visits were made on *F. religiosa.* The most common species that consumed *F. religiosa* were White-browed Bulbul *(Pycnonotus luteolus)* and Red-vented Bulbul *(Pycnonotus cafer)* and White-headed Babbler (*Turdoides affinis*).

White-browed Bulbul contributed 25 % of the visits, while Red-vented Bulbul contributed 21 % and White-headed Babbler 19 % (Figure 10). A total of *6* species consumed the fruits of *F. religiosa.*

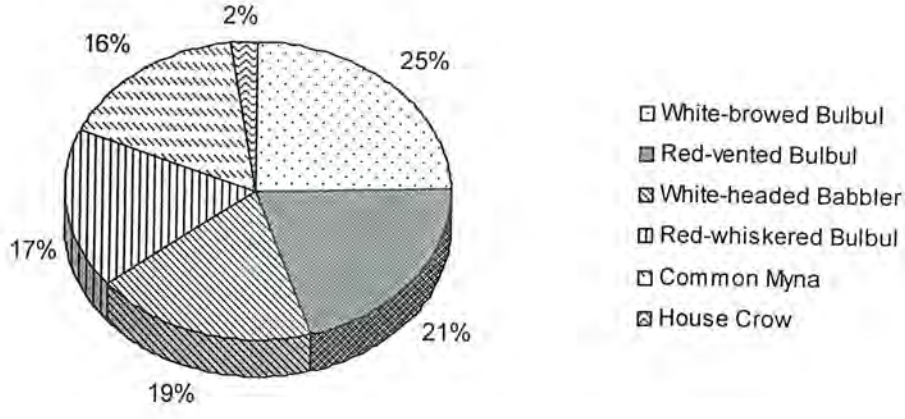


Figure 10. Avian frugivores of *Ficus religiosa*

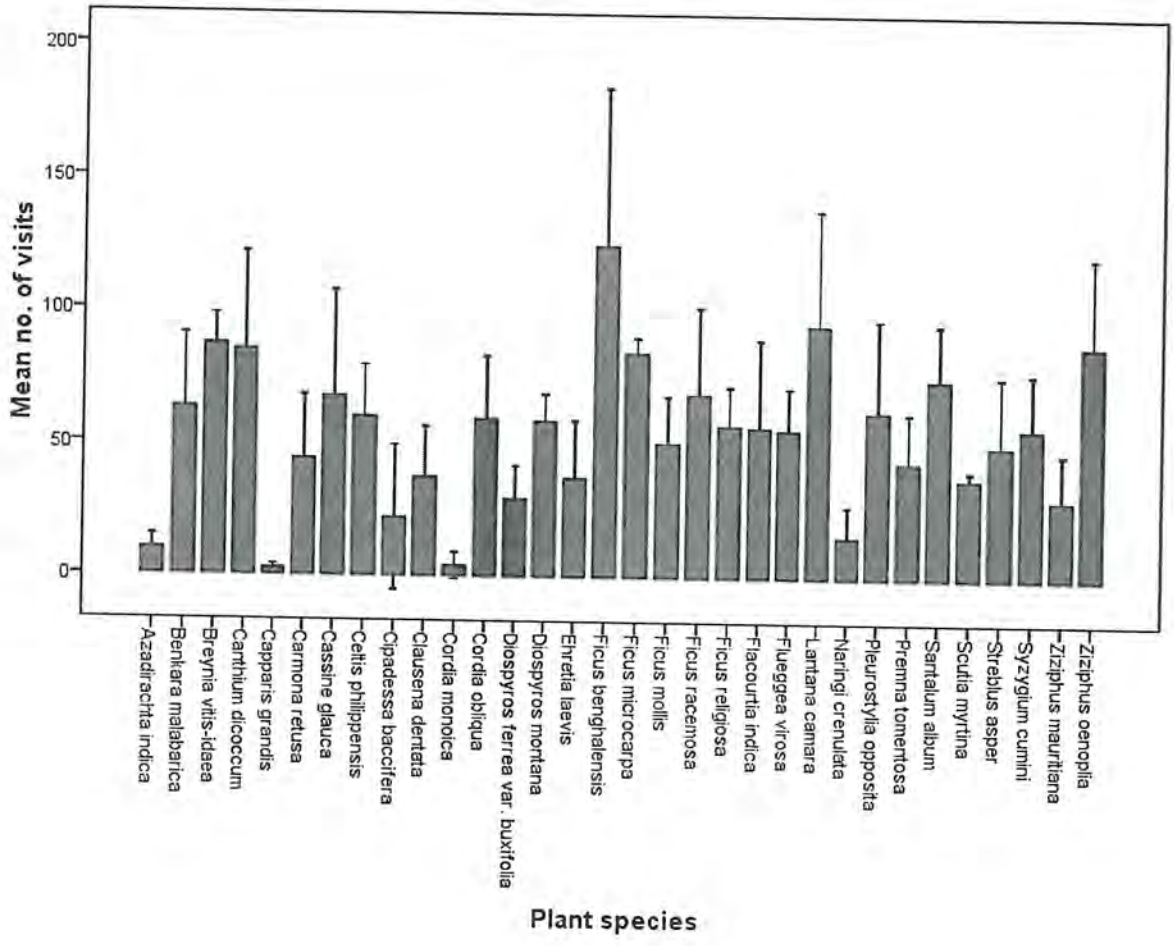


Figure 11. Mean number of visits on 32 fleshy fruited plant species (values in panels are mean ± SE) in the tropical mixed dry deciduous forest.

Mean number of visits of birds were highest for *F. benghalensis* (124.67 ± SE 13.69), than other thirty one plant species, and the mean number of visits of birds differed significantly between the tree species ($F_{31, 64} = 22.653$, $P < .000$) (Figure.11). The top ten fleshy fruited plant species that attracted avian frugivores in terms of mean number of visits are *Lantana camara* (95.00± SE 10.01), *Ziziphus oenoplia* (87.67± SE 7.68), *Breynia vitis-idaea* (87.00± SE 2.64), *Canthium dicoccum* (85.00± SE 8.50), *Ficus microcarpa* (84.33± SE 1.33), *Santalum album* (74.67± SE 4.80), *Ficus racemosa* (69.00± SE 7.54), *Cassine glauca* (67.67± SE 9.17) and *Benkara malabarica* (63.33± SE 6.38).

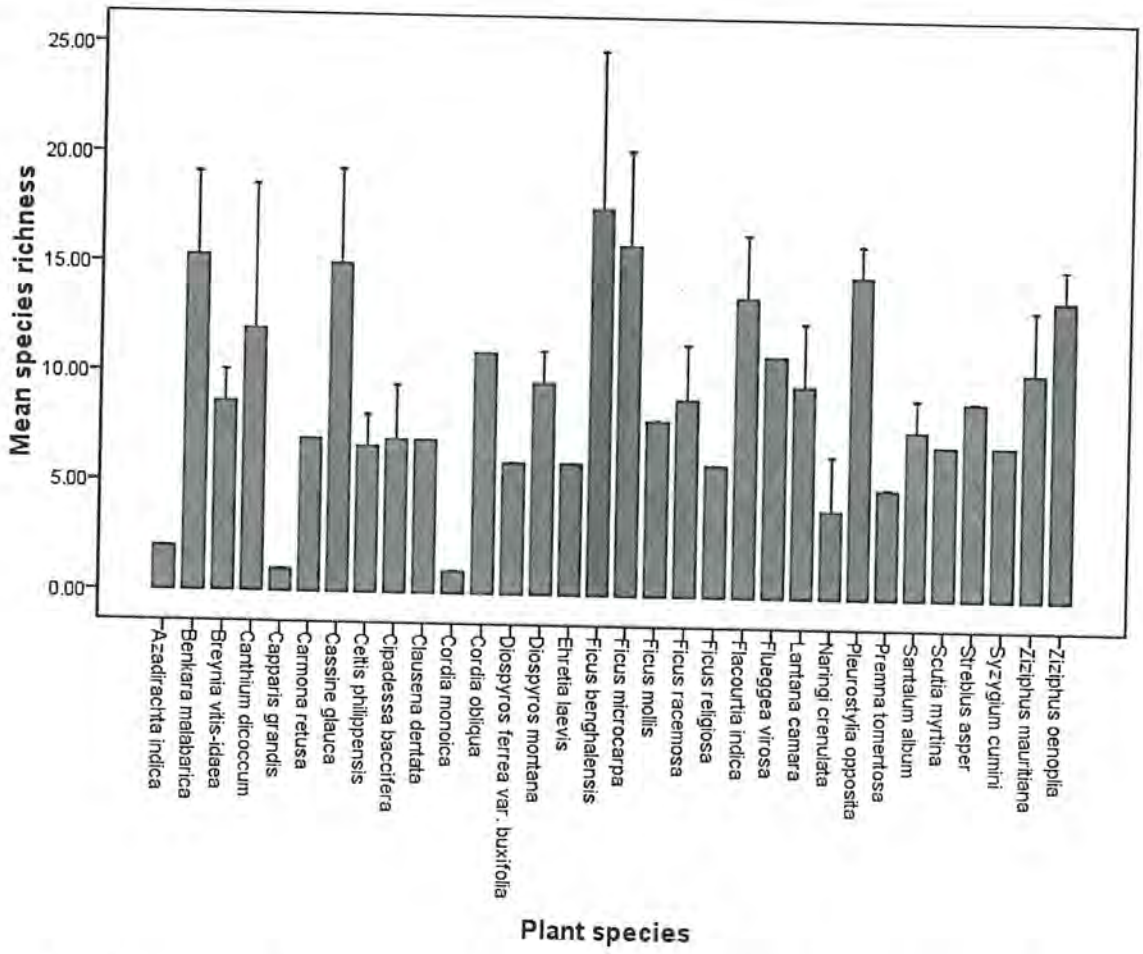


Figure 12. Mean species richness of 32 fleshy fruited plant species (values in panels are mean ± SE) in the tropical mixed dry deciduous forest

Mean species richness of birds were higher in *Ficus benghalensis* (17.67± SE 1.66), than other 31 fleshy fruited plant species and the mean species diversity of birds differed significantly between the tree species ($F_{31, 64} = 53.897$, $P < .000$) (Figure.12). The top ten fleshy fruited plant species that attracted avian frugivores in terms of mean species diversity are *Ficus microcarpa* (14.66± SE 1.00), *Benkara malabarica* (15.33± SE 0.88), *Cassine glauca* (15± SE 1.00), *Pleurostylia opposita* (15± SE 0.33), *Flacourtia indica* (13.66± SE 0.66), *Canthium dicoccum* (12± SE 1.52), *Ziziphus oenoplia* (13.66± SE 0.33), *Ziziphus mauritiana* (10.33± SE 0.66) and *Lantana camara* (9.66± SE 1.15) (Fig.13).

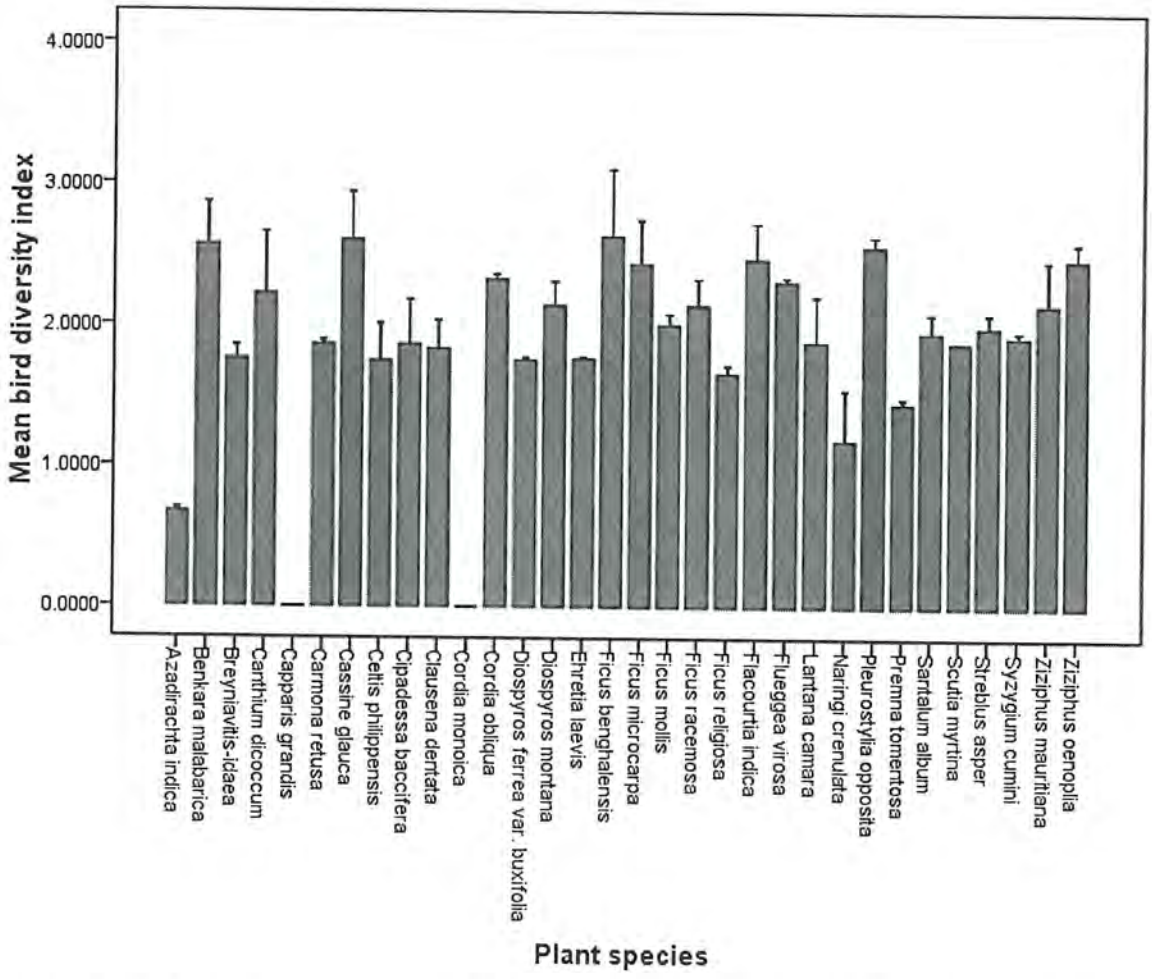


Figure 13. Mean bird diversity index of 32 fleshy fruited plant species (values in panels are mean ± SE) in the tropical mixed dry deciduous forest

Mean bird diversity index on tree species were higher on *F. benghalensis* (2.63± SE 0.11) than other 31 fleshy fruited plant species and the mean bird diversity of birds differed significantly between the tree species ($F_{31, 64}$ =172.352, P< .000), followed by *Cassine glauca* (2.60± SE 0.78), *Benkara malabarica* ,(2.57± SE 0.69), *Pleurostylia opposita* (2.56± SE 0.16), *Flacourtia indica* (2.47± SE 0.59), *Ziziphus oenoplia* (2.47± SE0.27), *Ficus microcarpa* (2.43± SE 0.71), *Cordia obliqua* (2.32± SE 0.007), *Flueggea virosa* (.31± SE 0.007) and *Canthium dicoccum* (2.22± SE 0.10) in the mixed dry deciduous forest (Figure.13).

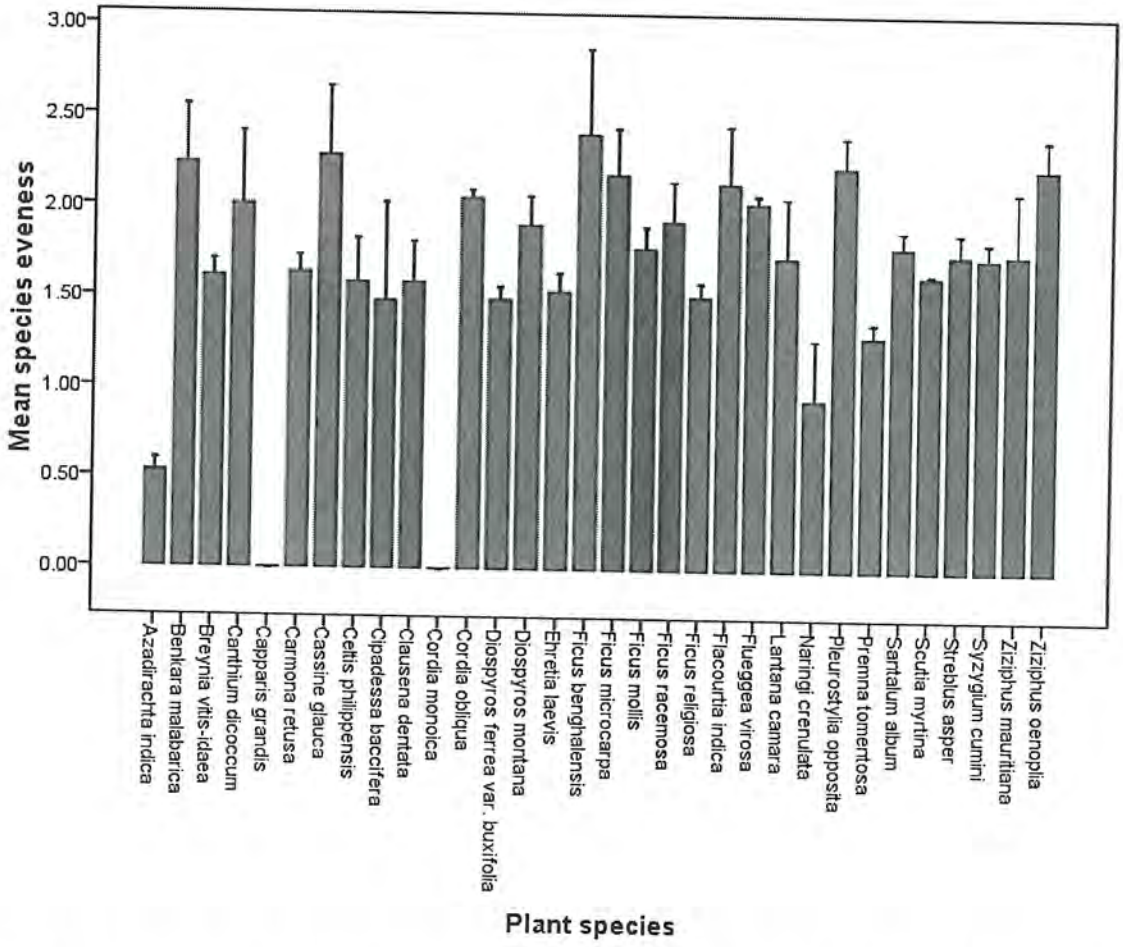


Figure 14. Mean bird species eveness of 32 fleshy fruited plant species (values in panels are mean ± SE) in the tropical mixed dry deciduous forest.

Mean bird species evenness on tree species were higher on *F. benghalensis* (2.40± SE 0.10) than other 31 fleshy fruited plant species and the mean bird species evenness of birds differed significantly between the tree species ($F_{31, 64}$ =114.952, P< .000), followed by *Cassine glauca* (2.28± SE 0.88), *Benkara malabarica* (2.23± SE 0.07), *Ziziphus oenoplia* (2.22± SE 0.03), *Pleurostylia opposita* (2.22± SE 0.03), *Flueggea virosa* (2.02± SE 0.009) *Ficus microcarpa* (2.18± SE 0.05), *Cordia obliqua* (2.05± SE 0.01), *Canthium dicoccum* (2.01± SE 0.09) and *Ficus racemosa* (1.92± SE 0.05) in the mixed dry deciduous forest (Figure.14).

Frugivory by birds on the exotic weed *Lantana camara*

A total of 36 hours of observation were made on *L. camara*. A total of 285 feeding visits was made by birds. 11 bird species were recorded to feed on these fruits. Bulbuls were the most frequent visitors (63%), followed by mynas (27%), babblers (10%). Red-vented Bulbul made maximum number of visits (26%), followed by Common Myna (22%) and Red-whiskered Bulbul (16%) (Figure 15).

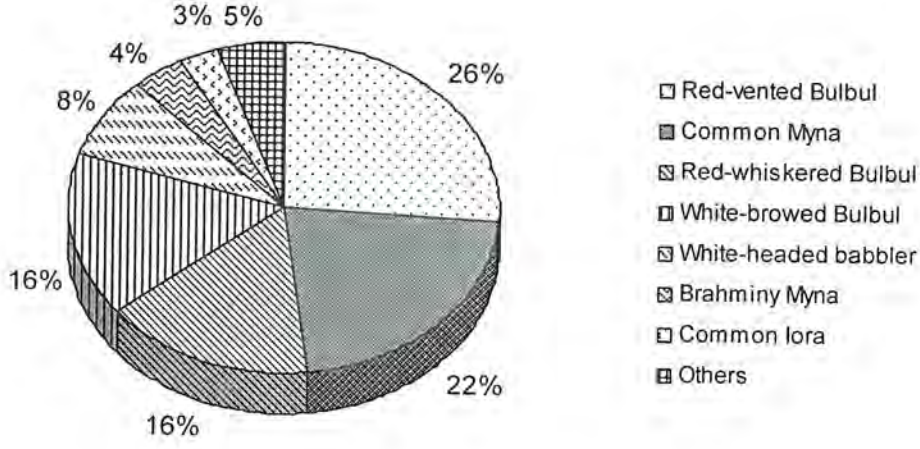


Figure 15. Avian frugivory on exotic *Lantana camara*.

Morphological classification of bird-dispersed fruits

The fruit types of all the 32 species were determined. Drupes were the predominant fruit type borne by 15 species (47%) while berries were borne on 7 species (22%), synconium 6 species (19%) and capsule 4 species (12%).(Figure 16)

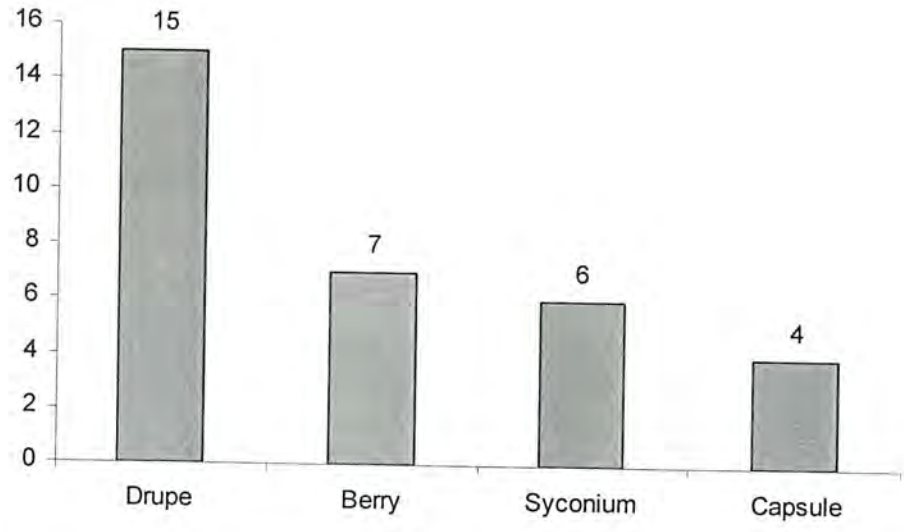


Figure 16. Morphological classification of bird-dispersed fruits in the tropical mixed dry deciduous forest (n=32).

Fruit Colour

Fruit colour analysis showed that 11 species produced black fruits (35%), 8 species (25%) constituted red colour and 7 species (22%) constituted yellow colour (Table 5).

Table 5. Colours of bird-dispersed plants in the study area

S.No	Colour category	# of plant species	%
1	Black	12	38
2	Red	7	22
3	Yellow	4	13
4	Orange	3	9
5	Pink	2	6
6	White	2	6
7	Blue	1	3
8	Brown	1	3

Frugivores favoured black fruits (45%) followed by red (20%) and yellow (12%) (Figure 17).

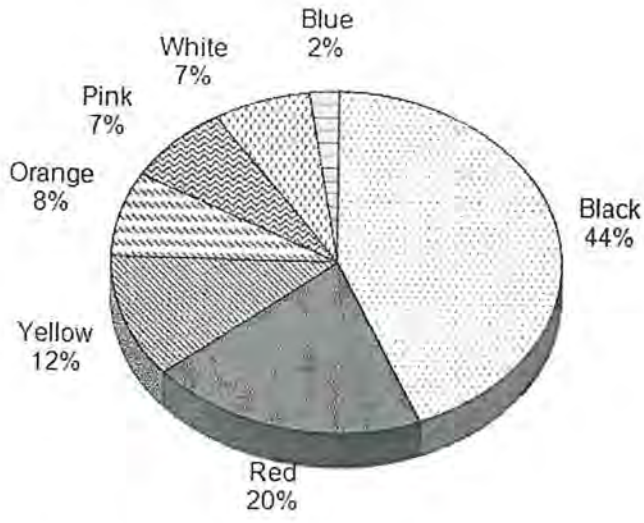


Figure 17. Dominant fruit colours of bird dispersed fruits

Fruit size

Analyses of the fruit diameter revealed that 16 species (50%) had their fruit size > 10 mm. while 14 species (44%) bore fruits in the size range 10-20 mm, 2 species (6%) in the range of 20-30 mm. (Fig 18.) Plants of families Verbenaceae, Boraginaceae, Rutaceae, Ulmaceae, Euphorbiaceae and Ebenaceae produced small fruits, while plants of families Flacourtiaceae, Meliaceae, Capparaceae, Rhamnaceae, Myrtaceae and Rubiaceae produced large fruits. Moraceae family produced both small (*Ficus microcarpa*) and large fruits (*Ficus racemosa*).

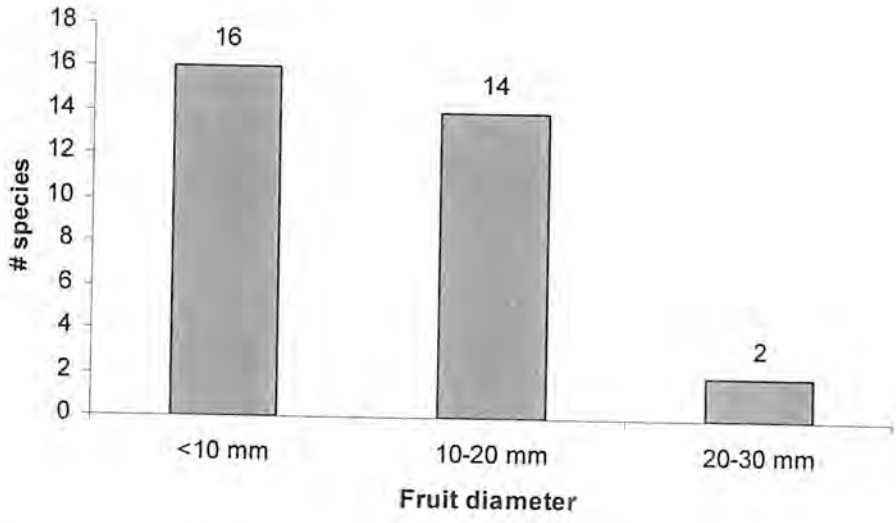


Figure 18. Fruit size classification of bird-dispersed fruits (n=32).

Preference of fruit size by birds

The fruit types were recognized in the study area namely small size <10mm, medium size 10-20 mm and big size (20-30mm). Small-sized fruits attracted majority of the avian frugivores (50%), followed by medium sized fruits (44%) and big sized fruits (6%). Bulbuls favoured small sized fruits (51%), followed by medium sized fruits (45%) and larger fruits (4%). Asian Koel favoured both small sized fruits (50%), followed by medium sized fruits (42%).

Common Myna favoured medium sized fruits (49%) followed by small sized fruits (47%) large sized fruits (4%). Babbler favoured medium sized fruits 52% followed by small sized fruits 45% and large sized fruits (3%). Oriole favoured medium sized fruits (67.4%) and small sized fruits (32.6%). Barbets favoured 68.3% medium sized fruits, 28.4% small sized fruits, large sized fruits (3.3%).

Avian frugivores

A total of 28 bird species belonging to 13 familes have been documented to eat fruits in the study area. Bird species of families Pycnonotidae (bulbuls) contributed to maximum number of frugivorous species (5 species; *Pycnonotus cafer, Pycnonotus jocosus, Pycnonotus luteolus, Pycnonotus priocephalus* and *Hypsipetes madagascariensis*).

While Capitonidae (barbets) with 3 species (*Megalaima haemacephala, Megalaima rubricapilla* and *Megalaima zeylanica*) and Muscicapidae with 4 species (*Acrocephalus dumetorum, Turdoides affinis, Turdoides striatus and Turdoides subrufus*). Major frugivores in the study area include Red-whiskered Bulbul and Red-vented Bulbul of the family Pycnonotidae that visited 29 plant species, followed by Common Myna (Sturnidae), White-browed Bulbul (Pycnonotidae), White-headed Babbler (Muscicapidae) that visited 28 plant species, and Asian Koel (Cuculidae) 27 plant species.

Major frugivorous birds

In the tropical mixed dry deciduous forest, Red-vented Bulbul constituted the most dominant avian frugivore which contributed 15% of feeding visits, and also used fruits of 29 species in the diet. This was followed by Red-whiskered Bulbul 15 % visits, with 29 species in its diet, and White-browed Bulbul utilized 14% of the feeding visits with 28 species in its diet. Common Myna contributed 14% of the feeding visits with 28 species in its diet White-headed Babbler contributed 11% visits, utilized 28 species in the diet (Table 6). The list of avian frugivores and the number of fruit species consumed are given in Table 7.

Table 6. Avian frugivory observed in the tropical mixed dry deciduous forest

S.No	Bird Name	Scientific Name	No. of visits	%	Body mass (g)
1	Red-vented Bulbul	*Pycnonotus cafer*	781	15	35
2	Red-whiskered Bulbul	*Pycnonotus jocosus*	747	15	35
3	White-browed Bulbul	*Pycnonotus luteolus*	738	14	35
4	Common Myna	*Acridotheres tristis*	725	14	98
5	White-headed Babbler	*Turdoides affinis*	579	11	67
6	Asian Koel	*Eudynamys scolopacea*	339	6.5	167
7	Coppersmith Barbet	*Megalaima rubricapilla*	205	3.9	38
8	Jungle Babbler	*Turdoides striatus*	141	2.7	77
9	Small Green-billed Malkoha	*Phaenicophaeus leschenaultii*	118	2.3	114
10	Crimson-throated Barbet	*Megalaima haemacephala*	113	2.2	47
11	Brahminy Myna	*Sturnus pagodarum*	103	1.9	54
12	Indian Tree Pie	*Dendrocitta vagabunda*	71	1.4	128
13	Gold-fronted Chloropsis	*Chloropsis aurifrons*	68	1.3	29
14	Common Iora	*Aegithina tiphia*	60	1.2	14
15	House Crow	*Corvus splendens*	54	1	280
16	Large green Barbet	*Megalaima zeylanica*	49	0.9	87
17	Eurasian Golden Oriole	*Oriolus oriolus*	43	0.8	65
18	Rose-ringed Parakeet	*Psittacula krameri*	42	0.8	139
19	Black Bulbul	*Hypsipetes madagascariensis*	41	0.8	35
20	Blue-winged Parakeet	*Psittacula columboides*	39	0.7	100
21	Indian Rufous Babbler	*Turdoides subrufus*	33	0.6	67.5
22	Indian Peafowl	*Pavo cristatus*	16	0.3	3000
23	Great Tit	*Parus major*	13	0.2	12
24	Tickell's Flower Pecker	*Dicaeum erythrorhynchos*	12	0.2	6.2
25	Grey-headed Bulbul	*Pycnonotus priocephalus*	8	0.6	35
26	Grey Jungle Fowl	*Gallus sonneratii*	8	0.2	800
27	Pompadour Green Pigeon	*Treron pompadora*	6	0.1	151
28	Blyth's Reed Warbler	*Acrocephalus dumetorum*	5	0.1	12

Table 7. Number of plant species visited by various avian frugivores the tropical mixed dry deciduous forest

S.No	Common Name	Scientific Name	Order	# of Plant Species
1	Red-whiskered Bulbul	*Pycnonotus jocosus*	Pycnonotidae	29
2	Red-vented Bulbul	*Pycnonotus cafer*	Pycnonotidae	29
3	Common Myna	*Acridotheres tristis*	Sturnidae	28
4	White-browed Bulbul	*Pycnonotus luteolus*	Pycnonotidae	28
5	White-headed Babbler	*Turdoides affinis*	Muscicapidae	28
6	Asian Koel	*Eudynamys scolopacea*	Cuculidae	27
7	Small Green-Billed Malkoha	*Phaenicophaeus leschenaultii*	Cuculidae	17
8	Coppersmith Barbet	*Megalaima rubricapilla*	Capitonidae	14
12	Jungle Babbler	*Turdoides striatus*	Muscicapidae	12
9	Indian Treepie	*Dendrocitta vagabunda*	Corvidae	10
11	Gold-fronted Chloropsis	*Chloropsis aurifrons*	Irenidae	10
10	Large Green Barbet	*Megalaima zeylanica*	Capitonidae	9
13	Crimson-throated Barbet	*Megalaima haemacephala*	Capitonidae	8
17	Eurasian Golden Oriole	*Oriolus oriolus*	Oriolidae	8
14	Common Iora	*Aegithina tiphia*	Irenidae	7
15	Brahminy Myna	*Sturnus pagodarum*	Sturnidae	7
16	House Crow	*Corvus splendens*	Corvidae	7
18	Black Bulbul	*Hypsipetes madagascariensis*	Pycnonotidae	5
19	Rose-ringed Parakeet	*Psittacula karmeri*	Psittacidae	4
20	Blue-winged Parakeet	*Psittacula columboides*	Psittacidae	4
21	Indian Peafowl	*Pavo cristatus*	Megapodiidae	2
22	Indian Rufous Babbler	*Turdoides subrufus*	Muscicapidae	2
23	Grey Jungle Fowl	*Gallus sonneratii*	Megapodiidae	2
24	Blyth's Reed Warbler	*Acrocephalus dumetorum*	Muscicapidae	2
26	Tickell's Flower pecker	*Dicaeum erythrorhynchos*	Dicaeidae	2
25	Great Tit	*Parus major*	Paridae	1
27	Pompadour Green Pigeon	*Treron pompadora*	Columbidae	1
28	Grey-headed Bulbul	*Pycnonotus priocephalus*	Pycnonotidae	1

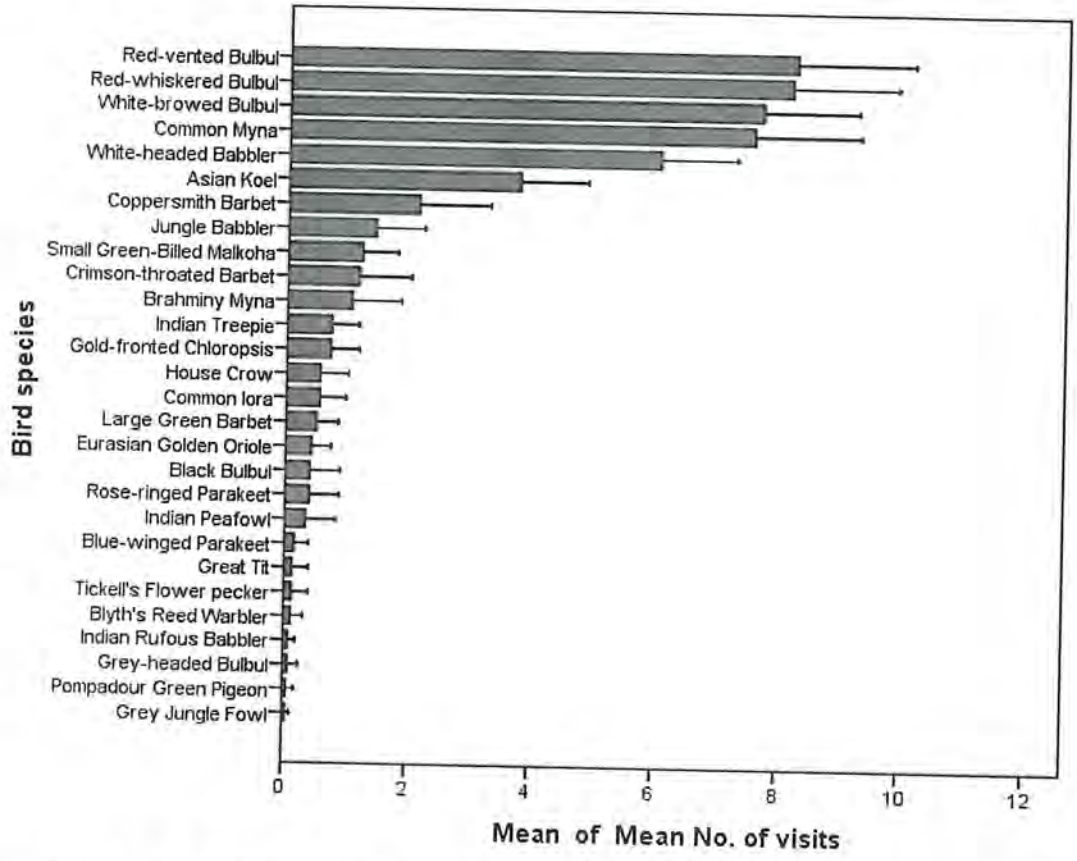


Figure 19. Mean no. of visits of twenty eight bird species (values in panels are mean ± SE) in the tropical mixed dry deciduous forest.

Mean number of visits of birds showed significant variation to the plant species (Kruskal Wallis $\chi 2$= 483.366 df= 27, $p < .000$). The top five avian frugivores in the tropical mixed dry deciduous forest are Red-vented Bulbul (8.24 ± SE 0.96), Red-whiskered Bulbul (8.16± SE 0.87), White-browed Bulbul (7.68 ± SE 0.79), Common Myna (7.55 ± SE 0.87) and White-headed Babbler (6.05± SE 0.60) (Figure.19)

Red-vented Bulbul utilized 29 plant species, among which *Lantana camara* (24.67± SE 2.33), *Ficus benghalensis* (19.33 ± SE 1.85), *Breynia vitis-idaea* (17.00 ± SE 1.73), *Canthium dicoccum* (15.33 ± SE 2.18) and *Ziziphus oenoplia* (13.67 ± SE 1.20) constituted the preferred plant species. Red-whiskered Bulbul consumed 29 species out of which *Breynia vitis-idaea* (19.67 ± SE 0.88), *Santalum album* (15.33± SE 1.85), *Lantana camara* (15.33± SE 2.72), *Ficus microcarpa* ((14.00± SE 1.45) and *Ficus benghalensis*

(12.67± SE 1.45) formed the preferred species. White-browed Bulbul utilised 28 species, out of which *Breynia vitis-idaea* (16.33 ± SE 0.88), *Lantana camara* (15.33± SE 1.76), *Ficus religiosa* (14.00± SE 1.00), *Celtis philippensis* (14.00± SE 1.52) and *Premna tomentosa* (14.00 ± SE 2.08) formed the dominant plant species. Of the 28 species consumed by Common Myna *Breynia vitis-idaea* (23.00 ± SE 1.15), *Lantana camara* (20.67± SE 1.45), *Ficus benghalensis* (13.67± SE 1.45), *Ziziphus oenoplia* (10.67 ± SE 1.45) and *Ficus racemosa* (9.33± SE 0.33) formed the preferred plant species. White-headed Babbler utilized 28 species, of which *Santalum album* (12.67± SE 1.76), *Ficus religiosa* (10.67 ± SE 0.33), *Diospyros montana* (10.67 ± SE 0.667), *Celtis philippensis* (10.67± SE 1.33) and *Canthium dicoccum* (9.33± SE 0.33) formed the preferred plant species (Appendix.1).

Bird size

The body mass varied considerably among avian frugivores (range 6.2-3000 g; Figure 17) Indian Peafowl was the heaviest followed by House Crow, Asian Koel and Pompadour Green Pigeon. Thirteen species were in the range of 6.2-50g, seven species in the range of 50-100 g, while 3 species 100-150g. Two species weighed 150-200g and three species weighed greater than 200g. From this data, it is very clear that the avian frugivores in this study area were light weighted (Figure.20).

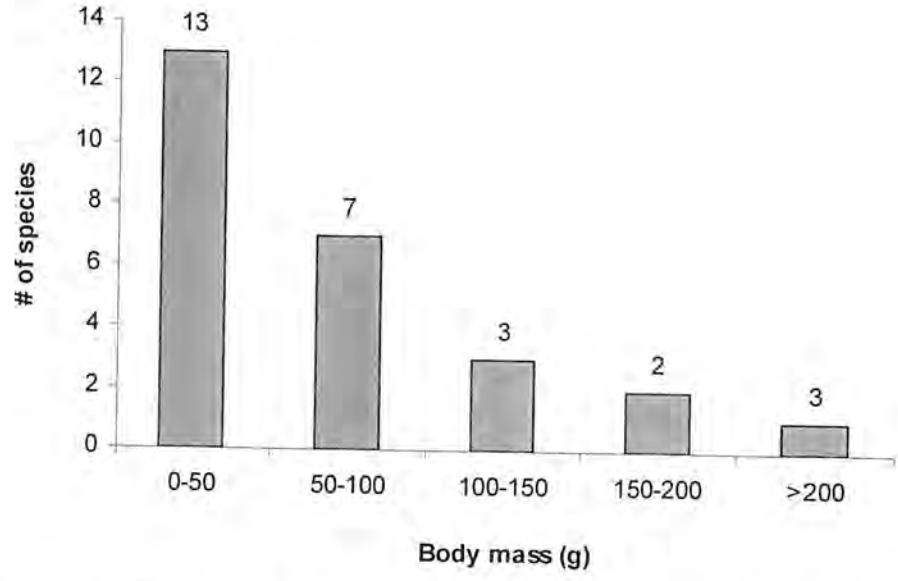


Figure 20. Body size of avian frugivores of the tropical mixed dry deciduous forest

Vegetation sampling

The regeneration of many forest species is linked to the occurrence of canopy gaps. Based on the gap requirement and general shade tolerance of different species, three regeneration types or guilds can be recognized as early pioneer species, late secondary species and primary species. The establishment, growth, reproduction, longevity and management potential of the species in each group are markedly different. The vegetation sampling results shows that a total of 54 woody plant species were recorded during the study and the density value shows that *Pleiospermium alatum* (Rutaceae) dominates the forest followed *by Cordia monoica, Albizia amara, Atalantia monophylla* and *Maba buxifolia*. A systematic list of the identified plant species is presented in Table 8. Out of 54 plant species, 31 (57.4%) are bird dispersed species.

Plate 3. Fleshy-fruited plants in the mixed dry deciduous forest

Azadirachta indica

Breynia vitis-idaea

Ficus benghalensis

Santalum album

Diospyros ferrea var. buxifolia

Ziziphus oenoplia

Plate 4. Plants attracting avian frugivores

Carmona retusa

Canthium dicoccum

Ficus racemosa

Flueggea virosa

Premna tomentosa

Streblus asper

Plate 5. Avian frugivores in the mixed dry deciduous forest

House Crow on Ficus *benghalensis*

Golden Oriole on *Azadirachta indica*

Red-vented Bulbul on *Premna tomentosa*

Plate 6. Seed dispersal by birds in the study area

Ficus benghalensis

Ficus religiosa

Azadirachta indica

Plate 7. Vegetation sampling, Mixed dry deciduous Forest

Albizia amara

Catunaregam spinosa

Celtis philippensis

Cordia monoica

Bauhinia racemosa

Tarenna asiatica

Table 8. Density of plant species in the tropical mixed dry deciduous forest, Western Ghats.

S.No.	Plant species	No of individuals	Density	Relative density
1	*Pleiospermium alatum* (Wall. ex Wight & Arn.) Swingle	267	4.45	17.72
2	*Cordia monoica* Roxb.*	124	2.07	8.23
3	*Albizia amara* (Roxb.) Boivin.	123	2.05	8.16
4	*Atalantia monophylla* (L.) DC.	97	1.62	6.44
5	*Diospyros ferrea* (Willd.) Bakh *var buxifolia* (Rottb.) Bakh..*	93	1.55	6.17
6	*Phyllanthus polyphyllus* Willd.	90	1.5	5.97
7	*Canthium dicoccum* (Gaertn.) Teijsm. & Binn.*	72	1.2	4.78
8	*Acacia torta* (Roxb.) Craib.	60	1	3.98
9	*Bauhinia racemosa* Lam.	56	0.93	3.72
10	*Celtis philippensis Blanco.* *	52	0.87	3.45
11	*Ziziphus oenoplia* (L.) Mill.*	48	0.8	3.19
12	*Capparis grandis* L. f.*	40	0.67	2.65
13	*Flacourtia indica* (Burm. f.) Merr.*	34	0.57	2.26
14	*Ehretia laevis* Roxb.*	32	0.53	2.12
15	*Chloroxylon swietenia* DC. *	31	0.52	2.06
16	*Alphonsea sclerocarpa* Thw.	29	0.48	1.92
17	*Ixora pavetta* Andr. *	27	0.45	1.79
18	*Grewia disperma* non Rottl. Ex Spreng. *	22	0.37	1.46
19	*Clausena dentata* (Willd.) Roem.*	18	0.3	1.19
20	*Tarenna asiatica* (L.) O. Ktze. ex K. Schum. *	18	0.3	1.19
21	*Manilkara roxburghiana* (Wight) Dubard.	17	0.28	1.13
22	*Diospryos montana* Roxb.*	15	0.25	1.00
23	*Cassine glauca* (Rottb.) O. Ktze. *	13	0.22	0.86
24	*Maytenus ovata* (Wall. ex Wight & Arn.) Loes. *	12	0.2	0.80
25	*Gyrocarpus americanus* non Jacq.	10	0.17	0.66
26	*Pleurostylia opposita* (Wall.) Alston*	9	0.15	0.60
27	*Premna tomentosa* Willd. *	9	0.15	0.60
28	*Capparis sepiaria* L. *	8	0.13	0.53
29	*Benkara malabarica* Lam. *	8	0.13	0.53
30	*Carissa spinarum* L. *	7	0.12	0.46
31	*Euphorbia antiquorum* L.	6	0.1	0.40
32	*Zizyphus xylopyrus* (Retz.) Willd.	6	0.1	0.40
33	*Sapindus emarginatus* Vahl.	6	0.1	0.40
34	*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guill. & Perr.	5	0.03	0.33
35	*Murraya paniculata* (L.) Jacq. *	5	0.08	0.33
36	*Tamarindus indica* L.	5	0.08	0.33
37	*Premna latifolia* Roxb. *	4	0.07	0.27

S.No.	Plant species	No of individuals	Density	Relative density
38	*Santalum album* L. *	4	0.07	0.27
39	*Bombax malabaricum* DC.	3	0.05	0.20
40	*Dichrostachys cinerea* (L.) Wight & Arn.	3	0.05	0.20
41	*Acacia leucophloea* (Roxb.) Willd.	2	0.03	0.13
42	*Commiphora caudata* (Wight & Arn.) Engl.	2	0.03	0.13
43	*Ficus mollis* Vahl. *	2	0.03	0.13
44	*Gardenia resinifera* Roth.	2	0.03	0.13
45	*Ziziphus mauritiana* Lam. *	2	0.03	0.13
46	*Albizia lebbeck* (L.) WIlld.	1	0.02	0.07
47	*Cassia fistula* L.	1	0.02	0.07
48	*Diospryos ebenum* Koenig.	1	0.02	0.07
49	*Ficus benghalensis* L. *	1	0.02	0.07
50	*Flueggea virosa* (Roxb. ex Willd.) Baill. *	1	0.02	0.07
51	*Jatropha curcas* L.	1	0.02	0.07
52	*Mundulea sericea* (Willd.) Cheval.	1	0.02	0.07
53	*Erythroxylum monogynum* Roxb. *	1	0.02	0.07
54	*Strychnos potatorum* L. f. *	1	0.02	0.07

SCRUB FOREST-EASTERN GHATS

RESULTS

Phenology

Fruiting phenology was studied for 22 taxa (21 species, 1 variety) belonging to 13 families. This included 2 species of figs and 20 species of non-figs. A peak was observed during July 2009 with 11 species in fruiting. Species that fruited during July include *Azadirachta indica, Diospyros ovalifolia, Ficus benghalensis, Ficus religiosa, Lannea coromandelica, Diospyros ferrea var buxifolia , Manilkara hexandra, Melia azedarach, Memecylon umbellatum, Strychnos potatorum* and *Syzygium cumini.* A dip was observed during March 2009 where only 2 species had fruits, viz. *Carissa spinarum* and *Ficus benghalensis* (Figure 21). The fruiting peak was noticed during July where 52 individuals (34.6%) were fruiting out of 150 individuals. A dip was noticed in March with 8 individuals (5.3%) in fruits (Figure 22).

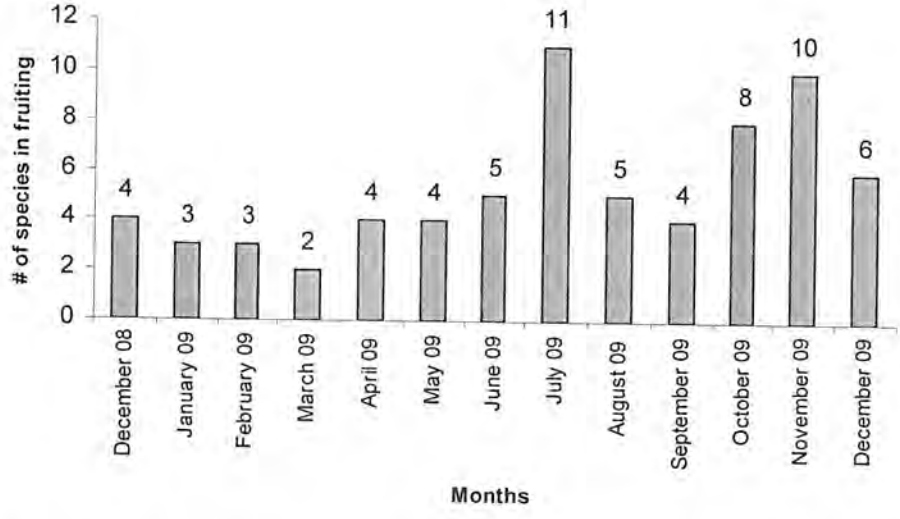


Figure 21. Phenology of fleshy fruited plants in the tropical mixed dry deciduous forest. (# of species in fruiting)

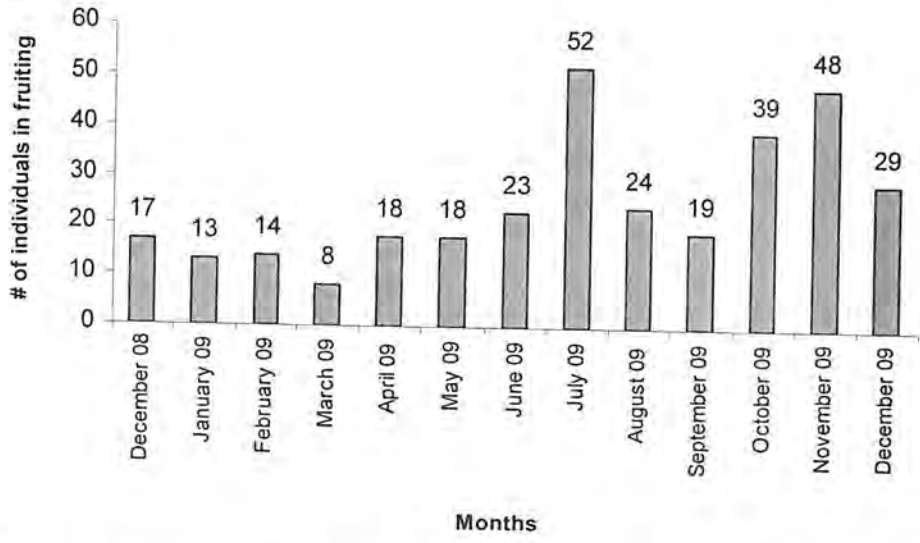


Figure 22. Phenology of fleshy fruited plants in the tropical mixed dry deciduous forest. (# of individuals in fruiting)

The phenology is discussed with regard to four seasons namely, Summer (March–May), South-west Monsoon (June–August), North-east Monsoon (September–November) and Post Monsoon (December–February). A peak was observed in South-west and North-east Monsoon and a dip in summer. (Table 9). Fruiting schedule of fleshy fruited woody plants of the study area are shown in Table 10.

Table 9. Fruiting phenology of woody plants in different seasons, scrub forest.

Season	# species in fruiting		
	Trees	Shrubs	Total
South-west monsoon	10	2	12
Post monsoon	2	5	7
Summer	6	0	6
North-east monsoon	3	9	12

Table 10. Fruiting schedule of fleshy fruited species in scrub forest

S.No.	Name of the plant species	Summer	South-West Monsoon	North-East Monsoon	Post-Monsoon
1	*Azadirachta indica*	√	√		
2	*Benkara malabarica*			√	√
3	*Canthium dicoccum*			√	√
4	*Carissa spinarum*			√	√
5	*Carissa spinarum var microphylla*			√	
6	*Carmona retusa*		√		
7	*Diospyros ferrea var buxifolia*		√	√	
8	*Diospyros ovalifolia*	√	√	√	√
9	*Ficus benghalensis*	√	√	√	
10	*Ficus religiosa*		√		
11	*Fluggea virosa*			√	√
12	*Glycosmis cymosa*			√	
13	*Grewia hirsute*			√	√
14	*Lannea coromandelica*	√	√		
15	*Manilkara hexandra*	√	√		
16	*Melia azedarach*		√		
17	*Memecylon umbellatum*		√	√	
18	*Phoenix pusilla*	√			
19	*Scutia myrtina*			√	
20	*Strychnos potatorum*		√		
21	*Syzygium cumini*		√		
22	*Ziziphus oenoplia*				√

Bird - dispersed plants

Extended feeding observations were made on 21 plant species belonging to 13 families. (Table 11). Moraceae, Rubiaceae, Rhamnaceae constituted the dominant families with 3 species each (14 %) *Ficus benghalensis, Ficus religiosa* and *Ficus racemosa* were found to be the most favoured fruit species in the study area.

Avian frugivory

Other than figs, major bird attracting species in the scrub forest include *Canthium dicoccum, Syzygium cumini, Ziziphus oenoplia, Flacourtia indica, Carissa spinarum, Carmona retusa, Diospyros montana, Lannea coromendelica, Azardirachta indica, Benkara malabarica, Flueggea virosa* and *Diospyros ferrea var buxifolia (*Figure 23).

Table 11. Observed frugivory by birds in the scrub forest.

S.No	Plant Name	Life form	Family	Fruit type	Ripe fruit colour	Fruit size (cm)	# of bird species visited
1	*Azadirachta indica*	Tree	Meliaceae	Drupe	Yellow	1.77	4
2	*Benkara malabarica*	Tree	Rubiaceae	Drupe	Black	1.76	4
3	*Canthium dicoccum*	Tree	Rubiaceae	Drupe	Black	1.75	7
4	*Carissa spinarum*	Shrub	Rubiaceae	Drupe	Black	1.5	5
5	*Carmona retusa*	Shrub	Cordiaceae	Drupe	Brown	0.93	5
6	*Diospyros ferrea var buxifolia*	Shrub	Ebenaceae	Berry	Orange	0.5	4
7	*Diospyros ovalifolia*	Tree	Ebenaceae	Berry	Orange	1.76	5
8	*Ficus benghalensis*	Tree	Moraceae	Synconium	Red	1.15	12
9	*Ficus racemosa*	Tree	Moraceae	Synconium	Red	2	7
10	*Ficus religiosa*	Tree	Moraceae	Synconium	Pink	1.17	9
11	*Flacourtia indica*	Tree	Flacourtiaceae	Berry	Black	1.75	6
12	*Fluggea virosa*	Shrub	Euphorbiaceae	Capsule	White	0.5	4
13	*Glycosmis cymosa*	Shrub	Rutaceae	Berry	Pink	0.94	3
14	*Grewia hirsuta*	Shrub	Tiliaceae	Drupe	Brown	0.8	1
15	*Lannea coromandelica*	Tree	Anacardiaceae	Drupe	Brown	0.94	5
16	*Melia azedarach*	Tree	Meliaceae	Drupe	Yellow	1.76	4
17	*Pleurostylia opposita*	Tree	Celastraceae	*Capsule*	*White*	0.4	4
18	*Scutia myrtina*	Shrub	Rhamnaceae	Drupe	Blue	1.16	3
19	*Syzygium cumini*	Tree	Myrtaceae	Berry	Black	1.62	7
20	*Ziziphus mauritiana*	Tree	Rhamnaceae	Drupe	Red	1.02	3
21	*Ziziphus oenoplia*	Shrub	Rhamnaceae	Drupe	Black	0.62	7

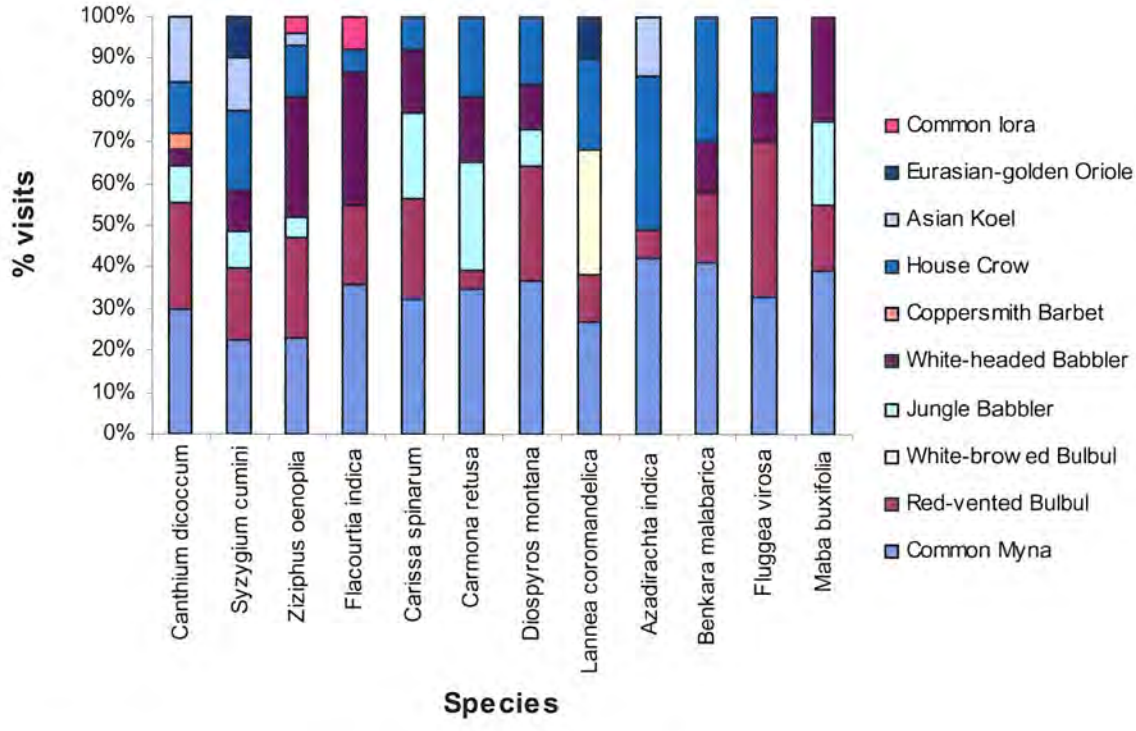


Figure 23. Percentage of visits by avian frugivores to fleshy fruited species in scrub forest

Figs – Keystone species

A total of 12 bird species visited fig plants. Among the figs *F. benghalensis* attracted 12 species, *F.religiosa* attracted 9 and *F.racemosa,* 7 species.

Ficus benghalensis

A total of 540 feeding observations were recorded on *F. benghalensis*. The most common species that consumed *F. benghalensis* was Common Myna *(Acridotheres tristis)*, followed by House crow (*Corvus splendens*), and Red-vented Bulbul *(Pycnonotus cafer)*.

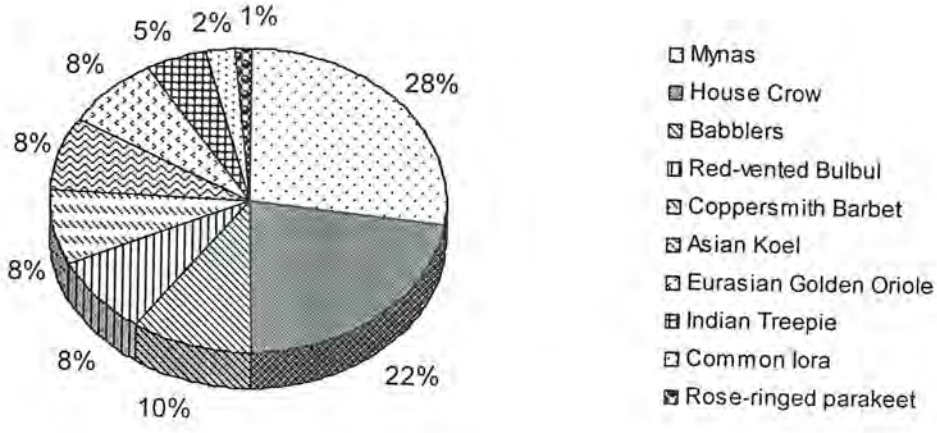


Figure 24. Avian frugivores on *Ficus benghalensis*

Mynas (*Acridotheres tristis and Sturnus pagodarum)* contributed 28% of the visits, while House crow (*Corvus splendens)* contributed 22% and babblers (*Turdoides striatus, Turdoides affinis*) 10% (Figure21). *F. benghalensis* attracted 12 species of birds (Figure.24).

Ficus religiosa

A total of 492 feeding visits were recorded on *F. religiosa.* The most common species that visited *F. religiosa* was Common Myna *(Acridotheres tristis),* followed by Jungle babbler (*Turdoides striatus*) and Red-vented Bulbul *(Pycnonotus cafer).*

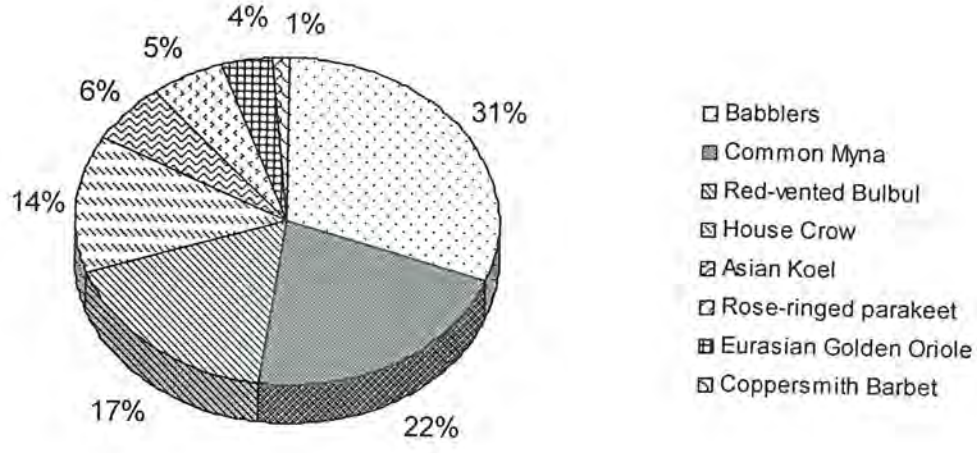


Figure 25. Avian frugivores on *Ficus religiosa*

Babblers (*Turdoides striatus, Turdoides affinis*) contributed 31% of the visits, while Common Myna (*Acridotheres tristis*) contributed 22% and Red-vented Bulbul (*Pycnonotus cafer*) 17% (Figure22). *F. religiosa* attracted 9 species of birds (Figure.25).

Ficus racemosa

A total of 357 feeding visits were recorded on *F. racemosa.* The most frequent visitors to *F. racemosa* include Red-vented Bulbul *(Pycnonotus cafer)*, followed by Common Myna (*Acridotheres tristis*) and House crow (*Corvus splendens*).

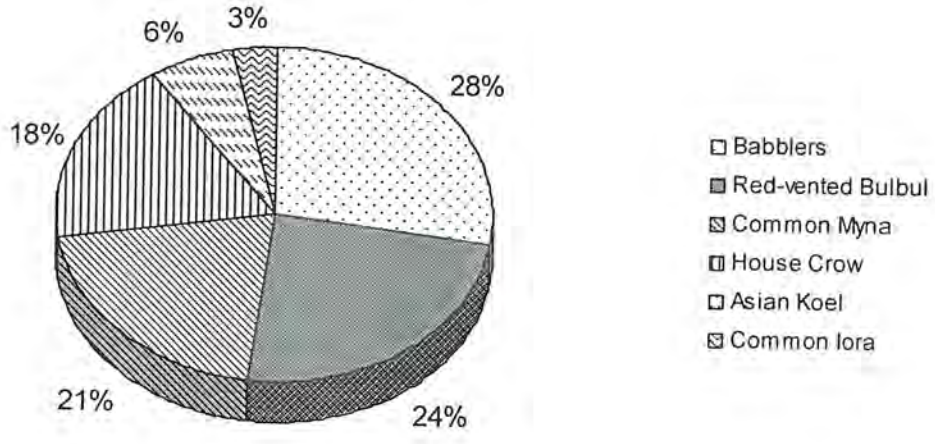


Figure 26. Avian frugivores on *Ficus racemosa.*

F. racemosa attracted 7 species of birds. Babblers (*Turdoides affinis* and *Turdoides striatus*) contributed 28% visits; followed by Red-vented Bulbul *(Pycnonotus cafer)* (24%) and Common Myna (21%) (Figure 26).

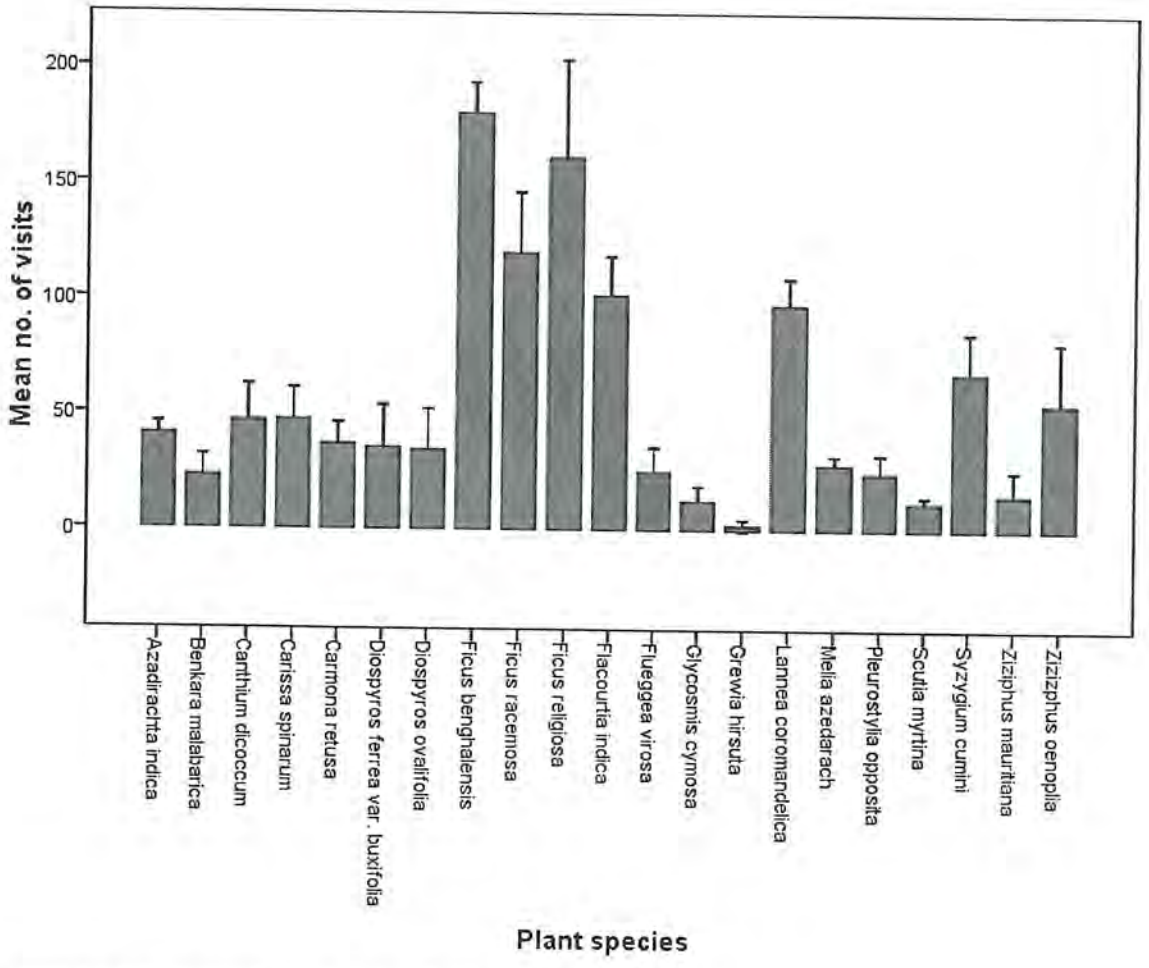


Figure 27. Mean number of visits of 32 fleshy fruited plant species (values in panels are mean ± SE) in scrub forest

Mean number of visits of birds were higher on *F. benghalensis* (180.00± SE 3.05), than other 31 plant species, and the mean number of visits of birds differed significantly between the plant species ($F_{20, 42}$ = 164.536, P< .000) (Figure 27). The top ten plant species that attracted avian frugivores in terms of mean number of visits are *Ficus religiosa* (160.67± SE 9.82), *Ficus racemosa* (119.67±SE 6.06), *Flacourtia indica* (101.33± SE 3.93), *Lannea coromendelica* (97.33± SE 2.67), *Syzygium cumini* (68.00± SE 4.04), *Ziziphus oenoplia* (54.66± SE 6.17), *Carissa spinarum* (47.33± SE 3.18), *Canthium dicoccum* (46.67± SE 6.35) and *Azadirachta indica* (41.00± SE 1.15).

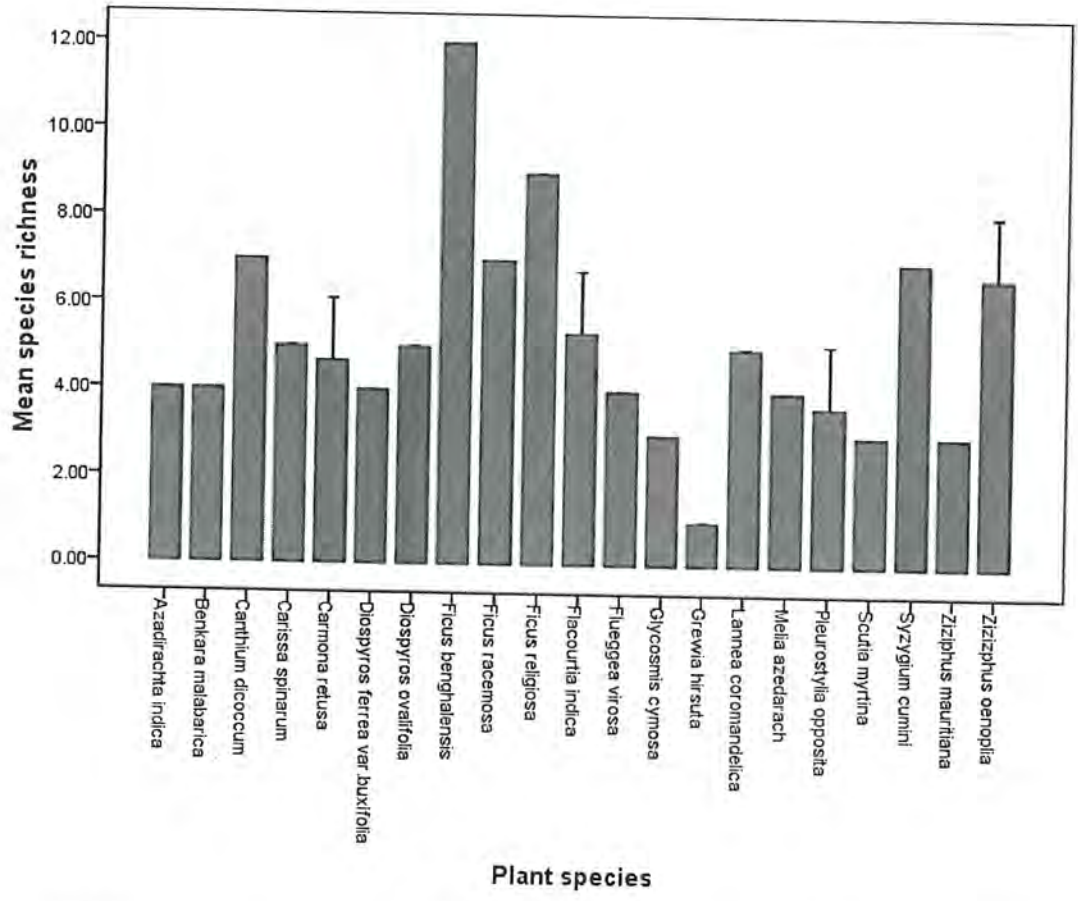


Figure 28. Mean species richness of of 32 fleshy fruited plant species (values in panels are mean ± SE) in scrub forest

Mean species richness of birds were higher on *Ficus benghalensis* (12.00± SE 0.00), than the other 31 plant species and the mean species diversity of birds differed significantly between the plant species ($F_{20, 42}$ = 270.550, P< .000) (Figure 28). The top ten plant species that attracted avian frugivores in terms of mean species diversity are *Ficus religiosa* (9.00± SE 0.00), *Ficus racemosa* (7.00± SE 0.00), *Canthium dicoccum* (7.00± SE 0.00), *Syzygium cumini* (7.00± SE 0.00), *Ziziphus oenoplia* (6.66± SE 0.33), *Flacourtia indica* (5.33± SE 0.33), *Diospyros ovalifolia* (5.00± SE 0.00), *Carissa spinarum* (5.00± SE 0.00) and *Lannea coromandelica* (5.00± SE 0.00).

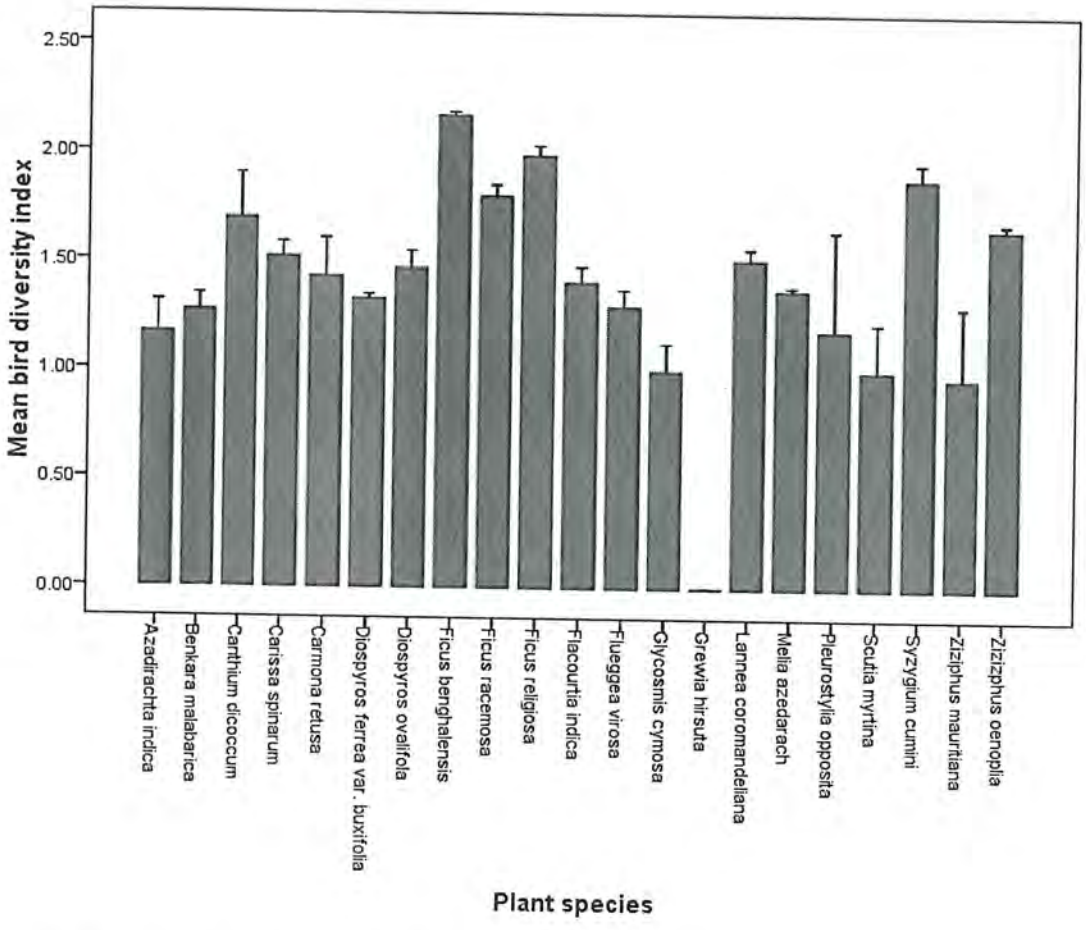


Figure 29. Mean bird diversity index of thirty two woody plant species (values in panels are mean ± SE) in scrub forest

Mean bird diversity index on tree species were higher on *F. benghalensis*, (2.17± SE 0.003) than the other 31 plant species and the mean bird diversity of birds differed significantly between the plant species ($F_{20, 42} = 154.219$, $P < .000$), (Figure 29). followed by *Ficus religiosa* (1.98± SE 0.01), *Syzygium cumini*,(1.88± SE 0.69), *Ficus racemosa* (1.80± SE 0.01), *Canthium dicoccum* (1.70± SE 0.59), *Ziziphus oenoplia* (1.66± SE0.27), *Carissa spinarum* (1.51± SE 0.01), *Lannea coromandelica* (1.51± SE 0.01), *Diospyros ovalifolia* (1.46± SE 0.01) and *Carmona retusa* (1.43± SE 0.04) in the scrub forest.

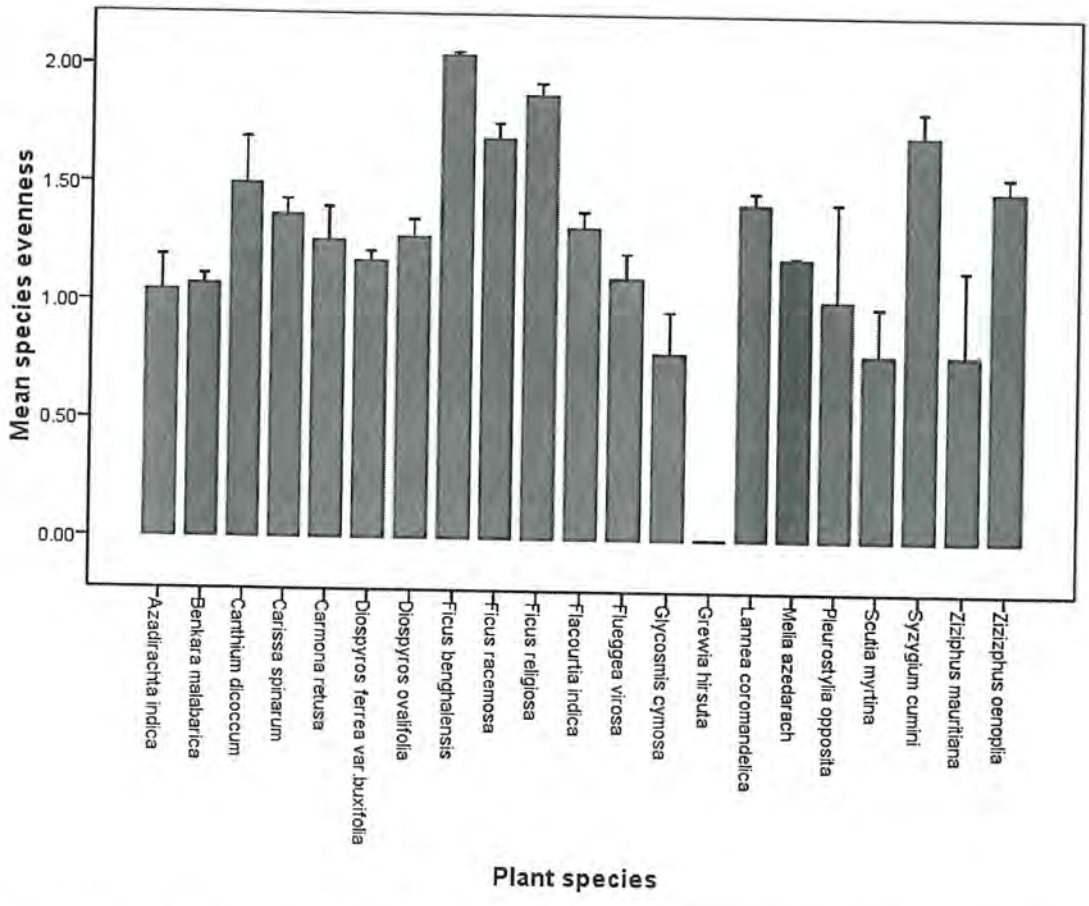


Figure 30. Mean bird evenness of thirty two woody plant species (values in panels are mean ± SE) in scrub forest

Mean bird species eveness on tree species were higher on F. benghalensis, (2.04± SE 0.002) than the other 31 plant species and the mean bird species evenness of birds differed significantly between the plant species ($F_{20, 42} = 152863$, $P < .000$), followed by *Ficus religiosa* (1.88± SE 0.01), *Syzygium cumini*,(1.71± SE 0.02), *Ficus racemosa* (1.69± SE 0.01), *Canthium dicoccum* (1.49± SE 0.04), *Ziziphus oenoplia* (1.48± SE0.01), *Lannea coromandelica* (1.42± SE 0.01), *Carissa spinarum* (1.36± SE 0.01), *Flacourtia indica* (1.31± SE 0.01) and *Diospyros ovalifolia* (1.27± SE 0.01) in the scrub forest (Figure 30).

Morphological classification of bird dispersed fruits

The fruit types of all the 21 species were determined. Drupes were the predominant fruit type borne by 11 species (52%) followed by berries 5 species (24%), synconium, 3 species (14%) and capsule 2 species (10%) (Figure 31).

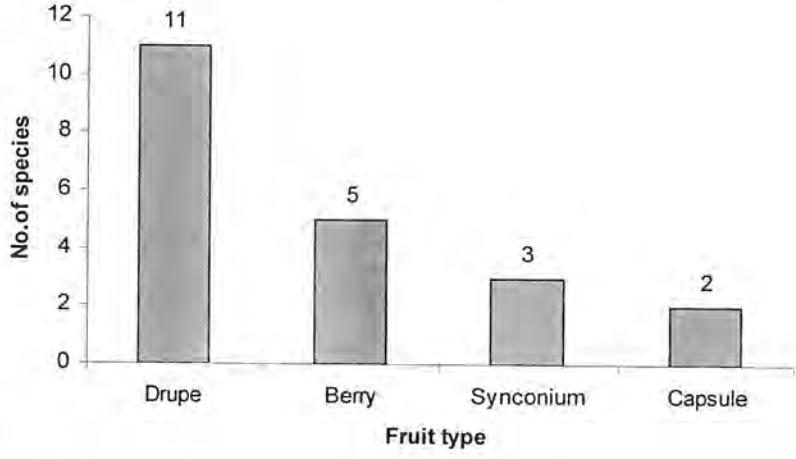


Figure 31. Morphological classification of bird-dispersed fruits in scrub forest (n=21)

Fruit colour

Colour

The analysis showed that six species produced black fruits (28.6%), three species red colour (19%), and three species yellow colour (14.3%) (Table 12).

Table12. Colours of bird-dispersed plants in the scrub forest

S.No	Colour Category	# of plant species	%
1	Black	6	28.6
2	Red	3	14.3
3	Brown	3	14.3
4	Orange	2	9.5
5	White	2	9.5
6	Yellow	2	9.5
7	Pink	2	9.5
8	Blue	1	4.8

Avian frugivores favoured fruit colour include black (29%) followed by red (27%) and pink (15%). (Figure 32)

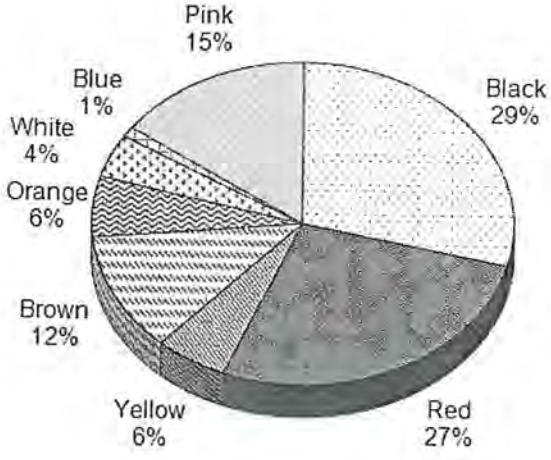


Figure 32. Colours of bird dispersed fruits in the scrub forest

Fruit size

Analyses of the fruit diameter revealed that eight species (38.1%) had their fruit size > 10mm. while 12 species (57.1%) bore fruits in the size range 10-20mm, one species (4.8%) in the size range 20-30mm. (Figure 33) Plants of families Anacardiaceae, Celastraceae, Cordiaceae, Rutaceae, Tiliaceae, Euphorbiaceae and Ebenaceae produced small fruits, while plants of families Flacourtiaceae, Meliaceae, Rhamnaceae, Myrtaceae and Rubiaceae produced large fruits. Moraceae had both medium (*Ficus benghalensis, Ficus religiosa*) and large fruits (*Ficus racemosa*).

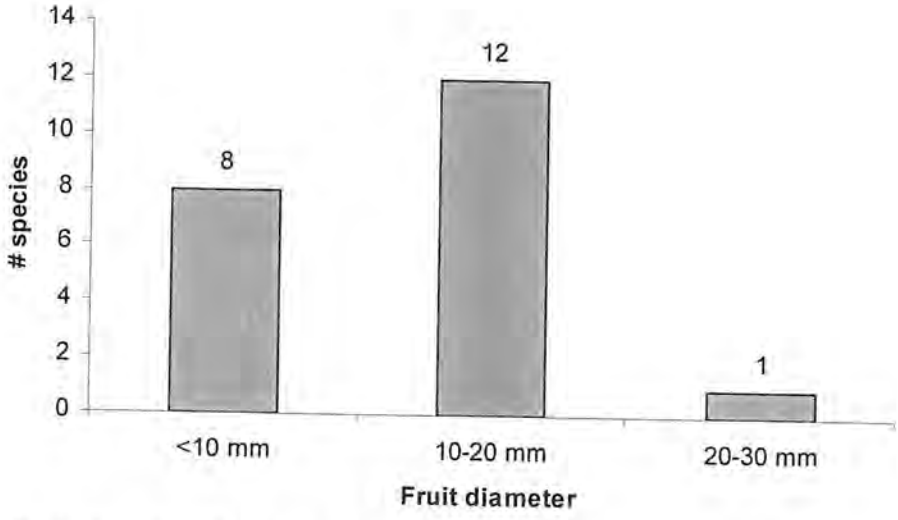


Figure 33. Fruit size classification of bird-dispersed fruits

Preference of fruit size by birds

The fruit types were recognized in the study area namely, small size <10mm, medium size 10-20 mm and big size (20-30mm). Medium sized fruits attracted majority of the avian frugivores (65%), followed by small sized fruits (25%) and big sized fruits (10%) in the scrub forest.

Bulbuls favoured medium sized fruits (58%), followed by small sized fruits (30%) and larger fruits (12%). Mynas favoured medium sized fruits (67%) followed by small sized fruits (25%) and (8%) of the large sized fruits. Babblers favoured medium sized fruits (59%), followed by small sized fruits (28%) and 13% large sized fruits.

House Crow favoured medium sized fruits 63%, followed by 26% small sized fruits and 11% large sized fruits. Asian Koel favoured medium sized fruits 83%, 14% large sized small sized fruits (3%).

Avian frugivores

In the scrub forest a total of 13 bird species from nine familes have been recorded to eat fruits (Table 13). Bird species of families Pycnonotidae (bulbuls) (2 species; *Pycnonotus cafer, Pycnonotus luteolus,*), Muscicapidae with 2 species (babblers) (*Turdoides affinis, Turdoides striatus*), Corvidaea (Asian Koel, House Crow), Sturnidae (Common myna, Brahminy myna) constituted a major share of frugivores.

Table 13. Avian frugivores observed in the scrub forest.

S.No	Common Name	Scientific Name	No of visits	% visits	Body mass (g)
1	Common Myna	*Acridotheres tristis*	855	25.14	98
2	Red-vented Bulbul	*Pycnonotus cafer*	614	18.05	35
3	House Crow	*Corvus splendens*	595	17.49	280
4	White-headed Babbler	*Turdoides affinis*	474	13.94	40
5	Jungle Babbler	*Turdoides striatus*	297	8.73	77
6	Asian Koel	*Eudynamys scolopacea*	168	4.94	167
7	Eurasian Golden Oriole	*Oriolus oriolus*	110	3.23	65
8	White-browed Bulbul	*Pycnonotus luteolus*	89	2.62	35
9	Common Iora	*Aegithina tiphia*	54	1.59	14
10	Coppersmith Barbet	*Megalaima rubricapilla*	50	1.47	38
11	Indian Treepie	*Dendrocitta vagabunda*	45	1.32	128
12	Rose-ringed Parakeet	*Psittacula karmeri*	35	1.03	139
13	Brahminy Myna	*Sturnus pagodarum*	15	0.44	54

Major frugivorous birds

In the scrub forest Common Myna (Sturnidae) formed the most dominant avian frugivore which contributed 25.14% of feeding visits, which used 20 species in the diet, followed by Red-vented Bulbul constituted 18.05% visits, with 19 species in its diet, followed by House crow utilized 17.49% of the feeding visits with 17 species in its diet. White-headed Babbler constituted 13.94% of the visits, utilized 19 species in the diet. The list of avian frugivores and the number of plants utilized by them are given in the table 14.

Table 14. Number of plant species visited by avian frugivores

S.No	Common Name	Scientific Name	Family	# of species
1	Common Myna	*Acridotheres tristis*	Sturnidae	*20*
2	Red-vented Bulbul	*Pycnonotus cafer*	Pycnonotidae	*19*
3	White-headed Babbler	*Turdoides affinis*	Muscicapidae	19
4	House Crow	*Corvus splendens*	Corvidae	17
5	Jungle Babbler	*Turdoides striatus*	Muscicapidae	10

S.No	Common Name	Scientific Name	Family	# of species
6	Asian Koel	*Eudynamys scolopacea*	Cuculidae	8
7	Eurasian-golden Oriole	*Oriolus oriolus*	Oriolidae	4
8	Common Iora	*Aegithina tiphia*	Irenidae	4
9	Coppersmith Barbet	*Megalaima rubricapilla*	Capitonidae	2
10	Indian Treepie	*Dendrocitta vagabunda*	Corvidae	2
11	Rose-ringed Parakeet	*Psittacula karmeri*	Psittacidae	2
12	White-browed Bulbul	*Pycnonotus luteolus*	Pycnonotidae	1
13	Brahminy Myna	*Sturnus pagodarum*	Sturnidae	1

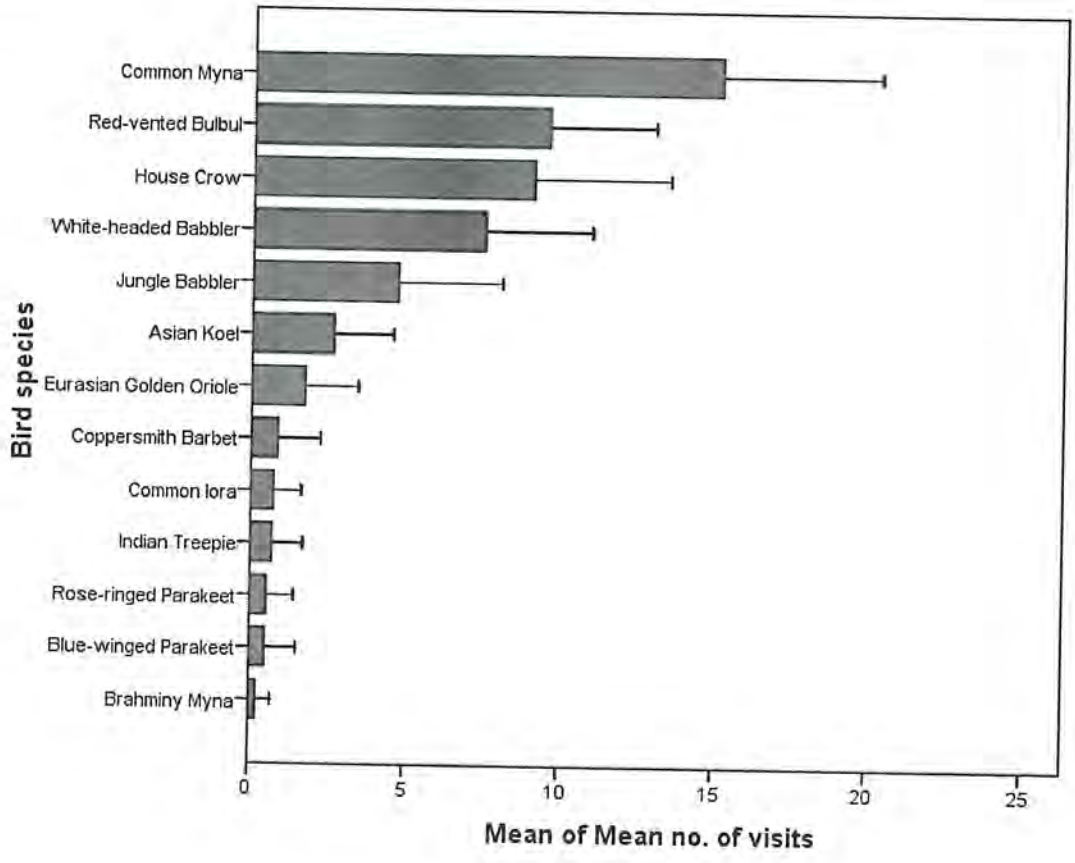


Figure 34. Mean number of visits of 13 bird species (values in panels are mean ± SE) in scrub forest.

Mean number of visits of birds showed significant variation among plant species (Kruskal Wallis $\chi 2 = 135.813$ df= 12, $p < .000$) (Figure 34). The top five avian frugivores

of the scrub forest are Common Myna (15.18 ± SE 2.59), Red-vented Bulbul (9.58 ± SE 1.70), House Crow (9.09± SE 2.20), White-headed Babbler (7.52± SE 1.73) and Jungle Babbler (4.71 ± SE1.69).

Common Myna

Common Myna consumed 20 species, *Ficus benghalensis* (44.00± SE 2.51), *Flacourtia indica* (36.66± SE 1.45), *Ficus religiosa* (35.00± SE4.04), *Lannea coromandelica* (26.00± SE 1.52) and *Ficus racemosa* (25.33 ± SE1.76) are the most prefered plant species. Red-vented Bulbul consumed 19 species, Ficus *racemosa* (29.00± SE 1.15), *Ficus religiosa* (25.33± SE 2.33), *Flacourtia indica* (18.66± SE 0.88), *Ficus benghalensis* (15.00± SE 1.15) and *Diospyros ovalifolia* (12.66± SE 1.76) are the preferred plants species. House crow utilized 17 species, the top five dominant plant species prefered are *Ficus benghalensis* (40.33± SE 1.20), *Ficus religiosa* (22.33± SE 0.66), *Lannea coromandelica* (21.66± SE 2.40), *Ficus racemosa* (21.00± SE 1.15) and *Azadirachta indica* (15.33± SE 1.4). White-headed Babbler consumed 19 species where *Flacourtia indica* (32.66± SE 2.72), *Ficus racemosa* (19.00± SE 1.52), *Ficus religiosa* (17. 33± SE 2.40), *Zizphus oenoplia* (15.66± SE2.40) and *Pleurostylia opposita* (10.33± SE 0.66) formed the top five preferred plant species. Jungle Babbler utilised 10 plant species where *Ficus religiosa* (32.66± SE 0.33), *Ficus racemosa* (13.66± SE 2.33), *Ficus benghalensis* (10. 66± SE 0.88), *Carissa spinarum* (9.66± SE 1.20) and *Carmona retusa* (9.33± SE 1.45) formed the top five preferred species (Appendix 2)

Bird size

The body size varied considerably among avian frugivores (range 6.2-280 g; (Figure 35) House Crow was the heaviest followed by Asian Koel. 5 species were in the range of 0-50g, 4 species were in the range of 50-100 g, while 2 species were in the range of 100-150g. One species were in the range of 150-200g, one species was >200g. From this data, it is very clear that the avian frugivores in the scrub forest were light weighted.

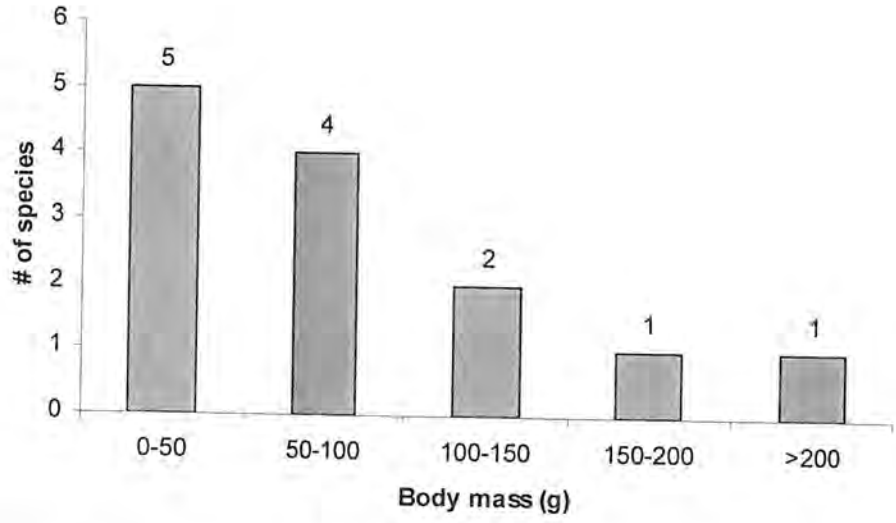


Figure 35. Body size of avian frugivores in the Scrub forest.

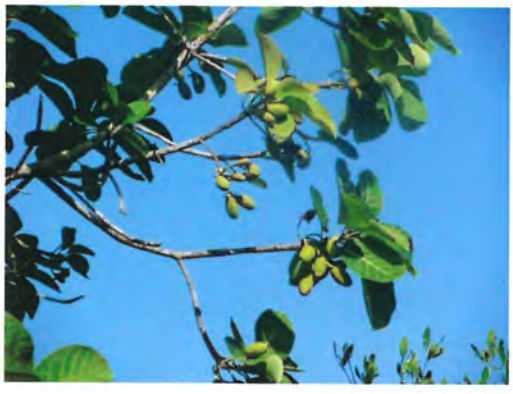
Vegetation sampling

The vegetation sampling results shows the occurrence of 53 woody plant species belonging to 24 families were recorded in the scrub forest. The density value shows that *Carissa spinarum* dominates the forest, followed *by Ziziphus oenoplia, Diospyros ferrea var buxifolia, Anogeissus latifolia* and *Fluggea virosa*. Fabaceae is the most dominant family, 11 species (21%), followed by Rubiaceae 7 species (13%). A systematic list of the identified plant species are presented in the Table 15. Out of 53 plant species, 30 (56.6%) are bird dispersed species.

Plate 8. Fleshy-fruited plants in the scrub forest

Azadirachta indica

Diospyros ovalifolia



Manilkara hexandra

Memecylon umbellatum

Phoenix pusilla

Strychnos potatorum

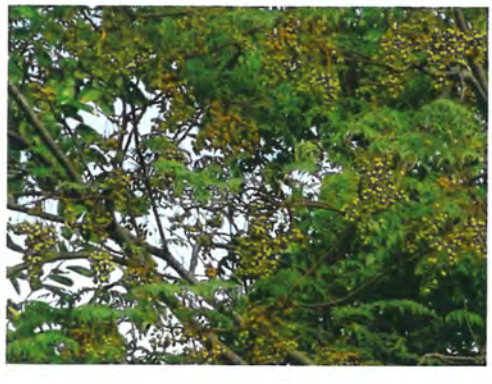
Plate 9. Fleshy-fruited plants in the scrub forest

Carissa spinarum

Glycosmis cymosa

Strychnos nux-vomica

Scutia myrtina



Melia azedarach

Syzygium cumini

Plate 10. Avian frugivores in the scrub forest

Coppersmith Barbet on *Ficus benghalensis*

Rose-ringed parakeet on *Ficus benghalensis*

White-browed bulbul on *Lannea coromandelica*

Plate 11. Vegetation sampling, Scrub forest

Anogeissus latifolia

Pleurostylia opposita

Gmelina asiatica

Randia malabarica

Wrightia tinctoria

Ziziphus xylopyrus

Table 15. Density of plant species in the scrub forest, Eastern Ghats

S.No	Plant species	Family	No of individuals	Density	Relative density
1	*Carissa spinarum* L.	Rubiaceae	76	1.27	7.74
2	*Ziziphus oenoplia* (L.) Mill.	Rhamnaceae	68	1.13	6.92
3	*Diospyros ferrea* (Willd.) Bakh *var buxifolia* (Rottb.) Bakh.	Ebenaceae	59	0.98	6.01
4	*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guill .& Perr.	Combretaceae	54	0.90	5.50
5	*Flueggea virosa* (Roxb. ex Willd.) Baill.	Euphorbiaceae	47	0.78	4.79
6	*Carmona retusa* (Vahl) Masamune	Cordiaceae	45	0.75	4.58
7	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	38	0.63	3.87
8	*Carissa spinarum* L. *var microphylla* Gamble	Rubiaceae	37	0.62	3.77
9	*Tarenna asiatica* (L.) O.Ktze. ex K. Schum.	Rubiaceae	37	0.62	3.77
10	*Grewia hirsuta* Vahl	Tiliaceae	34	0.57	3.46
11	*Memecylon edule* Roxb.	Melostamataceae	32	0.53	3.26
12	*Randia malabarica* Lam.	Rubiaceae	32	0.53	3.26
13	*Buchanania lanzan* Spreng.	Anacardiaceae.	27	0.45	2.75
14	*Maytenus emarginata* (Willd.) Ding Hou	Celastraceae	26	0.43	2.65
15	*Scutia myrtina* (Burm.f.) Kurz	Rhamnaceae	26	0.43	2.65
16	*Ixora arborea* Roxb. ex Smith	Rubiaceae	24	0.40	2.44
17	*Acacia leucophloea* (Roxb.) Willd.	Fabaceae	21	0.35	2.14
18	*Diospryos ovalifola* Wight	Ebenaceae	21	0.35	2.14
19	*Pleurostylia opposite (Wallich) Alston*	Euphorbiaceae	18	0.30	1.83
20	*Manilkara hexandra (Roxb.) Dubard*	Sapotaceae	16	0.27	1.63

S.No	Plant species	Family	No of individuals	Density	Relative density
21	*Cleistanthus collinus* (Roxb.) Benth. ex Hook .f.	Phyllanthaceae	16	0.27	1.63
22	*Albizzia amara* (Roxb.) Boivin	Fabaceae	15	0.25	1.53
23	*Breynia vitis idaea* (Burm.f.) C.Fischer	Euphorbiaceae	14	0.23	1.43
24	*Glycosmis cymosa* (Kurz) Narayanaswamy	Rutaceae	14	0.23	1.43
25	*Phoenix pusilla* Gaertn.	Arecaceae	14	0.23	1.43
26	*Ziziphus xylopyrus* (Retz.) Willd.	Rhamnaceae	14	0.23	1.43
27	*Atalantia racemosa Wight & Arn.*	Rutaceae	12	0.20	1.22
28	*Canthium dicoccum* (Gaertn.) Teijsm. & Binn.	Rubiaceae	12	0.20	1.22
29	*Capparis sepiaria* L.	Capparaceae	12	0.20	1.22
30	*Pterocarpus marsupium* Roxb.	Fabaceae	12	0.20	1.22
31	*Dichrostachys cinerea* (L.) Wight & Arn.	Fabaceae	9	0.15	0.92
32	*Azadirachta indica* A. Juss.	Meliaceae	8	0.13	0.81
33	*Cassia fistula* L.	Fabaceae	8	0.13	0.81
34	*Flacourtia indica* (Burm.f.) Merr.	Salicaceae	8	0.13	0.81
35	*Erythroxylum monogynum* Roxb.	Erythroxylaceae	8	0.13	0.81
36	*Morinda tinctoria* Roxb.	Rubiaceae	7	0.12	0.71
37	*Gmelina asiatica* L.	Verbenaceae	6	0.10	0.61
38	*Lannea coromendelica (*Houtt.) *Merr.*	Anacardiaceae.	6	0.10	0.61
39	*Albizia amara* (Roxb.) Boivin	Fabaceae	5	0.08	0.51
40	*Cassia auriculata* L.	Fabaceae	5	0.08	0.51
41	*Prosopsis juliflora* (Sw.) DC.	Fabaceae	5	0.08	0.51
42	*Tamarindus indica* L.	Caesalpiniaceae	5	0.08	0.51
43	*Albizia lebbeck* (L.) Willd.	Fabaceae	4	0.07	0.41
44	*Givotia mollucana*,(L.) Wheeler ex K.M.Matthew	Euphorbiaceae	4	0.07	0.41

S.No	Plant species	Family	No of individuals	Density	Relative density
45	*Pongamia pinnata* (L.) Pierre	Fabaceae	4	0.07	0.41
46	*Butea monosperma* (Lam.) Taub.	Fabaceae	3	0.05	0.31
47	*Ziziphus mauritiana Lam.*	Rhamnaceae	3	0.05	0.31
48	*Dolichandrone.atrovirens* (Roth) Sprague	Bignoniaceae	3	0.05	0.31
49	*Wrightia tinctoria* (Roxb.) R.Br.	Apocynaceae	3	0.05	0.31
50	*Premna tomentosa* Willd.	Verbenaceae	2	0.03	0.20
51	*Ficus benghalensi* L.	Moraceae	1	0.02	0.10
52	*Strychnos potatorum* L.f.	Loganiaceae	1	0.02	0.10
53	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	Combretaceae	1	0.02	0.10

DISCUSSION

Tropical mixed dry deciduous forest,Western Ghats

Phenology

The present study recorded fruiting seasonality in the tropical mixed dry deciduous forest. There was a peak in fruiting during the South-west monsoon (21 species) and a dip during Post monsoon (9 species). Majority of the fleshy-fruited species across the globe produce fruits during the peak rainy season (Hilty 1980, Lieberman 1982, Murali 1992, Luciana and Machado 2001, McLaren and McDonald 2005). Extreme seasonality in fruiting occurs in most tropical forests with distinct wet and dry seasons (Howe, 1984b). Balasubramanian & Bole (1993) observed fruiting peak during monsoon in the Tropical dry evergreen forest, Point Calimere, South India. In the coastal plain forest, where peak fruiting was observed during March to August (Morellato et al. 2000) Extreme seasonality in fruiting occurs in most tropical forest with distinct wet and dry seasons (Howe, 1984b). Ficus species in particular exhibit varied fruiting phenology patterns including continual year round fruiting at a population level and subannual fruiting at individual level (Spencer, Weiblen & Flick, 1996). Figs generally experience relatively short fruiting intervals (Lambert & Marshall, 1991), heavy fruit production (Mckey, 1989) and most often, asynchronous fruiting patterns (Estrada & Coates-Estrada, 1986).

In the present study, *Ficus benghalensis* fruited during March-May; *Ficus racemosa* fruited during March – August. A study in the moist deciduous forest in Simlipal Biosphere Reserve (Mishra *et al.* 2006) indicates that *Ficus benghalensis* was in fruiting during April - June and December – February. A study at a dry deciduous forest, Satlasana range forest, Gujarat (Desai and Patel, 2010) states that *Ficus benghalensis* was in fruiting during April, May and June, *Ficus religiosa* during April, October. *Ficus benghalensis* was reported to be fruiting during Post-monsoon (October–November) at Taleigao Plateau, Goa, India (Desai and Shanbhag, 2012). A study in a moist deciduous forest, Uttar Pradesh (Anoop *et al.* 2011) indicates that *Ficus benghalensis* bore fruits during April - June; *Ficus racemosa* during March-July.

In contrast, *Ficus racemosa* and *Ficus religiosa* were found to be available year round in the Western Ghats (Patel 1997). *Ficus benghalensis* was in fruiting during September-November at Goalpara, Assam (Namita, 2012). Seasonality in fruit production in tropical forest ecosystem has brought to light the roles played by keystone or pivotal species during periods of fruit scarcity. The present study indicates that *Ficus benghalensis* that fruited during the period of fruit scarcity (post-monsoon) could play a keystone role. Post monsoon had a dip with 9 species in fruit production, but *Ficus benghalensis* was fruiting during this season. In summer when only 13 species were in fruits *Ficus benghalensis* had fruits, *Ficus racemosa* also had fruits during summer and supported a large number of avian frugivores in the study area. Thus the present study clearly indicates that Ficus plays a keystone role in the tropical forests.

Avian frugivory

In the present study, bulbuls were found to be the predominant frugivores and seed dispersers, *Pycnonotus jocosus; Pycnonotus cafer* visited 29 plant species, while *Pycnonotus luteolus* consumed 28 fruit species.

Bulbuls of various species have established themselves as one of the dominant frugivores and seed dispersers of open, secondary vegetation throughout tropical and subtropical Asia, as well as much of Africa, and the Middle East, and have been widely introduced in similar environments outside their natural range (Lever 1987, Corlett 1998). Birds, principally bulbuls are the only known dispersal agents for all the fully naturalized species with fleshy fruits (Corlett, 2005). Bulbuls were particularly important frugivorous group, six bulbul species consumed at least 127 species (93.3% of all 136 plant species where frugivory by birds was observed in an intact tropical forest, north-east Thailand (Sankamethawee, *et al.* 2011).

Kimura *et al.* (2001) mentioned that bulbuls are one of the dominant avian frugivores in Mt. Kinabalu, Borneo. Bulbuls may be especially important dispersers of small-fruited under storey *Ficus* trees that fail to attract larger frugivores. For such trees in Sarawak, bulbuls were responsible for approximately 80% of all feeding visits (Shanahan & Compton, 2001). The ability of many bulbul species to survive in anthropogenically degraded landscapes suggests that they are important agents of forest regeneration

(Corlett, 1998). Red-vented Bulbul was the dominant avian frugivore both in Madhupur National Park (38 plant species i.e., 79.2% of the total food species) and Chittagong University Campus (24 species i.e., 52.2% of the food plant species), Bangladesh, Khan (2010). Bulbuls, in general, play an important role in seed dispersal in many tropical regions of the world (Kitamura *et al.* 2002; Cordeiro & Howe 2003; Weir & Corlett 2007).

Fruits comprised a major proportion of diet for *Pycnonotus luteolus* and *Pycnonotus cafer* in the tropical dry evergreen forest, Point Calimere (Vijayan, 1975). In Point Calimere, 74% of the feeding visits by birds on fruit bearing plants were made by two species of bulbuls, *P. cafér* and *P. luteolus* (Balasubramanian, 1996). In a dry mixed deciduous forest in Western Ghats, bulbuls formed the predominant frugivorous and seed dispersing species (Balasubramanian *et al.,* 1998), the largest number of visits (47.5%) were made by three species of bulbuls. The observations of the present study ca. 45% of frugivory by 5 species of bulbuls indicate that they form the principal frugivores and potential seed dispersing birds in the mixed dry deciduous forest habitat.

The Red-whiskered Bulbul and White-browed Bulbul consumed more species of fleshy-fruits than other birds in Sriharikota islands, India. (David *et al.* 2011). These two species are the most abundant birds in Sriharikota (David *et al.* 2008), and hence, they were able to exploit fruit resources available in all the habitats. Open area preferring species like Red-vented Bulbul, Jungle Crow and Common Myna did not exploit the entire fruit resources available in the dense forest and thus consumed less number of fleshy-fruited species.

The Red-whiskered Bulbul and the White-browed Bulbul consumed 34 of the 38 fleshy-fruits of Sriharikota. The Red-vented Bulbul was recorded to feed on 16 species and the Asian Koel on 23 species. The Coppersmith Barbet *Megalaima haemacephala* has a narrow diet range, using only 7 of the 38 species. (David *et al.* 2011)

In a tropical forest, Terborgh (1986a) pointed out that 12 plant species (mainly figs and palm fruits) provide the main energy source to sustain the frugivore community in periods of extensive fruit scarcity. Also, avian frugivores often feed on the fruits of

several plant species over short periods of time (Levey *et al.* 1994) in some non-random pattern (Herrera 1998). The Brown-eared Bulbul is a major dispersal agent in Lucidophyllous forests, where it is abundant throughout the seasons (Kominami *et al.* 2003) and eats fruits of a wide range of sizes. Fukui (1995) confirmed the efficiency of the Brown-eared Bulbul as a seed dispersal agent. The Brown-eared Bulbul (*Hypsipetes amaurotis*) was considered to be an important seed disperser for many fleshy-fruited plants because of its high frequency of occurrence throughout the fruiting season (Takanose and Kamitani, 2003).

Figs – Keystone species

In the tropical mixed dry deciduous forest, *Ficus benghalensis* was found to be the most preferred species to the frugivorous birds (21 species). Individuals bore ripe figs in all months of the year, as recorded in other *Ficus* species elsewhere in the tropics (Corlett, 1987; Windsor *et al.* 1989). Each tree has its own particular fruiting interval regardless of climate, but is influenced by the level of accumulated resources required to initiate a fruit crop. Thus, fruiting at different times of the year must be related to increasing each tree's chance of success with respect to seed set, pollen dispersal (since each fig species is pollinated by a specific short-lived wasp; Ramirez, 1970), and seed dispersal during its total lifetime. The observed fig eating community comprised 49 bird species in 13 families (Shanahan and Compton 2001) in Borneo.

The importance of figs as a dietary resource for frugivorous vertebrates arises not only because the fruits are of a design that is edible by a wide array of (not necessarily specialised) foragers but also because of the phenological patterns of fig production. Generally, in tropical forests, seasonal patterns of fruit production exist with one or two annual peaks in the availability of ripe fruit (Frankie *et al.* 1974). The number of fig eating avian families interacting most with *Ficus* to be Columbidae, Psittacidae, Pycnonotidae, Bucerotidae and Sturnidae.

The importance of figs as a resource for frugivores in tropical forests has been emphasized in many studies (Kinnaird *et al.* 1996; Kannan & James, 1999). Lambert & Marshall (1991) pointed out that the combination of attributes such as large crop size,

relative numerical abundance and availability even in periods of general fruit scarcity makes Ficus a unique and extremely important resource to frugivores. Also, figs are energy-rich foods and have higher caloric values than non fig-fruits, besides the fact that they include some protein (Wrangham *et al.* 1993). Moreover, most figs are succulent, soft, easily harvested and ingested whole or in piecemeal.

Due to their short crop persistence and synchronous maturation within a tree, a high proportion of fruits are available daily during the ripening period (Lambert & Marshall, 1991). These features, found in *F. calyptroceras*, presumably influenced the enhancement in fig consumption by several bird species in the dry season. As mentioned above, in the dry season, other fleshy fruits were scarce and the intense leaf loss by most trees presumably reduced arthropod availability included in the diet of most birds (Ridgely & Tudor, 1989), were recorded feeding on figs. Thus, apparently, *F. calyptroceras* plays a major role in the persistence of frugivores during the harsh dry season in such deciduous forests of western Brazil. The results also underline the potential role of *Ficus* as a keystone plant resource for avian frugivores in the tropics (Harrison 2005, Kissling *et al.* 2007).

Despite the poor nutritional quality of figs, they play the very important role of sustaining frugivorous animals through periods when alternative fruit resources are scarce in at least two tropical forest areas (Leighton & Leighton 1983, Terborgh 1986b). Whilst the well documented aseasonal fruiting phenology of *Ficus* (Raemaekers *et al.* 1980) is the overriding trait which enables *Ficus* to fulfil this role, several other factors of Ficus fruitings also make essential contributions. Thus the enormous crop sizes, distinctive intra-crown synchrony of fruit ripening, the relatively short intervals between fruiting by individual trees and the ease with which figs can be harvested by diverse assemblages of frugivores are all important fruiting traits which contribute to the unique role that Ficus plays in frugivore survival (Lambert 1987).

This work confirmed the high attractiveness of figs for avian frugivores documented in other studies (Stiles and Rosselli 1993, Heindl and Curio 1999). This could be demonstrated by both the high visitation rates by fruit-eating birds and the high diversity of frugivorous bird species visiting fig trees.

The Asiatic Koel (*Eudynamys scolopacea*) occurs from India to Australia and has been recorded eating the figs of 17 Ficus species. (Shanahan, *et al.* 2001). The bulbul family of Africa and Asia includes 62 confirmed fig-eating species of 16 genera. Bulbuls tend to make short feeding visits and fig seeds are defecated or regurgitated in pellets in a viable state. Members of this family have been recorded feeding on 63 Ficus species and, in terms of fig seed dispersal, are probably the most important smaller frugivores. Bulbuls may be especially important dispersers of small-fruited understorey Ficus trees that fail to attract larger frugivores. (Shanahan, *et al.* 2001)

The true crows (tribe Corvini) are omnivorous opportunists and have been recorded eating figs throughout the tropics. Even when other fruits were available, figs comprised 23±1 % of the diet of Brown Jay (*Psilhorinus morio*) in Mexico. The same species was responsible for up to 20 % of *Ficus pertusa* fig removal and made short feeding visits (1±8 min) that imply seed dispersal away from the source tree (Shanahan, *et al.* 2001).

The leafbirds (*Chloropsis spp.*) and Fairy Bluebird (*Irena puella*) are major fig-eaters in the Indo- Malayan region where they feed largely on hemi- epiphytes in the canopy but are also observed to descend to the understorey or forest edge (Shanahan, *et al.* 2001). McClure (1966) reported that these birds selectively fed on the ripest *F. sumatrana* figs in Malaysia.

(David *et al.* 2011) at Sriharikota islands, India found the highest number of opportunistic records were also made on *Ficus amplissima* (48), followed by *Ficus benghalensis* (44) and *Ficus microcarpa* (31). The Coppersmith Barbet was chiefly a fig-eater, 90% of its frugivory records (n = 30) were on three Ficus spp. Among the 21 species subjected to tree watches, the Coppersmith Barbet was recorded only on *F. amplissima* and *F. microcarpa.* The Orange-breasted Green-Pigeon *Treron bicinctus* also chiefly feeds on figs.

Figs are eaten by an impressive range of vertebrate frugivores, many of which are likely to act as seed dispersers to a greater or lesser degree. The diversity of fig-eaters arises because of the widespread distribution of Ficus, the year-round production of figs, considerable diversity in the manner in which figs are packaged and presented and

because figs are easily consumed and have high levels of calcium. Figs are not equal resources for all frugivores but a system of partitioning exists such that discrete guilds of Ficus species share (and potentially compete for) subsets of a given frugivore community. Membership of dispersal guilds is determined by differences in fig packaging and presentation that are, in turn, governed largely by phylogeny.

Lantana camara dispersal

Eleven species of avian frugivores consumed *Lantana camara* fruits in the mixed dry deciduous forest. Bulbuls were the dominant frugivores of *L. camara*. Mean number of visits of birds to plants shows that *Lantana camara* supported large number of avian frugivores than the *Ficus* species. This clearly shows the importance of *Lantana camara* for the avian frugivores in the tropical mixed dry deciduous forest. Ten percent of *Lantana* fruits were fed by Red-vented Bulbul in Haridwar (Bhatt & Kumar 2001). Thirteen species of avian frugivores fed on *Lantana camara* in Hong Kong shrubland (Corlett 1998), while 5 species were reported to feed on *Lantana camara* in urban Hong Kong (Corlett 2005). In continental areas, many indigenous bird species feed on the *Lantana* fruits, while on some of the island groups, seed dispersal have been mainly facilitated by the introduction of exotic bird species. By feeding on exotic species such as *Lantana*, birds may increase the density and distribution of the weed at the expense of native vegetation thereby displacing other bird species (Day *et al.* 2003).

In Australia, Brown Pigeon, Crow, Cuckoo, Emerald Dove, Emu, Fig bird, Fruit Doves, Indian Myna, Lewin's Honey Eater, Little Wattle Bird, Pied Currawong, Purple-crowned Pigeon, Rainbow Lorikeet, Red-crowned Pigeon, Regent and Satin Bower Bird, Silver Eye, Sparrow, Spiny-cheeked Honey Eater, Starling, Varied Triller and Wonga Pigeon fed on *Lantana camara* fruits (Carter 2000, Stansbury and Vivian-Smith 2003). *Lantana* fruits were available through out the year in this study and the same is also seen in Hong Kong, south China, (Corlett 2005) and South Africa (Graaff 1987).

A study made in the Society Archipelago (French Polynesia) shows that bulbuls, Silver eye and Fruit doves fed on *Lantana camara* fruits. Birds are the main dispersers of *Lantana camara* (Vivian-Smith *et al.* 2006), facilitating long-distance dispersal and

invasion to new areas (Cronk and Fuller 1995). *Lantana* fruits are fleshy and available year-round, making them an ideal food source for frugivores such as bulbuls, who are one of the main dispersers (Aravind *et al.* 2010).

Fruit colour

Red and black are the dominant fruit colours of bird dispersed fruits (Willson & Whelan 1990; Herrera 2002). Turcek's (1963) experimental study on European birds and fruits showed that red and black are preferred by birds. White, yellow, and blue fruit are less common and less popular. Most bird-dispersed under storey fruits (Melastomataceae and Rubiaceae) are easily accessible and coloured black (or dark purple), red or some-times white (Wheelwright and Janson, 1985). In the tropical dry evergreen forest of Point Calimere, red was most dominant fruit colour followed by black (Balasubramanian 1996).

In Central America, although most fruits eaten by birds are black or red, blue are also common. In New Guinea, the main fruit colour is red, but white and orange are common. Bicoloured fruit (black on white, purple on white) are also common and popular with birds in the tropics (Howe 1986). Although many species have been reported to prefer red fruits (Giles & Lill 1999), others have shown preferences for other colors (such as blue, orange or white) or a lack of preference for any particular color (Honkavaara *et al.* 2004; Schmidt & Schaefer 2004). In the tropics, the predominant colour choices may be wider. Black colour fruits were highly preferred (20.8% of the total used plant species) in Madhupur National Park and yellow colour (34.8% of the total used plant species) in Chittagong University Campus, Bangladesh, (Khan 2010).

Fruit size

Positive relationships between fruit size and the average size of fruit consumers have been previously documented in other geographic locales (Rey *et al.* 1997). Size-related coupling between fruits and frugivores has also been documented on larger spatial scales. Mack (1993) found that neotropical fruits are smaller than paleotropical fruits, which he attributed to geographic differences in the size of frugivores.

Small-fruited plant species have been hypothesized to attract more species of birds than large fruited ones (Terborgh and Diamond 1970), although Kantak (1979) found that intermediate-sized fruits drew the largest number of bird species among the five plant species studied in Mexico. Research on plant-bird interactions at Point Calimere, India showed that conspicuous colour combined with small size of fruit enabled frugivorous birds to access fruit resources easily (Balasubramanian 1996). This trend was consistent with findings from the Neotropics (Janson 1983, Howe 1986), Africa (Gautier-Hion *et al.* 1985), Papua New Guniea (Beehler 1983) and Indonesia (Suryadi *et al.* 1994). Corlett, (1996) observed that most of the bird dispersed seeds in Hong Kong had a mean diameter of less than 13 mm.

Vegetation sampling

Pleiospermium alatum formed the most dominant species in the tropical mixed dry deciduous forest. Even though this species was dominant fruits were not eaten by the avian frugivores. *Cordia monoica* was the second dominant species, even though this plant species was abundant, it did not attract the avian frugivores. The unattractive colour of the fruit might be one of the reasons for not attracting avian frugivores. Most of the plants which were dominant in the study area did not have fleshy fruits; hence birds did not feed on these fruits. *Ficus benghalensis* was (relative density 0.1) utilized by 21 species of birds, while *Ficus mollis* was (relative density 0.1) utilized by 8 bird species which clearly indicates the importance of figs in this forest. With the observed 54 plant species avian frugivores utilized 17 species in its diet.

DISCUSSION

Scrub forest

Phenology

Fruiting peak was recorded during both South-west and North-east monsoon with 12 species each fruiting. Bleher *et al.* (2003) in a South African Coastal forest reported the fruiting peak (August-October) (March-May). Periods of fruit scarcity were found during the dry season in July and August and during the rainy season in November and December. In the tropics and subtropics, the production of fleshy fruits tends to be highest early in the wet season (Liberman 1982, Guevarad *et al.* 1992).

Fruiting peak during wet season was reported from several tropical forests (Murali 1992, Sundarapandian *et al.* 2005). Kikim and Yadava (2001) reported fruiting peak during September in subtropical forest at Manipur which coincides with the present study. Selwyn and Parthasarathy (2007) in Coromandel Coast of India in their phenological studies observed that fruiting during dry season was less when compared to wet season. Yadav and Yadav (2008) observed that the peak period of maturation of fruits was September-October in most of the woody species in a tropical dry deciduous forest, Rajasthan, India.Balasubramanian and Bole (1993) observed peak of fleshy fruits during post monsoon season, in the tropical dry evergreen forest.

In the present study, *Ficus benghalensis* fruited during March- November; *Ficus religiosa* fruited during June – August. A study in the moist deciduous forest in Simlipal Biosphere Reserve (Mishra *et al.* 2006) indicates that *Ficus benghalensis* bore fruits during April - June and December – February; *Ficus religiosa* fruited during June to October. In another study at a dry deciduous forest, Satlasana range forest, Gujarat (Desai and Patel, 2010) states that *Ficus benghalensis* was in fruiting during April, May and June, *Ficus religiosa* during April, October.

In contrast, *Ficus racemosa* and *Ficus religiosa* were found to be available year around in a deciduous forest and evergreen forest, Western Ghats (Patel 1997). *Ficus benghalensis* bore fruits during September-November, *Ficus religiosa* during April - May at Goalpara, Assam (Namita, 2012).

In some seasonal tropical forests, the number of animal-dispersed species peaks during the rainy season (Milton *et al.* 1982; Stocker and Irvine 1983). In aseasonal tropical forests, such as those in Malaysia, fruiting occurs throughout the year; usually without defined peaks in fruit or frugivores abundance (Putz 1979; Rathcke and Lacey 1985).

In the present study, it was observed that summer had a dip with 6 species in fruits, but *Ficus benghalensis* was fruiting during this period of fruit scarcity and supported a large number of avian frugivores which clearly shows that Ficus is a keystone species in this study area. Patel (1997) reported the peak fruiting in figs coincided with peak in non-fig fruiting in a wet evergreen forest site in Western Ghats which coincides with the present study in Eastern Ghats.

Carmona retusa, Glycosmis cymosa and Ziziphus oenoplia were seasonal as the fruiting occurred only during one season i.e, South-west Monsoon, North-east Monsoon, Post-Monsoon respectively. Some species fruited during two or three seasons *Ficus benghalensis* bore fruits in three seasons.

Avian frugivory

In the scrub forest, Common Myna is found to be the predominant frugivore followed by Red-vented Bulbul. A study on plant-bird interactions in the Tropical Evergreen Forest in Chengalpattu district, Coromandel Coast, southern India, showed that 130 out of 180 woody plants (72%) bore fleshy fruits (Narasimhan *et al.* 1993). Major fleshy fruited species included *Ziziphus oenoplia, Allophyllus serratus, Ficus benghalensis, Benkara malabarica, Hugonia mystax, Tarenna asiatica, Memecylon umbellatum, Carmona retusa* and *Dendrophthoe falcate*. Though 150 bird species have been recorded from this region (Siromoney 1971), only 20 are involved in seed dispersal. Families of frugivorous birds include Columbidae, Cuculidae, Capitonidae, Oriolidae, Sturnidae, Corvidae, Irenidae, Pycnonotidae and Muscicapidae.

In the tropical dry evergreen, as well as dry mixed deciduous forests of South India bulbuls are the predominant frugivorous and seed dispersing species (Vijayan, 1975; Balasubramanian, 1996; Balasubramanian *et al.* 1998). In the tropical dry evergreen

forest of Point Calimere (Balasubramanian, 1996), 74% of the avian visits on the fruiting plants were by two species of bulbuls (*Pycnonotus cafer, P. luteolus*). Red-whiskered and White-browed bulbuls were the major avian frugivores in the tropical dry evergreen forest of Sriharikota island, Southern India. (David *et al.* 2011). In southern India, 66 species of birds from 16 families has been documented for frugivory with Columbidae, Pycnonotidae and Muscicapidae representing the most number of species (Balasubramanian and Maheswaran 2002).

In a study conducted in Uttarkhand (Palita *et al.* 2011) the most common frugivorous birds in the study site include Jungle Myna, Common Myna, Himalayan Bulbul, Red-vented Bulbul, Red-billed Blue Magpie, Grey Tree pie, Rufous Tree pie and White Eye.

Figs – Keystone species

In Hawaii, Starr *et al.* (2003) observed various birds foraging and roosting on *Ficus* spp. Trees on Maui include Common Myna (*Acridotheres tristis*), Blue-faced Doves (*Geopelia striata*), Lace-necked Dove (*Streptopelia chinensis*), Japanese-white-eye (*Zosterops japonicus*), Northern Cardinal (*Cardinalis cardinalis*), and House Sparrows (*Passer domesticus*), though there are probably more. *Ficus benghalensis* was the top most preferred food plant to the birds in both the study areas, Madhupur National Park and Chittagong University Campus in Bangladesh. This plant supported 13 species of birds in Madhupur National Park and 11 species in Chittagong University Campus, Khan (2010)

Common Myna accounted for 72.3% of bird visitation to fig trees, followed by House Crow (15.5%), Asian Koel (6.2%) and Red-vented Bulbul (3.6%). All these bird species were frequently seen eating figs, three other bird species and unidentified birds made up the remaining 2.6% of visitations in a study made near Kalakad-Mundanthurai Tiger Reserve in Tirunelveli district (Caughlin *et al.* 2012). The nomadic Hill Myna feeds on the figs of 19 hemi- epiphytic species throughout its range. This species accounted for up to 50 % of avian feeding visits to Ficus crops in Peninsular Malaysia (Lambert, 1989b). Starlings are found across the tropics and 64 species in 22 genera are known to eat figs. (Shanahan *et al.* 2001). According to (Barua and Tamuly 2011) in Assam, India the three

most common visitors to Ficus, in decreasing order, were the Yellow-footed Green Pigeon, Jungle Myna, and Chestnut-tailed Starling. A majority of the most common species were either in the Pigeon, Starling, Barbet or Bulbul guilds.

Turdus species in Hong Kong selectively took the ripest figs of *Ficus microcarpa* and *F.virens* (So, 1999). In the subfamily Sylviinae, species of babblers (tribe Timaliini) and warblers (tribe Sylviini) are both recorded feeding figs. Among the former, *Alcippe brunneicauda* was one of the most frequently recorded species visiting figs in Malaysia (Lambert, 1989b) and *Pomatorhinus montanus* was observed to consume the ripest *Ficus sumatrana* figs available (McClure, 1966). The other major families of fig-eaters in the African and Indo-Australian regions are bulbuls (Pycnonotidae) Shanahan, *et al.* (2001). Bulbuls tend to make short feeding visits and fig seeds are defecated or regurgitated in pellets in a viable state Shanahan (2000).

Fruit colour

Fleshy fruits consumed by avian frugivores are often coloured red or black, sometimes blue, purple, pink, or white, but rarely orange, yellow, green, or brown (Janson 1983, Willson *et al.* 1989). Studies have shown that bird disseminated fruits frequently would be either black or red in colour (Wheelwright *et al.* 1984; Willson 1986). Fruit colors are commonly considered to increase the conspicuousness of a ripe fruit crop and/or attract the birds that eat fruits and disperse the enclosed seeds (Darwin 1859, Ridley 1930). In the Tropical Evergreen Forest in Chengalpattu district, Coromandel Coast, southern India, red (48%) followed by black (31%) were the predominant ftuit colours (Narasimhan *et al.* 1993). Red and black colors are often considered to signify a bird-dispersed syndrome, based on the assumption that their abundance is a consequence of an overall preference by birds for these colors (Schaefer & Schaefer 2007).

Frugivorous birds often discriminate fruits on the basis of fruit colour and show preferences for brightly coloured (red, orange and black) as well as UV-reflecting fruits over white and dull (green and yellow) fruits (Honkavaara *et al.* 2004). Fruit colour, however, may also be aimed at factors unrelated to consumption by dispersers.

Ridley (1930) considered red to be the most common colour of bird fruits. Later data from European plants corroborated Ridley's impression (Turcek 1963) and cemented the idea that bird fruits are typically red (Raven *et al.* 1976), a perception echoed by researchers in the Neotropics (McKey 1975; Janzen 1983a) and supported by data on fruits eaten by birds of paradise (Beehler 1983). In Peru, Janson (1983) showed that the fruits eaten by birds are small, lack scent, have no husk, and are red, black, white and sometimes blue, purple or mixed in colour.

The predominance of red and black fruit colours seems unlikely to be maintained by colour preferences by the birds (Willson *et al.* 1990). Red and black fruits were equally consumed and both were more consumed than white fruits in a study conducted in south-east Brazil (Galetti *et al.* 2003). A study conducted by David *et al.* (2011) in Sriharikota islands, India shows that Red, yellow and black were the major colours displayed by fleshy-fruits. Green, brown and violet were displayed only by one species each.

Fruit size

A study in the Tropical Evergreen Forest in Chengalpattu district, Coromandel Coast, southern India, showed that 72% of the fruits were less than 1cm in diameter, indicating the role of generalist frugivore in dispersal (Narasimhan *et al.* 1993). A high proportion of fruits (71%) were ≤15 mm in diameter, the largest fruit recorded was *Strychnos nux-vomica* (44 mm) and the smallest was the seedless fruits of *Salvadora persica* (2.4 mm) (David *et al.* 2011). Wilson *et al.* 1990, considered fruits of less than 20mm diameter to be primarily adapted for seed dispersal by volant birds.

Diamond (1973) reported that New Guinea fruit Pigeons ignored fruits that were small relative to their own size; big birds ate big fruits, medium birds ate medium fruits, and so on. Snow (1973) noted the correspondence between bellbird (*Procnias spp.*) gape widths and the sizes of their favoured fruits, species in the Lauraceae, and recognized that fruits, if too large, would not attract seed dispersers.

Studies from Malawi (Dowsett & Lemaire, 1998) have also brought out similar results. Khan (2010) reported that the diameter of the preferred fruit ranged from 16.5 to 19.6 mm (18.1 ± 0.8) in Madhupur National Park and 16.3 to 19.6 mm (17.9 ± 0.9) in

Chittagong University Campus, Bangladesh. In Australian surveys it was found that plant species with smaller fruits (<15 mm diameter) were visited by more avian frugivorous species than those with larger fruits (Stansbury and Vivian-Smith 2003), as the latter rely on frugivores with larger gape widths (Wheelwright 1985).

Small fruits with small seeds are typically dispersed by a greater number of animals than large fruits with large seeds (Stiles 2000). Large soft fruits, that contain many small seeds, however, can also be dispersed by small frugivores, that are able to peck and swallow seeds with pieces of the pulp (Jordano 2000).

Vegetation sampling

Carissa spinarum of the family Rubiaceae (7.7 relative density) dominates the scrub forest, Eastern Ghats and is consumed by 5 bird species, *Ziziphus oenoplia* of the family Rhamnaceae (6.9 relative density) was the second dominant species which attracted 7 species of birds. *Diospyros ferrea var buxifolia* of the family Ebenaceae was the third dominant species which was consumed by 4 species of avian frugivores. *Canthium dicoccum* of the family Rubiaceae (relative density 1.2) was consumed by 7 species of avian frugivores. *Ficus benghalensis* was found to be rare only (relative density 0.1) but it was utilized by 12 species of frugivorous birds. Out of the total 53 plant species, avian frugivores utilized 14 species in the scrub forest, Eastern Ghats. The above mentioned 14 species had fleshy fruits and had conspicuous colours like black, yellow, red, white, orange and blue.

CONCLUSION

A study on avian frugivory was conducted in two tropical forests namely mixed dry deciduous forest and scrub forest in Southern India.

Tropical mixed dry deciduous forest

Fruiting seasonality was reported with a peak in July and a dip in December.

Among the various fruit types eaten by birds, drupes were the predominant type borne by 15 species (47%) followed by berries on 7 species (22%), synconium 6 species (19%) and capsule 4 species (12%). Frugivorous birds favoured black fruits (44%). Red (20%) and yellow (12%) are other favoured colours.

Fruits were categorized into three types, based on size namely small size <10mm, medium size 10-20mm and big size (20-30mm). Small sized fruits attracted higher number of avian frugivores (50%), followed by medium sized fruits (44%) and big sized fruits (6%).

About 57% of woody plant species bore fleshy fruits.
Highest number of avian frugivores were observed on *F. benghalensis* (21) followed by *F. microcarpa* (17), *F.racemosa* (10) *F.mollis* (8) and *F.religiosa* (6). A total of 24 bird species consumed figs (5 species).

A total of 28 bird species belonging to 13 familes have been documented to eat fruits in the study area. Mean number of visits of birds showed significant variation to the plant species (Kruskal Wallis $\chi 2$= 483.366 df= 27, $p < .000$). The top five avian frugivores in the tropical mixed dry deciduous forest are Red-vented Bulbul (8.24 ± SE 0.96), Red-whiskered Bulbul (8.16± SE 0.87), White-browed Bulbul (7.68 ± SE 0.79), Common Myna (7.55 ± SE 0.87) and White-headed Babbler (6.05± SE 0.60).

Scrub forest

Fruiting seasonality was reported with a peak in July and dip in March.

Drupes constituted the predominant fruit type borne by 11 species (52%) followed by berries by 5 species (24%), synconium, 3 species (14%) and capsule 2 species (10%).

Avian frugivores'favoured fruit colour include black (29%) followed by red (27%) and pink (15%). In the scrub forest, medium-sized fruits attracted majority of the avian frugivores (65%), followed by small sized fruits (25%) and big sized fruits (10%).

About 57 % of woody plant species bore fleshy fruits. A total of 12 bird species were feeding on figs (3 species). Highest number of avian frugivores were observed on *F. benghalensis* (12) followed by *F.religiosa* (9) and *F.racemosa* (7).

A total of 13 bird species from 9 familes have been documented to eat fruits in the scrub forest. Mean number of visits of birds showed significant variation among plant species (Kruskal Wallis $\chi 2$= 135.813 df= 12, $p < .000$). The top five avian frugivores of the scrub forest are Common Myna (15.18 ± SE 2.59), Red-vented Bulbul (9.58 ± SE 1.70), House Crow (9.09± SE 2.20), White-headed Babbler (7.52± SE 1.73) and Jungle Babbler (4.71 ± SE1.69).

SUMMARY

Introduction

Mutualistic plant-animal interactions exist in a wide variety with one of the most important being seed dispersal or the transport of seeds away from a parent plant by animals. Not only plants depend on animals for the dispersal of their seeds, animals, too, rely on plants for fruit as a food resource. Avian frugivores are considered the most important seed dispersers in several ecosystems, as assessed by the numbers of successful propagules disseminated. Fruit-eating birds play a critical role in the functioning of tropical ecosystems and may assist in the natural regeneration of forests by dispersing seeds into cleared areas. Seed dispersal by animals and frugivory have reached their pinnacle in tropical forests, where a percentage of up to 90% of tree and shrub species produce fleshy fruits adapted to animal dispersal and eaten by a large number of vertebrates. In tropical forests, frugivorous animals are the dominant group of vertebrates. The challenge of frugivores is to find, eat and subsist partly or entirely on fruits that are mostly deficient in protein, but rich in carbohydrates or lipids. Fruit availability is one crucial factor influencing the frugivore community.

A study on frugivory by birds was carried out in two forest types namely, Tropical mixed dry deciduous forest in the Western Ghats and Scrub forest in the Eatern Ghats, Southern India. The research work was carried out in the tropical mixed dry deciduous forest of the Anaikatty hills of Nilgiri Biosphere Reserve, Attappady hills, Western Ghats. Anaikatty is situated between 76°39'and 76°47'E and from 11°5' to11°31'N. Attappady is located at the Middle East portion of Kerala State between 10° 55' 10" and 11° 14' 19" N and between 76° 27' 11" and 76° 48' 8" E.

Study on scrub forest observations were made in Thiruporur, Kancheepuram district in Eastern Ghats. Kancheepuram district is situated on the northern East Coast of Tamil Nadu and is adjacent by Bay of Bengal and Chennai city and is bounded in the west by Vellore and Thiruvannamalai district, in the north by Thiruvallur district and Chennai

district, in the south by Villuppuram district in the east by Bay of Bengal. It lies between 11° 00' to 12° 00' North latitudes and 77° 28' to 78° 50' East longitudes.

Methodology

A total of 150 woody plants belonging to 30 species were marked with aluminium tags and observed for fruiting phenology. The phenology of fruit production was observed twice in a month to assess the periodicity of fruiting. During the observation, percentage fruiting in the canopy was noted for each individual. Phenological observations were carried out for a continuous period of 1 year (November 2006 – October 2007) in the tropical mixed dry deciduous forest, Anaikatty. In the scrub forest, 110 individuals belonging to 22 species were observed for phenology. Phenological observations were carried out for a continuous period of 1 year (December 2008 – December 2009) in the scrub forest, Thiruporur, Eastern Ghats.

Foraging observation was made by extended bird feeding watches. Fruit-bearing plants with good visibility were selected for extended feeding watches. Observations were made between 6.00 and 9.00 hours on the bird visitation to fruit-yielding plants, with the help of binoculars. The visit by each individual bird followed by pecking/swallowing of fruits were considered as a fruit-feeding visit by a bird and recorded in the data form. Plants selected for observation had drupes, berries or similar soft fruits having one or a few seeds or with composite fruits with many small seeds (Moraceae). Colours of ripe fruits for plant species were assigned to one of eight broad colour categories as used by Wheelright and Janson (1985). Diameter of the fruits was measured using vernier caliper.

In each of the site, vegetation sampling was done by using quadrat method, Six transects were selected for sampling. Six, 1 km transects were laid for sampling the vegetation. In each transect, 10 quadrats of 10x10 mm were laid. In total 60 quadrats were laid. The woody species measuring more than 20 cms (GBH- Girth at Breast Height) were recorded. The plant specimens were identified with the help of Floras. The vegetational data were quantitatively analysed for density, relative density and other ecological values.

Results

Tropical mixed dry deciduous forest: A fruiting peak was noticed in July where 49 out of 150 individuals were fruiting and dip was noticed in December with 14 individuals in fruits. During the south west monsoon there was a peak in fruiting with 21 species and Post monsoon recorded the lowest fruting activity (9 species).

Fruits of 32 species belonging to 16 families have been found to be eaten by avian frugivores in the tropical mixed dry deciduous forest, among which Moraceae family constituted 6 plant species (5 *Ficus* spp and *Streblus asper*). The genus *Ficus* is known for their ability to produce asynchronously and support the avian frugivores during periods of scarcity. The favoured plant species for the frugivores in the study area include *Ficus benghalensis, Ficus microcarpa* and *Ficus mollis*. Moraceae, Rutaceae, Euphorbiaceae, Rubiaceae and Rhamnaceae constituted 50% of the frugivores food plant species.

Mean number of visits of birds were higher for *F. benghalensis* (124.67 ± SE 13.69), than the remaining 31 woody plant species, and the mean number of visits of birds differed significantly between the plant species ($F_{31, 64}$ = 22.653, P< .000). The top ten woody plant species that attracted avian frugivores in terms of mean number of visits are *Lantana camara* (95.00± SE 10.01), *Ziziphus oenoplia* (87.67± SE 7.68), *Breynia vitis-idaea* (87.00± SE 2.64), *Canthium dicoccum* (85.00± SE 8.50), *Ficus microcarpa* (84.33± SE 1.33), *Santalum album* (74.67± SE 4.80), *Ficus racemosa* (69.00± SE 7.54), *Cassine glauca* (67.67± SE 9.17) and *Benkara malabarica* (63.33± SE 6.38).

Mean species richness of birds were higher in *Ficus benghalensis* (17.67± SE 1.66), than other 31 woody plant species and the mean species diversity of birds differed significantly between the plant species ($F_{31, 64}$ = 53.897, P< .000). The top ten woody plant species that attracted avian frugivores in terms of mean species diversity are *Ficus microcarpa* (14.66± SE 1.00), *Cassine glauca* (15± SE 1.00), *Benkara malabarica*

(15.33± SE 0.88), *Pleurostylia opposita* (15± SE 0.33), *Flacourtia indica* (13.66± SE 0.66), *Canthium dicoccum* (12± SE 1.52), *Ziziphus oenoplia* (13.66± SE 0.33), *Ziziphus mauritiana* (10.33± SE 0.66) and *Lantana camara* (9.66± SE 1.15).

Mean bird diversity index on plant species were higher on *F. benghalensis* (2.63± SE 0.11) than other 31 woody plant species and the mean bird diversity of birds differed significantly between the plant species ($F_{31, 64}$ =172.352, P< .000), followed by *Cassine glauca* (2.60± SE 0.78), *Benkara malabarica* ,(2.57± SE 0.69), *Pleurostylia opposita* (2.56± SE 0.16), *Flacourtia indica* (2.47± SE 0.59), *Ziziphus oenoplia* (2.47± SE0.27), *Ficus microcarpa* (2.43± SE 0.71), *Cordia obliqua* (2.32± SE 0.007), *Flueggea virosa* (.31± SE 0.007) and *Canthium dicoccum* (2.22± SE 0.10).

A total of 24 bird species consumed figs (5 species). Highest number of avian frugivores were observed on *F. benghalensis (21)* followed *by* F. *microcarpa (17), F.racemosa (*10) *F.mollis* (8) and *F.religiosa* (6).

Among the various fruit types eaten by birds, drupes formed the predominant type borne by 15 species (47%) followed by berries 7 species (22 %), synconium 6 species (19%) and capsule 4 species (12%). Avian frugivores favoured black fruits (45%) followed by red (20%) and yellow (11%). The fruit types were recognized namely small size <10mm, medium size 10-20mm and big size (20-30mm). Small sized fruits attracted higher number of avian frugivores (50%), followed by medium sized fruits (44%) and big sized fruits (6%).

A total of 28 bird species from 13 familes have been documented to eat fruits. Pycnonotidae contributed maximum number of species (5 species; *Pycnonotus cafer, Pycnonotus jocosus, Pycnonotus luteolus, Pycnonotus priocephalus* and *Hypsipetes madagascariensis*) followed by Muscicapidae, 4 species (*Acrocephalus dumetorum, Turdoides affinis, Turdoides striatus* and *Turdoides subrufus*) and Capitonidae (barbets) with 3 species (*Megalaima haemacephala, Megalaima rubricapilla* and *Megalaima zeylanica*).

Among the various frugivorous bird species, Red-vented Bulbul formed the most dominant avian frugivore (15.14%) and used 29 species in its diet, followed by Red-whiskered Bulbul, 14.49% visits with 29 species in its diet, White-browed Bulbul utilized

14.31% of the feeding visits with 28 species in its diet. Mean number of visits of birds showed significant variation to the plant species (Kruskal Wallis $\chi 2 = 483.366$ df= 27, $p < .000$). The top five avian frugivores in the tropical mixed dry deciduous forest are Red-vented Bulbul (8.24 ± SE 0.96), Red-whiskered Bulbul (8.16± SE 0.87), White-browed Bulbul (7.68 ± SE 0.79), Common Myna (7.55 ± SE 0.87) and White-headed Babbler (6.05± SE 0.60).

The body mass varied considerably among avian frugivores (range 6.2-3000 g.) Indian Peafowl was the heaviest followed by House Crow, Asian Koel and Pompadour Green Pigeon. Thirteen species were in the range of 6-50g, seven species in the range of 50-100 g, while 3 species 100-150g. Two species weighed 150-200g and three species greater than 200g.

Pleiospermium alatum formed the most dominant species in the tropical mixed dry deciduous forest. Even though this species was dominant, fruits were not eaten by the avian frugivores. *Cordia monoica* was the second dominant species, even though this species was abundant, it did not attr act the avian frugivores. The unattractive colour of the fruit might be one of the reasons for not attracting avian frugivores. Most of the dominant species in the study area did not have fleshy fruits; hence birds did not feed on these fruits. *Ficus benghalensis* was (relative density 0.1) utilized by 21 species of birds, while *Ficus mollis* was (relative density 0.1) utilized by 8 bird species which clearly indicates the importance of figs in this forest. In the tropical mixed dry deciduous forest 57 % of the woody species bear fleshy fruits suitable for bird consumption.

Scrub forest

A fruiting peak was observed in July where 52 individuals out of 150 bore fruits and a dip was noticed in March with 8 individuals in fruiting. During the South-west monsoon there was a peak in fruiting with 12 species fruiting and a dip in summer (6 species).

Extended feeding observations were made on 21 plant species belonging to 13 families. Moraceae, Rubiaceae, Rhamnaceae constituted the dominant families with 3 species each (14%) *Ficus benghalensis, Ficus religiosa* and *Ficus racemosa* were found to be the most favoured fruit species in the study area.

Mean number of visits of birds were higher on *F. benghalensis* (180.00± SE 3.05), than other 31 plant species, and the mean number of visits of birds differed significantly between the plant species ($F_{20, 42}$ = 164.536, P< .000) (Figure24). The top ten plant species that attracted avian frugivores in terms of mean number of visits are *Ficus religiosa* (160.67± SE 9.82), *Ficus racemosa* (119.67±SE 6.06), *Flacourtia indica* (101.33± SE 3.93), *Lannea coromendelica* (97.33± SE 2.67), *Syzygium cumini* (68.00± SE 4.04), *Ziziphus oenoplia* (54.66± SE 6.17), *Carissa spinarum* (47.33± SE 3.18), *Canthium dicoccum* (46.67± SE 6.35) and *Azadirachta indica* (41.00± SE 1.15).

Mean species richness of birds were higher on *Ficus benghalensis* (12.00± SE 0.00), than the other 31 plant species and the mean species diversity of birds differed significantly between the plant species ($F_{20, 42}$ = 270.550, P< .000) (Figure25). The top ten plant species that attracted avian frugivores in terms of mean species diversity are *Ficus religiosa* (9.00± SE 0.00), *Ficus racemosa* (7.00± SE 0.00), *Canthium dicoccum* (7.00± SE 0.00), *Syzygium cumini* (7.00± SE 0.00), *Ziziphus oenoplia* (6.66± SE 0.33), *Flacourtia indica* (5.33± SE 0.33), *Diospyros ovalifolia* (5.00± SE 0.00), *Carissa spinarum* (5.00± SE 0.00) and *Lannea coromandelica* (5.00± SE 0.00).

Mean bird diversity index on tree species were higher on *F. benghalensis*, (2.17± SE 0.003) than the other 31 plant species and the mean bird diversity of birds differed significantly between the plant species (F20, 42 = 154.219, P< .000), (Figure26). followed by *Ficus religiosa* (1.98± SE 0.01), *Syzygium cumini*,(1.88± SE 0.69), *Ficus racemosa* (1.80± SE 0.01), *Canthium dicoccum* (1.70± SE 0.59), *Ziziphus oenoplia* (1.66± SE0.27), *Carissa spinarum* (1.51± SE 0.01), *Lannea coromandelica* (1.51± SE 0.01), *Diospyros ovalifolia* (1.46± SE 0.01) and *Carmona retusa* (1.43± SE 0.04) in the scrub forest.

Mean bird species eveness on tree species were higher on F. benghalensis, (2.04± SE 0.002) than the other 31 plant species and the mean bird species evenness of birds differed significantly between the plant species (F20, 42 = 152863, P< .000), followed by *Ficus religiosa* (1.88± SE 0.01), *Syzygium cumini*,(1.71± SE 0.02), *Ficus racemosa* (1.69± SE 0.01), *Canthium dicoccum* (1.49± SE 0.04), *Ziziphus oenoplia* (1.48± SE0.01),

Lannea coromandelica (1.42± SE 0.01), *Carissa spinarum* (1.36± SE 0.01), *Flacourtia indica* (1.31± SE 0.01) and *Diospyros ovalifolia* (1.27± SE 0.01) in the scrub forest.

A total of 12 bird species were feeding on figs (3 species). Among the figs *F. benghalensis* attracted 12 species followed by *F.religiosa* (9) and *F.racemosa* (7). Drupes constituted the predominant fruit type borne by 11 species (52%) followed by berries 5 species 24(%), synconium, 3 species (14%) and capsule 2 species (10%). Avian frugivores favoured fruit colour include black (29%) followed by red (27%) and pink (15%). In the scrub forest medium-sized fruits attracted majority of the avian frugivores (65%), followed by small sized fruits (25%) and big sized fruits (10%).

A total of 13 bird species from 9 familes have been documented to eat fruits in the scrub forest. Common Myna (Sturnidae) formed the most dominant avian frugivore which constituted 25.14% of feeding visits, used 20 species in its diet, followed by Red-vented Bulbul, 19 species (18.05%), and House Crow 17 species (17.49%). Mean number of visits of birds showed significant variation among plant species (Kruskal Wallis $\chi 2$= 135.813 df= 12, $p < .000$). The top five avian frugivores of the scrub forest are Common Myna (15.18 ± SE 2.59), Red-vented Bulbul (9.58 ± SE 1.70), House Crow (9.09± SE 2.20), White-headed Babbler (7.52± SE 1.73) and Jungle Babbler (4.71 ± SE1.69).

The body size varied considerably among avian frugivores (range 14-280 g). House Crow was the heaviest followed by Asian Koel. Five species were in the range of 14-50g, four species in the range of 50-100 g, while 2 species 100-150 g. One species each was recorded in the range of 150-200g and >200g. From the data, it is clear that the avian frugivores in the study area were light weighted.

Carissa spinarum, (relative density 7.7) dominates the scrub forest and its fruits are consumed by 5 bird species. *Ziziphus oenoplia,* (6.9 relative density) was the second dominant species which attracted 7 species of birds. *Ficus benghalensis* which is not abundant (relative density 0.1) was utilized by 12 species of birds. In the scrub forest 57 % of the woody species bear fleshy fruits suitable for bird consumption.

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Annexure I

	Bird species													
Plant species	RVB	RWB	WBB	BB	WHB	JB	CM	BM	AK	CSB	CTB	LGB	SGBM	IT
Azadirachta indica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00
Benkara malabarica	5.00	7.33	6.33	0.67	4.33	6.00	7.33	0.00	1.00	3.00	4.67	2.00	3.33	2.00
Breynia vitis-idaea	17.00	19.67	16.33	0.00	4.00	0.00	23.00	1.33	2.33	0.00	0.00	0.00	0.67	0.00
Canthium dicoccum	15.33	8.33	12.67	0.00	9.33	0.67	9.33	7.00	12.33	3.33	0.00	1.00	0.00	0.67
Capparis grandis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carmona retusa	7.67	7.33	9.33	0.00	6.33	0.00	7.33	0.00	3.33	0.00	0.00	0.00	2.67	0.00
Cassine glauca	5.67	7.00	6.33	1.00	7.00	5.33	6.33	0.00	2.00	4.67	5.00	1.00	4.00	2.33
Cetis philippensis	12.00	10.00	14.00	0.00	10.67	0.00	9.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cipadessa baccifera	3.33	3.67	2.67	0.00	3.67	0.00	4.00	0.00	3.00	0.00	0.00	0.00	1.00	0.00
Clausena dentata	6.00	6.33	6.00	0.00	8.00	3.33	5.67	0.00	2.00	0.00	0.00	0.00	0.00	0.00
Cordia monoica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00
Cordia obliqua	6.33	8.00	6.33	0.00	7.33	4.67	7.67	0.00	4.67	5.00	2.67	0.00	0.00	0.00
Diospyros montana	8.33	7.00	7.33	0.00	10.67	2.33	8.00	0.00	4.00	7.00	0.00	0.00	1.67	2.33
Ehraetia laevis	5.67	8.00	6.33	0.00	5.33	0.00	5.00	0.00	7.00	0.00	0.00	0.00	0.00	0.00
Ficus benghalensis	19.33	12.67	10.00	0.67	6.33	2.00	13.67	0.00	5.33	14.67	0.00	4.00	1.00	4.67
Ficus microcarpa	11.67	14.00	12.33	6.33	3.33	2.67	9.00	4.00	2.67	7.33	0.00	2.67	1.33	2.00
Ficus mollis	7.33	7.00	8.00	0.00	8.67	0.00	8.33	0.00	4.00	4.00	0.00	0.00	3.33	0.00
Ficus racemosa	9.00	12.00	7.67	0.00	9.33	0.00	9.33	0.00	9.33	0.00	4.00	0.00	0.00	2.33
Ficus religiosa	12.00	10.00	14.00	0.00	10.67	0.00	9.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Flacourtia indica	5.00	7.33	6.33	0.00	4.33	6.00	7.33	0.00	1.00	3.00	4.67	2.00	3.33	2.00
Flueggea virosa	5.67	7.00	6.33	0.00	7.00	5.33	6.33	0.00	2.00	4.67	5.00	0.00	4.00	2.33
Lantana camara	24.67	15.33	15.33	0.00	8.00	1.33	20.67	3.33	2.00	0.00	0.00	0.00	0.67	0.00
Maba buxifolia	4.67	4.00	5.00	0.00	6.33	0.00	5.33	0.00	4.00	0.00	0.00	0.00	0.00	0.00
Naringi crenulata	7.67	3.00	0.00	0.00	0.67	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00
Pleurostylia opposita	4.67	4.67	5.33	5.00	5.67	6.33	6.33	0.00	6.00	4.00	1.67	0.67	2.67	3.00
Premna tomentosa	10.67	10.00	14.00	0.00	0.00	0.00	7.67	0.00	7.67	0.00	0.00	0.00	0.00	0.00
Santalum album	9.33	15.33	8.33	0.00	12.67	0.00	9.33	7.00	12.33	0.00	0.00	0.00	1.33	0.00
Scutia myrtina	5.00	6.33	7.00	0.00	7.00	0.00	6.33	0.00	4.00	2.00	0.00	0.00	0.00	0.00
Streblus asper	6.00	6.33	10.67	0.00	8.00	0.00	9.33	4.67	2.67	0.00	0.00	0.00	1.00	0.00
Syzygium cumini	9.00	7.33	9.33	0.00	8.00	0.00	6.67	0.00	0.00	0.00	10.00	0.00	0.00	0.00
Ziziphus mauritiana	6.00	4.67	4.00	0.00	3.33	0.00	3.00	0.00	2.00	1.00	0.00	1.00	1.33	0.00
Ziziphus oenoplia	13.67	9.33	8.67	0.00	7.67	0.00	10.67	6.67	3.33	4.67	0.00	2.00	6.00	0.00

Mean of Mean visitation rate of avian frugivores in the Tropical mixed dry deciduous forest, Western Ghats

	Bird species													
Plant species	GFC	CI	HC	EGO	RRP	BWP	IP	IRB	GJF	BRW	TFP	GT	PGP	GHB
Azadirachta indica	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benkara malabarica	1.33	0.00	0.00	0.83	0.00	0.00	6.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00
Breynia vitis-idaea	0.00	2.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canthium dicoccum	0.00	2.67	0.00	0.33	1.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00
Capparis grandis	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carmona retusa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cassine glauca	3.33	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.67
Cetis philippensis	1.67	2.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cipadessa baccifera	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clausena dentata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cordia monoica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cordia obliqua	2.67	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diospyros montana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ehraetia laevis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ficus benghalensis	2.00	0.00	4.33	4.33	4.67	2.33	0.00	0.00	0.00	3.00	4.33	4.33	2.00	0.00
Ficus microcarpa	1.67	0.00	0.33	1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Ficus mollis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ficus racemosa	0.00	0.00	2.67	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ficus religiosa	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Flacourtia indica	1.33	0.00	0.00	0.83	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00
Flueggea virosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lantana camara	0.00	2.67	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Maba buxifolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Naringi crenulata	0.00	3.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pleurostylia opposita	1.67	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Premna tomentosa	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Santalum album	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scutia myrtina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Streblus asper	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Syzygium cumini	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ziziphus mauritiana	0.00	2.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ziziphus oenoplia	0.00	4.00	0.00	1.00	6.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Mean of Mean visitation rate of avian frugivores in the Tropical mixed dry deciduous forest, Western Ghats

	Bird species												
Plant species	CM	RVB	HC	WHB	JB	AK	EGO	WBB	CI	CSB	IT	RRP	BM
Azadirachta indica	17.33	2.66	15.33	0.00	0.00	5.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benkara malabarica	9.33	4.00	7.00	2.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canthium dicoccum	14.00	12.00	5.66	1.66	4.00	7.33	0.00	0.00	2.00	0.00	0.00	0.00	0.00
Carissa spinarum	15.33	11.33	4.00	7.00	9.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carmona retusa	13.00	1.33	7.00	6.00	9.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diospyros ovalifolia	9.33	12.66	5.66	3.66	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ficus benghalensis	44.00	15.00	40.33	7.00	10.66	14.00	14.00	4.00	14.33	9.00	2.66	0.00	5.00
Ficus racemosa	25.33	29.00	21.00	19.00	13.66	7.66	0.00	4.00	0.00	0.00	0.00	0.00	0.00
Ficus religiosa	35.00	25.33	22.33	17.33	32.66	10.33	6.33	0.00	2.33	0.00	9.00	0.00	0.00
Flacourtia indica	36.66	18.66	5.00	32.66	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fluggea virosa	8.33	9.33	4.66	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glycosmis cymosa	2.33	0.00	4.33	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grewia hirsuta	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lannea coromandelica	26.00	10.66	21.66	0.00	0.00	0.00	9.33	8.00	0.00	0.00	0.00	10.66	0.00
Maba buxifolia	13.66	5.66	0.00	9.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Melia azedarach	8.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00
Pleurostylia opposita	4.00	2.33	8.00	10.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scutia myrtina	2.33	4.00	0.00	5.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Syzygium cumini	15.33	11.33	12.66	6.66	6.00	9.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00
Ziziphus mauritiana	7.00	5.66	0.00	2.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ziziphus oenoplia	12.66	13.33	6.33	15.66	3.00	1.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Mean of mean visitation rate of avian frugivores in scrub forest, Eastern Ghats

LIST OF ABBREVIATIONS

RVB	-	Red-vented Bulbul
RWB	-	Red –whiskered Bulbul
WBB	-	White-browed Bulbul
BB	-	Black Bulbul
WHB	-	White-headed Babbler
JB	-	Jungle Babbler
CM	-	Common Myna
BM	-	Brahminy Myna
AK	-	Asian Koel
CSB	-	Coppersmith Barbet
CTB	-	Crimson-throated Barbet
LGB	-	Large Green Barbet
SGBM	-	Small Green- Billed Malkoha
IT	-	Indian Treepie
GFC	-	Gold -fronted Chloropsis
CI	-	Common Iora
HC	-	House Crow
EGO	-	Eurasian Golden Oriole
RRP	-	Rose-ringed parakeet
BWP	-	Blue-winged parakeet
IP	-	Indian Peafowl
IRB	-	Indian Rufous Babbler
GJF	-	Grey Jungle Fowl
BRW	-	Blyth's reed Warbler
TFP	-	Tickell's Flowerpecker
GT	-	Great Tit
PGP	-	Pompadour Green Pigeon
GHB	-	Grey-headed Bulbul

Annexure II

ROLE OF FRUGIVOROUS BIRDS IN SEED DISPERSAL IN THE MIXED DRY DECIDUOUS FORESTS OF ATTAPPADY AND ANAIKATTY, WESTERN GHATS

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Introduction

Fleshy fruits, which are apparently adapted for consumption by vertebrate seed-dispersers are very common in most tropical forests (Willson *et al.*, 1989). The survival of a plant species is best ensured by the dispersal of fruits and seeds to as many different and far off localities as possible (Venkateswaralu, 1982). Among the regular methods of seed dispersal, birds play a vital role, because of their fruit eating habits and the long distances they travel (Ridley, 1936). It is generally regarded that seeds defecated by birds germinate much faster than the normal seeds. A variety of birds and mammals depend predominantly on fruits to fulfill their nutritional requirements. Frugivorous animals also help seeds to escape from the deleterious effects of seed and seedling predators (Janzen, 1970). Due to the fact that forest birds are generally more abundant than mammals, birds are expected to move large quantities of seeds from the parent plants.

The study of relationships between bird-dispersed plants and fruit-eating birds in the tropical region has received considerable attention (Howe and Estabrook, 1977; Frost, 1980; Beehler, 1983; Wheelwright *et al.*, 1984; Gautier-Hion *et al.*, 1985; Lambert, 1989; Dowsett-Lemaire, 1988) Green (1993) has dealt on the role of birds in the restoration of tropical forests in Australian region. According to Green (1993) frugivores can also be poor dispersers (disperse a few seeds), fruit thieves (eat fruits but leave the seeds on or under the tree) or seed predators (digest the seeds). Hence, it is imperative to know which bird in a community is the ideal disperser of a particular plant species of that area. In India, only a few studies have been undertaken (Ali, 1931; Vijayan, 1975; Balasubramanian, 1996; Balasubramanian *et al.*, 1998). Hence the present study was undertaken in an important landscape in Western Ghats. The study aimed to document avian frugivory and find out the plant species that depend on birds for seed dispersal and suggest such plants for restoration of the degraded landscapes.

Study Area

The study was carried out in Attappady (10° 55' - 11° 14' North latitudes and 76° 27' - 76° 48' East longitudes) and the adjoining Anaikatty reserve forests

*Attappady Hills Area Development Society, Agali (Kerala).

Table 1

Observed frugivory by birds during extended watches on fruit bearing trees

Sl. No.	Common Name	Scientific Name	# of visits	%
1.	Red-vented Bulbul	*Pycnonotus cafer*	781	15.10
2.	Red-whiskered Bulbul	*Pycnonotus jocosus*	747	14.50
3.	White-browed Bulbul	*Pycnonotus luteolus*	738	14.30
4.	Common Myna	*Acridotheres tristis*	725	14.10
5.	Yellow-billed Babbler	*Turdoides affinis*	579	11.20
6.	Asian Koel	*Eudynamys scolopacea*	339	6.50
7.	Copper-smith Barbet	*Megalaima rubricapilla*	205	3.90
8.	Jungle Babbler	*Turdoides striatus*	141	2.70
9.	Green-billed Malkoha	*Phaenicophaeus tristis*	118	2.30
10.	Crimson-throated Barbet	*Megalaima haemacephala*	113	2.20
11.	Brahminy Starling	*Sturnus pagodarum*	103	1.90
12.	Indian TreePie	*Dendrocitta vagabunda*	71	1.40
13.	Gold fronted Leafbird	*Chloropsis aurifrons*	68	1.30
14.	Common Iora	*Aegithina tiphia*	60	1.20
15.	House Crow	*Corvus splendens*	54	1.00
16.	Large Green Barbet	*Megalaima zeylanica*	49	0.90
17.	Eurasian Golden Oriole	*Oriolus oriolus*	43	0.80
18.	Rose-ringed Parakeet	*Psittacula krameri*	42	0.80
19.	Black Bulbul	*Hypsipetes madagascariensis*	41	0.80
20.	Blue-winged Parakeet	*Psittacula columboides*	39	0.70
21.	Rufous Babbler	*Turdoides subrufus*	33	0.60
22.	Indian Peafowl	*Pavo cristatus*	16	0.30
23.	Great Tit	*Parus major*	13	0.20
24.	Tickell's Flowerpecker	*Dicaeum erythrorhynchos*	12	0.20
25.	Grey-headed Bulbul	*Pycnonotus priocephalus*	8	0.60
26.	Grey Junglefowl	*Gallus sonneratii*	8	0.15
27.	Pompadour Green Pigeon	*Treron pompadora*	6	0.10
28.	Blyth's Reed Warbler	*Acrocephalus dumetorum*	5	0.09
29.	Thick-billed Flowerpecker	*Dicaeum agile*	1	0.01

feeding visits. About 70% of the fruit feeding visits were made by these five species. Hence, these species could be considered as major frugivores and seed dispersers of the study area. In addition, Koel (*Eudynamys scolopacea)* and barbets (*Megalaima spp*) were also found to be important for seed dispersal.

1	2	3	4	5	6
27	*Ficus religiosa*	Tree	19	0.74	6
28	*Ficus benghalensis*	Tree	18	0.70	21
29	*Glycosmis mauritiana*	Shrub	18	0.70	8
30	*Azadirachta indica*	Tree	16	0.62	2
31	*Ficus mollis*	Tree	15	0.58	8
32	*Ehretia laevis*	Tree	14	0.54	6
33	*Carissa carandas*	Shrub	12	0.47	8
34	*Ficus microcarpa*	Tree	12	0.47	17
35	*Diospyros montana*	Tree	12	0.47	10
36	*Carissa spinarum*	Shrub	10	0.39	7
37	*Murraya paniculata*	Shrub	6	0.23	5
38	*Mallotus philippensis*	Tree	6	0.23	2
39	*Cordia monoica*	Tree	1	0.04	1
40	*Capparis grandis*	Tree	1	0.04	1

*Exotics

racemosa (3.37%), *Canthium dicoccum* (2.53%), *Syzygium cumini* (2.38%), *Cassine glauca* (2.22%) and *Streblus asper* (2.02%). Highest number of bird species was recorded in *Ficus benghalensis* (n=21) followed by *Ficus microcarpa*, *Benkara malabarica* and *Cassine glauca*, 17 species each.

A total of 17 plant families were found to attract avian frugivores in the study area. Predominant plant families that attracted frugivorous birds include, Moraceae (6 species), Rutaceae (5 species), Euphorbiaceae (4 species) and Rubiaceae (4 species) (Fig. 1). Moraceae, Rutaceae, Euphorbiaceae, Rubiaceae, Rhamnaceae and Verbenaceae members constituted about 60 % of the food plants for frugivores. Families that comprised only a few species but favoured by birds include Santalaceae, Meliaceae and Capparaceae. Important plant species for frugivores in the study area include *Ficus benghalensis*, *Ficus microcarpa* and *Ficus mollis* belonging to the family Moraceae.

Discussion

Fruiting plants that sustain frugivores during times of general fruit scarcity are known as "keystone species" (Leighton and Leighton, 1983; Terborgh, 1986a; Lambert and Marshall, 1991). They are of great ecological significance because they appear to set the carrying capacity of the frugivore community (Terborgh, 1986b). Fruiting fig trees attract highly diverse frugivores assemblages that disperse huge number of seeds over large areas. Figs (*Ficus*) have been identified as keystone plants for frugivore communities in South American and South-East Asian tropical forests during lean periods (Leighton and Leighton, 1983; Terborgh, 1986a; Kannan and James, 1999). In southern India, figs form a major diet of several avian frugivores. *Ficus* spp. (Moraceae)

Light-vented Bulbul (*Pycnonotus sinensis*)were responsible for a large proportion of seed dispersal (Corlett, 1998, Weir and Corlett, 2007). In the present study, majority of the fruit-feeding visits (44.50%) were made by five species of bulbuls. It indicates that they are the principal frugivores and potential seed dispersers in the dry forest habitats across the tropics.

In conclusion, it is stated that to restore the degraded dry deciduous forest sites in Attappady, bird-attracting native tree species reported in the paper could be chosen for planting.

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SUMMARY

The Attappady Hills Area Development Society (AHADS) as part of eco-restoration programmes in Attappady hills, Western Ghats, initiated tree planting programmes to identify the bird-attracting species. Study sites were chosen in the degraded dry deciduous forests of Attappady and the adjoining Anaikatty reserve forests representing the mixed dry deciduous forest. Frugivorous birds were ascertained by making extended feeding watches on fleshy-fruited plant species and bird counts along transects. Twenty nine bird species were observed to eat fruits. Among the frugivore visitors, bulbuls (5 species) made highest number of feeding visits (45%), followed by mynas, 2 species (16%), babblers, 3 species (14.5%) and others. A total of 40 bird-attracting species were recorded in the study area. Moraceae represented by six species was found to be the most dominant bird-attracting family followed by Rutaceae and Euphorbiaceae. Among the 40 species, *Ficus benghalensis* attracted maximum number of avian frugivores followed by *Ficus microcarpa*, *Benkara malabarica*, *Cassine glauca* and *Canthium dicoccum*. A suggestion is made to plant the bird-attracting native species in the degraded sites of Attappady.

Key words **: Frugivory, Birds, Seed dispersal, Western Ghats.**

अट्टपाडि और अनैकट्टी पश्चिमी घाट प्रदेश के मिश्र शुष्क पर्णपाती वनों में बीज विकिरण में फल भक्षी पक्षियों की भूमिका

आर० अरुणा, पी० बालसुब्रामनियन् व पी० राधाकृष्णन्

सारांश

अट्टापाडि पर्वतीय क्षेत्र विकास परिषद ने अट्टापाडि पहाडियों पश्चिमी घाट प्रदेश के पुनस्थापन कार्यक्रमों के अंगस्वरूप पक्षियों को आकर्षित करती जातियों का पता लगाने के लिए एक वृक्षारोपण कार्यक्रम आरम्भ किया है। इसके अध्ययन स्थल अट्टापाडि के व्याहसित शुष्क पर्णपाती वनों और उनके साथ लगते अनैकट्टी आरक्षित वन में चुने गए जो मिश्र शुष्क पर्णपाती वन का प्रतिनिधित्व करते हैं। फलभक्षी पक्षियों का पता गूदेदार फल पादपों पर भोजन करते पक्षियों की विस्तारपूर्वक चौकसी करते और सक्षेत्रों के किनारे–किनारे पक्षियों की गिनती करके लगाया गया। उनत्तीस पक्षिजातियां फलों को खाती पर्यवेक्षित हुई। फलभक्षी आगन्तुकों में बुलबुले (पांच जातियां)

FLOWERING AND FRUITING PHENOLOGY OF A TROPICAL MIXED DRY DECIDUOUS FOREST IN ANAIKATTY HILLS, WESTERN GHATS

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Abstract: This paper describes the flowering and fruiting phenology of 30 woody plant species in a mixed dry deciduous forest, Anaikatty hills. A total of 150 individuals of woody plants belonging to 30 species and 15 families (24 tree species and 6 shrubs) were observed for flowering and fruiting phenology. The flowering peak was recorded during April and May and the fruiting peak in June, July. *Ficus benghalensis* that fruited during fruit scarcity appear to play a keystone role in the study area.

INTRODUCTION

Phenology is defined as the study of the periodicity or timing of recurring biological events in relation to short-term climatic change. Tropical plants with their high level of species diversity display phenological events such as leaf drop, leaf flushing, flowering and fruiting, etc. in relation to time and space (Justiniano and Fredericksen, 2000; Singh and Singh, 1992). Study of such events is useful in evolving proper management strategy as well as better understanding of natural forest regeneration and community level interactions (Fox, 1976). The phenology of tropical species has received much attention in the last three decades (Morellato, 2003, Medeiros *et al.*, 2007), The general phenological aspects of leafing, flowering and fruiting in tropical tree species are fairly known (Borchert 1983; Frankie *et al.*, 1974; Opler *et al.*, 1980; Putz, 1979; Sun *et al.*, 1996). Studies from different parts of the world have shown that climatic factors are mainly responsible for vegetative and reproductive phenology at both community and species level. The tropical forests have a distinctive array of species different from temperate forests. It supports different varieties of over-storey and under-storey plant species, which are major food resources for a variety of biota (Bhat and Murali, 2001). In India, studies have been done on phenology of dry tropical forests (Prasad and Hegde, 1986; Singh and Singh, 1992), forests in North Eastern India (Boojh and Ramakrishnan 1981; Shukla and Ramakrishnan 1982, Kikim and Yadava, 2001), and the wet forests of Western Ghats (Kannan, 1994; Menon, 1993). The present work aimed to document the flowering and fruiting phenology of a tropical mixed dry deciduous forest, in Western Ghats.

MATERIALS AND METHODS

The study was carried out in the mixed dry deciduous forests of Anaikatty hills of Nilgiri Biosphere Reserve, Western Ghats. The area lies between 76° 39' and 76° 47' E longitude and 11° 5' to 11° 31' N latitude Coimbatore. This reserve forest falls between Nilgiri on the South and Sathyamangalam Forest Divisions on the North, Erode division on the East and Palghat Forest Division of Kerala on the South. Total area of this reserve forest is 4447.7 ha. This forest has an undulating terrain (610 – 750 msl) with seasonal waterways with hill tops and rising upto 1600 msl. The study area receives maximum rainfall during the Northeast. The major vegetation type seen in the study area is southern tropical mixed dry deciduous forest (Champion and Seth, 1968). The climate of this area is semi-arid as it is located in the rain shadow part of the Western Ghats.

A total of 150 individuals of woody plants belonging to 30 species and 15 families (23 tree species and 7 shrubs) were tagged and observed for phenology. The phenology of flower and fruit production was observed twice in a month to assess the periodicity of flowering and fruiting. (Frankie *et al.*, 1974). The families studied were Rubiaceae, Cordiaceae, Capparaceae, Moraceae, Rutaceae, Verbenaceae, Rhamnaceae, Ebenaceae, Ulmaceae, Celastraceae, Euphorbiaceae, Loganiaceae, Santalaceae, Myrtaceae and Meliaceae. During the observation, percent flowering and fruiting were noted for each individual. Phenological observations were carried out from October 2006 to November 2007 in the mixed dry deciduous forests. The phenology is discussed with regard to four seasons namely, Summer (March – May), South-West Monsoon (June –

Table -2: Flowering and Fruiting schedule of various fleshy fruited species in Anaikatty hills, Western Ghats

S. No.	Plant species	Summer	South-West Monsoon	North-East Monsoon	Post-Monsoon
1	*Azadirachta indica*	*	□		
2	*Breynia rhamnoides*	*	* □	* □	
3	*Canthium dicoccum*	□			* □
4	*Capparis grandiflora*	*	□	□	
5	*Capparis grandis*	*	□	□	
6	*Capparis zeylanica*	*	□	□	*
7	*Carmona retusa*	*		* □	
8	*Canthium parviflorum*				* □
9	*Cassine glauca*	*	*	□	*
10	*Celtis philippensis*	* □	□		
11	*Clausena dentata*		□		*
12	*Cordia monoica*	*	□		*
13	*Cordia obliqua*	*	□		
14	*Diospyros montana*	*	* □	□	
15	*Ehretia ovalifolia*	*	□	□	* □
16	*Ficus benghalensis*	□		*	□
17	*Ficus racemosa*	□	□	*	
18	*Glycosmis pentaphylla*	□	□		*
19	*Tarenna asiatica*	* □	□	□	* □
20	*Lantana camara*	* □	* □	* □	* □
21	*Maba buxifolia*	*	* □	□	
22	*Murraya paniculata*	*	* □		
23	*Ixora pavetta*	□	□		*
24	*Premna tomentosa*	□	□	*	
25	*Santalum album*	□		* □	* □
26	*Streblus asper*	□	□		*
27	*Strychnos potatorum*	* □	*		□
28	*Syzygium cumini*	□	□	*	*
29	*Ziziphus mauritiana*			* □	
30	*Ziziphus oenoplia*			* □	□

Contd.

* Flowers and □ Fruits

seen during July to December in the forests of Costa Rica (Koptur *et al.*, 1988). Extreme seasonality in fruiting occurs in most tropical forests with distinct wet and dry seasons (Howe, 1984). Fruiting peak during wet season was reported from several tropical forests (Hilty, 1980; Lieberman, 1982; Wheelwright and Janson 1985) Balasubramanian and Bole, 1993 observed fruiting peak during monsoon (October – December), in Point Calimere, South India. The peak in fruit production of *Cullenia exarillata* at Agasthiyamalai range, Western Ghats was from May to September whereas there was a fruiting depression from December to April. (Ganesh and Davidar, 1997). In the coastal plain forest peak fruiting was seen during March to August was reported by (Morellato *et al.*, 2000). Kikim and Yadava (2001) reported flowering peak during April and fruiting peak during September at Manipur which coincides with the present study. Fruiting peak during wet season was reported from many tropical forests (Hilty 1980, Murali and Sukumar 1994), (Croat, 1969, Arthur and Parthasarathy, 2007) in their phenological studies at Central Panama and Coromandel coast of India observed that the fleshy fruited species that fruited during the dry season was less when compared to wet season. Seasonality in fruit production in tropical forest ecosystem has brought to light the roles played by keystone or pivotal species during period of scarcity. The present study indicates that *Ficus benghalensis* that fruited during the period of fruit scarcity (post-monsoon) could play a keystone role.

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Avian frugivory and seed dispersal of Indian Sandalwood *Santalum album* in Tamil Nadu, India

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Santalum album (Santalaceae) is a medium sized evergreen tree found in dry forest tracts of the Deccan Peninsula, where the major sandal growing tracts are located in Karnataka and Tamil Nadu. Sandal is also distributed in parts of Maharashtra, Andhra Pradesh and Kerala. The species was introduced to several areas of central and northern India, where it has naturalized and spread. It can grow up to an elevation of 1200m and in rainfall zones of 300–3000 mm. Flower panicles appear during December–April and fruiting occurs throughout the year (Matthew 1991). The fruit is a fleshy purplish-black globose drupe measuring approximately a centimetre in diameter. This species also regenerates from wood suckers. Viable seeds are produced after five years and dispersed by birds (Asian Regional Workshop 1998). Fire, grazing and exploitation of the wood for fine furniture, carving and oil are threatening the species (Asian Regional Workshop 1998). There is much concern regarding over-exploitation due to smuggling for trade. *Santalum album* is a Vulnerable (IUCN 2010) and threatened species in southern India (Ravikumar et al. 2000).

Although known as a bird-dispersed species, very little information is available on frugivory and seed dispersal of *S. album*. Biotic dispersal consists of removal of plant propagules by animal frugivores and the deposition of seeds away from the source plant. The pulp of fleshy fruits, with the soft, edible, nutritious tissues surrounding the seeds is a primary food source for many animals, notably birds and mammals (Howe 1986). These animals regurgitate, defecate, spit out or otherwise drop the undamaged seeds away from the parent plants; they are the seed dispersers that establish a dynamic link between the fruiting plant and the seed-seedling bank in natural communities (Jordano 2000). Avian frugivores are considered as the most important seed dispersers in most ecosystems (Herrera 1995; Stiles 2000). Parrots, some pigeons and finches are seed predators (Corlett 1998). The study of interactions between avian frugivores and plant species is important for identifying the roles of individual disperser species play in plant recruitment dynamics, thus having implications for both theoretical understanding of mutualisms, species interactions and for applied work, including conservation and restoration (Jordano 1987; Loiselle & Blake 1999). The present study was carried out to assess the role of different frugivores in the seed dissemination of sandalwood tree in Tamil Nadu.

Materials and Methods

Trees with ripe fruits were selected for field observations. A pair of binoculars was used by the observer, who sat near the tree, usually 10–15 m away and watched the canopy for recording animal visits. Extended watches of 3-hr duration were made for a total of 54-hr in Anaikatty Hills, the Western Ghats and 24-hr in Pachaimalai Hills, the Eastern Ghats. During the extended watches, the observer noted the name of the visitor (bird/mammal), frequency of fruit-feeding visits by different species, and fruit handling behaviour (whether fruit ingested whole or

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growing in the middle of thorny bushes, where the birds seem to have dropped the seeds. Birds that are beneficial to sandalwood dispersal and regeneration were Koel, Common Myna, Brahminy Starling, Brown-headed Barbet, White-headed Babbler and Indian Grey Hornbill. These species visited the fruit crop more frequently and swallowed the fruit wholly. Hence, these species could be considered as major seed dispersers. Asian Koel seems to have preference to sandal fruits. Bulbuls could not swallow the whole fruit, due to their smaller beak and narrow gape. They appear to play a minor role only. Parakeets did not play any role in seed dispersal. They consumed the fruits mainly to digest the seeds and hence considered as seed predators. Green-billed Malkoha made very few visits, thus contributing only a minor role.

Sustaining the Asian Koel population will ensure the regeneration of sandal trees in the forests. Efforts need to be undertaken to provide a healthy habitat for the seed dispersing bird species such as koel, as the population of Sandalwood tree is drastically dwindling in the wild.

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Annexure II

ROLE OF FRUGIVOROUS BIRDS IN SEED DISPERSAL IN THE MIXED DRY DECIDUOUS FORESTS OF ATTAPPADY AND ANAIKATTY, WESTERN GHATS

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Introduction

Fleshy fruits, which are apparently adapted for consumption by vertebrate seed-dispersers are very common in most tropical forests (Willson *et al.*, 1989). The survival of a plant species is best ensured by the dispersal of fruits and seeds to as many different and far off localities as possible (Venkateswaralu, 1982). Among the regular methods of seed dispersal, birds play a vital role, because of their fruit eating habits and the long distances they travel (Ridley, 1936). It is generally regarded that seeds defecated by birds germinate much faster than the normal seeds. A variety of birds and mammals depend predominantly on fruits to fulfill their nutritional requirements. Frugivorous animals also help seeds to escape from the deleterious effects of seed and seedling predators (Janzen, 1970). Due to the fact that forest birds are generally more abundant than mammals, birds are expected to move large quantities of seeds from the parent plants.

The study of relationships between bird-dispersed plants and fruit-eating birds in the tropical region has received considerable attention (Howe and Estabrook, 1977; Frost, 1980; Beehler, 1983; Wheelwright *et al.*, 1984; Gautier-Hion *et al.*, 1985; Lambert, 1989; Dowsett-Lemaire, 1988) Green (1993) has dealt on the role of birds in the restoration of tropical forests in Australian region. According to Green (1993) frugivores can also be poor dispersers (disperse a few seeds), fruit thieves (eat fruits but leave the seeds on or under the tree) or seed predators (digest the seeds). Hence, it is imperative to know which bird in a community is the ideal disperser of a particular plant species of that area. In India, only a few studies have been undertaken (Ali, 1931; Vijayan, 1975; Balasubramanian, 1996; Balasubramanian *et al.*, 1998). Hence the present study was undertaken in an important landscape in Western Ghats. The study aimed to document avian frugivory and find out the plant species that depend on birds for seed dispersal and suggest such plants for restoration of the degraded landscapes.

Study Area

The study was carried out in Attappady (10° 55' - 11° 14' North latitudes and 76° 27' - 76° 48' East longitudes) and the adjoining Anaikatty reserve forests

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(11° 5' - 11° 31' North latitudes, 76° 39' - 76° 47' East longitudes) in the Western Ghats. Attappady is located at the middle eastearn portion of Kerala stretching over an area of 745 km² in Palakkad Revenue District touching the Nilgiri and Coimbatore districts of Tamil Nadu as its Northern and Eastern boundaries, respectively. The Ecosystem of Attappady is highly fragile due to its physiographical and meteorological characteristics. Excessive fragmentation of the land holdings and unscientific agricultural practices made the soil and vegetation in a poor state. The region is totally degraded, only remnant vegetation is found. Anaikatty Reserve Forest is a part of the Nigiri Biosphere Reserve, occurs at an elevation of 610 - 750 m amsl. This is an undulating terrain predominated by mixed dry deciduous forest.

Methods

Observations were carried out both in degraded and undisturbed sites. Degraded site comprised of small patches of mixed dry deciduous vegetation which are less dense occurring in Attappady. The undisturbed site occurs in Anaikatty, comprised of large patches of mixed dry deciduous forests. The study was carried out during October 2006 - September 2007.

Avian frugivory was documented by recording the activities of birds foraging on fruit-bearing plants. Two methods were followed; in the first method, extended watches were carried out in focal fruit bearing trees to record frugivore visitation. Plants selected for observation had drupes, berries or similar soft fruits having one or a few seeds or with composite fruits with many small seeds (Moraceae). The observer sat 10 m away from the focal plant, and observed the activities of avian visitors with the help of a pair of binoculars. Observations were usually done between 6.00 am and 9.00 am. The visit by each individual bird followed by pecking/ swallowing of fruits was considered as a fruit-feeding visit. In the second method, birds foraging on fruit-bearing plants were recorded while walking along the census transects. The number of birds in a foraging flock and the fruit species eaten by birds were noted. Most of the observations were done within four hours after sunrise, which is the most active foraging time for birds.

Results

Fruit-eating birds : During the extended bird feeding watches on 32 fleshy-fruited plant species, 29 fruit-eating birds were recorded (Table 1). Among the 29 fruit-eating species, *Psittacula krameri, P. columboides* are considered as seed predators as they mainly consumed the seeds. Remaining species of birds ate the fruits whole or partly, and regurgitated/ defecated the seeds and hence, considered as seed dispersers. Among the frugivore visitors, bulbuls (5 species) made highest number of feeding visits (45%), followed by mynas, 2 species (16%), babblers, 3 species (14.50%) and others that include barbets, koel, etc. Amog the bird species, Red-vented Bulbul *(Pycnonotus cafer)* (15.10%), followed by Red-whiskered Bulbul *(Pycnonotus jocosus)* (14.5%), White-browed Bulbul (*Pycnonotus luteolus)* (14.30%), Common Myna *(Acridotheres tristis)* (14.10%) and Yellow-billed Babbler *(Turdoides affinis)* (11.20%) were recorded as frequent frugivore visitors. These species visited large number of plant species as well as made frequent fruit

Table 1

Observed frugivory by birds during extended watches on fruit bearing trees

Sl. No.	Common Name	Scientific Name	# of visits	%
1.	Red-vented Bulbul	*Pycnonotus cafer*	781	15.10
2.	Red-whiskered Bulbul	*Pycnonotus jocosus*	747	14.50
3.	White-browed Bulbul	*Pycnonotus luteolus*	738	14.30
4.	Common Myna	*Acridotheres tristis*	725	14.10
5.	Yellow-billed Babbler	*Turdoides affinis*	579	11.20
6.	Asian Koel	*Eudynamys scolopacea*	339	6.50
7.	Copper-smith Barbet	*Megalaima rubricapilla*	205	3.90
8.	Jungle Babbler	*Turdoides striatus*	141	2.70
9.	Green-billed Malkoha	*Phaenicophaeus tristis*	118	2.30
10.	Crimson-throated Barbet	*Megalaima haemacephala*	113	2.20
11.	Brahminy Starling	*Sturnus pagodarum*	103	1.90
12.	Indian TreePie	*Dendrocitta vagabunda*	71	1.40
13.	Gold fronted Leafbird	*Chloropsis aurifrons*	68	1.30
14.	Common Iora	*Aegithina tiphia*	60	1.20
15.	House Crow	*Corvus splendens*	54	1.00
16.	Large Green Barbet	*Megalaima zeylanica*	49	0.90
17.	Eurasian Golden Oriole	*Oriolus oriolus*	43	0.80
18.	Rose-ringed Parakeet	*Psittacula krameri*	42	0.80
19.	Black Bulbul	*Hypsipetes madagascariensis*	41	0.80
20.	Blue-winged Parakeet	*Psittacula columboides*	39	0.70
21.	Rufous Babbler	*Turdoides subrufus*	33	0.60
22.	Indian Peafowl	*Pavo cristatus*	16	0.30
23.	Great Tit	*Parus major*	13	0.20
24.	Tickell's Flowerpecker	*Dicaeum erythrorhynchos*	12	0.20
25.	Grey-headed Bulbul	*Pycnonotus priocephalus*	8	0.60
26.	Grey Junglefowl	*Gallus sonneratii*	8	0.15
27.	Pompadour Green Pigeon	*Treron pompadora*	6	0.10
28.	Blyth's Reed Warbler	*Acrocephalus dumetorum*	5	0.09
29.	Thick-billed Flowerpecker	*Dicaeum agile*	1	0.01

feeding visits. About 70% of the fruit feeding visits were made by these five species. Hence, these species could be considered as major frugivores and seed dispersers of the study area. In addition, Koel (*Eudynamys scolopacea)* and barbets (*Megalaima spp*) were also found to be important for seed dispersal.

Bird-attracting plants : During the transect walk count, fruits of 40 plant species were found to be eaten by birds (Table 2). Among the 40 species, the exotic weed *Lantana camara* attracted maximum number of birds (22.97%). Notable native trees which attracted birds include *Santalum album* (4.28%), *Celtis philippensis* (3.41%), *Ficus*

Table 2

Bird-attracting plants observed in the study area

Sl. No.	Species	Habit	# of birds observed	% proportion	# of frugivorous species observed
1	2	3	4	5	6
1	*Lantana camara**	Shrub	580	22.55	11
2	*Flueggea virosa*	Shrub	158	6.14	11
3	*Ziziphus oenoplia*	Shrub	145	5.64	14
4	*Carmona retusa*	Shrub	112	4.35	7
5	*Cipadessa baccifera*	Shrub	135	5.25	8
6	*Santalum album*	Tree	108	4.20	8
7	*Scutia myrtina*	Shrub	106	4.12	7
8	*Breynia rhamnoides*	Shrub	101	3.93	9
9	*Celtis philippensis*	Tree	86	3.34	7
10	*Ficus racemosa*	Tree	85	3.30	10
11	*Trema orientalis**	Tree	74	2.88	6
12	*Flacourtia indica*	Tree	69	2.68	15
13	*Toddalia asiatica*	Straggler	65	2.53	5
14	*Canthium dicoccum*	Tree	64	2.49	15
15	*Syzygium cumini*	Tree	60	2.33	7
16	*Cassine glauca*	Tree	56	2.18	17
17	*Benkara malabarica*	Shrub	52	2.02	17
18	*Streblus asper*	Tree	51	1.98	9
19	*Pleurostylia opposita*	Tree	50	1.94	15
20	*Ziziphus mauritiana*	Tree	39	1.52	11
21	*Premna tomentosa*	Tree	35	1.36	6
22	*Pithecellobium dulce**	Tree	32	1.24	6
23	*Glycosmis pentaphylla*	Shrub	28	1.09	6
24	*Maba buxifolia*	Tree	27	1.05	6
25	*Cordia obliqua*	Tree	24	0.93	11
26	*Clausena dentata*	Shrub	23	0.89	7

Contd...

1	2	3	4	5	6
27	*Ficus religiosa*	Tree	19	0.74	6
28	*Ficus benghalensis*	Tree	18	0.70	21
29	*Glycosmis mauritiana*	Shrub	18	0.70	8
30	*Azadirachta indica*	Tree	16	0.62	2
31	*Ficus mollis*	Tree	15	0.58	8
32	*Ehretia laevis*	Tree	14	0.54	6
33	*Carissa carandas*	Shrub	12	0.47	8
34	*Ficus microcarpa*	Tree	12	0.47	17
35	*Diospyros montana*	Tree	12	0.47	10
36	*Carissa spinarum*	Shrub	10	0.39	7
37	*Murraya paniculata*	Shrub	6	0.23	5
38	*Mallotus philippensis*	Tree	6	0.23	2
39	*Cordia monoica*	Tree	1	0.04	1
40	*Capparis grandis*	Tree	1	0.04	1

*Exotics

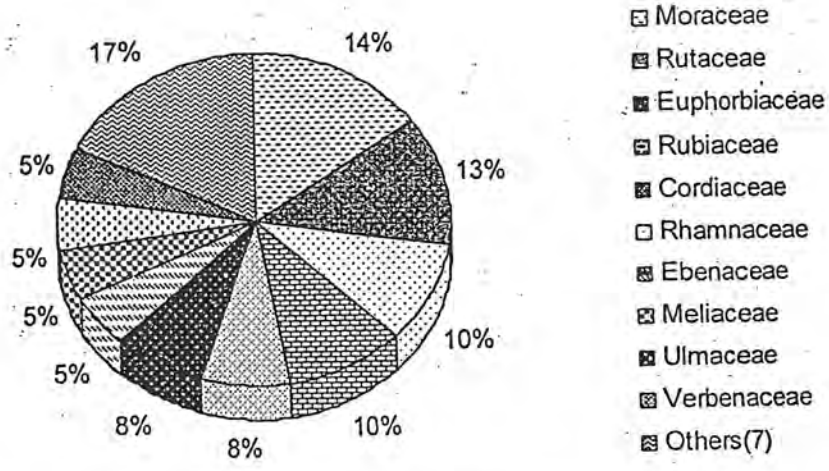
racemosa (3.37%), *Canthium dicoccum* (2.53%), *Syzygium cumini* (2.38%), *Cassine glauca* (2.22%) and *Streblus asper* (2.02%). Highest number of bird species was recorded in *Ficus benghalensis* (n=21) followed by *Ficus microcarpa, Benkara malabarica* and *Cassine glauca*, 17 species each.

A total of 17 plant families were found to attract avian frugivores in the study area. Predominant plant families that attracted frugivorous birds include, Moraceae (6 species), Rutaceae (5 species), Euphorbiaceae (4 species) and Rubiaceae (4 species) (Fig. 1). Moraceae, Rutaceae, Euphorbiaceae, Rubiaceae, Rhamnaceae and Verbenaceae members constituted about 60 % of the food plants for frugivores. Families that comprised only a few species but favoured by birds include Santalaceae, Meliaceae and Capparaceae. Important plant species for frugivores in the study area include *Ficus benghalensis, Ficus microcarpa* and *Ficus mollis* belonging to the family Moraceae.

Discussion

Fruiting plants that sustain frugivores during times of general fruit scarcity are known as "keystone species" (Leighton and Leighton, 1983; Terborgh, 1986a; Lambert and Marshall, 1991). They are of great ecological significance because they appear to set the carrying capacity of the frugivore community (Terborgh, 1986b). Fruiting fig trees attract highly diverse frugivores assemblages that disperse huge number of seeds over large areas. Figs (*Ficus*) have been identified as keystone plants for frugivore communities in South American and South-East Asian tropical forests during lean periods (Leighton and Leighton, 1983; Terborgh, 1986a; Kannan and James, 1999). In southern India, figs form a major diet of several avian frugivores. *Ficus* spp. (Moraceae)

Fig. 1



Dominant bird-attracting plant families in Anaikatty and Attappady (n=17)

supported diversity of avian frugivores in the study area; 21 species of avian frugivores fed on *Ficus* spp.

Birds are recognized as the main dispersal agent of many invasive plant species (Glyphis *et al.*, 1981; Dean and Milton, 2000; Stansbury, 2001; Renne *et al.*, 2002). *Lantana camara*, an exotic shrub attracted large number of avian frugivores in the present study; 23% of feeding observations by birds were recorded on *Lantana camara*. Mishra and Mishra (1996) recorded eight species of birds eating *Lantana camara* fruits in Central India. Balasubramanian *et al* (1998) recorded 13 avian frugivores on *Lantana camara* in the Western Ghats. In the present study, 11 bird species were recorded to feed on *Lantana camara*. In all these sites bulbuls, mynas and barbets are found to be the major frugivores on *Lantana camara*.

Bulbuls have established themselves as one of the dominant frugivores and seed dispersers in scrub jungles or forests of secondary vegetation in Asia, Africa and the Middle East (Lever, 1987). Most species of bulbuls are frugivores and important seed dispersers. (Kitamura *et al.*, 2002). Fruits comprised a major proportion of diet for *Pycnonotus luteolus* and *Pycnonotus cafer* in the tropical dry evergreen forest, Point Calimere, India (Vijayan, 1975). In Point Calimere, 74% of the feeding visits by birds on fruit bearing plants were made by two species of bulbuls, *P. cafer* and *P. luteolus* (Balasubramanian, 1996). In a dry mixed deciduous forest in Western Ghats, bulbuls are the predominant frugivorous and seed dispersing species (Balasubramanian *et al.*, 1998). In the sub-tropical shrublands of Hong Kong, two species of bulbuls Red-whiskered Bulbul (*Pycnonotus jocosus*) and

Light-vented Bulbul (*Pycnonotus sinensis*)were responsible for a large proportion of seed dispersal (Corlett, 1998, Weir and Corlett, 2007). In the present study, majority of the fruit-feeding visits (44.50%) were made by five species of bulbuls. It indicates that they are the principal frugivores and potential seed dispersers in the dry forest habitats across the tropics.

In conclusion, it is stated that to restore the degraded dry deciduous forest sites in Attappady, bird-attracting native tree species reported in the paper could be chosen for planting.

Acknowledgements

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SUMMARY

The Attappady Hills Area Development Society (AHADS) as part of eco-restoration programmes in Attappady hills, Western Ghats, initiated tree planting programmes to identify the bird-attracting species. Study sites were chosen in the degraded dry deciduous forests of Attappady and the adjoining Anaikatty reserve forests representing the mixed dry deciduous forest. Frugivorous birds were ascertained by making extended feeding watches on fleshy-fruited plant species and bird counts along transects. Twenty nine bird species were observed to eat fruits. Among the frugivore visitors, bulbuls (5 species) made highest number of feeding visits (45%), followed by mynas, 2 species (16%), babblers, 3 species (14.5%) and others. A total of 40 bird-attracting species were recorded in the study area. Moraceae represented by six species was found to be the most dominant bird-attracting family followed by Rutaceae and Euphorbiaceae. Among the 40 species, *Ficus benghalensis* attracted maximum number of avian frugivores followed by *Ficus microcarpa*, *Benkara malabarica*, *Cassine glauca* and *Canthium dicoccum*. A suggestion is made to plant the bird-attracting native species in the degraded sites of Attappady.

Key words **: Frugivory, Birds, Seed dispersal, Western Ghats.**

अट्टपाडि और अनैकट्टी पश्चिमी घाट प्रदेश के मिश्र शुष्क पर्णपाती वनों में
बीज विकिरण में फल भक्षी पक्षियों की भूमिका

आर० अरुणा, पी० बालसुब्रामनियन् व पी० राधाकृष्णन्

सारांश

अट्टापाडि पर्वतीय क्षेत्र विकास परिषद ने अट्टापाडि पहाडियों पश्चिमी घाट प्रदेश के पुनस्थापन कार्यक्रमों के अंगस्वरूप पक्षियों को आकर्षित करती जातियों का पता लगाने के लिए एक वृक्षारोपण कार्यक्रम आरम्भ किया है। इसके अध्ययन स्थल अट्टापाडि के व्याहसित शुष्क पर्णपाती वनों और उनके साथ लगते अनैकट्टी आरक्षित वन में चुने गए जो मिश्र शुष्क पर्णपाती वन का प्रतिनिधित्व करते हैं। फलभक्षी पक्षियों का पता गूदेदार फल पादपों पर भोजन करते पक्षियों की विस्तारपूर्वक चौकसी करते और सक्षेत्रों के किनारे–किनारे पक्षियों की गिनती करके लगाया गया। उनत्तीस पक्षिजातियां फलों को खाती पर्यवेक्षित हुई। फलभक्षी आगन्तुकों में बुलबुले (पांच जातियां)

सर्वाधिक संख्या में भोजन करने वहां आई (45%), इसके बाद मैना (2%) जातियां (16%) सतभैया, 3 जातियां (14.5%) और अन्य पक्षि रहे। कुल मिलाकर 40 पक्षि आकर्षक पादप जातियां अधीत क्षेत्र से आलेखित की गई। इनमें वटकुल, जिसकी यहां छह जातियां थी सर्वाधिक बहुल पक्षि आकर्षक कुल पाया गया जिसके पश्चात निम्बु कुल और एरण्ड कुल आते हैं। 40 जातियों में से *फाइकस बेगालेसिस* ने फलभक्षी पक्षिजातों की अधिकतम संख्या को आकर्षित किया जिसके पश्चात *फाइकस माइक्रोकार्पा, बेंकांरा मलाबारिका, कैसाइन ग्लौका* और *कैन्थियम आरकोक्कम* आते हैं। अट्टापटि के व्याहसित स्थलों में पक्षियों को आकर्षित करने वाली देशज पादप-जातियां रोपने का सुझाव भी दिया गया है।

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FLOWERING AND FRUITING PHENOLOGY OF A TROPICAL MIXED DRY DECIDUOUS FOREST IN ANAIKATTY HILLS, WESTERN GHATS

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Abstract: This paper describes the flowering and fruiting phenology of 30 woody plant species in a mixed dry deciduous forest, Anaikatty hills. A total of 150 individuals of woody plants belonging to 30 species and 15 families (24 tree species and 6 shrubs) were observed for flowering and fruiting phenology. The flowering peak was recorded during April and May and the fruiting peak in June, July. *Ficus benghalensis* that fruited during fruit scarcity appear to play a keystone role in the study area.

INTRODUCTION

Phenology is defined as the study of the periodicity or timing of recurring biological events in relation to short-term climatic change. Tropical plants with their high level of species diversity display phenological events such as leaf drop, leaf flushing, flowering and fruiting, etc. in relation to time and space (Justiniano and Fredericksen, 2000; Singh and Singh, 1992). Study of such events is useful in evolving proper management strategy as well as better understanding of natural forest regeneration and community level interactions (Fox, 1976). The phenology of tropical species has received much attention in the last three decades (Morellato, 2003, Medeiros *et al.*, 2007), The general phenological aspects of leafing, flowering and fruiting in tropical tree species are fairly known (Borchert 1983; Frankie *et al.*, 1974; Opler *et al.*, 1980; Putz, 1979; Sun *et al.*, 1996). Studies from different parts of the world have shown that climatic factors are mainly responsible for vegetative and reproductive phenology at both community and species level. The tropical forests have a distinctive array of species different from temperate forests. It supports different varieties of over-storey and under-storey plant species, which are major food resources for a variety of biota (Bhat and Murali, 2001). In India, studies have been done on phenology of dry tropical forests (Prasad and Hegde, 1986; Singh and Singh, 1992), forests in North Eastern India (Boojh and Ramakrishnan 1981; Shukla and Ramakrishnan 1982, Kikim and Yadava, 2001), and the wet forests of Western Ghats (Kannan, 1994; Menon, 1993). The present work aimed to document the flowering and fruiting phenology of a tropical mixed dry deciduous forest, in Western Ghats.

MATERIALS AND METHODS

The study was carried out in the mixed dry deciduous forests of Anaikatty hills of Nilgiri Biosphere Reserve, Western Ghats. The area lies between 76° 39' and 76° 47' E longitude and 11° 5' to 11° 31' N latitude Coimbatore. This reserve forest falls between Nilgiri on the South and Sathyamangalam Forest Divisions on the North, Erode division on the East and Palghat Forest Division of Kerala on the South. Total area of this reserve forest is 4447.7 ha. This forest has an undulating terrain (610 – 750 msl) with seasonal waterways with hill tops and rising upto 1600 msl. The study area receives maximum rainfall during the Northeast. The major vegetation type seen in the study area is southern tropical mixed dry deciduous forest (Champion and Seth, 1968). The climate of this area is semi-arid as it is located in the rain shadow part of the Western Ghats.

A total of 150 individuals of woody plants belonging to 30 species and 15 families (23 tree species and 7 shrubs) were tagged and observed for phenology. The phenology of flower and fruit production was observed twice in a month to assess the periodicity of flowering and fruiting. (Frankie *et al.*, 1974). The families studied were Rubiaceae, Cordiaceae, Capparaceae, Moraceae, Rutaceae, Verbenaceae, Rhamnaceae, Ebenaceae, Ulmaceae, Celastraceae, Euphorbiaceae, Loganiaceae, Santalaceae, Myrtaceae and Meliaceae. During the observation, percent flowering and fruiting were noted for each individual. Phenological observations were carried out from October 2006 to November 2007 in the mixed dry deciduous forests. The phenology is discussed with regard to four seasons namely, Summer (March – May), South-West Monsoon (June –

August), North-East Monsoon (September–November) and Post Monsoon (December–February).

RESULTS

The peak flowering was observed during April and May 2007 with eight species (Fig.1). Species in flowers during this period were *Azadirachta indica, Strychnos potatorum, Cordia monoica, Carmona retusa, Cassine glauca, Maba buxifolia, Diospyros montana, Breynia rhamnoides* and *Murraya paniculata.* A dip was noticed during September 2007 where only 4 species were flowering, viz. *Ziziphus oenoplia, Ziziphus mauritiana, Lantana camara* and *Carmona retusa.*

The fruiting peak was observed during June, July and September, with 10 species. Species in fruits during June were *Premna tomentosa, Celtis philippensis, Ficus racemosa, Glycosmis pentaphylla, Lantana camara, Cordia obliqua, Syzygium cumini, Ehraetia ovalifolia, Maba buxifolia, Murraya paniculata.* The species in fruits during July included *Capparis grandis, Celtis philippensis, Glycosmis pentaphylla, Lantana camara, Breynia rhamnoides, Cordia obliqua, Syzygium cumini, Ehretia ovalifolia, Maba buxifolia* and *Murraya paniculata* (Fig.2). Species in fruits during September 2007 were *Lantana camara, Breynia rhamnoides, Carmona retusa, Ehretia laevis, Maba buxifolia, Santalum album, Diospyros montana, Tarenna asiatica, Capparis grandis and Capparis zeylanica.* A dip was noticed during December 2006 where only 3 species had fruits, viz. *Breynia rhamnoides, Ziziphus oenoplia* and *Ziziphus mauritiana* (Fig.2). *Lantana camara* and *Tarenna asiatica* fruits were available allround the year.

During South West monsoon, 7 species had flowers of which 5 were trees and 2 shrubs. In the post monsoon 13 species were recorded in flowering of which 10 were trees and 3 shrubs. Summer had a peak in flowering with 17 species, where 12 were trees and 5 shrubs. During Northeast monsoon, 10 species were flowering out of which 6 were trees and 4 shrubs. (Table -1) During the South West monsoon there was a peak in fruiting with 21 species, where 17 were trees and 4 shrubs. Post monsoon had 9 fruiting plants with 6 trees and 3 shrubs, while summer showed 13 species with 11 trees and 2 shrubs. During North East monsoon, 14 species had fruits and it included 8 trees and 6 shrubs (Table -1). Flowering and fruiting schedule of woody plants of the study area are shown in Table -2.

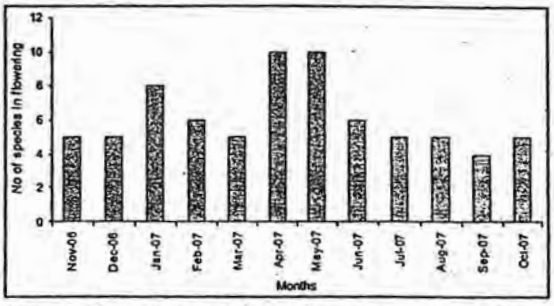

Fig. 1. Phenology of flowering of woody plants at Anaikatty, Western Ghats.

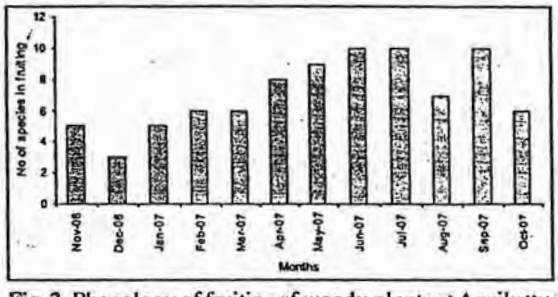

Fig. 2. Phenology of fruiting of woody plants at Anaikatty, Western Ghats.

DISCUSSION

The extensive literature on flowering phenology of tropical plants is largely focused on the timing or seasonality of flowering at the community level (Janzen, 1967; Frankie *et al.,* 1974; Opler *et al.,* 1980; Wright and Calderon, 1995). Phenological studies of tropical forests have shown the greatest seasonality in leafing and flowering in lowland dry forests (Frankie *et al.,* 1974, Rathcke and Lacey, 1985). In several tropical forests flowering peak was reported to occur during dry season (Janzen, 1967, Wright and Cornejo, 1990, Yadav and Yadav, 2008). Mass flowering was

Table -1: Phenology of woody plants in different seasons in Anaikatty hills

Season	Species in flowering			Species in fruiting		
	Trees	Shrubs	Total	Trees	Shrubs	Total
South West monsoon	5	2	7	17	4	21
Post monsoon	10	3	13	6	3	9
Summer	12	5	17	11	2	13
North East monsoon	6	4	10	8	6	14

Table -2: Flowering and Fruiting schedule of various fleshy fruited species in Anaikatty hills, Western Ghats

S. No.	Plant species	Summer	South-West Monsoon	North-East Monsoon	Post-Monsoon
1	*Azadirachta indica*	*	▫		
2	*Breynia rhamnoides*	*	* ▫	* ▫	
3	*Canthium dicoccum*	▫			* ▫
4	*Capparis grandiflora*	*	▫	▫	
5	*Capparis grandis*	*	▫	▫	
6	*Capparis zeylanica*	*	▫	▫	*
7	*Carmona retusa*	*		* ▫	
8	*Canthium parviflorum*				* ▫
9	*Cassine glauca*	*	*	▫	*
10	*Celtis philippensis*	* ▫	▫		
11	*Clausena dentata*		▫		*
12	*Cordia monoica*	*	▫		*
13	*Cordia obliqua*	*	▫		
14	*Diospyros montana*	*	* ▫	▫	
15	*Ehretia ovalifolia*	*	▫	▫	* ▫
16	*Ficus benghalensis*	▫		*	▫
17	*Ficus racemosa*	▫	▫	*	
18	*Glycosmis pentaphylla*	▫	▫		*
19	*Tarenna asiatica*	* ▫	▫	▫	* ▫
20	*Lantana camara*	* ▫	* ▫	* ▫	* ▫
21	*Maba buxifolia*	*	* ▫	▫	
22	*Murraya paniculata*	*	* ▫		
23	*Ixora pavetta*	▫	▫		*
24	*Premna tomentosa*	▫	▫	*	
25	*Santalum album*	▫		* ▫	* ▫
26	*Streblus asper*	▫	▫		*
27	*Strychnos potatorum*	* ▫	*		▫
28	*Syzygium cumini*	▫	▫	*	*
29	*Ziziphus mauritiana*			* ▫	
30	*Ziziphus oenoplia*			* ▫	▫

* Flowers and ▫ Fruits

seen during July to December in the forests of Costa Rica (Koptur *et al.*, 1988). Extreme seasonality in fruiting occurs in most tropical forests with distinct wet and dry seasons (Howe, 1984). Fruiting peak during wet season was reported from several tropical forests (Hilty, 1980; Lieberman, 1982; Wheelwright and Janson 1985) Balasubramanian and Bole, 1993 observed fruiting peak during monsoon (October – December), in Point Calimere, South India. The peak in fruit production of *Cullenia exarillata* at Agasthiyamalai range, Western Ghats was from May to September whereas there was a fruiting depression from December to April. (Ganesh and Davidar, 1997). In the coastal plain forest peak fruiting was seen during March to August was reported by (Morellato *et al.*, 2000). Kikim and Yadava (2001) reported flowering peak during April and fruiting peak during September at Manipur which coincides with the present study. Fruiting peak during wet season was reported from many tropical forests (Hilty 1980, Murali and Sukumar 1994), (Croat, 1969, Arthur and Parthasarathy, 2007) in their phenological studies at Central Panama and Coromandel coast of India observed that the fleshy fruited species that fruited during the dry season was less when compared to wet season. Seasonality in fruit production in tropical forest ecosystem has brought to light the roles played by keystone or pivotal species during period of scarcity. The present study indicates that *Ficus benghalensis* that fruited during the period of fruit scarcity (post-monsoon) could play a keystone role.

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Avian frugivory and seed dispersal of Indian Sandalwood *Santalum album* in Tamil Nadu, India

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Santalum album (Santalaceae) is a medium sized evergreen tree found in dry forest tracts of the Deccan Peninsula, where the major sandal growing tracts are located in Karnataka and Tamil Nadu. Sandal is also distributed in parts of Maharashtra, Andhra Pradesh and Kerala. The species was introduced to several areas of central and northern India, where it has naturalized and spread. It can grow up to an elevation of 1200m and in rainfall zones of 300–3000 mm. Flower panicles appear during December–April and fruiting occurs throughout the year (Matthew 1991). The fruit is a fleshy purplish-black globose drupe measuring approximately a centimetre in diameter. This species also regenerates from wood suckers. Viable seeds are produced after five years and dispersed by birds (Asian Regional Workshop 1998). Fire, grazing and exploitation of the wood for fine furniture, carving and oil are threatening the species (Asian Regional Workshop 1998). There is much concern regarding over-exploitation due to smuggling for trade. *Santalum album* is a Vulnerable (IUCN 2010) and threatened species in southern India (Ravikumar et al. 2000).

Although known as a bird-dispersed species, very little information is available on frugivory and seed dispersal of *S. album*. Biotic dispersal consists of removal of plant propagules by animal frugivores and the deposition of seeds away from the source plant. The pulp of fleshy fruits, with the soft, edible, nutritious tissues surrounding the seeds is a primary food source for many animals, notably birds and mammals (Howe 1986). These animals regurgitate, defecate, spit out or otherwise drop the undamaged seeds away from the parent plants; they are the seed dispersers that establish a dynamic link between the fruiting plant and the seed-seedling bank in natural communities (Jordano 2000). Avian frugivores are considered as the most important seed dispersers in most ecosystems (Herrera 1995; Stiles 2000). Parrots, some pigeons and finches are seed predators (Corlett 1998). The study of interactions between avian frugivores and plant species is important for identifying the roles of individual disperser species play in plant recruitment dynamics, thus having implications for both theoretical understanding of mutualisms, species interactions and for applied work, including conservation and restoration (Jordano 1987; Loiselle & Blake 1999). The present study was carried out to assess the role of different frugivores in the seed dissemination of sandalwood tree in Tamil Nadu.

Materials and Methods

Trees with ripe fruits were selected for field observations. A pair of binoculars was used by the observer, who sat near the tree, usually 10–15 m away and watched the canopy for recording animal visits. Extended watches of 3-hr duration were made for a total of 54-hr in Anaikatty Hills, the Western Ghats and 24-hr in Pachaimalai Hills, the Eastern Ghats. During the extended watches, the observer noted the name of the visitor (bird/mammal), frequency of fruit-feeding visits by different species, and fruit handling behaviour (whether fruit ingested whole or

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only partly eaten and seeds dropped). The field study was carried out between 2006 and 2009 in Anaikatty hills (11°5'–11°31'N & 76°39'–76°47'E), the Western Ghats and Pachaimalai hills (11°15'N & 76°38'E), the Eastern Ghats in Tamil Nadu. Bird's names have been followed as per Ali (2002). Observations from Hasanur in Sathyamangalam Forest Division (11°29'–11°48'N & 76°50'–77°27'E), the Eastern Ghats are also discussed. The forest type (Champion & Seth 1968) of the study sites comprise of southern dry mixed deciduous forest (5A/C3). Predominant trees of the sites include *Bauhinia racemosa, Santalum album,* and *Chloroxylon swietenia.*

Results and Discussion

A total of 217 birds belonging to eight species visited *Santalum album* (Table 1) in Anaikatty Hills, Western Ghats. These included three species of bulbuls, *Pycnonotus* sp., Brahminy Starling *Sturnus pagodarum*, Common Myna *Acridotheres tristis*, Asian Koel *Eudynamys scolopacea,* White-headed Babbler *Turdoides affinis* and Small Green-Billed Malkoha *Phaenicophaeus viridirostris.* Highest proportion of feeding visits was contributed by Red-whiskered Bulbul, *Pycnonotus jocosus* (20.3%) followed by White-headed Babbler (16.7%) and Asian Koel (16.3%). Among the various avian families, Pycnonotidae (bulbuls) made the majority of the visits (43.6%) followed by Sturnidae (mynas) (21.6%). Brown-headed Barbet *Megalaima zeylanica* was also found to be an important seed disperser in Parali Hills, the Western Ghats (Balasubramanian et al. 1998). Among the birds, Asian Koel, Brown-headed Barbet, Mynas, Starlings and Indian Grey Hornbill swallowed the whole fruit. Most often, bulbuls ate the fruit in piecemeal and dropped the seeds under the canopy itself. Occasionally, small fruits were swallowed by them.

In the Pachaimalai Hills, 349 birds belonging to three species visited the focal tree during the study period. Among the frugivorous birds, the highest proportion of visits was made by the Asian Koel (50.4%) followed by Common Myna (38.6%), and Rose-ringed Parakeet *Psittacula krameri* (11%). In addition to birds, Three-striped Palm Squirrel *Funambulus palmarum* also visited the plant to eat fruit. While koel and myna consumed the whole fruit, parakeets ate the seeds. Three-striped Squirrel ate the pulp and dropped the seeds.

In the Sathyamangalam Forest Division, Balasubramanian & Santhoshkumar (2009) observed Indian Grey Hornbill *Ocyceros birostris* playing an important role in the seed dispersal of *S. album.* The Indian Grey Hornbill's diet comprised a reasonable proportion of *Santalum album* fruits both in breeding season (7%) and non-breeding season (4%). Role of Indian Grey Hornbill in regeneration of *S. album* was evidenced by the presence of sandalwood seedlings in hornbill's nest middens. Three percent of the seedlings in hornbill middens comprised of *S. album.*

Birds constituted the principal seed dispersers of *Santalum album.* Except squirrels no other mammals were foraging on *S.album* fruit crops during this study. Most of the natural seedlings of sandal were found

Table 1. Avian seed dispersers of *Santalum album* at Anaikatty, Parali (Western Ghats), Hasanur, Pachaimalai (Eastern Ghats)

Common Name	Scientific Name	Feeding visits		Locations
		#	%	
Red-vented Bulbul	*Pycnonotus cafer*	28	12.90	Anaikatty
Red-whiskered Bulbul	*Pycnonotus jocosus*	36	16.59	Anaikatty
White-browed Bulbul	*Pycnonotus luteolus*	25	11.52	Anaikatty
Common Myna	*Acridotheres tristis*	28	12.90	Anaikatty, Pachaimalai
Brahminy Starling	*Sturnus pagodarum*	21	9.68	Anaikatty
Asian Koel	*Eudynamys scolopacea*	37	17.05	Anaikatty, Pachaimalai
White-headed Babbler	*Turdoides affinis*	38	17.51	Anaikatty
Small Green-billed Malkoha	*Phaenicophaeus viridirostris*	4	1.84	Anaikatty
Brown-headed Barbet	*Megalaima zeylanica*	-	-	Parali Hills
Indian Grey Hornbill	*Ocyceros birostris*	-	-	Hasanur

growing in the middle of thorny bushes, where the birds seem to have dropped the seeds. Birds that are beneficial to sandalwood dispersal and regeneration were Koel, Common Myna, Brahminy Starling, Brown-headed Barbet, White-headed Babbler and Indian Grey Hornbill. These species visited the fruit crop more frequently and swallowed the fruit wholly. Hence, these species could be considered as major seed dispersers. Asian Koel seems to have preference to sandal fruits. Bulbuls could not swallow the whole fruit, due to their smaller beak and narrow gape. They appear to play a minor role only. Parakeets did not play any role in seed dispersal. They consumed the fruits mainly to digest the seeds and hence considered as seed predators. Green-billed Malkoha made very few visits, thus contributing only a minor role.

Sustaining the Asian Koel population will ensure the regeneration of sandal trees in the forests. Efforts need to be undertaken to provide a healthy habitat for the seed dispersing bird species such as koel, as the population of Sandalwood tree is drastically dwindling in the wild.

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