

FRUGIVORY, SEED DISPERSAL AND REGENERATION BY BIRDS IN SOUTH INDIAN FORESTS

(With seven text-figures and one plate)

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Key words: Tropical forest, bird-fruits, avian frugivores, seed dispersal, fruit size, forest regeneration, Western Ghats

Plants, unlike animals, are immobile and have little control over the choice of site where they can live and grow. Over aeons, plants have perfected the art of survival in spite of this disability by steadily interacting with the animals in their habitat. The evolution of brilliant, attractive colours and endowment of the fruits with nutritious supplements such as proteins, lipids and carbohydrates, have appealed to the dietary needs of birds and mammals. Furthermore, the plant's ability to asynchronously produce fruits, for the assemblage of vertebrates dependent on fruits have made their dispersal possible. Plant-bird interactions play a pivotal role in maintaining the structural and functional integrity of natural ecosystems. Also, the interactions guide the process of evolution of biodiversity as well as ecological communities. On account of their unparalleled richness, tropical communities are treasure troves of biological interactions between plants and animals. Ecological degradations, as in shrinking habitats and fragmentation, necessitate a comprehensive understanding of the basic tenets of interacting entities, in order to evolve effective strategies to preserve and enrich our biodiversity.

INTRODUCTION

Birds play a prominent role in pollination and seed dispersal of plants. The flower visiting birds, while harvesting nectar, pollinate their food plants. Similarly, the fruit eating birds by devouring the pulpy fruits distribute the seeds of their food plant species. Birds, by virtue of their habits, can play a more effective role in seed dissemination than other animals. Compared to other vertebrates, which disseminate the seeds in clumps, the seed deposition pattern of birds is more efficient. The interactions between flower-birds and bird-flowers have been discussed (Ali 1931, Subramanya and Radhamani 1993). A variety of birds and mammals depend predominantly on fruit to fulfil their nutritional requirements. Such fruit-eating birds and mammals are termed as frugivores. Fruit traits such as colour, size and nutritional supplements have evolved in response to interacting vertebrates. The evolution of fruit syndromes, complemented by the birds' adaptive ability to recognise these syndromes, along with

physiological and anatomical modifications to process the fruit diet have been the key in the contemporaneous plant-bird interactive relations. Such persistent relationships have given rise to mutual dependence, benefiting both elements.

Though fruit-frugivore interactions have been studied by various authors during recent times, there is no consolidated information on the role of birds in seed dispersal and forest regeneration. Information is available on the fruit types consumed by various bird species in India, but only a few studies attempted to quantify the role of birds in forest regeneration. A review of those studies and reference to the various floras indicate that several families benefit from birds for their regeneration. Known syndromes of bird-dispersed fruits help to identify various bird-fruits from hitherto unexplored bird habitats.

Frugivores help seeds escape from the deleterious effects of seed and seedling predators (Janzen 1970). Differences in frugivore activity have profound effects on the conditions under which seeds and seedlings must survive, and consequently should influence the evolution of tree demographies. The relationship between seed dispersal and seedling demography has profound implications for tropical conservation policy

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(Howe 1984). Seasonality in fruit production in tropical forest ecosystems has brought to light the roles played by 'keystone' or 'pivotal' species during periods of scarcity.

Studies on fruit-frugivore interactions conducted by us as part of research programmes under the Bombay Natural History Society (BNHS) and the Sálím Ali Centre for Ornithology and Natural History (SACON) for the past two decades helped us to arrive at certain conclusions and also comprehensively list the plant genera dispersed by birds in south India. The material for this paper has been derived mainly from the Tropical Dry Evergreen Forests of Point Calimere, and the Semi-evergreen, Dry and Mixed Deciduous Forests of the Western Ghats. Though seed dispersal is effected by exozoochorous methods (dispersal effected by seeds clinging on to body parts of birds and animals) also, we would like to state that the review exclusively deals with endozoochory (dispersal wherein fruits are ingested, the pulp digested and the seeds defecated or regurgitated).

OBSERVATIONS

Frugivory and seed dispersal in south India

The present review is based on three major research efforts in south India – on the Tropical Dry Evergreen Forests in Point Calimere, Dry Mixed Deciduous Forests of Coimbatore Division and Semi-evergreen forests of Mudumalai Wildlife Sanctuary (MWLS), Western Ghats. The lists of fruit-eating birds and bird-dispersed fruit species have been compiled chiefly from these three major studies and have been summarised in Appendix I and II.

A total of 66 species (36 genera) of Indian birds from 16 families have been documented for frugivory in south India. Bird species of families Columbidae (pigeons), Pycnonotidae (bulbuls) and Muscicapidae (flycatchers) contributed the maximum number of frugivorous species (7 species). While Sturnidae (mynas) hold 6

frugivorous species, Psittacidae (parrots) and Capitonidae (barbets; Plate 1, Fig. 1) hold 5 species each. Among the 66 species of fruit-eating birds, members of Columbidae (except the mountain imperial-pigeon) and Psittacidae (parrots) digest the seeds and hence are considered as seed predators. Other frugivores could be considered as legitimate seed dispersers.

The body size varied considerably among frugivorous birds (range 5-2,500 g; Appendix I; Fig. 1). Hornbills (Family Bucerotidae) were the heaviest birds, having a mean body weight of 1,246 g (n=3) followed by Family Corvidae (crows) and Columbidae (pigeons) whose mean body weight was 288 g (n=4) and 246 g (n=7) respectively. The great pied hornbill *Buceros bicornis*, a charismatic flagship species of the Western Ghats and northeastern India, is the heaviest among frugivores, weighing 2,500 g followed by Malabar pied hornbill *Anthracoceros coronatus* (1,000 g), jungle crow *Corvus macrorhynchos* (650 g) and the mountain imperial-pigeon *Ducula badia* (580 g). Hornbills and pigeons are also voracious frugivorous bird species in their habitat.

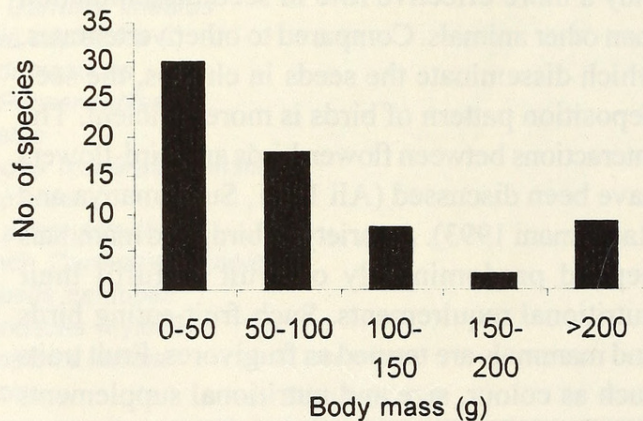


Fig 1: Body mass of frugivorous birds in south Indian forests (n=66)

Bird attracting flora in south India

Fruits of 219 species (141 genera) belonging to 61 plant families were recorded to be used by frugivorous birds. The members of the families Lauraceae (21 species), Euphorbiaceae



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Fig. 1: Coppersmith barbet *Megalaima haemacephala*, a frugivore and major seed disperser of forest trees, at Coimbatore Forest Division



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Fig. 2: *Ficus benghalensis*, a keystone species for avian frugivores, in the Coimbatore Forest Division

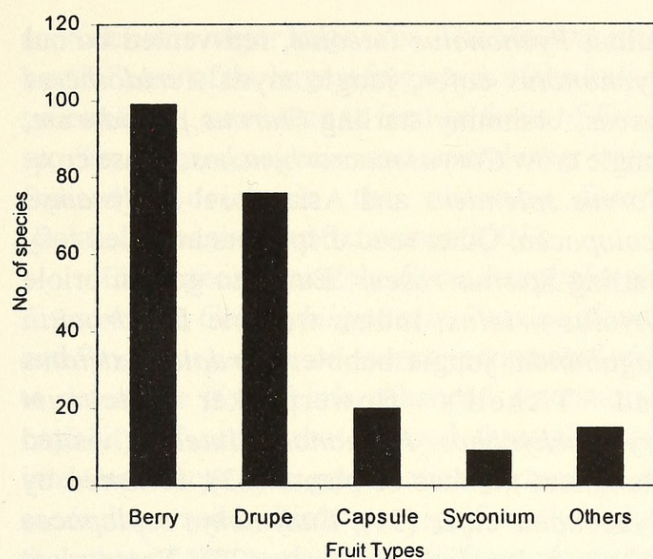


Fig. 2: Morphological classification of bird-dispersed fruits in south Indian forests (n= 219)

(13 species), Rubiaceae (12 species), Moraceae (10 species), Meliaceae and Annonaceae (9 species each) were most represented among fleshy-fruited species adapted for frugivory. The genus *Ficus* (figs), known for their ability to produce fruits asynchronously and support the frugivore community during periods of scarcity, was represented by 8 species. The genera *Eugenia* and *Litsea* were represented by 5 species each, while *Capparis*, *Cinnamomum*, *Diospyros*

and *Zizyphus* were represented by 4 species each (Appendix II).

The fruit types of all the 219 species were determined. Berries were the predominant fruit type borne by 99 species (45%) while drupes were borne on 76 species (35%) and together accounted for 80% of the fruits for the whole of south India (Fig. 2). Fleshy-fruited plants are very common in tropical forests, with frequencies usually over 70% (of woody plants) in the forests and lesser in the dry forests. The frequency of fleshy-fruited plants in the Dry Deciduous Forests of Coimbatore was 65%, while in Tropical Dry Evergreen Forests of Point Calimere it was 73%. In the Semi-evergreen Forest of Mudumalai Wildlife Sanctuary, Western Ghats, 57% of the species and 74% of individuals were fleshy-fruited species.

Colours of ripe fruits for all the 219 species were assigned to one of eight broad colour categories as used by Wheelwright and Janson (1985). The analysis showed that 94 species (43%) produced black fruit while 58 species (26%) produced red fruit and 39 species (18%) produced yellow fruit (Fig. 3). Black and red accounted for 70% of species.

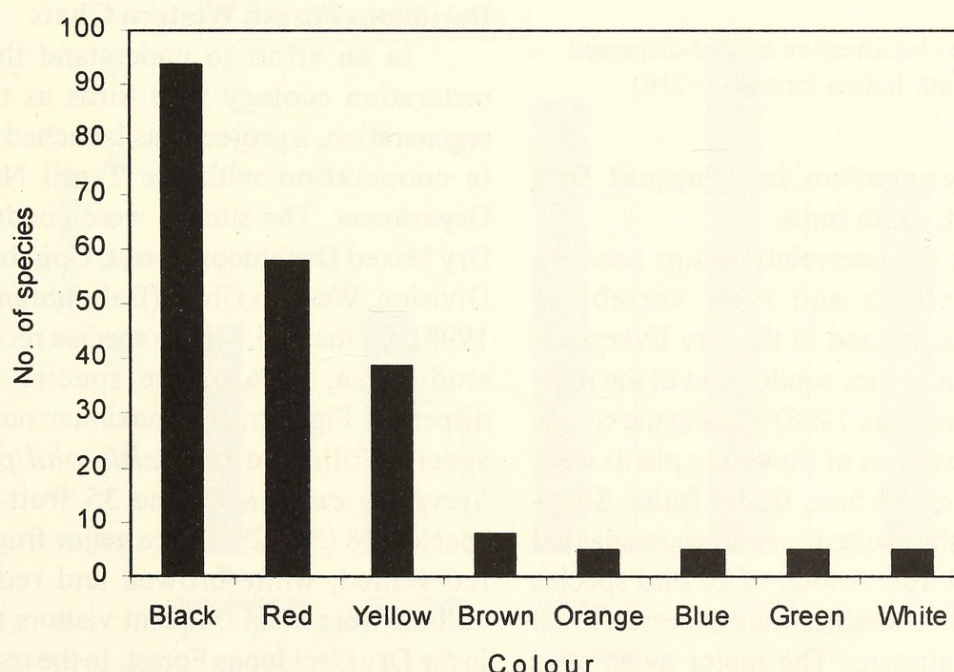


Fig. 3: Colours of bird-dispersed fruits in south Indian forests (n=219)

Analyses of the fruit diameter revealed that 98 species (45%) had their fruit sizes 10-20 mm, while another 85 species (39%) bore fruits in the size range <10 mm. Only 36 of the 219 species (16%) bore fruits of size greater than 20 mm (Fig. 4). About 83% of fruits were less than 20 mm in diameter. Plants of Families Annonaceae, Burseraceae, Elaeocarpaceae, Meliaceae, Moraceae and Myristicaceae produced large fruits while plants of Families Cucurbitaceae, Cordiaceae, Ebenaceae, Lauraceae, Melastomataceae, Menispermaceae, Oleaceae and Rubiaceae produced small fruits.

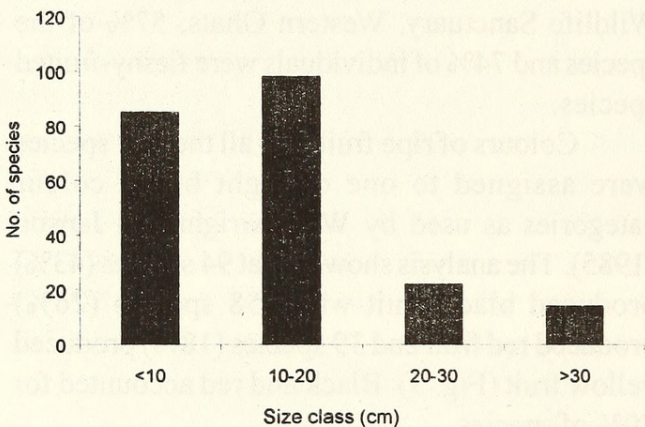


Fig. 4: Fruit size classification of bird-dispersed fruits in south Indian forests (n=219)

Birds and regeneration in Tropical Dry Evergreen Forest, south India

A study on the interrelationships between fleshy-fruited plants and their vertebrate consumers was conducted in the Dry Evergreen Forest in Point Calimere, south India in the mid-1980s (Balasubramanian 1996). During the course of the study, 317 species of flowering plants were recorded, of which 88 bore fleshy fruits. Sixty-four of the 88 fleshy-fruited species were adapted for frugivory by birds. A total of 20 bird species of 14 genera from 10 families were observed to eat fruits at Point Calimere. The major avian seed dispersers documented were the white-browed

bulbul *Pycnonotus luteolus*, red-vented bulbul *Pycnonotus cafer*, jungle myna *Acridotheres fuscus*, brahmyn starling *Sturnus pagodarum*, jungle crow *Corvus macrorhynchos*, house crow *Corvus splendens* and Asian koel *Eudynamys scolopacea*. Other seed dispersers included rosy starling *Sturnus roseus*, Eurasian golden oriole *Oriolus oriolus*, Indian tree pie *Dendrocitta vagabunda*, jungle babbler *Turdoides striatus* and Tickell's flowerpecker *Dicaeum erythrorhynchos*. *Pycnonotus luteolus* visited maximum number of plants (63), followed by *Pycnonotus cafer* (51), *Eudynamys scolopacea* (32) and *Acridotheres tristis* (27). Three plant species were visited by more than 10 bird species. *Salvadora persica* was visited by maximum number of bird species (15), followed by *Manilkara hexandra* (12) and *Ficus infectoria* (11).

Even though nearly 50% of the fleshy-fruited species in Point Calimere were consumed by mammals, only 10% of the species were solely dispersed by mammals. Most plant species are chiefly dispersed by birds.

Birds and natural regeneration in Dry Mixed Deciduous Forest, Western Ghats

In an effort to understand the tenets of restoration ecology with birds as the basis of regeneration, a project was launched by SACON in cooperation with the Tamil Nadu Forest Department. The studies were conducted in the Dry Mixed Deciduous Forest, Coimbatore Forest Division, Western Ghats (Balasubramanian *et al.* 1998). Of the 115 woody species recorded in the study area, 52% of the species were bird-dispersed. Figs attracted maximum number of bird species followed by *Celtis philippensis* and *Syzygium cumini*. Of the 35 fruit-eating bird species, 18 (51.42%) were major frugivores. The red-vented, white-browed and red-whiskered bulbuls were most frequent visitors to fruit trees in the Dry Deciduous Forest. In the riverine forest, barbets, bulbuls, mynas, the Asian fairy bluebird

and koel were major frugivores. The Malabar pied hornbill, one of the largest frugivores of the Indian subcontinent, were seen to feed on fruits of *Ficus* sp., *Strychnos nux-vomica* and several other large-fruited species in the riverine forest (Balasubramanian and Saravanan 2001).

Five species, namely *Ficus benghalensis*, *F. racemosa*, *Celtis philippensis*, *Cassine glauca* and *Strychnos potatorum*, were experimented with to determine if the birds enhanced germination capacity of seeds that passed through their intestinal tracts. The germination percentage of seeds dispersed by birds was significantly higher than that of the seeds collected from plants for four species. In one species *Celtis philippensis*, although a similar trend was observed, the difference was not significant (Fig. 5).

Natural regeneration of bird-dispersed plants was studied in the Dry Mixed Deciduous Forests of Coimbatore Division in Tamil Nadu. The density of seedlings and saplings of bird-dispersed trees varied from 279 per hectare in the highly degraded habitat to 640 in the undisturbed habitat. Twelve out of the 15 species had good

regeneration potential, represented by more than 10 saplings. In the highly degraded habitat, only 3 out of 9 species had more than 10 saplings.

Hornbills and forest regeneration in Semi-evergreen and Evergreen Forests

Malabar grey hornbill (*Ocyrceros griseus*), an endemic frugivore of restricted range in the moist forests of Western Ghats, south India, is dependent on fruit resources and suitable nest trees for subsistence. As a consequence of its specialised breeding habits and dependence on fruits as a predominant source of food, this hornbill is known to interact with a variety of tree species. The Malabar grey is considered one of the keystone species and a major seed disperser in the Western Ghats region (Mudappa 2000).

Like most other hornbills, the Malabar grey is known to bring a large load of fruit to the nesting site to feed the incarcerated female and chicks during the breeding season. Seeds of fruits consumed are squirted out through the nest slit, and get embedded in the litter-strewn forest floor. These seed deposits are usually termed as midden.

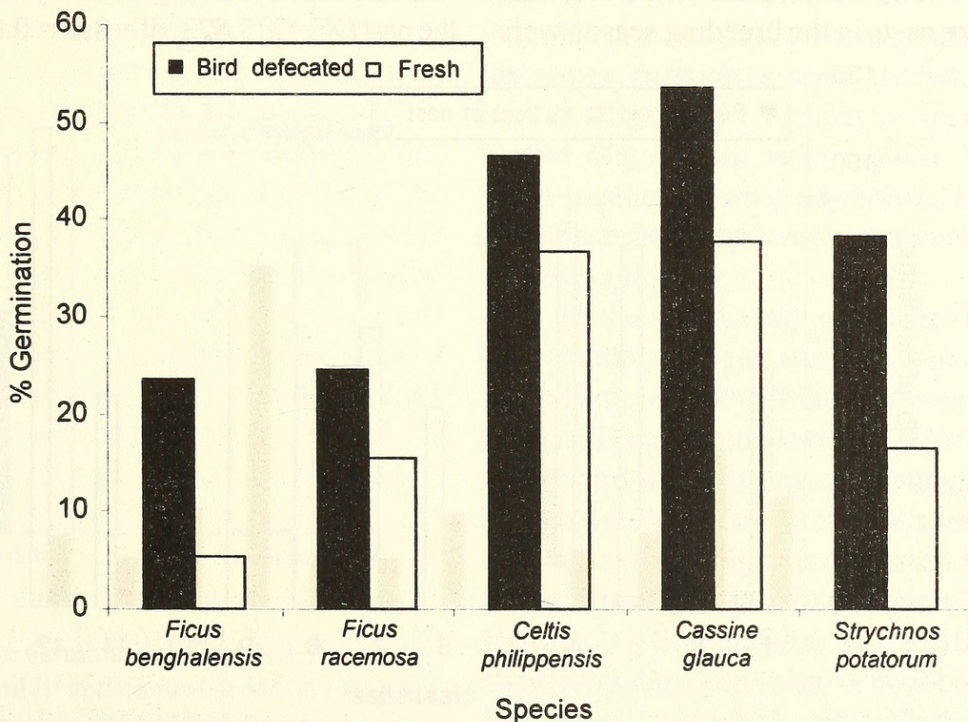


Fig. 5: Percentage germination of bird-defecated and fresh seeds, Coimbatore Forest Division

Monitoring the midden deposits and analysing the seeds therein during breeding season, helped to determine the variety of fruit species consumed and dispersed by this hornbill. The study was conducted in the Semi-evergreen Forests of Mudumalai Wildlife Sanctuary (Balasubramanian and Maheswaran 2001). Tree species common to this vegetation type are *Olea dioica*, *Actinodaphne malabarica*, *Persea macrantha*, *Cinnamomum verum*, *Lagerstroemia microcarpa*, and *Terminalia* sp.

Of the 1,430 individuals belonging to the 70 tree species present, 74% of individuals and 56% of the species were adapted for frugivory. Major disperser species in this habitat, apart from the Malabar grey hornbill (*Ocyrceros griseus*), were the fruit pigeons (*Ducula badia*), barbets (*Megalaima* sp.), mynas (*Acridotheres* sp.) and starlings (*Sturnus* sp.). During the breeding season, an intensive nest search was conducted in the semi-evergreen patches of Mudumalai Wildlife Sanctuary for nesting activity of the Malabar grey hornbill. Cavities of trees used by hornbills for nesting were located by following breeding pairs of hornbills, prior to the breeding season. Twelve nests in the breeding season were

selected for studying midden regeneration. Two square plots (5 sq. m each) were demarcated for each nest site, one behind and one in front of the nest. During the post-breeding season (May-January), these sites were visited every week to study regeneration from the midden deposits.

New seedlings of a total of 19 species belonging to 13 families were enumerated from the square plots. *Olea dioica*, one of the favoured fruits of this birds was recorded in all the 12 midden sites, while *Cinnamomum verum* was recorded from 11 midden sites. Lauraceae and Flacourtiaceae (3 species each) were the most represented families among the regenerated seedlings. The number of seedlings regenerated in front of the nest was significantly higher than those behind the nest ($X^2 = 298.378$; $df = 9$; $P < 0.005$). While 13 species comprising 280 regenerated seedlings were recorded behind the nests, 18 species comprising 761 seedlings had regenerated in front of the nest site, just below the nest hole, i.e. 63% more seedlings regenerated in front of the nest. Greater regeneration in front of the nest was seen at all the sites except nest site 9 (Fig. 6). Regeneration within a species was also found to be significantly higher in front of the nest ($X^2 = 213.823$; $df = 8$; $P < 0.005$).

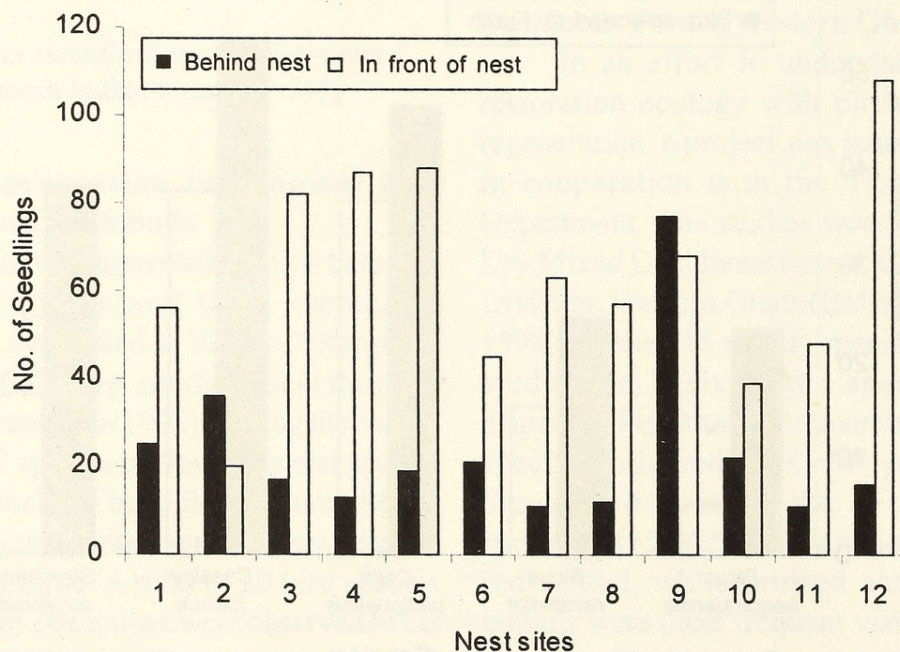


Fig. 6: Regeneration of seeds behind and in front of Malabar grey hornbill nests in a Semi-evergreen Forest at Mudumalai Wildlife Sanctuary, Western Ghats

Germination experiments were conducted at the study site using seeds collected from the midden, and control seeds of ripe fruits collected directly from trees for comparison. Seeds of two preferred fruit species, *Olea dioica* and *Persea macrantha*, were chosen for seed germination studies. The soil conditions in which the experimental seeds were planted were the same as they would be in the midden. Seeds were sown in polythene bags under open conditions and watered regularly.

After four months of continuous monitoring of the seedlings, it was observed that bird-defecated seeds had a higher regeneration potential than control seeds collected directly from plants. Bird-defecated seeds of *Olea dioica* showed 41.67% higher germination rate than fresh seeds while for *Persea macrantha*, the bird-defecated seeds showed 75% enhanced germination over the control seeds (Fig. 7). A statistical comparison of the bird-defecated and control seeds for both the species showed a significantly higher rate of germination for bird-defecated seeds ($X^2 = 90.739$; $df = 1$; $P < 0.005$).

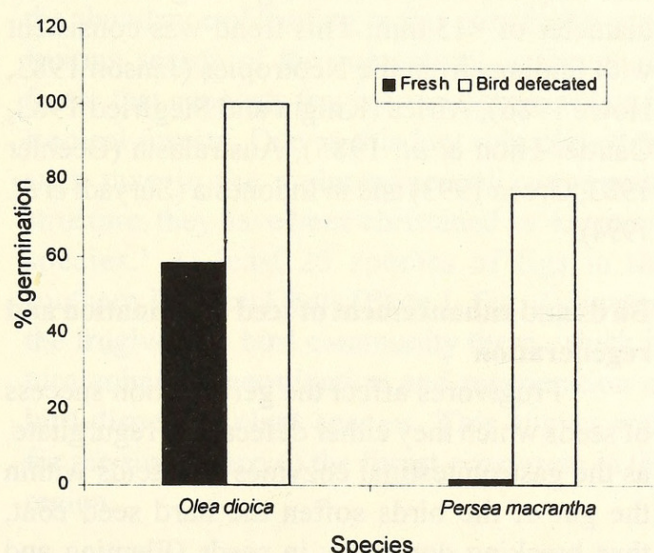


Fig. 7: Percentage germination of seeds defecated by Malabar grey hornbill and control seeds, in two plant species at Mudumalai Wildlife Sanctuary, Western Ghats

Bird-aided regeneration in other forests of the Western Ghats and coastal plains

Hornbills are one of the dominant frugivores and seed dispersers of the palaeotropical region. In the Asian tropical forests, they have been well studied for frugivory, especially in the breeding season, and are known to disperse the seeds undamaged (Leighton 1981). Hornbills, for most part of the year, are scatter dispersers, but during the nesting season large numbers of seeds are deposited under the nests, creating conspicuous middens. Our study in the Semi-evergreen Forests of Mudumalai Wildlife Sanctuary, Western Ghats has established that the Malabar grey hornbill utilises 27 different fleshy-fruit species, and 16 species were recorded to have regenerated from the midden under nest trees of hornbills. Kannan and James (1999) identified 21 species of trees with lipid-rich fruits, utilised by hornbills (*Buceros bicornis* and *Ocyrceros griseus*). These included 12 *Cinnamomum*, 2 *Myristica*, 2 *Beilschmedia*, 2 *Dysoxylum*, 1 *Persea* and 2 *Polyalthia* species.

In a study in the Moist Deciduous Forest habitat in the Western Ghats of Kerala (Vijayakumar and Zacharias, in press) showed that the major frugivores were the white-cheeked barbet *Megalaima viridis*, crimson-throated barbet *Megalaima rubricapilla*, pompadour green-pigeon *Treron pompadora*, black bulbul *Hypsipetes leucocephalus* and common hill-myna *Gracula religiosa*.

In the Wet Evergreen Forest of Kalakad-Mundanthurai Tiger Reserve, southern India, birds dispersed 59% of the 65 fleshy-fruited tree species (Ganesh and Davidar 2001). About 33% (16) of bird-dispersed species belonged to Family Lauraceae. While small birds dispersed 86% of the plant species, pigeons dispersed 14% of large fruited species. The six common frugivorous species of that habitat were black bulbul *Hypsipetes leucocephalus*, yellow-browed bulbul *Iole indica*, red-whiskered bulbul *Pycnonotus jocosus*, white-cheeked barbet *Megalaima viridis*,

mountain imperial-pigeon *Ducula badia* and Nilgiri wood-pigeon *Columba elphinstonii*.

Effects of hornbills on seeds have been documented for 34 species in Dja Reserve, Cameroon (Whitney *et al.* 1998). Seeds of most species were egested without much physical damage. Germination trials on 24 species showed that 23 species germinated after egestion by two hornbills, *Ceratogymna atrata* and *C. cylindricus*, and a major proportion of these species did not exhibit a fall from the germination rate in control seeds.

A study on plant-bird interaction in the Tropical Evergreen Forest of the erstwhile Chengalpattu district, Coromandel coast, southern India, showed that 130 out of the 180 woody plants (72%) bore fleshy fruits (Narasimhan *et al.* 1993). Major fleshy-fruited species included *Zizyphus oenopia*, *Allophylus serratus*, *Ficus benghalensis*, *Benkara malabarica*, *Hugonia mystax*, *Tarenna asiatica*, *Memecylon umbellatum*, *Carmona retusa* and *Dendrophthoe falcata*. Though 150 birds have been recorded from this region (Siromoney 1971), only 20 are involved in seed dispersal. Families of frugivorous birds recorded include Columbidae, Cuculidae, Capitonidae, Oriolidae, Sturnidae, Corvidae, Irenidae, Pycnonotidae and Muscicapidae. In this forest, berries and drupes were the major fruit types encountered, while red (48%) followed by black (31%) were the predominant fruit colours. The study also showed that 72% of the fruits were less than 1 cm in diameter, indicating the role of generalist frugivores in dispersal.

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). 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 Point Calimere (Balasubramanian 1996), 74% of the visits by birds on fruiting plants were by two species of bulbuls. In the Dry Deciduous Forests of Coimbatore (Balasubramanian *et al.* 1998), the largest number of visits (47.5%) were by 3 species of bulbuls followed by 3 species of barbets (18.46%). In a study in the subtropical shrub lands of Hong Kong, two species of bulbuls, the red-whiskered bulbul (*Pycnonotus jocosus*) and the light-vented bulbul (*Pycnonotus sinensis*), were the most important seed dispersal agents. These species have an unusually large gape width for their size, and they utilise this advantage to the maximum (Corlett 1998). The dominant role of bulbuls in frugivory and dispersal in tropical forest communities makes them a valuable group of birds.

Research on plant-bird interactions at Point Calimere showed that conspicuous colour combined with small size of fruit enabled frugivorous birds to access fruit resources easily (Balasubramanian 1996). According to Terborgh and Diamond (1970), small-fruited plant species attract more species of birds than large-fruited ones. Corlett (1996) observed that most of the bird-dispersed seeds in Hong Kong had a mean diameter of <13 mm. This trend was consistent with findings from the Neotropics (Janson 1983, Howe 1986), Africa (Knight and Siegfried 1983, Gautier-Hion *et al.* 1985), Australasia (Beehler 1983, Green 1993) and in Indonesia (Suryadi *et al.* 1994).

Birds and enhancement of seed germination and regeneration

Frugivores affect the germination success of seeds which they either defecate or regurgitate, as the gastrointestinal enzymes and acids within the gut of the birds soften the hard seed coat, thus breaking dormancy in seeds (Fleming and Heithaus 1981). Our study has clearly established the role played by birds in enhancement of seed germination in Dry Mixed Deciduous and Semi-evergreen Forests of the Western Ghats. Seeds

of *Olea dioica*, *Persea macrantha* (both in Semi-evergreen Forest), *Ficus benghalensis*, *F. racemosa*, *Celtis philippensis*, *Cassine glauca* and *Strychnos potatorum* (Dry Mixed Deciduous Forest) showed significant enhancement in germination after passing through the guts of birds. Similar results have been reported by Midya and Brahmachary (1991) for *Ficus benghalensis* (58% germination in bird-dispersed seeds against 34% in control seeds), and by Mishra *et al.* (1987) for *Azadirachta indica* (76% germination in bird-dispersed seeds against 42% in control seeds). In South Australia, Yan (1993) observed more than 90% germination of mistletoe (*Amyema preissii* and *Lysium excocarpum*) seeds dispersed by birds.

Though figs occur in low abundance, they play a very prominent role in sustaining frugivorous populations in tropical forests. Being aseasonal in fruit production, figs have evolved as one of the most reliable diet resources for the vertebrate community. The role of plant taxa that fruit in times of scarcity, in maintaining the population of the frugivore community was first propounded by Terborgh (1986), followed by Lambert and Marshall (1991). According to them, the abundance of fruiting in figs outside the peak fruiting season of the community, is the single factor that supports frugivorous communities in tropical forests. Due to this key role played by such taxa in the maintenance of community structure, they have been christened as 'keystone species.' At least 25 species of figs in the southern Western Ghats (Plate 1, Fig. 2) support the frugivorous bird community there, which in turn enhances germination and regeneration of bird-dispersed plant species. This augurs well for the sustenance of the forest ecosystem in the region.

CONCLUSION

Birds help determine the structure of tropical forests, as a major proportion of plant species are

consumed and dispersed by them. As seen in this study, 73.7% of species in Tropical Dry Evergreen Forests of Point Calimere, 50% of species in Dry Mixed Deciduous Forests of Coimbatore Forest Division, Western Ghats, and 55.7% of species in Semi-evergreen Forest in Mudumalai Wildlife Sanctuary are bird-dispersed. Dispersion of seeds by birds was also seen in 35-70% of woody plants in Australian Wet Tropical and Dry Tropical Forests, and 47-54% of woody plants in North American Deciduous Forest and 49-66% in Mediterranean scrublands. Furthermore, seeds egested by birds have improved germination and regeneration vigour, thus increasing the dependence of plants on birds as a reliable and effective mode of dispersal. Thus birds have a pivotal role in shaping the structure of the forest. Plant communities in the present era have survived on account of their ability to interact mutualistically with birds.

Seed dispersal and regeneration are two processes that are absolutely indispensable to the maintenance of tropical forests (Galetti 2000, Herrera 1984, 1995, Howe 1984, 1990, Stiles 1985, 1992, Willson 1992). In spite of their fundamental importance in sustenance of tropical forests, very little is known about the role played by dispersers and the mechanism of dispersal. Research initiatives have been few and far between in the tropics and are mostly restricted to the Neotropics (Howe 1983, 1985, 1986, Howe and Vande Kerckhove 1981). Far greater efforts are needed to show the effectiveness of frugivores in dispersal and regeneration.

Though information is available for a few species, community-wide assessments of dispersers are negligible. Documentation of frugivory is only the first step in understanding the complex and manifold interactions between birds and plants. Being mobile links in tropical forest ecosystems, frugivores deserve greater attention, especially on the intricacies of their role in enhancement of germination and forest regeneration.

ACKNOWLEDGEMENTS

The senior author (P.B.) expresses his gratitude to Mr. J.C. Daniel, Honorary Secretary, Bombay Natural History for encouragement. He also thanks Dr. G. Kumaravelu, Conservator of

Forests—Research, the U.S. Fish and Wildlife Service, the Ministry of Environment and Forests, Government of India, and the Tamil Nadu Forest Department for funding his projects on plant-bird interactions. Thanks are due to Dr. V.S. Vijayan, Director, SACON for encouragement.

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FRUGIVORY IN SOUTH INDIAN FORESTS

Appendix I: Frugivorous birds of south Indian forests

Species	Common name	Body mass (g)	Feeding guild
COLUMBIDAE			
<i>Chalcophaps indica</i>	Emerald dove	144	G
<i>Columba elphinstonii</i>	Nilgiri wood-pigeon	379	F
<i>Ducula badia</i>	Mountain Imperial-Pigeon	580	F
<i>Streptopelia decaocto</i>	Eurasian collared-dove	210	G
<i>Streptopelia chinensis</i>	Spotted dove	128	G
<i>Treron bicincta</i>	Orange-breasted green-pigeon	128	F
<i>Treron pompadora</i>	Pompadour green-pigeon	151	F
PSITTACIDAE			
<i>Loriculus vernalis</i>	Indian hanging-parrot	50	G
<i>Psittacula columboides</i>	Blue-winged parakeet	100	G
<i>Psittacula cyanocephala</i>	Plum-headed parakeet	70	G
<i>Psittacula eupatria</i>	Alexandrine parakeet	225	G
<i>Psittacula krameri</i>	Rose-ringed parakeet	139	G
CUCULIDAE			
<i>Clamator jacobinus</i>	Pied crested cuckoo	74	I
<i>Hierococcyx varius</i>	Brainfever bird	104	I
<i>Eudynamys scolopacea</i>	Asian koel	167	F
<i>Phaenicophaeus viridirostris</i>	Small green-billed malkoha	114	I
TROGONIDAE			
<i>Harpactes fasciatus</i>	Malabar trogon	64	I
BUCEROTIDAE			
<i>Anthraceroceros coronatus</i>	Malabar pied hornbill	1,000	F
<i>Buceros bicornis</i>	Great pied hornbill	2,500	F
<i>Ocyrceros griseus</i>	Malabar grey hornbill	238	F
<i>Ocyrceros birostris</i>	Indian grey hornbill	200	F
CAPITONIDAE			
<i>Megalaima asiatica</i>	Blue-throated barbet	100	F
<i>Megalaima haemacephala</i>	Coppersmith barbet	38	F
<i>Megalaima rubricapilla</i>	Crimson-throated barbet	47	F
<i>Megalaima viridis</i>	White-cheeked barbet	80.5	F
<i>Megalaima zeylanica</i>	Brown-headed barbet	87	F
ORIOOLIDAE			
<i>Oriolus oriolus</i>	Eurasian golden oriole	65	I
<i>Oriolus xanthornus</i>	Black-headed oriole	79	I
STURNIDAE			
<i>Acridotheres fuscus</i>	Jungle myna	94	F
<i>Acridotheres tristis</i>	Common myna	98	I
<i>Gracula religiosa</i>	Hill myna	126	F
<i>Sturnus malabaricus</i>	Grey-headed starling	44	F
<i>Sturnus pagodarum</i>	Brahminy starling	54	F
<i>Sturnus roseus</i>	Rosy starling	75	F
CORVIDAE			
<i>Corvus macrorhynchos</i>	Jungle crow	650	O
<i>Corvus splendens</i>	House crow	280	O
<i>Dendrocitta leucogastra</i>	White-bellied treepie	95	F
<i>Dendrocitta vagabunda</i>	Indian treepie	128	F
CAMPEPHAGIDAE			
<i>Coracina melanoptera</i>	Black-headed cuckoo-shrike	36	I
<i>Coracina macei</i>	Large cuckoo-shrike	36	I

FRUGIVORY IN SOUTH INDIAN FORESTS

Appendix I: Frugivorous birds of south Indian forests (contd.)

Species	Common name	Body mass (g)	Feeding guild
IRENIDAE			
<i>Aegithina tiphia</i>	Common iora	14	I
<i>Chloropsis aurifrons</i>	Gold-fronted chloropsis	29	F
<i>Chloropsis cochinchinensis</i>	Jerdon's chloropsis	35	I
<i>Irena puella</i>	Asian fairy bluebird	30	F
PYCNONOTIDAE			
<i>Iole indica</i>	Yellow-browed Bulbul	31.5	F
<i>Hypsipetes leucocephalus</i>	Black bulbul	35	F
<i>Pycnonotus cafer</i>	Red-vented bulbul	35	F
<i>Pycnonotus jocosus</i>	Red-whiskered bulbul	35	F
<i>Pycnonotus leucotis</i>	White-eared bulbul	35	F
<i>Pycnonotus luteolus</i>	White-browed bulbul	35	F
<i>Pycnonotus priocephalus</i>	Grey-headed bulbul	35	F
<i>Pycnonotus xantholaemus</i>	Yellow-throated bulbul	32	F
MUSCICAPIDAE			
<i>Acrocephalus dumetorum</i>	Blyth's reed warbler	12	I
<i>Copsychus saularis</i>	Oriental magpie-robin	12	I
<i>Parus major</i>	Great tit	11.9	I
<i>Sylvia curruca</i>	Common lesser whitethroat	12	I
<i>Turdoides caudatus</i>	Common babbler	40	I
<i>Turdoides striatus</i>	Jungle babbler	77	I
<i>Turdoides subrufus</i>	Indian rufous babbler	67.5	I
DICAEIDAE			
<i>Dicaeum agile</i>	Thick-billed flowerpecker	9.5	F
<i>Dicaeum concolor</i>	Plain flowerpecker	6	F
<i>Dicaeum erythrorhynchos</i>	Tickell's flowerpecker	6.2	F
NECTARINIIDAE			
<i>Nectarinia asiatica</i>	Purple sunbird	7.5	N
<i>Nectarinia lotenia</i>	Loten's sunbird	9.5	N
<i>Nectarinia zeylonica</i>	Purple-rumped sunbird	5	N
ZOSTEROPIDAE			
<i>Zosterops palpebrosus</i>	Oriental white-eye	5.5	I

F = Frugivore; G = Granivore; I = Insectivore; N = Nectarivore and O = Omnivore

Feeding guilds are described based on Ali and Ripley (1983).

Appendix II: Bird-dispersed plant species in south Indian forests

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
ANACARDIACEAE			
<i>Lannea coromandelica</i>	Drupe	Brown	0.94
ANNONACEAE			
<i>Alphonsea zeylanica</i>	Carpel	Yellow	2.93
<i>Alphonsea lutea</i>	Carpel	Yellow	3.51
<i>Alphonsea sclerocarpa</i>	Carpel	Yellow	1.50
<i>Goniothalamus wightii</i>	Carpel	Black	1.54
<i>Meiogyne pannosa</i>	Carpel	Black	1.60
<i>Orophea uniflora</i>	Carpel	Black	1.17
<i>Polyalthia cerasoides</i>	Carpel	Red	0.77
<i>Polyalthia coffeoides</i>	Carpel	Red	2.34

FRUGIVORY IN SOUTH INDIAN FORESTS

Appendix II: Bird-dispersed plant species in south Indian forests (contd.)

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
<i>Polyalthia longifolia</i>	Carpel	Red	2.00
APOCYNACEAE			
<i>Carissa carandas</i>	Berry	Black	0.59
<i>Carissa spinarum</i>	Berry	Black	0.70
<i>Tabernaemontana heyneana</i>	Follicle	Red	0.94
ARECACEAE			
<i>Bentinckia condapanna</i>	Drupe	Black	1.40
<i>Calamus rotang</i>	Drupe	Yellow	1.40
<i>Calamus viminalis</i>	Drupe	Yellow	0.94
<i>Caryota urens</i>	Drupe	Red	2.50
<i>Phoenix pusilla</i>	Berry	Black	2.50
<i>Phoenix sylvestris</i>	Berry	Black	2.90
BISCHOFIACEAE			
<i>Bischofia javanica</i>	Berry	Black	1.00
BURSERACEAE			
<i>Canarium strictum</i>	Drupe	Black	4.00
CACTACEAE			
<i>Opuntia stricta</i>	Berry	Red	1.00
CAPPARACEAE			
<i>Capparis brevispina</i>	Berry	Red	3.50
<i>Capparis grandis</i>	Berry	Red	2.34
<i>Capparis sepiaria</i>	Berry	Blue	1.17
<i>Capparis zeylanica</i>	Berry	Red	4.50
<i>Crateva adansonii</i>	Berry	Red	2.00
<i>Crateva magna</i>	Berry	Red	3.51
CAPRIFOLIACEAE			
<i>Viburnum punctatum</i>	Drupe	Black	1.76
CELASTRACEAE			
<i>Cassine glauca</i> (Rottb.)	Capsule	Black	1.00
<i>Euonymus indicus</i>	Capsule	Black	1.76
<i>Maytenus emarginata</i>	Capsule	Red	0.77
<i>Maytenus wallichiana</i>	Capsule	Red	1.20
<i>Pleurostylia opposita</i>	Capsule	White	0.40
CLUSIACEAE			
<i>Garcinia indica</i>	Berry	Black	5.00
CONNARACEAE			
<i>Connarus wightii</i>	Follicle	Black	3.51
CORDIACEAE			
<i>Carmona retusa</i>	Drupe	Black	0.94
<i>Cordia obliqua</i>	Drupe	Yellow	1.17
<i>Cordia wallichii</i>	Drupe	Yellow	1.17
CUCURBITACEAE			
<i>Coccinia grandis</i>	Berry	Red	2.50
<i>Mukia maderaspatana</i>	Berry	Red	1.17
<i>Trichosanthes cucumerina</i>	Berry	Red	2.50
<i>Trichosanthes tricuspidata</i>	Berry	Red	1.50
DAPHNIPHYLLACEAE			
<i>Daphniphyllum</i> sp.	Drupe	Red	1.25
EBENACEAE			
<i>Diospyros ferrea</i> (Willd.)	Berry	Red	1.20
<i>Diospyros melanoxylon</i>	Berry	Yellow	1.76

FRUGIVORY IN SOUTH INDIAN FORESTS

Appendix II: Bird-dispersed plant species in south Indian forests (contd.)

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
<i>Diospyros montana</i>	Berry	Yellow	1.76
<i>Diospyros oocarpa</i>	Berry	Yellow	2.34
EHRETIACEAE			
<i>Ehretia ovalifolia</i>	Drupe	Red	1.17
ELAEOCARPACEAE			
<i>Elaeocarpus serratus</i>	Drupe	Yellow	3.51
ERICACEAE			
<i>Gaultheria fragratissima</i>	Capsule	Black	1.17
ERYTHROXYLACEAE			
<i>Erythroxylum monogynum</i>	Drupe	Black	0.77
EUPHORBIACEAE			
<i>Antidesma menasu</i>	Drupe	Black	0.59
<i>Aporosa lindleyana</i>	Capsule	Black	0.94
<i>Breynia vitis-idaea</i>	Capsule	Black	1.17
<i>Bridelia crenulata</i>	Drupe	Red	0.80
<i>Drypetes roxburghii</i>	Drupe	Red	2.80
<i>Drypetes sepiaria</i>	Drupe	Red	1.17
<i>Glochidion velutinum</i>	Capsule	Red	1.17
<i>Macaranga peltata</i>	Capsule	Orange	1.25
<i>Mallotus ferrugineus</i>	Capsule	Black	0.80
<i>Mallotus philippensis</i>	Capsule	Red	1.17
<i>Phyllanthus reticulatus</i>	Berry	Black	2.50
<i>Securinega leucopyrus</i>	Capsule	White	0.37
<i>Securinega virosa</i>	Capsule	White	0.94
FLACOURTIACEAE			
<i>Casearia elliptica</i>	Capsule	Red	1.76
<i>Casearia ovata</i>	Capsule	Yellow	1.50
<i>Flacourtia indica</i>	Berry	Black	1.76
<i>Flacourtia montana</i>	Berry	Red	2.34
<i>Scolopia crenata</i>	Drupe	Black	0.75
<i>Xyiosma latifolium</i>	Drupe	Black	0.75
GNETACEAE			
<i>Gnetum ula</i>	Drupe	Orange	2.81
HIPPOCRATEACEAE			
<i>Salacia chinensis</i>	Berry	Red	1.76
ICACINACEAE			
<i>Gomphandra tetrandra</i>	Drupe	Black	1.17
<i>Gomphandra coriacea</i>	Drupe	Black	1.75
<i>Nothapodytes nimmoniana</i>	Drupe	Black	1.75
LAURACEAE			
<i>Actinodaphne bourdillonii</i>	Berry	Black	1.50
<i>Actinodaphne malabarica</i>	Berry	Black	1.17
<i>Alseodaphne semecarpifolia</i>	Berry	Black	0.77
<i>Apollonias arnottii</i>	Berry	Black	0.59
<i>Beilschmiedia wightii</i>	Berry	Black	0.77
<i>Cassytha filiformis</i>	Berry	Black	0.94
<i>Cinnamomum filipedicellatum</i>	Berry	Black	1.25
<i>Cinnamomum sulphuratum</i>	Berry	Black	1.25
<i>Cinnamomum travancoricum</i>	Berry	Black	1.25
<i>Cinnamomum verum</i>	Berry	Black	1.50
<i>Cryptocarya bourdillonii</i>	Berry	Black	1.20

FRUGIVORY IN SOUTH INDIAN FORESTS

Appendix II: Bird-dispersed plant species in south Indian forests (contd.)

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
<i>Cryptocarya lawsonii</i>	Berry	Black	1.25
<i>Litsea glabrata</i>	Berry	Black	1.25
<i>Litsea insignis</i>	Berry	Black	1.25
<i>Litsea mysorensis</i>	Berry	Black	1.00
<i>Litsea stocksii</i>	Berry	Black	1.25
<i>Litsea wightiana</i>	Berry	Black	1.25
<i>Neolitsea cassia</i>	Berry	Black	1.25
<i>Neolitsea fischeri</i>	Berry	Black	0.70
<i>Persea macrantha</i>	Berry	Black	1.76
<i>Phoebe lanceolata</i>	Berry	Black	1.51
LEEACEAE			
<i>Leea indica</i>	Berry	Black	0.23
LILIACEAE			
<i>Asparagus racemosus</i>	Berry	Red	0.50
LINACEAE			
<i>Hugonia mystax</i>	Drupe	Red	1.76
LOGANIACEAE			
<i>Fagraea ceilanica</i>	Berry	Black	3.50
<i>Strychnos nux-vomica</i>	Berry	Red	3.50
<i>Strychnos potatorum</i>	Berry	Black	2.81
LORANTHACEAE			
<i>Dendrophthoe falcata</i>	Berry	Orange	0.94
<i>Viscum capitellatum</i>	Berry	Green	0.94
<i>Viscum orientale</i>	Berry	Black	0.94
MAGNOLIACEAE			
<i>Michelia champaca</i>	Carpel	Brown	3.50
<i>Michelia nilagirica</i>	Carpel	Brown	2.50
MELASTOMACEAE			
<i>Memecylon malabaricum</i>	Berry	Blue	1.50
<i>Memecylon molestum</i>	Berry	Blue	1.10
<i>Memecylon umbellatum</i>	Berry	Blue	1.10
MELIACEAE			
<i>Aglaiia elaeagnoidea</i>	Drupe	Yellow	1.76
<i>Aphanamixis polystachya</i>	Capsule	Red	1.87
<i>Azadirachta indica</i>	Drupe	Yellow	1.76
<i>Cipadessa baccifera</i>	Drupe	Red	0.59
<i>Dysoxylum malabaricum</i>	Drupe	Red	4.68
<i>Melia azaderach</i>	Drupe	Yellow	1.76
<i>Melia dubia</i>	Drupe	Yellow	1.17
<i>Trichilia connaroides</i>	Capsule	Black	1.17
<i>Walsura trifoliata</i> (Juss.)	Berry	Brown	0.59
MELIOSMACEAE			
<i>Meliosma simplicifolia</i>	Drupe	Red	1.20
MENISPERMACEAE			
<i>Cocculus hirsutus</i>	Drupe	Red	2.34
<i>Pachygone ovata</i> (Poir.)	Drupe	Red	0.70
<i>Tinospora cordifolia</i>	Drupe	Red	1.20
MORACEAE			
<i>Ficus amplissima</i>	Syconium	White	1.00
<i>Ficus benghalensis</i>	Syconium	Red	1.17
<i>Ficus drupacea</i>	Syconium	Orange	2.93

Appendix II: Bird-dispersed plant species in south Indian forests (contd.)

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
<i>Ficus microcarpa</i>	Syconium	Yellow	0.25
<i>Ficus mollis</i>	Syconium	Yellow	0.70
<i>Ficus religiosa</i>	Syconium	Yellow	1.17
<i>Ficus tsjahela</i>	Syconium	Green	0.59
<i>Ficus virens</i>	Syconium	Green	0.47
<i>Plecosperrum spinosum</i>	Achene	Yellow	0.50
<i>Streblus asper</i>	Syconium	Yellow	1.40
MYRISTICACEAE			
<i>Knema attenuata</i>	Capsule	Red	3.51
<i>Myristica dactyloides</i>	Capsule	Red	3.50
MYRSINACEAE			
<i>Ardisia amplexicaulis</i>	Berry	Red	0.94
<i>Ardisia rhomboidea</i>	Berry	Red	0.94
<i>Embelia adnata</i>	Berry	Red	1.17
<i>Embelia ribes</i>	Berry	Red	0.29
<i>Maesa dubia</i>	Berry	Red	1.17
<i>Maesa perrottetiana</i>	Berry	White	1.17
<i>Maesa velutina</i>	Berry	Red	1.17
<i>Rapanea wightiana</i>	Berry	Red	1.17
MYRTACEAE			
<i>Eugenia argentea</i>	Berry	Black	1.40
<i>Eugenia discifera</i>	Berry	Black	0.59
<i>Eugenia floccosa</i>	Berry	Black	1.17
<i>Eugenia indica</i> (Wt.)	Berry	Black	0.47
<i>Eugenia thwaitesii</i>	Berry	Red	1.25
<i>Syzygium cumini</i> (L.)	Berry	Black	1.64
<i>Syzygium gardneri</i>	Berry	Black	1.25
<i>Syzygium travancoricum</i>	Berry	Black	1.25
OCHNACEAE			
<i>Ochna obtusata</i>	Drupe	Black	0.59
OLACACEAE			
<i>Olax scandens</i>	Drupe	Yellow	0.94
OLEACEAE			
<i>Jasminum angustifolium</i>	Drupe	Black	0.59
<i>Jasminum auriculatum</i>	Drupe	Black	0.47
<i>Olea dioica</i>	Drupe	Black	0.94
<i>Olea glandulifera</i>	Drupe	Black	0.94
OPILIACEAE			
<i>Cansjera rheedii</i>	Drupe	Red	1.76
PASSIFLORACEAE			
<i>Passiflora foetida</i>	Berry	Yellow	1.50
<i>Passiflora leschenaultii</i>	Berry	Yellow	1.76
PROTEACEAE			
<i>Helicia nilagirica</i>	Nut	Black	1.00
RHAMNACEAE			
<i>Rhamnus virgata</i>	Drupe	Yellow	1.17
<i>Scutia myrtina</i>	Drupe	Blue	1.17
<i>Zizyphus glabrata</i>	Drupe	Orange	0.59
<i>Zizyphus mauritiana</i>	Drupe	Yellow	1.00
<i>Zizyphus oenoplia</i>	Drupe	Yellow	0.60
<i>Zizyphus rugosa</i>	Drupe	Yellow	0.70

Appendix II: Bird-dispersed plant species in south Indian forests (contd.)

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
ROSACEAE			
<i>Photinia integrifolia</i>	Berry	Red	0.50
<i>Rubus fulvus</i>	Drupe	Red	0.80
RUBIACEAE			
<i>Benkara malabarica</i>	Drupe	Black	1.76
<i>Canthium dicoccum</i>	Drupe	Black	1.76
<i>Canthium parviflorum</i>	Drupe	Black	1.76
<i>Gardenia latifolia</i>	Berry	Green	2.50
<i>Ixora nigricans</i>	Drupe	Black	1.25
<i>Ixora pavetta</i>	Drupe	Black	1.76
<i>Morinda coreia</i>	Drupe	Black	1.76
<i>Octotropis travancorica</i>	Berry	Black	1.50
<i>Pavetta breviflora</i>	Drupe	Black	1.76
<i>Pavetta indica</i>	Drupe	Black	1.76
<i>Pavetta thomsonii</i>	Drupe	Black	1.50
<i>Tricalysia apiocarpa</i>	Berry	Black	0.90
RUTACEAE			
<i>Clausena dentata</i>	Berry	Black	0.94
<i>Glycosmis pentaphylla</i>	Berry	Yellow	0.94
<i>Melicope indica</i>	Berry	Yellow	0.94
<i>Murraya koenigii</i>	Berry	Black	0.94
<i>Naringi crenulata</i>	Berry	Yellow	0.70
<i>Toddalia asiatica</i>	Berry	Yellow	1.40
SALVADORACEAE			
<i>Azima tetracantha</i>	Berry	Black	0.94
<i>Salvadora persica</i>	Drupe	Black	0.94
SANTALINACEAE			
<i>Santalum album</i>	Drupe	Black	0.94
SAPINDACEAE			
<i>Allophyllus cobbe</i>	Drupe	Black	0.94
<i>Filicium decipiens</i>	Drupe	Black	1.17
<i>Lepisanthes tetraphylla</i>	Drupe	Black	0.94
<i>Schleichera oleosa</i>	Drupe	Yellow	1.87
SAPOTACEAE			
<i>Donella roxburghii</i>	Berry	Yellow	2.93
<i>Isonandra lanceolata</i>	Berry	Red	2.00
<i>Madhuca longifolia</i>	Berry	Green	2.93
<i>Manilkara hexandra</i>	Berry	Yellow	1.17
<i>Manilkara roxburghiana</i>	Berry	Yellow	1.76
<i>Mimusops elengi</i>	Berry	Red	2.34
<i>Xantolis tomentosa</i>	Berry	Yellow	2.34
SMILACACEAE			
<i>Smilax zeylanica</i>	Drupe	Yellow	1.10
SOLANACEAE			
<i>Solanum pubescens</i>	Berry	Red	0.70
<i>Solanum trilobatum</i>	Berry	Red	0.94
THEACEAE			
<i>Ternstroemia japonica</i>	Berry	Red	1.20
TILIACEAE			
<i>Grewia hirsuta</i>	Drupe	Brown	0.80
<i>Grewia obtusa</i>	Drupe	Brown	0.59

Appendix II: Bird-dispersed plant species in south Indian forests (contd.)

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
<i>Grewia orbiculata</i>	Drupe	Black	0.70
<i>Grewia ovalifolia</i>	Drupe	Brown	0.59
<i>Grewia rhamnifolia</i>	Drupe	Brown	0.35
<i>Grewia tiliifolia</i>	Drupe	Black	0.59
ULMACEAE			
<i>Celtis philippensis</i>	Drupe	Red	0.94
<i>Trema orientalis</i>	Drupe	Black	0.59
VERBENACEAE			
<i>Lantana camara</i>	Drupe	Black	0.23
<i>Premna serratifolia</i>	Drupe	Yellow	0.23
<i>Vitex altissima</i>	Drupe	Black	0.47
VITACEAE			
<i>Cissus quadrangularis</i>	Berry	Black	0.23
<i>Cissus vitigenia</i>	Berry	Black	0.35

Sources: Balasubramanian 1996, Balasubramanian and Maheswaran 2001, Balasubramanian *et al.* 1998, Ganesh and Davidar 2001, Kannan and James 1999.

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Balasubramanian, P and Maheswaran, B. 2003. "Frugivory, Seed Dispersal and Regeneration by Birds in South Indian Forests." *The journal of the Bombay Natural History Society* 100, 411–431.

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