

## Frugivory and seed dispersal by birds and mammals in the coastal tropical dry evergreen forests of southern India: A review

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**Abstract:** We review the findings of studies carried out on frugivory and seed dispersal in coastal Tropical Dry Evergreen Forests (TDEF) of southern India, derived largely from studies in Sriharikota (Andhra Pradesh) and Point Calimere (Tamil Nadu). A family-wise list of fruit-eating birds and mammals recorded at these sites, the fruit-species eaten and dispersed by them, and the physical traits of fruit species are discussed. Important fruit resources for birds and mammals are highlighted. In total, 34 species of birds of 17 families and 12 species of mammals of 11 families were recorded eating fruits. The major avian frugivores were from the families Pycnonotidae, Sturnidae, Corvidae, and Cuculidae. Among mammals, the major frugivores were from the families Cercopithecidae, Canidae, Viverridae, and Pteropodidae. Birds and mammals in coastal TDEFs utilized fruit from 49 different families. Fruit colour was dominated by red, black, and yellow and fruit type by drupe and berry.

**Resumen:** Revisamos los hallazgos de los estudios realizados sobre frugivoría y dispersión de semillas en los bosques tropicales secos perennifolios (BTSP) costeros del sur de la India, derivados en gran medida de los estudios en Sriharikota (Andhra Pradesh) y Point Calimere (Tamil Nadu). Se discute una lista organizada por familias de las aves y mamíferos frugívoros registrados en estos sitios, las especies de frutoconsumidas y las características físicas de los frutos. Se destacan algunos recursos frutales importantes para las aves y los mamíferos. En total, se registró que 34 especies de aves de 17 familias y 12 especies de mamíferos de 11 familias comen frutos. Las principales aves frugívoras fueron de las familias Pycnonotidae, Sturnidae, Corvidae y Cuculidae. Entre los mamíferos, los principales frugívoros fueron de las familias Cercopithecidae, Canidae, Viverridae y Pteropodidae. Las aves y los mamíferos en los BTSP costeros utilizaron frutos de 49 familias diferentes. Los colores dominantes de los frutos fueron rojo, negro y amarillo, y los tipos de fruto dominantes fueron las drupas y las bayas.

**Resumo:** Analisámos os resultados de estudos realizados sobre a dispersão de sementes e frugivoria em florestas costeiras tropicais secas sempre-verdes (TDEF) do sul da Índia, derivados em grande parte de estudos em Sriharikota (Andhra Pradesh) e Ponto Calimere (Tamil Nadu). Uma lista informada de famílias de aves e mamíferos que se alimentam de frutos, registrados nesses locais, das espécies frutíferas ingeridas e dispersas por elas, bem como sobre as características físicas das espécies de frutos, são discutidos. Recursos importantes em frutos para as aves e os mamíferos são realçados. No total, 34 espécies de aves pertencentes a 17 famílias e 12 espécies de mamíferos de 11 famílias foram registradas a comer fruta. Os maiores frugívoros entre as aves pertenciam às famílias Pycnonotidae, Sturnidae, Corvidae e Cuculidae. Entre os mamíferos, os principais frugívoros pertenciam às famílias Cercopithecidae, Canidae,

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Viverridae e Pteropodidae. Aves e mamíferos em TDEFs costeiras utilizam frutos de 49 famílias diferentes. A cor dos frutos foi dominada pelo vermelho, preto e amarelo e por frutos do tipo drupa e bagas.

**Key words:** Birds, frugivory, fruit trait, mammals, Point Calimere, seed dispersal, Sriharikota.

## Introduction

Tropical forests are rich in fruit resources which are used by a variety of frugivorous (i.e. fruit-eating) birds and mammals (Corlett 1998b; Fleming 1991; Fleming *et al.* 1987; Hanya & Bernard 2013; Snow 1981). When eating fruits, frugivores consume the seeds and disperse them by such mechanisms as carrying the fruit or seed away from the parent tree via the gut or dropping them after chewing the pulp. Seed dispersal helps seeds escape predation, competition, and fungal attack under the parent tree, thereby increasing the chance of survival (Howe 1980; Janzen 1970; Pizo 1997). However, some birds and mammals (e.g., monkeys and parakeets) also depredate seeds or regurgitate or drop them below fruiting trees, thus not aiding seed dispersal. Investigating how frugivores handle fruits helps to discern genuine seed dispersers from seed predators (Howe 1977) and also provides insight into patterns of plant species distributions in forests.

Loss of dispersal agents has been reported to lead to reduced recruitment and elimination of plant species in some forests (Benjamin *et al.* 2007; Gabriella & Howe 2007). Inversely, loss of certain fleshy-fruit plants or keystone fruit resources have led to or could lead to local elimination of some frugivores (Bleher *et al.* 2003; David *et al.* 2011). Hence, studies on frugivory and seed dispersal are essential to devise conservation measures for frugivores and the plants dispersed by them (Howe 1984).

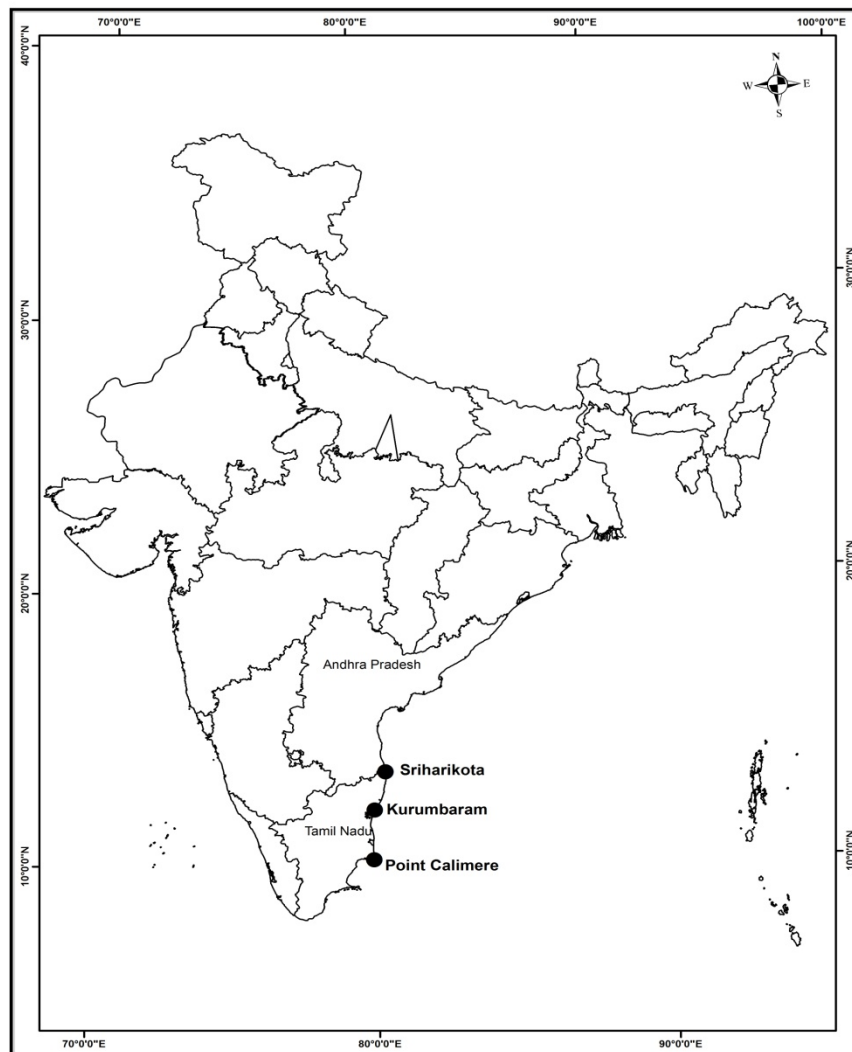
A plethora of studies has been undertaken throughout the world on the subject of frugivory and seed dispersal (Corlett 1998b; Fleming 1991; Fleming *et al.* 1987; Snow 1981), including the coastal Tropical Dry Evergreen Forest (TDEF's) of south India (Balasubramanian 1989a,b; Balasubramanian 1993, 1995, 1996; Balasubramanian & Bole 1993; David *et al.* 2009, 2011; Krishnamani 1994; Narasimhan *et al.* 1993). Tropical Dry Evergreen Forest represents a vegetation type confined mainly to Northern Ceylon, regions of the

Coramandel Coast of India, the Caribbean, and north and east Africa (Blasco & Legris 1972; Mani & Parthasarathy 2009; Parthasarathy *et al.* 2008). In India, historically the forest extended from northern Andhra Pradesh to southern Tamil Nadu, as a belt of vegetation between 30 and 50 km wide. Subsequently, due to deforestation, it is now only found in isolated small pockets. Among these the largest tracts are found in Sriharikota (13° 43' N-80° 13'E) and Point Calimere (10° 18' N-79° 57' E; Fig. 1). Detailed description of the TDEF sites in India can be found in (Balasubramanian 1996; David *et al.* 2012; Krishnamani 1994; Mani & Parthasarathy 2009).

In Tamil Nadu, TDEF are found in Nagapattinam, Cuddalore, Pondicherry, Pudukottai, and Villuppruam districts, whereas in Andhra Pradesh, they are mainly confined to the Nellore district. In most of these sites there is high anthropogenic pressure on the habitat, but in a few sites they are protected as sacred groves and human disturbance is low. Many species found in TDEF are of immense medicinal value and are widely used in traditional medicine (Parthasarathy *et al.* 2008). Given the importance of TDEFs we provide a review of avian and mammalian frugivores present in this ecosystem.

## Methods

Our review of avian frugivory is based on two papers (Balasubramanian 1996; David *et al.* 2011) and one conference proceeding (Narasimhan *et al.* 1993), which provides a complete list of birds recorded as fruit eaters. Similarly, our review of mammalian frugivory is based on three papers (Balasubramanian & Bole 1993; Krishnamani 1994; David *et al.* 2011) and three short notes. The review of fruit species either consumed by birds and mammals or adapted for zoochory is based on five papers (Balasubramanian 1996; Balasubramanian & Bole 1993; David *et al.* 2011; Krishnamani 1994; Selwyn & Parthasarathy 2006).



**Fig. 1.** Large Tropical Dry Evergreen Forest sites along the Coramandel Coast.

To analyze fruit colour across species we grouped violet with black, and orange with yellow. In the remaining fruit traits (size, type, and life form) all the categories were separately used. To assess for differences in fruit traits used by birds and mammals we used a chi-square test with  $P \leq 0.05$  considered significant.

## Results and discussion

### *Avian Frugivores*

A total of 34 bird species from 17 families were recorded as frugivores in coastal TDEFs. Among these, eight species are major frugivores (common in occurrence and consumed > 10 fruit species (Table 1), and the remaining are minor frugivores (uncommon or consumed < 10 fruit species). The

Columbidae, Cuculidae, and Sturnidae families were represented by the highest number of species (four each), followed by Corvidae and Pycnonotidae (three each). However, when the abundance of avian frugivores and the number of fruit species consumed are considered, members of the family Pycnonotidae, Sturnidae, Corvidae, Cuculidae, and Psittacidae are the major frugivores of TDEF. For eight species of frugivores, the fruit species consumed is not listed but has been identified as one of the species consuming fruits (Narasimhan *et al.* 1993).

### *Pycnonotidae*

Pycnonotidae is represented by three species of bulbuls; Red-whiskered (*Pycnonotus jocosus*), White-browed (*Pycnonotus luteolus*), and Red vented

**Table 1.** Major frugivores in coastal Tropical Dry Evergreen Forests of southern India.

Common name	Scientific name	Family	# Fruit-species consumed		
			Sriharikota	Point Calimere	Total
Birds					
White-browed Bulbul	<i>Pycnonotus luteolus</i>	Pycnonotidae	29	63	71
Red-vented Bulbul	<i>Pycnonotus cafer</i>	Pycnonotidae	16	51	54
Red-whiskered Bulbul	<i>Pycnonotus jocosus</i>	Pycnonotidae	31	-	31
Asian Koel	<i>Eudynamys scolopacea</i>	Cuculidae	23	32	25
Common Myna	<i>Acridotheres tristis</i>	Sturnidae	12	27	33
House Crow	<i>Corvus splendens</i>	Corvidae	5	12	13
Large billed Crow	<i>Corvus (macrorhynchos) culminatus</i>	Corvidae	12	12	13
Rose-ringed Parakeet	<i>Psittacula krameri</i>	Psittacidae	10	13	12
Mammals					
Bonnet Macaque	<i>Macaca radiata</i>	Cercopithecidae	34	39	63
Golden Jackal	<i>Canis aureus</i>	Canidae	21	22	33
Small Indian Civet	<i>Viverricula indica</i>	Viverridae	16	23	31
Three-striped Palm Squirrel	<i>Funambulus palmarum</i>	Sciuridae	38	17	-
Short-nosed Fruit Bat	<i>Cynopterus sphinx</i>	Pteropodidae	21	36	-
Indian Flying Fox	<i>Pteropus giganteus</i>	Pteropodidae	21	-	21

Note: Bird names follow Grimmett *et al.* (1999), while mammal names follow Menon, V. (2003).

Bulbul (*Pycnonotus cafer*). All three species occur in Sriharikota, but the Red-whiskered Bulbul is absent in Point Calimere. In Point Calimere 63 different fruit species ( $n = 64$ ) were eaten by the White-browed Bulbul, whereas in Sriharikota it was recorded to feed on 29 species ( $n = 38$ ). Similarly, the number of fruit species eaten by the Red-vented Bulbul was higher in Point Calimere (51) than Sriharikota (16). The Red-whiskered Bulbul consumed fruits of 31 fleshy-fruit species in Sriharikota (81.5 %). All the three bird species are seed dispersers. In general, bulbuls are the most important frugivores in anthropogenic open habitats in the Oriental Region (Corlett 1998b), such as the Red-whiskered and Light-vented bulbul (*Pycnonotus sinensis*) in a Hong Kong shrubland (Corlett 1998a), and the Brown-eared Bulbul (*Ixos amaourotis*) in central Japan. Introduced Red-whiskered and Red-vented bulbuls are now the major frugivores in many Pacific Ocean islands and in North America (Carleton & Owre 1975; Friefeld 1999).

#### *Sturnidae and Corvidae*

Sturnidae is represented by four species, including the Common Myna (*Acridotheres tristis*), which is a major frugivore. The Common Myna is a

resident species and was recorded to feed on 27 fruit species in Point Calimere and 12 fruit species in Sriharikota. The other three species in the Sturnidae family are either vagrant visitors [Brahminy Starling (*Sturnus pagodarum*) and Chestnut-tailed Starling (*Sturnus malabaricus*)] or winter visitors [(Rosy Starling (*Sturnus roseus*))]. The Rosy Starling is a regular winter visitor to Point Calimere, whereas in Sriharikota it was recorded only in the southern parts, where sampling was not carried out due to difficult logistics. On one occasion, a flock was observed feeding on *Phoenix farinifera* fruits in April (Manakadan & Sivakumar 2004), probably on return migration from their wintering grounds in the south. The Chestnut-tailed Starling, a minor frugivore in Point Calimere and Chengalpet was not recorded in Sriharikota.

Corvidae is represented by three species, the House Crow (*Corvus splendens*), the Large-billed Crow (*Corvus macrorhynchos culminatus*), and the Rufous Treepie (*Dendrocitta vagabunda*). The former two species are major frugivores in TDEF's. Visitation rates indicate that both the House Crow and the Large-billed Crow have special preference for fruits of *Lannea coramandelica*, *Manilkara hexandra*, *Ficus benghalensis*, and *Securinega*

*leucopyrus* (David *et al.* 2011). The open country starlings and mynas (*Acridotheres*, *Sturnus*), and crows (*Corvus*) are among the largest and most abundant frugivores in many human-dominated oriental landscapes and are probably major seed dispersal agents (Corlett 1998b).

#### Cuculidae

Four species of family Cuculidae were recorded to eat fruits in TDEFs. In Point Calimere, only the Asian Koel (*Eudynamis scolopacea*) was recorded to eat fruits. In Sriharikota, besides the Asian Koel, the Blue-faced Malkoha (*Phaenicophaeus viridirostris*) was recorded feeding on fruits. The Black-headed Cuckooshrike (*Coracina melanoptera*) and Large Cuckooshrike (*Coracina macei*) were recorded eating fruits in Chengalpet, but the fruit species eaten were not mentioned.

Among the four species, only the Asian Koel figures as a major avian frugivore. Most cuckoos are insectivorous, but the Asian Koel includes large quantities of fruit in its diet (Ali & Ripley 1987). In Point Calimere, the Asian Koel was recorded to feed on 32 fruit species, whereas in Sriharikota it was recorded to feed on 23 species and is next in importance to the bulbuls. Because the Asian Koel is highly secretive the number of fruit species consumed could be an underestimate. Fruits such as *Syzygium cumini*, which cannot be swallowed whole by other avian frugivores, may be dispersed by the Asian Koel as it has a large gape. In Hong Kong, three large fruits (*Arenga engleri*, *Livistona chinensis*, and *Syzygium cumini*) were recorded to be swallowed whole only by the Asian Koel (Corlett & Ping 1995). However, seed dispersal distances by the Asian Koel may be limited as they tend to defend the fruiting tree and rarely move away from it (Corlett 1998b; Pratt 1984).

#### Psittacidae

The Rose-ringed Parakeet (*Psittacula krameri*) is the only member of the Psittacidae family observed to eat fruits in TDEFs. In Point Calimere, it was recorded to feed on 13 fruit species, and on ten species in Sriharikota. In Sriharikota, it had particular preference for *Alangium salvifolium* fruits (David *et al.* 2010). Besides being a frugivore, the Rose-ringed Parakeet is a seed predator and causes immense damage to agricultural crops (Ali & Ripley 1987; Kumar 1994; Rasmussen & Anderton 2005). Seed predation by Rose-ringed Parakeets was also documented in Sriharikota and Point Calimere for

all the fruit-species consumed, hence it appears to play limited role in seed dispersal.

#### Columbidae

Columbidae of the genus *Treron* (green pigeons) is represented by two species in TDEFs, the Orange-breasted Green Pigeon (*Treron bicincta*) and the Yellow-footed Green Pigeon (*Treron phoenicoptera*). Both the species of Green pigeons are known to be voracious fig feeders, and pigeons in general form one of the principal groups of fig-eating birds in Southeast Asian forests (Lambert 1989). Although there is no listing of fruit species consumed by the Yellow-footed Green Pigeon in Chengalpet (where it was recorded), the Orange-breasted Green Pigeon was recorded to feed on five species of fruit in Point Calimere and seven in Sriharikota. In Sriharikota, Orange-breasted Green-Pigeon display a preference for *Ficus amplissima*, and flocks of upto 30 birds were recorded to feed on these fruits.

In spite being highly frugivorous, the Orange-breasted Green-Pigeons (Ali & Ripley 1987) were recorded to feed on only few fruit species as they are migratory and exploit fruit resources available only during their occasional visits. Regarding their role in seed dispersal, complete seeds of *Manilkara hexandra* and *Zizyphus oenoplia* were found under roosting sites in Point Calimere (Balasubramanian 1996). Since they are nomadic and move from one forest patch to another in search of fruit resources, they could be extremely important seed dispersal agents over large distances.

Two minor frugivores of Columbidae are reported in the TDEFs of Point Calimere and Sriharikota, the Spotted Dove (*Streptopelia chinensis*) and the Laughing Dove (*Streptopelia senegalensis*). In Sriharikota the Spotted Dove was recorded to feed only on *Securinega leucopyrus* fruits (David *et al.* 2011), whereas in Point Calimere it was recorded to feed on six fruit species (Balasubramanian 1996).

#### Capitonidae and Oriolidae

Both Capitonidae and Oriolidae have been grouped together as they were recorded to feed only on fig fruits at both the sites. Capitonidae is represented by the Coppersmith Barbet (*Megalaima haemacephala*) and Oriolidae by the Eurasian Golden Oriole (*Oriolus oriolus*). In Point Calimere, the Eurasian Golden Oriole, was recorded to feed on three fig species, *Ficus benghalensis*, *F. religiosa*, and *F. Infectoria*, while in Sriharikota

it was recorded to feed on *Ficus amplissima*. Orioles are highly frugivorous and seem to be particularly fond of figs (Corlett 1998b).

The Coppersmith Barbet was not recorded in Point Calimere (probably due to paucity of fig trees), but has been recorded in Vedaranyam (11 km to its north), which have fig trees along roads and in temples (Balachandran & Thirunavukarasu 2009; Ranjit Manakadan *pers. comm.*). In Sriharikota, the Coppersmith Barbet was recorded to feed chiefly on figs. Most of the frugivory records were on five species of figs, *Ficus amplissima*, *F. microcarpa*, *F. benghalensis*, *F. racemosa*, and *F. religiosa*. On one occasion each, it was observed feeding on fruits of *Syzygium cumini* and *Lannea coromandelica*. The almost total dependence of the species on figs suggests that loss of fig trees could lead to their local extirpation on the island (David *et al.* 2011). Barbets are among the most highly frugivorous birds of the Oriental region and several species feed largely on figs, for which they are the major dispersal agents (Corlett 1998b).

#### Other fruit-eating birds

Bird species of the families Picidae, Dicaeidae, Irenidae, Nectarinidae, Sylviidae, and Turdidae were also recorded to feed on fruits in TDEFs (Table 2). These other bird species included the Black-rumped Flameback (*Dinopium bengalense*), which was recorded feeding on *Lannea coromandelica* fruits in Sriharikota, and the Pale-billed Flower-pecker (*Dicaeum erythrorhynchos*), which showed a strong preference for the epiphytic Loranthus (*Dendrophthae falcata*) fruits and is an important disperser of Loranthus at both sites. It is also an important consumer and disperser of the epiphytic *Viscum orientale* and *V. capitellatum* in Point Calimere.

The Nectarinidae family is represented by three species in coastal TDEFs; Purple-rumped (*Nectarinia zeylonica*), Purple (*Nectarinia asiatica*), and Loten's Sunbird (*Nectarinia lotenia*). The Loten's Sunbird was not reported from Point Calimere. All the three species feed mostly on the juice and pulp of fruits and leave the seeds intact. In Sriharikota, they were recorded frequently visiting the fruits of *Lepisanthes tetraphylla* (which has high water content) during summer.

Species of the family Sylviidae were recorded rarely feeding on fruits in TDEF. For example, the migrant insectivorous Blyths Reed-Warbler (*Acrocephalus dumetorum*) was observed feeding on *Salvadora persica* fruits at both the sites. Accord-

ing to Fry *et al.* (1970), *S. persica* fruits are rich in 'sugar and lipid free' and are readily assimilated by birds. In Africa, warbler species are reported to feed intensively on *Salvadora* fruits before returning to their breeding grounds. Another warbler noted was the Lesser White Throat (*Sylvia curruca*), which was recorded feeding on fruits of *Securinega leucopyrus* in Sriharikota. Among the other records, the Orange-headed Thrush (*Zoothera citrina*) was recorded feeding on *Securinega leucopyrus* fruits.

#### Mammalian Frugivores

Among mammals, 12 frugivorous species were reported from ten families in coastal TDEFs. Of the 12 species, six include a large amount of fruit in their diet (Table 1). A family-wise listing is given below:

##### *Cercopithecidae*

In coastal TDEFs the family Cercopithecidae is represented by the Bonnet Macaque (*Macaca radiata*), which consumes fruit as a major portion of its diet (Ali 1986; Krishnamani 1994; Kuruvilla 1980). Generally, Macaques eat anything edible, ripe or unripe, also seeds and leaves, soft or hard skinned fruits and thus contribute both to dispersal and predation of seeds (Pijl 1982). In Sriharikota the Bonnet Macaque was recorded feeding on 34 species of fruit. The majority of seeds recorded in the droppings were fig species (*Ficus*) and *Cordia dichotoma*. Most of the opportunistic frugivory records obtained were also on fig trees. More than 50 % of the droppings contained vegetable matter other than seeds, such as leaves, skins of fruits, flowers, and twigs (David *et al.* 2011)

In Kurumbaram, fruits formed the major part of the diet of the Macaques (Krishnamani 1994). Among the 20 top food items, 45 % were fruits. Fruits of *Ficus benghalensis* and *Azadirachta indica* were the major food items. Regarding their role in seed dispersal, the low number of seeds in droppings and record of fruit skins without seeds in Sriharikota indicated that the Bonnet Macaque either drop or grind seeds more than swallowing and defaecating them intact (David *et al.* 2011). However, in Point Calimere, fruits of 39 species were identified in Macaque dung, indicating that they are efficient seed dispersers (Balasubramanian & Bole 1993). Seeds of *Scutia myrtina*, *Lannea coromandelica*, *Manilkara hexandra*, *Drypetes sepiaria*, and *Ficus benghalensis* were

frequently recorded. Notably, the Bonnet Macaque is an important disperser of the invasive plant *Prosopis chilensis* (Balasubramanian & Bole 1993). The Bonnet Macaque is a widespread species in India and lives close to human habitations (Menon 2003). Furthermore, the Macaque can live in tiny forest patches, use young secondary forest, cross open ground, and eat a wide variety of foods (Corlett 1998b).

#### *Canidae and Viverridae*

The Golden Jackal (*Canis aureus*) represents Family Canidae. In Point Calimere, seeds of 22 species were recorded in its scat, including frequent records of *Cassia fistula*, *Zizyphus oenoplia*, *Manilkara hexandra*, and *Syzygium cumini*. In Sriharikota 21 fruit species were recorded in its scat, with the bulk of the fruit found in the diet (judging by the abundance and frequency of occurrence of seeds in scats) being *Syzygium cumini* (33 %, n = 473), *Phoenix farinifera* (18 %), *Cordia dichotoma* (15 %), and *Memecylon umbellatum* (14 %). Jackals were also directly observed feeding on fruits of *Ficus benghalensis* and *F. microcarpa* as well as the introduced species *Anacardium occidentale*, *Calamus rotang*, *Morinda tinctoria*, and *Guazuma ulmifolia*. Among the 12 frugivorous mammals, the Golden Jackal had the greatest number of seeds in its droppings (David *et al.* 2011).

The family Viverridae is represented by the Small Indian Civet (*Viverricula indica*), which feeds on 23 fruit species in Point Calimere. Fruits of *Zizyphus oenoplia* and *Manilkara hexandra* were the most preferred. In Sriharikota Civet scat contained seeds of 16 fruit species. The bulk of the fruit diet was contributed by species recorded in Jackal scats (David *et al.* 2011).

Both the Golden Jackal and Small Indian Civet are opportunistic feeders that eat significant amounts of fallen fruits and disperse them. In Sriharikota, the most common species in the forest such as *C. dichotoma*, *D. ferrea*, *G. rhamnifolia*, *M. umbellatum*, *P. farinifera*, and *S. cumini* and large-sized fruits such as *Mimusops elengi* and *Zizyphus mauritiana* are chiefly dependent on the Golden Jackal and Small Indian Civet for dispersal (David *et al.* 2011).

#### *Pteropodidae*

The Short-nosed Fruit Bat (*Cynopterus sphinx*) and the Indian Flying Fox (*Pteropus giganteus*) are the only two species of fruit bats recorded from the two sites. While both species have been reported in

Sriharikota, the Indian Flying Fox is absent in Point Calimere. In Point Calimere fruits were regularly collected from a Short-nosed Fruit Bat roost site (Balasubramanian & Bole 1993), while in Sriharikota evidence could be obtained only from fruit debris left behind by fruit bats (David *et al.* 2011). Hence in Sriharikota, it was not possible to distinguish fruit resources of the two species.

In Point Calimere 36 fruit species were utilised compared to 21 species in Sriharikota. In both sites fruit bats are sole dispersers of *Atlantia monophylla* (Balasubramanian 1989a; David *et al.* 2011). In Sriharikota *Opilia amantaceae* is also solely dispersed by fruit bats. The important fruit resources for fruits bats in Sriharikota are *Atlantia monophylla*, *Garcinia spicata*, *Opilia amantaceae* and *Syzygium cumini*. Among the two species, the Short-nosed Fruit Bat is an efficient seed disperser as it plucks the fruit from the host tree and flies a short distance before beginning to feed on another tree, whereas the Indian Flying Fox crash lands in a fruiting tree and mostly eats the fruits in the fruiting tree itself (David & Atkore 2010).

In Sriharikota, four fig species (*Ficus amplissima*, *F. benghalensis*, *F. microcarpa*, and *F. racemosa*) were intensively used by fruit bats. Figs produced ripe fruits almost throughout the entire study period and fruit debris (spat-out pellets) indicated that fruit bats utilized figs throughout most of the study period (David *et al.* 2011). Members of the family Pteropodidae are the major consumers of figs in the tropics (Shahnahan *et al.* 2001), whereas in the neotropics, figs constitute the dominant portion in the diet of Phyllostomid bats (Kalko *et al.* 1996).

#### *Sciuridae*

Fruits of 38 species were consumed by the Three-striped Palm Squirrel (*Funambulus palmarum*) in Point Calimere and 17 in Sriharikota. The squirrel is either a seed eater or a seed dropper and does not contribute to seed dispersal. For instance, while feeding on *Cordia dichotoma* fruits in Sriharikota, the pulp was eaten while intact seeds were dropped below the fruiting tree. Thus, it is likely that when feeding on unripe fruits the seeds are eaten while in ripe fruits the pulp is eaten and the seeds dropped (David *et al.* 2011).

#### *Other fruit-eating mammals*

In Sriharikota, fruit-species recorded in the faeces of other mammals were *Catunerigum spinosa*

**Table 2.** Minor frugivores in coastal TDEF's.

Common name	Scientific name	Family	No. of fruit species consumed
Birds			
Coppersmith Barbet	<i>Megalaima haemacephala</i>	Capitonidae	6
Orange-breasted Green Pigeon	<i>Treron bicincta</i>	Columbidae	9
Yellow-footed Green Pigeon	<i>Treron phoenicoptera</i>	Columbidae	-
Laughing Dove	<i>Streptopelia decaocto</i>	Columbidae	2
Spotted Dove	<i>Streptopelia chinensis</i>	Columbidae	1
Pied cuckoo	<i>Clamator jacobinus</i>	Cuculidae	-
Common Hawk Cuckoo	<i>Hierococcyx varius</i>	Cuculidae	-
Blue-faced Malkoha	<i>Pheanicophaeus viridirostris</i>	Cuculidae	1
Black-rumped Flameback	<i>Dinopium bengalense</i>	Picidae	1
Large Cuckooshrike	<i>Coracina macei</i>	Campephagidae	-
Black-headed Cuckooshrike	<i>Coracina melanoptera</i>	Campephagidae	-
Rufous Treepie	<i>Dendrocitta vagabunda</i>	Corvidae	4
Common Iora	<i>Aegithina tiphia</i>	Irenidae	-
Oriental Magpie Robin	<i>Copsychus saularis</i>	Muscicapidae	2
Chestnut-tailed Starling	<i>Sturnus malabaricus</i>	Sturnidae	4
Brahminy Starling	<i>Sturnus pagodarum</i>	Sturnidae	9
Rosy Starling	<i>Sturnus roseus</i>	Sturnidae	3
Orange-headed Thrush	<i>Zoothera citrina</i>	Turdidae	2
Yellow-billed Babbler	<i>Turdoides affinis</i>	Leiothrichidae	1
Jungle Babbler	<i>Turdoides striatus</i>	Leiothrichidae	9
Blyth's Reed Warbler	<i>Acrocephalus dumetorum</i>	Sylviidae	2
Lesser Whitethroat	<i>Sylvia curucca</i>	Sylviidae	1
Pale-billed Flowerpecker	<i>Dicaeum erythrorhynchos</i>	Dicaeidae	1
Purple-rumped Sunbird	<i>Nectarinia zeylonica</i>	Nectarinidae	1
Purple Sunbird	<i>Nectarinia asiatica</i>	Nectarinidae	1
Eurasian Golden Oriole	<i>Oriolus oriolus</i>	Oriolidae	1
Mammals			
Spotted Deer	<i>Axis axis</i>	Cervidae	1
Wild Boar	<i>Sus scrofa</i>	Sciuridae	6
Grey Mongoose	<i>Herpestes edwardsii</i>	Herpestidae	6
Black Buck	<i>Antilope cervicapra</i>	Bovidae	1
Feral Pony	-	Equidae	3
Indian Gerbille	<i>Tatera indica</i>	Muridae	2

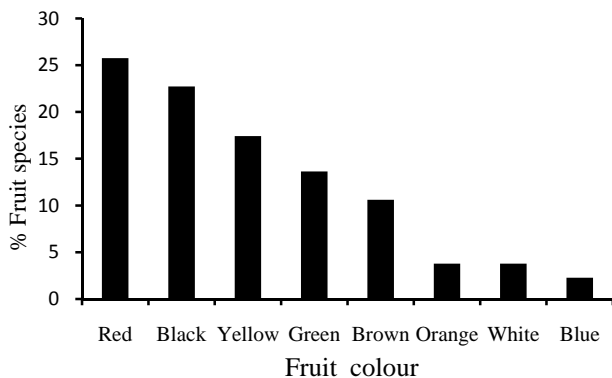
in Spotted Deer (*Axis axis*), *Syzygium cumini* in Wild Boar (*Sus scrofa*), and *Phoenix farinifera*, *Grewia rhamnifolia*, and *Syzygium cumini* in Grey Mongoose (*Herpestes edwardsii*) (David *et al.* 2009). In Point Calimere in addition to these mammal species, seeds were recorded in dung of feral ponies, cattle, and Black Buck (*Antilope cervicapra*). In both the sites the Spotted Deer is an important disperser of *Catunigerum spinosa* (spiny shrub), a pioneer coloniser in open sandy areas (Balasubramanian & Bole 1993; David *et al.* 2011)

#### *Fruit traits*

A total of 132 plant species from 49 families

were recorded as fruit resources for birds and mammals or adapted for zoochory in TDEF's (including introduced species). Of the 132 species, 112 are consumed by frugivores, with the remaining species showing adaptations for animal dispersal and could be used by birds and mammals, even though no records of frugivory exist to indicate if they are actually consumed. The greatest number of species were from the family Rubiaceae (9.8 %), followed by Moraceae (6 %), and Capparaceae (5.3 %). Among the life forms 50.0 % were trees, 28.0 % shrubs, 18.9 % climbers, and the rest epiphytes. Of the 132 plant species 114 (86.4 %) are native while the remaining are introduced species.





**Fig. 2.** Proportion of fruits with various fruit colours ( $n = 132$ ).

Fruit color was dominated by red (25.8 %), black (22.7 %), and yellow (17.4 %; Fig. 2). Ripe green fruits were consumed only by fruit bats. Most fruits (74.3 %) were berries and drupes (Fig. 3), with medium sized fruits (fruit diameter  $> 5$  and  $\leq 15$  mm) dominant in the diet of birds and mammals (75.5 %; Fig. 4). Birds and mammals differed significantly in their preference for fruit size ( $\chi^2 = 8.2$ ,  $df = 2$ ,  $P = 0.01$ ), but not in their overall preference with respect to fruit color ( $\chi^2 = 11.5$ ,  $df = 6$ ,  $P = 0.07$ ), fruit type ( $\chi^2 = 7.7$   $df = 5$ ,  $P = 0.16$ ), and life form ( $\chi^2 = 3.2$ ,  $df = 2$ ,  $P = 0.19$ ).

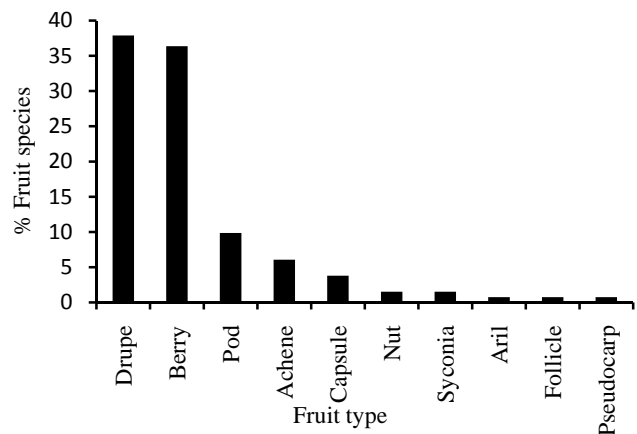
#### Dispersal mode

A majority of the fruit species (56.3 %, 53 of 94 species) are dependent both on birds and mammals to disperse their seeds. Mammals solely disperse 21 fruit species (24 %) and birds solely disperse 20 species (21 %; Appendix Table 1). In the absence of hornbills (which are capable of dispersing large fruits), large sized fruits are extremely dependent on mammals for dispersal. The largest fruit dispersed by a mammal was *Strychnos nux-vomica* (44 mm; by fruit bats and the Bonnet Macaque) and the smallest was *Cassine glauca* (10.2 mm; by fruit bats).

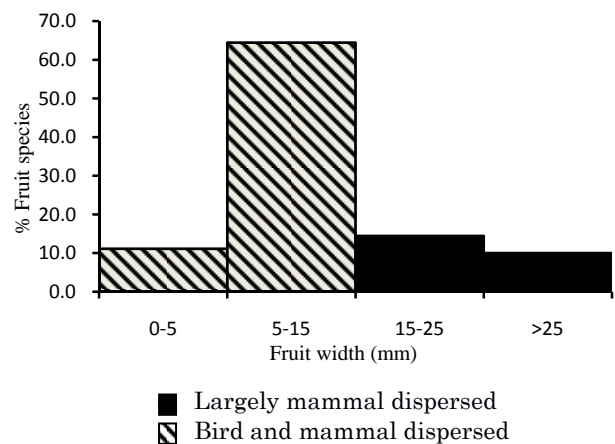
### Threats and recommendations

Almost 80 % of plant species in TDEF's are zoochoric (Selwyn & Parthasarathy 2006; David unpublished data). Hence conservation of frugivores that are vital for seed dispersal, and subsequently plant regeneration and recruitment, is critical for long term stability and restoration of this forest type. One major conservation issue in Sriharikota is road kill, which is a major threat to

two important mammalian frugivores; the Golden Jackal and Small Indian Civet (Sivakumar & Manakadan 2010). Incidence of road kills should be controlled through awareness programmes, speed limits for vehicles, creation of speed breakers, culverts (i.e. underpasses for animal crossing), and installing sign boards at road kill prone areas. Decreasing the extent of the road network (where possible) could also be explored (Sivakumar & Manakadan 2010).



**Fig. 3.** Proportion of fruits with various fruit types ( $n = 131$ ).



**Fig. 4.** Proportion of fruits under various size classes ( $n = 90$ ).

Another important conservation measure in Sriharikota is to protect the abandoned village forest, where most of the fig trees are found. Since non-fig fruits are unreliable and unpredictable in Sriharikota (David *et al.* 2012), figs are a very important resource for most of the frugivores, as they ensure continuous food supply (David *et al.* 2011). These areas should be given low priority for land acquisition plans for the expansion of the

**Table 3.** Important fruit-species for frugivores in coastal TDEF.

Species	Life form	Fruiting period	Consumer group
<i>Atlantia monophylla</i>	Tree	July-October	Fruit Bats
<i>Azadirachta indica</i>	Tree	July-August	Birds and Bonnet Macaque
<i>Cansjeera rheedei</i>	Climber	January-April	Birds
<i>Cissus vitiginea</i>	Climber	August-October	Birds
<i>Cordia dichotoma</i>	Tree	June-August	Birds and Mammals
<i>Ehretia pubescens</i>	Tree	August-November	Birds
<i>Eugenia bracteata</i>	Shrub	March-May	Birds
<i>Ficus amplissima</i>	Tree	Aseasonal	Birds and Mammals
<i>Ficus benghalensis</i>	Tree	Aseasonal	Birds and Mammals
<i>Ficus microcarpa</i>	Tree	Aseasonal	Birds and Mammals
<i>Ficus racemosa</i>	Tree	Aseasonal	Mammals
<i>Hugonia mystax</i>	Climber	August-September	Birds
<i>Garcinia spicata</i>	Tree	June-August	Mammals
<i>Glycosmis pentaphylla</i>	Shrub	September-November	Birds and Mammals
<i>Lannea coromandelica</i>	Tree	June-August	Birds, Bonnet Macaque and Three-striped Palm Squirrel
<i>Manilkara hexandra</i>	Tree	March-May	Birds and Mammals
<i>Memecylon umbellatum</i>	Shrub	June-October	Mammals
<i>Ochna obtusata</i>	Tree	May-July	Birds
<i>Olex scandens</i>	Climber	May-December	Birds
<i>Opilia amantaceae</i>	Climber	July-October	Fruit Bats
<i>Pachygone ovata</i>	Climber	May-September	Mammals
<i>Pamburus missionis</i>	Tree	August-October	Mammals
<i>Phoenix farinifera</i>	Shrub	March-June	Mammals
<i>Salvadora persica</i>	Tree	March-June	Birds
<i>Securinega leucopyrus</i>	Shrub	July-November	Birds
<i>Syzygium cumini</i>	Tree	August-October	Mammals
<i>Walsura trifolia</i>	Tree	May-August	Birds
<i>Zizyphus mauritiana</i>	Tree	January-February	Mammals
<i>Zizyphus oenoplia</i>	Climber	January-February	Birds and Mammals

space port. Where acquisition is unavoidable, possibilities of avoiding cutting of *Ficus* trees should be explored (David *et al.* 2011). Logging or selective felling of other important fruit species for different groups of frugivores in TDEF's (Table 3) should be avoided in all the sites. In addition to these important fruit species, visually attractive species such *Breynia vitis-idaea*, *Casaeria esculenta*, *Cansjeera rheedei*, *Pavetta indica*, and *Phoenix farinifera* can be grown in gardens and residential facilities as a conservation measure.

In small sized TDEF's, where there is moderate level of disturbance, restoring the disturbed sites with characteristic TDEF species and revitalizing

the cultural traditions associated with sacred groves by promoting awareness of the ecological and bio-resource values of TDEFs is recommended (Parthasarathy *et al.* 2008). In severely disturbed habitats legal status must be provided to these sites and a system of managing the biodiversity through community participation must be evolved.

## Conclusions

The frugivore assemblage in the coastal TDEFs of southern India is representative of disturbed secondary forests which are not averse to living near human habitations. The TDEFs are

dominated by three species of bulbuls, Bonnet Macaque, Golden Jackal, Small Indian Civet, and two species of Fruit bats. Large fruits and fruits with seed protection, such as *Strychnos nuxvomica*, *Phoenix sylvestris*, *Mimusops elengi*, and *Garcinia spicata*, are solely dependent on mammals for their dispersal. Fruits with a thick pericarp or green in colour (e.g., *Atlantia monophylla*, *Opilia amantaceae*, *Cassine glauca*) are solely dispersed by fruit bats. Figs are important resource for birds. Loss of fig trees could lead to local extinction of Coppersmith Barbet in Sriharikota. Among mammals, figs are very important fruit resources for Bonnet Macaque and Fruit Bats. Fruit traits are similar to what has been reported from other forests in the tropics. Fruit type was dominated by drupe and berry and fruit colour by red, black and yellow.

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**Appendix Table 1.** Fruit traits and dispersal mode.

Species name	Family	Life form	Fruit type	Fruit colour	Fruit width (mm)
Species dispersed both by birds and mammals					
<i>Allophylus serratus</i>	Sapindaceae	Tree	Drupe	Red	9.1
<i>Asparagus recemosus</i>	Liliaceae	Climber	Berry	Red	6.0
<i>Azadirachta indica</i>	Meliaceae	Tree	Drupe	Yellow	10.7
<i>Azima tetracantha</i>	Salvadoraceae	Shrub	Berry	White	6.3
<i>Breynia vitis idaea</i>	Euphorbiaceae	Shrub	Capsule	Red	6.5
<i>Cansjeera rheedei</i>	Opiliaceae	Climber	Drupe	Red	11.9
<i>Canthium dicoccum</i>	Rubiaceae	Tree	Drupe	Black	8.4
<i>Canthium parviflorum</i>	Rubiaceae	Shrub	Drupe	Yellow	11.8
<i>Carissa spinarum</i>	Apocynaceae	Shrub	Berry	Black	9
<i>Catunigerum malabarica</i>	Rubiaceae	Shrub	Berry	Black	8.2
<i>Cissua vitiginea</i>	Vitaceae	Climber	Berry	Black	8
<i>Coccinea grandis</i>	Cucurbitaceae	Climber	Berry	Red	21
<i>Cordia dichotoma</i>	Boraginaceae	Tree	Drupe	Yellow	8.9
<i>Cordia obliqua</i>	Boraginaceae	Tree	Berry	Yellow	10.0
<i>Diospyros ferrea</i>	Ebenaceae	Tree	Berry	Red	11
<i>Drypetes sepiaria</i>	Euphorbiaceae	Tree	Drupe	Red	-
<i>Ehretia ovalifolia</i>	Boraginaceae	Tree	Drupe	Yellow	3
<i>Ehretia pubescence</i>	Boraginaceae	Tree	Drupe	Red	4.6
<i>Ficus amplissima</i>	Moraceae	Tree	Achene	Green/Black	13.6
<i>Ficus benghalensis</i>	Moraceae	Tree	Achene	Red	18.3
<i>Ficus microcarpa</i>	Moraceae	Tree	Achene	Yellow	7.3
<i>Ficus racemosa</i>	Moraceae	Tree	Achene	Red	27.8
<i>Ficus religiosa</i>	Moraceae	Tree	Achene	Red	7.7
<i>Ficus tsjakela</i>	Moraceae	Tree	Achene	Red	12.0
<i>Flacourtia indica</i>	Flacourtiaceae	Shrub	Drupe	Black	8.2
<i>Glycosmis pentaphylla</i>	Rutaceae	Shrub	Drupe	Red	9.1
<i>Hugonia mystax</i>	Linaceae	Climber	Drupe	Red	8.5
<i>Ixora pavetta</i>	Rubiaceae	Shrub	Drupe	Black	6
<i>Jasminum angustifolium</i>	Oliaceae	Climber	Berry	Black	7.5
<i>Lannea coromandelica</i>	Anacardiaceae	Tree	Drupe	Red	6.6
<i>Lepisanthes tetraphylla</i>	Sapindaceae	Tree	Drupe	Yellow	20.1
<i>Manilkara hexandra</i>	Sapotaceae	Tree	Berry	Yellow	8.6
<i>Memecylon umbellatum</i>	Melastomataceae	Shrub	Berry	Black	7.8
<i>Ochna obtusata</i>	Ochnaceae	Tree	Drupe	Black	8.3
<i>Olax scandens</i>	Olaceae	Climber	Drupe	Yellow	12
<i>Pachygone ovata</i>	Menispermaceae	Climber	Drupe	Red	11.2
<i>Pavetta breviflora</i>	Rubiaceae	Shrub	Berry	Green	6.3
<i>Phoenix pusilla</i>	Arecaceae	Shrub	Drupe	Black	7.4
<i>Plecosperrum spinosum</i>	Moraceae	Climber	Achene	Brown	14
<i>Premna serratifolia</i>	Verbenaceae	Shrub	Drupe	Black	6
<i>Salacia chinensis</i>	Hyppocrataceae	Climber	Berry	Red	13.6
<i>Salvadora persica</i>	Salvadoraceae	Tree	Drupe	Red	8
<i>Scutia myrtina</i>	Rhamnaceae	Climber	Drupe	Violet	10
<i>Securinega leucopyrus</i>	Euphorbiaceae	Shrub	Berry	White	5.1
<i>Solanum trilobatum</i>	Solanaceae	Climber	Berry	Red	9.4
<i>Syzygium cumini</i>	Myrtaceae	Tree	Berry	Black	14.7

Contd...

Appendix Table 1. Continued.

Species name	Family	Life form	Fruit type	Fruit colour	Fruit width (mm)
<i>Tinospora cordifolia</i>	Menispermaceae	Climber	Drupe	Red	9.3
<i>Toddalia asiatica</i>	Rutaceae	Shrub	Berry	Yellow	6.8
<i>Walsura trifolia</i>	Viscaceae	Tree	Berry	Brown	12.1
<i>Zizyhus oenoplia</i>	Rhamnaceae	Climber	Drupe	Black	7.6
Species solely dispersed by mammals					
<i>Alangium salvifolium</i>	Alangiaceae	Tree	Berry	Red	16
<i>Anacardium occidentale</i>	Anacardiaceae	Shrub	Pseudocarp	Yellow	-
<i>Atlantia monophylla</i>	Rutaceae	Tree	Berry	Green	22.3
<i>Cassine glauca</i>	Celastraceae	Tree	Drupe	Green	10.2
<i>Catunigerum spinosa</i>	Rubiaceae	Shrub	Drupe	Green	20
<i>Crataeva adansonii</i>	Capparaceae	Tree	Berry	Green	40
<i>Crataeva magna</i>	Capparaceae	Tree	Berry	Yellow	32
<i>Garcinia spicata</i>	Clusiaceae	Tree	Berry	Yellow	30
<i>Gmelina asiatica</i>	Verbenaceae	Shrub	Drupe	Yellow	19
<i>Grewia rhamnifolia</i>	Tiliaceae	Climber	Drupe	Brown	11.4
<i>Madhuca longifolia</i>	Sapotaceae	Tree	Berry	Green	-
<i>Mimusops elengi</i>	Mimosaceae	Tree	Berry	Yellow	15.8
<i>Morinda pubesence</i>	Rubiaceae	Tree	Syconia	Black	-
<i>Opilia amantaceae</i>	Opiliaceae	Climber	Drupe	Green	14.4
<i>Pamburus missionis</i>	Rutaceae	Tree	Berry	Yellow	21.8
<i>Phoenix sylvestris</i>	Arecaceae	Tree	Drupe	Orange	28
<i>Pithecellobium dulce</i>	Mimosaceae	Tree	Pod	Green	-
<i>Polyalthia longifolia</i>	Annonaceae	Tree	Drupe	Black	-
<i>Rivea hypocrateriformis</i>	Convolvulaceae	Climber	Capsule	Brown	-
<i>Spondias pinnata</i>	Anacardiaceae	Tree	Drupe	Green	30.8
<i>Strychnos nux-vomica</i>	Longaniaceae	Tree	Berry	Orange	44
<i>Tamarindus indica</i>	Caesalpiniaceae	Tree	Pod	Brown	-
<i>Zizyphus mauritiana</i>	Rhamnaceae	Tree	Drupe	Red	20.1
Species largely dispersed by birds					
<i>Capparis brevispina</i>	Capparaceae	Shrub	Berry	Red	15
<i>Capparis rotundifolia</i>	Capparaceae	Shrub	Berry	Red	16.5
<i>Carmona retusa</i>	Coridaceae	Shrub	Drupe	Red	5.6
<i>Casaeria esculenta</i>	Flacourtiaceae	Shrub	Aril	Red	8.6
<i>Cassytha filliformis</i>	Lauraceae	Epiphyte	Drupe	White	7.0
<i>Cissus quadrangularis</i>	Vitaceae	Climber	Berry	Red	6.5
<i>Dendrophthae falcata</i>	Loranthaceae	Epiphyte	Berry	Red	6.5
<i>Eugenia bracteata</i>	Myrtaceae	Shrub	Berry	Red	10
<i>Ficus infectoria</i>	Moraceae	Tree	Achene	Red	-
<i>Jasminum auriculatum</i>	Oleaceae	Climber	Berry	Black	-
<i>Lantana camara</i>	Verbenaceae	Shrub	Drupe	Black	6
<i>Maytenus emarginata</i>	Celastraceae	Shrub	Capsule	Green	-
<i>Opuntia dilenii</i>	Cactaceae	Shrub	Berry	Red	3.2
<i>Pavetta indica</i>	Rubiaceae	Shrub	Drupe	Black	6.5
<i>Phyllanthus reticulatus</i>	Euphorbiaceae	Shrub	Berry	Black	5
<i>Pleurostylia opposita</i>	Celastraceae	Tree	Nut	Green	4.5
<i>Premna latifolia</i>	Verbenaceae	Tree	Drupe	Black	5.9
Unidentified species	-	Tree	-	White	4.6

Contd...

**Appendix Table 1.** Contiued.

Species name	Family	Life form	Fruit type	Fruit colour	Fruit width (mm)
<i>Viscum capitellatum</i>	Viscaceae	Epiphyte	Berry	Green	4.2
<i>Viscum orientale</i>	Viscaceae	Epiphyte	Berry	Yellow	4.2
Species consumed by birds and mammals but adapted for other dispersal modes					
<i>Acacia auriculiformis</i>	Fabaceae	Tree	Pod	Brown	Autochory
<i>Acacia nilotica</i>	Fabaceae	Tree	Pod	Brown	Water
<i>Albizia amara</i>	Fabaceae	Tree	Pod	Brown	Autochory
<i>Albizia lebbek</i>	Fabaceae	Tree	Pod	Yellow	Autochory
<i>Borassus flabellifer</i>	Arecaceae	Tree	Drupe	Black	Water
<i>Calamus rotang</i>	Arecaceae	Climber	Drupe	White	Water
<i>Calophyllum inophyllum</i>	Arecaceae	Tree	Drupe	Green	Water
<i>Cassia auriculata</i>	Caesalpineaceae	Tree	Pod	Brown	Autochory
<i>Cassia fistula</i>	Caesalpineaceae	Tree	Pod	Black	Autochory
<i>Cassia siamea</i>	Caesalpineaceae	Tree	Pod	Green	Autochory
<i>Casuarina</i> sp	Casuarinaceae	Tree	Nut	Brown	Autochory
<i>Dalbergia paniculata</i>	Fabaceae	Tree	Pod	Green	Autochory
<i>Dichrostachys cineria</i>	Mimosaceae	Shrub	Pod	Yellow	Autochory
<i>Guazuma ulmifolia</i>	Sterculiaceae	Tree	Capsule	Brown	Autochory
<i>Pterospermum canesence</i>	Sterculiaceae	Tree	Capsule	Brown	Anemochory
<i>Prosopis chilensis</i>	Fabaceae	Shrub	Pod	Green	Autochory

**Note:** The value under Fruit width is a mean of ten fruits and is provided only for species where the size is known. Plant species name follow Suryanarayana *et al.* 1998.