Environmental factors and pollinator activity

Temperature and relative humidity were identified as important environmental correlates controlling honey bee foraging activity by Bisht and Pant[30]. In a comparative study of Megachilid bees, Kapil and Jain[31] have shown that temperature, humidity and light intensity affect the commencement and cessation of flights and also the tripping efficiency.

In a novel attempt to explain the factors influencing pollination activity of *Apis dorsata*, Abrol[32] conducted a path coefficient analysis of a few environmental factors and nectar content. Bee abundance was shown to be significantly correlated with air temperature, light intensity, solar radiation and nectar concentration but negatively with relative humidity. Path coefficient analysis revealed that the direct effects of air temperature and light intensity were pronounced and positive while the effects of other factors did not substantially affect the bee activity.

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Pollination by birds and bats

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The available Indian literature on bird and bat pollination has been reviewed. Analysis of the information shows a generalized relationship among flowering plants and their pollinators. We discuss the probable reasons for such generalized relationship. Literature on bat pollination shows that anthesis and phenology in certain plants are cued towards the activity and breeding cycle of bats.

INDIA being a tropical country offers a vast potential for studying the role of birds and bats in pollination. However, except for a few studies[1–6], the subject has received very little attention. Here we review the available Indian literature on bird and bat pollination. Our discussions mainly rest on the two appendices generated following our survey of the Indian literature.

Flower birds

A total of 58 Indian bird species from 16 different families and four orders are reported to be involved in the pollination (Appendix I) of 93 species of flowering plants belonging to 34 families and 20 orders (Appendix II). Over 80% of the plant species are frequented by more than one bird species (Figure 1). On the other

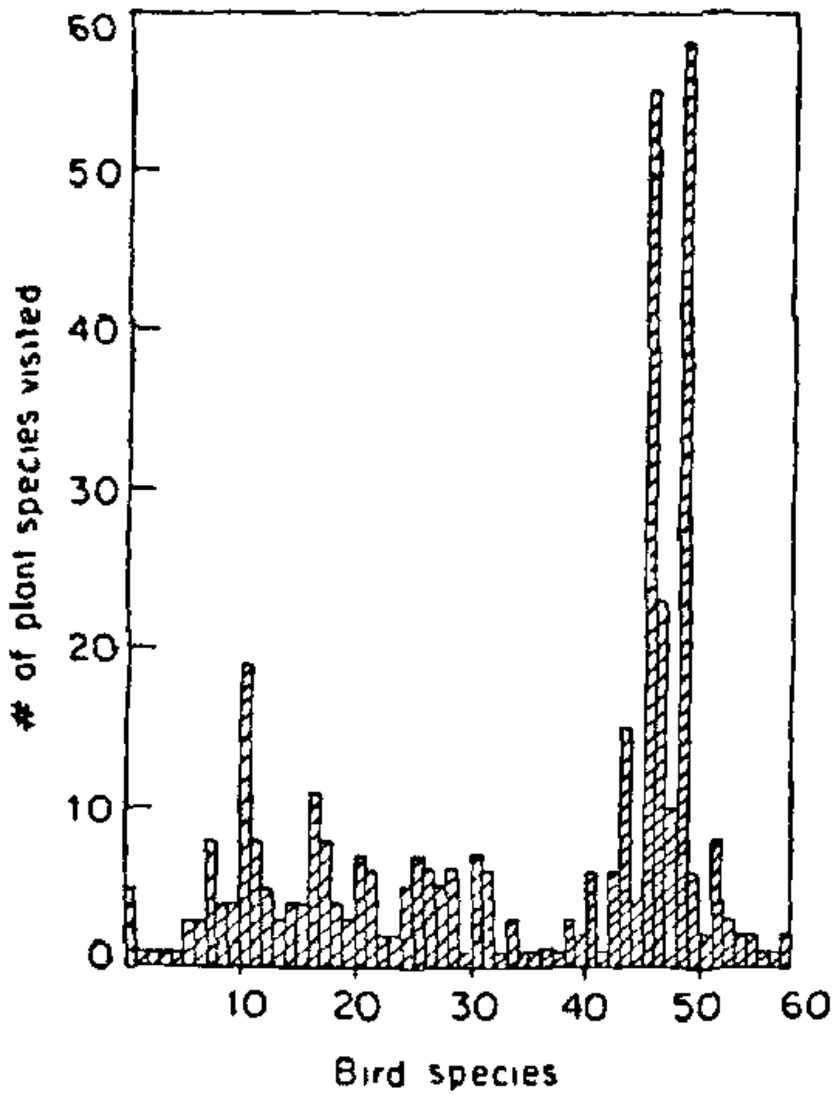

Figure 1. Number of plant species visited by different bird species. Data from appendices I and II.

hand an equal percentage of bird species frequented more than one species of plant (Figure 2). This clearly indicates the generalized relationship among plants and their bird pollinators.

Nectar is a good source of energy, but generally a poor supplier of the essential amino acids. Hence, even the specialized nectarivorous birds must consume animal matter to meet their protein requirement[7,8]. Probably due to this habit, an obligate association of birds and flowering plants is rare.

When bird flowers and flower birds[1] of different continents were compared, there was a minimal overlap in the families and genera of plants and pollinators. This suggests an independent evolution of their associations subsequent to the establishment of the main faunal regions[8]. However, in the absence of any clear fossil evidence it is difficult to infer about the early origin of bird pollination systems. According to Procter and Yeo[9], it appears that the evolution of ornithophily followed that of entomophily. In fact, Grant and Grant[10] have shown that many of the hummingbird-pollinated flowers of western North America belong to genera that are predominantly insect-pollinated. Even in the Indian context, this appears to be true. As can be seen from Appendix I, a majority of the ornithophilous plants seem to be a sub-set of a much larger entomophilous group of plants.

Bird features that aid in pollination

The body size and beak characteristics of nectarivorous birds vary considerably[7]. Among all the nectar feeders members of the families Dicaeidae and Nectariniidae show a higher ratio of beak length to body size (range 0.15–0.27) (Appendix I, Figure 3). This might enable them to harvest nectar from deep tubular flowers.

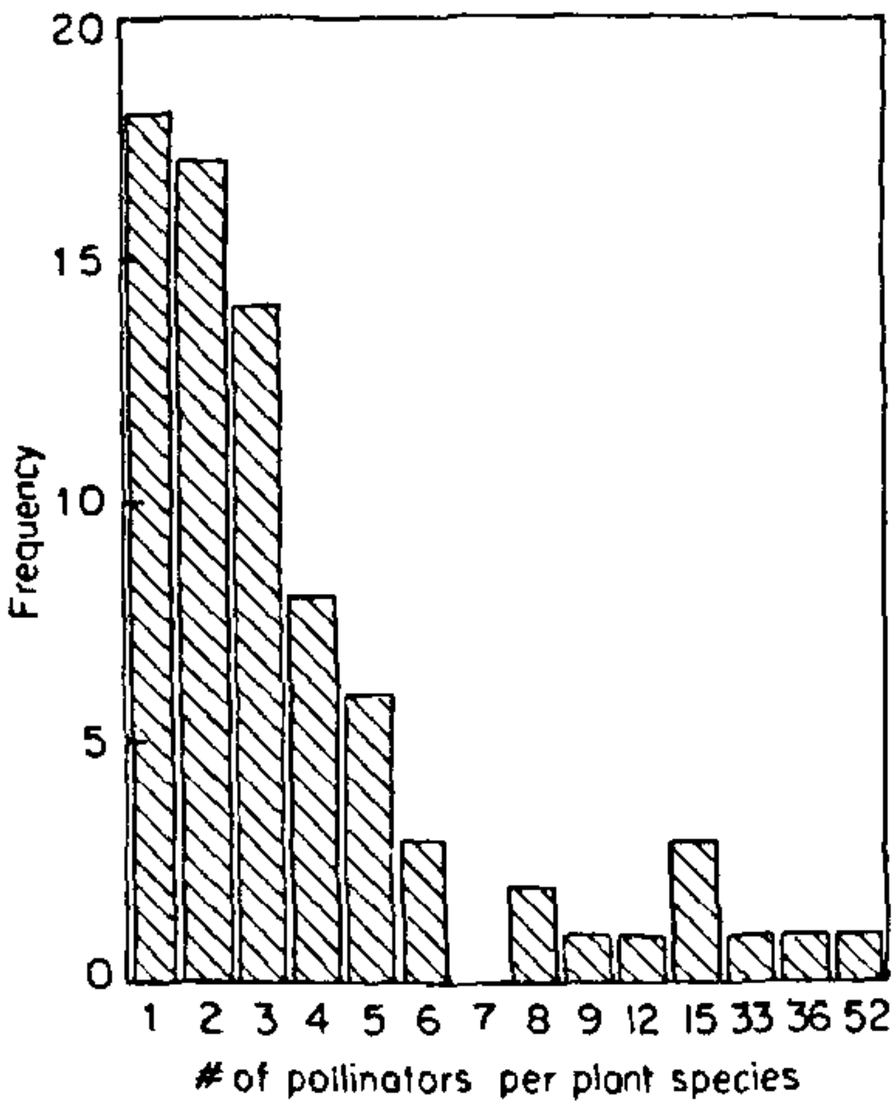

Figure 2. Number of pollinating bird species per plant species. Data from appendices I and II.

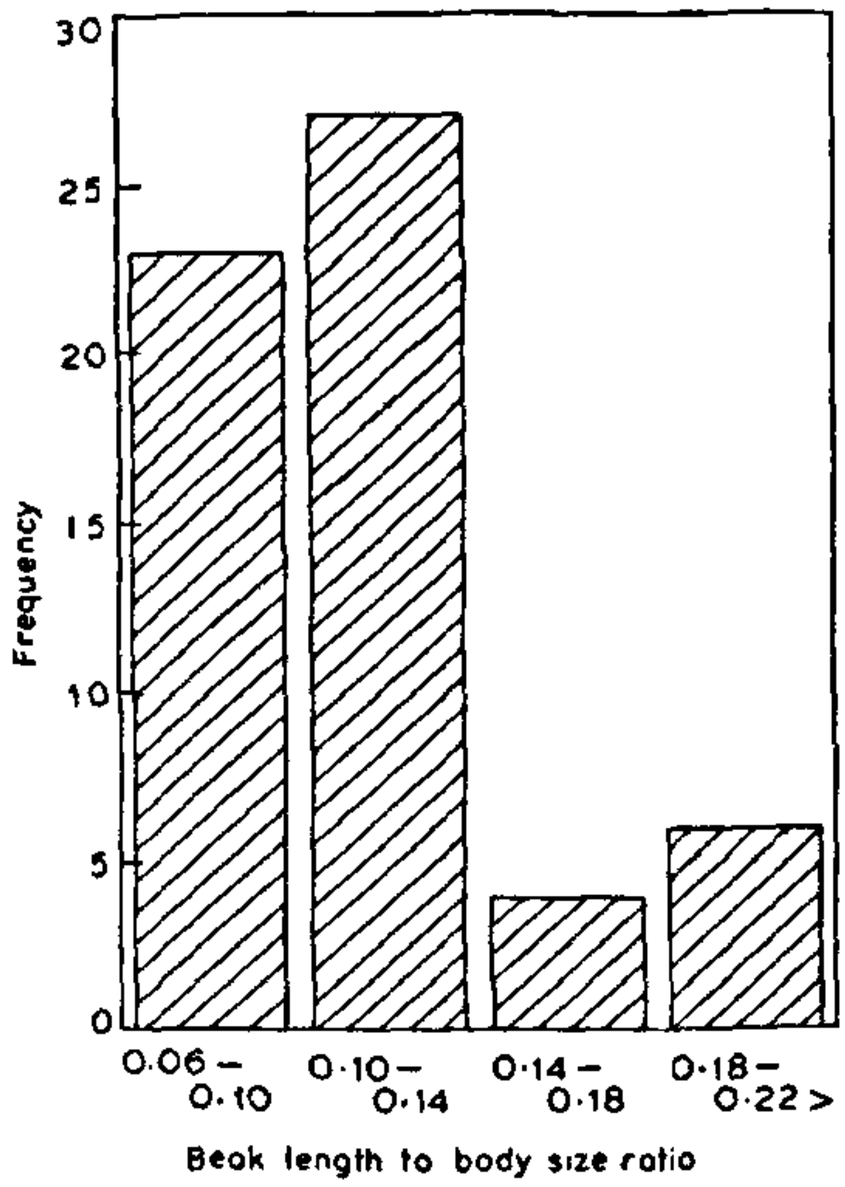

Figure 3. Beak length to body size ratios in pollinating bird species. Data from appendix I.

Some of the non-specialized nectar feeders possess certain morphological features that seem to aid in transfer of pollen grains. For example, the tuft of bristle-like feathers at the base of the upper mandible in case of Jungle Myna, Jungle Crow, Hair crested Drongo and Racket-tailed Drongos seem to serve this specific purpose (see Ali and Ripley[7]; Kannan[6]).

Based on the beak and tongue characteristics, the members of the bird families Dicaeidae (flowerpeckers), Irenidae (leafbirds), Nectariniidae (sunbirds) and Zosteropidae (white-eyes) can be labelled as the specialized nectar feeders among Indian birds[6]. These species have long tubular tongues which facilitate easy nectar harvest[6]. Sunbirds (members of the family Nectariniidae) that frequent up to 58 species of flowering plants, constitute one of the most important group of bird pollinators.

Such a wide host-breadth could be mainly due to the behavioural plasticity. Besides being directly involved in pollinating certain plant species, they visit a few species to steal nectar also. Using their tubular tongues, these birds employ a short-cut method[1,11] to reach nectar in flowers with tubular corolla, by puncturing a hole at the base of the flower[6,11]. Consequently, several plants do not get pollinated from these bird species. In fact Kannan[6] showed that of the 31 species observed by him, at least 21 were frequently robbed off their nectar by sunbirds. Also, sunbirds did not show any significant differences in their visitation pattern among indigenous and exotic ornithophilous flowers, entomophilous and chiropterous flowers[6] (Table 1). Old world sunbirds (Nectariniidae) by some aspects of their behaviour and ecology, parallel hummingbirds closely; but unlike hummingbirds they are relatively a more uniform group[8]. They also do not exhibit clear territoriality. Nevertheless, they have been observed to defend a clump of flowers temporarily to a period up to which the renewed nectar is sufficient to meet their requirement. Other bird pollinators are also known to show varied degrees of territoriality and site specificity[5].

Bird flowers

The members of the families Malvaceae, Leguminoceae, Myrtaceae, Bignoniaceae and Verbanaceae are the most ornithophilous plants of India[1]. Certain plant species namely *Bombax ceiba*, *B. insigne*, *Erythrina variegata* and *E. stricta* are visited by nearly 50 different bird species for nectar. Mistletoes (family Loranthaceae) are probably one of the well studied groups of ornithophilous plants[1-5].

Floral adaptation to bird pollination

Characteristically, ornithophilous plants possess large, both tubular and disc type of flowers that are brightly coloured and scented. Such flowers often have hypogynous multiovulated ovaries and larger pollen grains. According to Stressman[12] and Ali[1] the pollen grains of Phrygilanthus, Loranthus and other ornithophilous loranthi are equipped with tiny wing-like processes that make it easier for them to cling between the barbules of the bird feathers.

The bird flowers are generally open and have unprotected nectar that is rich in fructose and glucose compared to insect-pollinated flowers (e.g. *Hybanthus ennaespermus*) that contain sucrose-rich nectar[13]. The composition, quantity and quality of amino acids are also known to be different in entomophilous and ornithophilous flowers[14] (Table 2). Relatively the ornithophilous flowers have amino acid-poor nectar; the predominant amino acids being thiamine and isoleucine. Nevertheless, they occasionally do offer amino acid-rich rewards to birds. For instance, calyx water in *Spathodea companulata* is rich in amino acids

Table 1. Number of flowers visited by birds of different families

Families	Indigenous ornitho-philus flowers (14)	Exotic ornitho-philus flowers (14)	Butterfly-pollinated (10)	Bee-polli-nated (11)	Bat-polli-nated (1)	Total no. of flowers (out of 50) noted to be visited by each family
Psittacidae	5	1	—	2	—	8
Oriolidae	6	—	—	—	—	6
Dicruridae	5	—	—	1	—	6
Sturnidae	6	1	—	2	—	10
Corvidae	4	1	—	2	—	7
Irenidae	12	1	—	1	—	14
Pycnonotidae	7	1	—	1	—	9
Muscicapidae	7	1	—	1	—	10
Dicaeidae	11	1	—	—	—	12
Nectarinidae	14	14	10	11	1	50
Zosteropidae	6	—	—	—	1	7

Source: Kannan[6]. Values in parentheses indicate the number of plant families.

Table 2. Composition of amino acids in the nectar of entomophilous and ornithophilous plant species

Amino acids	*Hybanthus ennaespermus*	*Spathodea companulata*
Alanine	−	+
Phenyl alanine	−	−
Phosphorserine	+	−
Proline	+ +	−
Glutamic acid	+ +	−
Ethanolamine	+	−
Amino-*n*-caproic acid	+	−
-butanc acid	−	−
-amino octanoic acid	−	−
Valine	+	−
Leucine	+	−
Tryptophan	−	−
Isoleucine	−	+

+ = Present; + + = More; − = Absent.
Adapted from Bahadur *et al.*[14]

Table 3. Flower and fruit colour of some dicaeid-pollinated misletoes in Nilgiris

	Flower	Fruit
Species	Dicaeid visited	Dicaeid dispersed
Taxillus tomentosus	Brown	Brown-purple
T. recurvus	Brown-yellow	Brown-yellow
T. cuneatus	Green-yellow	Green
Dendrohthoe trigona	Green-yellow	Green
D. neelgherrensis	Green-yellow pink variant	Green
	Others	
Helixanthera hookerina	Red	Brown
H. wallichina	Orange	Brown
H. intermedia	Pink	Brown
Dendrophthoe falcata	Red	Green
D. memecylifolia	Orange-red	Green

Source: Davidar[3].

and is easily available to any bird with pointed beak[14].

The flowers of the members of the family Loranthaceae generally require an external pressure to open, otherwise the flowers do not get pollinated and in due course wither off. Sunbirds and flowerpeckers are known to exercise such pressure on flowers and help in pollination and fertilization[1]. However, a study by Davidar[3] clearly points out that this is not always true. The flowers of *Helixanthera intermedia* and *Dendropthe memecylifolia* spontaneously open without any external pressure.

Davidar[3] showed that both flowers and fruits of certain species have common characteristics and thus facilitate attraction of vector for both pollination and dispersal. For instance, as shown in the Table 3, both flowers and fruits of species *Texillus tomentosus* have similar colours and equally attract flowerpeckers. She argues that such convergence represents a case of facultative mimicry where the flower is the mimic and the fruit is the model as the reward offered by the flower is less than that by the fruit.

Despite these studies the obligate need for birds in pollination has not yet been demonstrated. Nevertheless, the observations by Wesley[15] show that in *Erythrina indica* up to 2.97 per cent of seed set occurs due to the activity of bird pollinators. Davidar[4] has also shown that in a few species of mistletoes at least bird pollination is obligately essential to realize a higher percentage of fruit set. By controlled experimentation she estimated the contribution to fruit set exclusively by birds and found it to range from 24 to 71% (Table 4). More work in this area is however required before the importance of birds in pollination can be clearly established.

Mistletoes are visited by a definite set of pollinators (Appendices I and II). As shown in Table 5 the small sunbirds visit the open flowered *H. intermedia* and *D. memecylifolia*. The closed flowered *T. recurvus* and *D. neelgherrensis* are visited by the flowerpecker and the white-eye. The small sunbird, flowerpecker and white-

Table 4. Influence of pollinator visitation on per cent fruit set in mistletoes

Species	Bird pollinator	Self-pollinated	Insect-pollinated	Open-pollinated
H. hookerina		*n* = 1	*n* = 2	*n* = 12
		27	57.5	91.5 ± 9.5
H. intermedia	47	—	*n* = 1	*n* = 9
			53 0	77.7 ± 16.0
T. recurvus	44, 52	*n* = 4	*n* = 2	*n* = 83
		0	0	71 0 ± 36.0
T. cuneatus	44, 47	*n* = 3	*n* = 3	*n* = 44
		0	0	62.0 ± 33.0
D. neelgherrensis	44, 52	*n* = 4	*n* = 3	*n* = 8
		2.2	9	71.0 ± 8.0
D. memecylifolia	47	*n* = 2	*n* = 2	*n* = 3
		0	12	74.0
D. falcata		*n* = 1	*n* = 1	*n* = 7
		0	0	32

*Number of pollinators as in Appendix I.
1 number of experiments
2 number of inflorescences
Adapted from Davidar[4].

Table 5. Flower characteristics and preferences by pollinators

Species	Corolla length (mm)	Corolla colour	Dc	Nm	Visits/hour/clump Nl	Na	Zp	Remarks
					$n=33$ hours			
H. intermedia	16.5±1.5	Pink	0.1	4.4	—	—	—	SPO
					$n=28$ hours			
H. memecylifolia	25.5±1.5	Orange red	—	3.9	—	—	—	SPO
					$n=15$ hours			
T. recurvus	10.5±1.5	Brown yellow	1.2	—	—	—	1.1	EXP
					$n=21$ hours			
D. neelgherrensis	13.5±2.5	Green yellow	0.7	—	—	—	1.4	EXP
					$n=15$ hours			
T. cuneatus	19.0±3.0	Green yellow	0.8	1.2	—	—	0.2	EXP
					$n=10$ hours			
D. falcata	35.5±2.5	Red	0.3	0.5	—	—	0.4	EXP
					$n=33$ hours			
M. parsiticus	33.0±6.0	Scarlet	—	3.1	0.7	0.6	1.3	EXP

Dc, *Dicaeum concolor*; Nm, *Nectarinia minima*; Nl, *N. lotenia*; Na, *N. asiatica*; Zp, *Zosterops palpebrosa*; Source: Davidar[4], SPO, Opens spontaneously; EXP, Exploding bud.

eye visit *T. cuneatus* and *D. falcata*. Both species of sunbirds and the white-eye visit *Macrosolen parasiticus*. This is the only mistletoe species in the area that is visited by the purple sunbird. Flowerpeckers preferentially visit closed flowers and do not visit flowers once they are opened whereas, the sunbirds preferentially visit flowers which are opened. The white-eyes opportunistically visit both types of flowers (Table 6; Davidar[3]).

Davidar[5] has also shown that *H. intermedia* and *D. mimecylifolia* which are restricted to sholas in Nilgiris, South India, are pollinated by *Nectarina minima*. The related mistletoes *T. recurvens* and *T. cuneatus* which occur in a wide variety of habitats are pollinated by flowerpeckers. Further, she shows that within a given genus of mistletoes there could be a gradation of species dependence on different pollinators (e.g. *Helixanthera*) to reduce competition. Such pollinator specialization in specific habitats is thought to be a strong selection against interspecific hybridization[4].

Bats as pollinators

Studies on the role of bats in pollination in India are lacking. Whatever little is known on their involvement in pollination comes from the observations of Mc Cann[16–19]. Based on the information thus obtained a list of species of bats along with the plants they pollinate is provided (Appendix III).

From the studies of Mc Cann it is evident that the mechanism of pollen transfer in bats is similar to that seen in birds. While lapping nectar, pollen grains adhere to the faces of bats and get transferred to other flowers. To aid the visitation of bats the flower opening

Table 6. Frequencies of bird visitation to open and closed flowers in a clump

Species	Number of observation (hours)	Number of flowers visited: Open	Number of flowers visited: Closed	Number of flowers & mature buds in clump	Proportion flower: buds during observation (hours)	
			T. recurvus		($n=46$)	
D. concolor	5	1	21	23	7.6	1
Z. palpebrosa	5	2	19	25	7.6	1
			T. cuneatus		($n=13$)	
Z. palpebrosa	5	—	3	8	9.0	1
N. minima	5	35	3	10, 8	9.0	1

n = number of inflorescences.
Source: Davidar[3]

and anthesis of certain trees are cued towards the nocturnal activity of bats. In *B. ceiba* for example, the flowers open from 17.00 to 19.00 hr when nectar production is at its peak[18]. Further, his observations clearly indicate that the flowering seasons of bat-pollinated trees coincide with the breeding season of bats, a time when the need for food is greatest[18,19].

According to Walker[20] bats that frequent flowers feed mainly on pollen and nectar and such species usually possess long pointed heads and long tongues with brush-like tips to aid in food gathering. Similar morphological traits appear to prevail with the Indian species too.

Appendix I

List of birds known to regularly frequent flowers for nectar

Order: Psittaciformes		
Family: Psittacidae		
1. *Psittacula krameri* (Scopoli)	Roseringed parakeet	[0.074]
2. *Loriculus vernalis* (Sparrman)	Lorikeet	[0.093]
Order: Cuculiformes		
Family: Cuculidae		
3. *Eudynamys scolopacea* (Linn.)	Koel	[0.077]
Order: Piciformes		
Family: Picidae		
Sub-family: Picinae		
4. *Dinopium benghalense* (Linn.)	Lesser goldenbacked woodpecker	[0.1.31]
Order: Passeriformes		
Family: Laniidae		
5. *Lanius schach* Linn.	Rufousbacked shrike	[0.084]
Family: Oriolidae		
6. *Oriolus oriolus* (Linn.)	Golden oriole	[0.124]
7. *Oriolus xanthornus* (Linn.)	Blackheaded oriole	[0.126]
Family: Dicruridae		
8. *Dicrurus adsimilis* (Bechstein)	Black drongo	[0.084]
9. *Dicrurus lecophaeus* Jerdon	Grey drongo	[0.088]
10. *Dicrurus caerulescens* (Linn.)	Whitebellied drongo	[0.098]
11. *Dicrurus hottentotus* Linn.	Haircrested drongo	[0.090]
12. *Dicrurus paradiseus* (Linn.)	Racket-tailed drongo	[0.119]
Family: Sturnidae		
13. *Sturnus malabaricus* (Gmelin)	Greyheaded myna	[0.107]
14. *Sturnus malabaricus* blythi (Jerdon)	Whiteheaded myna	[0.112]
15. *Sturnus pagodarum* (Gmelin)	Blackheaded myna	[0.100]
16. *Sturnus roseus* (Linn.)	Rosy pastor	[0.109]
17. *Acridotheres tristis* (Linn.)	Indian myna	[0.120]
18. *Acridotheres fuscus* (Wagler)	Jungle myna	[0.117]
19. *Gracula religiosa* Linn.	Hill myna	[0.124]
Family: Corvidae		
20. *Dendrocitta vagabunda* (Latham)	Tree pie	[0.125]
21. *Corvus splendens* Vieillot	House crow	[0.127]
22. *Corvus macrorhynchos* Lesson	Jungle crow	[0.124]
Family: Irinidae		
23. *Aegithina tiphia* Linn.	Common iora	[0.132]
24. *Chloropsis aurifrons* (Temminck)	Goldfronted chloropsis	[0.129]
25. *Chloropsis cochinchinensis* (Gmelin)	Goldmantled chloropsis	[0.131]
Family. Pycnonotidae		
26. *Pycnonotus jocosus* (Linn.)	Redwhiskered bulbul	[0.093]
27. *Pycnonotus cafer* (Linn.)	Redvented bulbul	[0.100]
28. *Pycnonotus luteolus* (Lesson)	Whitebrowed bulbul	[0.093]
29. *Hypsipetes madagascariensis* (P. L. S. Muller)	Black bulbul	[0.115]
Family: Muscicapidae		
Subfamily: Timalinae		
30. *Xiphirhynchus superciliaris* (Blyth)	Scimitar babbler	[0.146]
31. *Turdoides striatus* (Dumont)	Jungle babbler	[0.092]
32. *Turdoides affinis*	Whiteheaded babbler	[0.091]
33. *Dumetia hyperythra albogularis* Blyth	Rufousbellied babbler	[0.112]
34. *Chrysomma sinensis* Gmelin	Yellow-eyed babbler	[0.083]
Subfamily: Muscicapinae		
35. *Muscicapa tickelliae* (Blyth)	Tickell's flycatcher	[0.108]
36. *Rhipidura albicollis* (Viellot)	Whitespotted fantail flycatcher	[0.089]
37. *Terpsiphone paradise* (Linn.)	Paradise flycatcher	[0.125]
38. *Monarcha azurea* (Boddaert)	Monarch flycatcher	[0.097]
Subfamily: Sylvinae		
39. *Prinia subflava* (Gmelin)	Indian wren warbler	[0.100]
40. *Prinia socialis* Sykes	Ashy wren warbler	[0.108]
41. *Orthotomus sutorius* (Pennant)	Tailor bird	[0.119]
Subfamily: Turdinae		
42. *Copsychus saularis* (Linn.)	Magpie robin	[0.110]
43. *Turdus merula nigropileus* (Lafresnaye)	Blackcapped blackbird	[0.106]
Family: Dicaeidae		
44. *Dicaeum erythrorhynchos* (Latham)	Tickell's flowerpecker	[0.150]
45. *Dicaeum concolor*	Nilgiri flowerpecker	[0.156]
Family: Nectariniidae		
46. *Nectarinia zeylonica* (Linn.)	Purplerumped sunbird	[0.180]
47. *Nectarinia minima*	Small sunbird	[0.194]
48. *Nectarinia lotenia*	Maroonbreasted sunbird	[0.211]
49. *Nectarinia asiatica* (Latham)	Purple sunbird	[0.210]
50. *Aethopyga siparaja* (Raffles)	Yellowbacked sunbird	[0.210]
51. *Arachnothera longirostris* (Latham)	Little spiderhunter	[0.262]
Family: Zosteropidae		
52. *Zosterops palpebrosa* (Temminck)	White-eye	[0.125]
Family: Ploceidae		
Subfamily: Passarinae		
53. *Passer domesticus* (Linn.)	House sparrow	[0.093]
54. *Passer zanthocollis* (Burton)	Yellowthroated sparrow	[0.104]

Subfamily: Ploceinae		
55. *Ploceus philippinus* (Linn.)	Baya weaverbird	[0.117]
56. *Lonchura malabarica* (Linn.)	Whitethroated munia	[0.105]
57. *Lonchura striata* (Linn.)	Whitebacked munia	[0.120]
Family: Fringillidae		
Subfamily: Fringillinae		
58. *Carpodacus erythrinus* (Pallas)	Rose Finch	[0.093]

Source: Ali[1]; Davidar[2-5]; Pandey[21]; Singh[22], Wesley[15]. Values in parentheses indicate the beak length to body size ratios of bird species based on the data by Ali and Ripley[7].

Appendix II

List of flowering plants/trees regularly frequented by birds

Dicotyledones

Order: Rhamnales
Family: Bombacaceae

1. *Bombax ceiba* Linn. (1, 6–22, 25, 27, 29, 30, 32, 34, 39, 41, 43, 46, 48–54)
2. *Bombax insigne* Wallich. (6–8, 10–18, 20–22, 26–28, 31, 32, 34, 39, 41, 43, 46, 48, 49, 50, 52–55)
3. *Chorisia speciosa* St. Hill (11)

Family: Malvaceae
4. *Hibiscus rosa-sinensis* L. (27, 45–47, 49, 50)
5. *Thespesia populnea* (L.) Sol. ex Corr (19, 46, 49)
6. *Eriodendron aufractosum**

Family: Sterculiaceae
7. *Firmiana colorata* (Roxb.) R.Br. (44, 46, 49)
8. *Helicteres isora* Linn. (19, 46, 47)

Order: Geraniales
Family: Burseraceae
9. *Garuga pinnata* Roxb. (46, 49, 52, 58)

Order: Rhoeadales
Family: Capparidaceae
10. *Capparis aphylla**

Family: Moringaceae
11. *Moringa oleifera* Lamk. (46, 49)

Order: Rosales
Family: Crassulaceae
12. *Bryophyllum calycinum* Salisb. (46)
13. *Kalanchoe pinnata* (Lamk.) Pers. (46)

Family: Fabaceae
14. *Erythrina variegata* Lamk (1–18, 20–29, 31, 33–43, 46, 48–50, 52–58)
15. *Erythrina stricta* Roxb. (8, 12, 17, 22, 25, 26, 28, 29, 31, 32, 41, 43, 46, 48, 49)
16. *Erythrina crista-galli* Linn. (29, 46, 49)
17. *Erythrina suberosa* (8, 12, 17, 21, 25, 26, 28, 29, 31, 32, 41, 43, 46, 48, 49)
18. *Erythrina subumbrans* (8, 12, 17, 22, 25, 26, 28, 29, 31, 32, 41, 43, 46, 48, 49)
19. *Butea monosperma* (Lamb.) Taub (8, 11–13, 17, 18, 21, 22, 31, 32, 46, 49)
20. *Delonix regia* (Boj. ex Hook) Rafin (49)
21. *Caesalpina pulcherrima* (L.) Swartz (1, 46, 49)
22. *Bauhinia purpurea* Linn. (46, 49)
23. *Bauhinia racemosa* Lam. (46, 49)
24. *Bauhinia variegata* L. (11)
25. *Acacia nilotica* Willd. (23, 46, 49)
26. *Sesbania grandiflora* Pers. (1, 17, 21, 44, 45, 47–49)
27. *Mucuna pruriens* (L.) Dc (26, 27, 46, 49)
28. *Prosopis juliflora* (46, 49)
29. *Acrocarpus fraxinifolius* Wight & Arn. (11)
30. *Dalbergia sissoo* Roxb. (11)
31. *Parkia biglandulosa* W. & A. (11)
32. *Peltophorum pterocarpum* (DC.), Backer ex K. Heyne (11)
33. *Saraka asoka* Roxb. (11)
34. *Cassia fistula* L. (11)
35. *Cassia javanica* L. (11)
36. *Amherstia nobilis* Wall.*
37. *Sophora* sp. Linn. (46, 47)

Order: Rubiales
Family: Caprifoliaceae
38. *Lonicera leschenaultii* Linn. (46, 47, 49)

Order: Myrtales
Family: Lythraceae
39. *Woodfordia fruticosa* Linn. (44, 46, 47, 49, 50)
40. *Lagerstroemia speciosa* L. Pers. (11)

Family: Combretaceae
41. *Calycopteris floribunda* Lamk. (40, 46, 49)
42. *Lumnitzera coccinea* Wgt. et Arnott.*
43. *Quisqualis indica* Linn.*

Family: Eleganaceae
44. *Elaegnus* sp.*
45. *Hippophae rhamnoides**

Family: Myrtaceae
46. *Careya arborea* Roxb. (16–18, 46, 49)
47. *Eucalyptus globulus* Lab. (10, 46, 49)
48. *Eucalyptus* sp. L' Hen. (11)
49. *Callistemon lanceolatus* (DC.) (11, 46, 49)

Family: Onagraceae
50. *Fuchsia* sp.*

Family: Sonneratiaceae
51. *Sonneratia acida* L.f.*

Order: Gentianales
Family: Asclepiadaceae
52. *Calotropis gigantieus* (Linn.) R. Br. (46, 49)

Order: Personales
Family: Scrophulariaceae
53. *Russelia equisetiformis* Schelecht & Cham. (46, 47, 49)

Order: Peritales
Family: Bignoniaceae
54. *Millingtonia hortensis* Linn. f. (46, 49)
55. *Spathodea campanulata* Beauv. (11, 17, 18, 21, 26, 27, 46, 49)
56. *Tecoma stans* (Linn.) (46, 49)
57. *Jacaranda mimosifolia* D. Don. (11)

Family: Caricaceae
58. *Carica papaya* Linn. (46, 49)

Family: Acanthaceae
59. *Adhatoda zeylonica* Medic. (46, 49)

Order: Tubiflorae
Family. Convolvulaceae
60. *Quamoclit cocinea* Moench (= *Ipomcea coccinea* Linn.) (46, 47)

Family: Labiatae
61. *Salvia coccinea* Tuss. (46, 47)
62. *Leonotis nepetaefolia* Br.*
63. *Lucospectrum* sp *

Family: Verbenaceae
64. *Gmelina arborea* Linn. (46, 49)
65. *Duranta plumieri* Jacq. (46, 47, 49)
66. *Stachytarphata indica* (Linn.) Vahl (47–49)
67. *Starchytarphata mutabilis* (Jacq.) Vahl (47–49)
68. *Lantana camara* Linn. (46, 49)
69. *Holmskioldea sanguinea* Retz. (46, 49)
70. *Petrea volubilis* (Linn. (46, 49)
71. *Vitex pubiscens* Vahl.*

Order: Centrospermae
Family: Nyctaginaceae
72. *Bougainvillea spectabilis* Willd. (46, 47, 49, 50)

Order: Santalales
Family: Loranthaceae
73. *Elytranthe parasitica* (Linn.) Dans. (44, 47, 49)
74. *Scurrula parasitica* Linn. (24, 44, 46, 47, 49)
75. *Helixanthera obtusatus* (shult.) Dans. (44, 46, 47, 49)
76. *Loranthus obtusatus* Wall. (44, 46, 47, 49)
77. *Helixanthera intermedia* (wt.) Danser (44, 46, 47, 49)
78. *Dendrophthoe memecylifolius* (wt. & Arn.) Danser (44, 46, 47, 49)
79. *Dendrophthoe neelgherrensis* (wt. & Arn.) (44–47, 49, 52)
80. *Dendrophthoe falcata* (Linn. f.) Etting = (44, 46–48, 49)
81. *Macrosolen parasiticus* (Linn.) Danser (44, 46, 47, 49, 52)
82. *Taxillus recurvus* (DC.) van Tieghem (44–47, 49, 52)
83. *Taxillus cuneatus* (Roth) Danser (44–47, 49, 52)

Order: Ericales
Family: Ericaceae
84. *Rhododendron companulatum* (49)
85. *Rhododendron arboreum* (49)

Order: Companulateae
Family: Companulaceae
86. *Lobeliai* Linn.*

Order: Scitaminaeae
Family: Cannaceae
87. *Canna indica* Linn.*

Family: Musaceae
88. *Musa paradisiaca* (51)

Order: Liliflorae
Family: Liliaceae
89. *Gloriosa superba* Linn. (46, 49)

Order: Proteales
Family: Proteaceae
90. *Grevillea robusta* A. Cunn. (8, 9, 11, 13, 15, 17, 18, 46, 49)

Order: Ranales
Family: Magnoliaceae
91. *Magnolia* sp *

Order: Bixales
Family: Bixaceae
92. *Cochlospermum gossypium* DC. (11)

Monocotyledone

Order: Principes
Family: Palmae
93. *Cocos nucifera* Linn. (44, 46, 47, 49)

*Plant species considered to be entirely or partly ornithophillus, though birds feeding on their nectar have not been observed.

Numbers in parentheses refer to those of bird species (Appendix I) that are known to visit the flowers of respective plant species, (Ali[1], Davidar[2–5], Kannan[6], Pandey[21], Singh[22], personal observations).

Appendix III

List of pollinator species of bats and the plant species visited by them:

1. *Rousettus leschenaulti* Desm. Fulvous fruit bat

Plant species

Adansonia digitata L.
Bombax ceiba L.
Ceiba pentandra Garten.
Eugenia jambolana Lamk.
Psidium gujava L.
Careya arborea Roxb.
Bassia latifolia
Oroxylum indicum
Heterophragma roxburghii Dc.
Rudermachera xylocarpa K. Schum.
Acacia sp.
Mangifera indica
Anacardium occidentale
Mimusops hexandra
Sonneratia apeata
Sonneratia acida L.f.

2. *Pteropus giganteus*, The flying fox

Plant species

Eucalyptus sp.
Grevillea robusta
Bombax malabaricum
Anacardium occidentale
Mangifera indica

3. *Cynopterus sphinx* Vahl., Shortnosed fruit bat

Plant species

Kigelia pinnata
Bombax ceiba
Ceiba pentandra
Bassia latifolia

4. *Eonycteris spelaea* Dobson., Dobson's long-tongued fruit bat
5. *Sphaerias blanfordi* Thomas., Blandford's fruit bat
6. *Latidens salimalli.*

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