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# Study on Fruit and Seed Eating by Birds in the Upper Nilgiris, Tamil Nadu, Southern India

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**Abstract**
In this study we studied fruit eating behaviour of birds through two methods, i.e. direct observation and bird dropping. Data of 100 hours of field observation were collected and 17 bird species were recorded. The majority of bird species (*N*=17) was attracted by *Solanum mauritianum* and *Rubus niveus* with the total visits of 240 and 215 followed by 16 bird species attracted by *Cestrum aurantiacum* with the total visits of 239. On the other hand, *Phytolacca americana* was attracted by fewer number of bird species (*N*=8) with 191 sightings during the survey period. Among 17 bird species, the Red-whiskered Bulbul *Pycnonottus jocosus*, Oriental White-eye *Zosterops palpebrosus* and Jungle Myna *Acridotheres fuscus* were found predominantly feeding on the exotic plants (non- native plants) and proved them as perfect frugivores. Totally two hundred bird droppings belonging to four abundant bird species namely Jungle Myna *Acridotheres fuscus*, Oriental White-eye *Zosterops palpebrosus*, Pied Bush Chat *Saxicola caprata*, and Red-whiskered Bulbul *Pycnonottus jocosus* were collected from three different localities, under nests (*N*=109), under trees (*N*=77) and few of them (*N*=14) were collected in other places such as human traits and paths. Seeds of five plant species, namely *Cestrum aurantiacum, Pytolacca americana, Rubus ellipticus, Rubus niveus* and *Solanum mauritianum* were recorded. It was interesting to note that all these plants were exotic species. The high variations were seen in the Jungle Myna droppings where *Solanum marutianum* seeds were seen high in number in the droppings (22.23±11.45, N=978) because *Solanum maruritianum* fruit contain more number of seeds compared with that of other fruits. This study clearly indicates that the exotic plants attract bird communities than native plants by providing food for them and thereby they vigorously disperse their seeds than native plants.

## 1. Introduction

Some plant species provide food resources for a large number of bird communities. Subsequently, the generality of the relationships between plants and birds can be ascertained and likely specialized plant-bird interactions (pollination or seed dispersal) identified. Seed dispersal is the process of seed transportation from the mother plant to another place, and thus plays a key role in the subsequent recruitment of new plants (Herrera 2002). The contribution of frugivores to plant fitness depends on both the quantity and quality of seed dispersal (Schupp1993). The pulp furnishes food to the bird or animal, which in turn carries the seeds about in its digestive system until they are ejected in its droppings and thus are scattered about the countryside.

The ability of frugivores to monitor the abundance of fruit, both spatially and seasonally, is fundamental for efficient seed dispersal. In fact, this link between frugivores and fruit has been documented in various geographical zones with regard to its seasonal dimension (i.e. phonological synchrony), observing a consistent pattern and generalized

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adjustment between the abundances of both kinds of interacting organisms (Loiselle & Blake 1991; García *et al.* 2011). ).

Vertebrate animals are important dispersal agents and among them birds are perhaps most commonly associated with spread of seeds into new habitats by seed dispersal (Pijl 1972). However, if the offer of fruit in the environment falls, the birds do not behave as strict frugivores but rather as facultative frugivores, consuming other dietary resources (e.g. invertebrates). This change in diet allows the birds to link themselves seasonally and spatially with alternative resources, aside from fruits. In this way, they sustain their nutritional requirements throughout the year (Rey 1995). The fruit-frugivore interactions have been studied in recent decades but there is no consolidated information on the role of birds in the seed dispersal.

Plant-animal interactions range from the broad to highly exact relationships and involve intricate evolutionary adaptations. Plant-birds interactions play a vital role in maintaining the structural and functional integrity of natural ecosystems. Some plant species supply food resources for a large number of bird communities. Fruits are usually seasonal resources used by many animals as part of their diet, and because of their high level of carbohydrates or lipids, they are considered as rich-energy sources for frugivorous species (Rio & Restrepo 1993). Consequently, the generality of the relationships between plants and birds can be ascertained and likely specialized plant-bird interactions can be identified (i.e. pollination or seed dispersal).

Frugivorus refers to the consumption of plants. Frugivory birds are visited at trees during the morning and evening hours. Many bird species depend directly on plants for their food and shelter. For food, they use many plant resources, including nectars, parts of flowers, pollen, leaves, exudates, seeds and fruits. Similarly, some plant species depend on birds to achieve pollination or seed dispersal (Crome 1975; Paton & Ford 1977; Holmes 1987; French 1990; Green 1993). Fruit colors are habitually considered in avian dispersion, since they have excellent colours. While, red and black fruits are predominantly dispersed by birds, it is still contentious as whether the occurrence of fruit colours especially black and red match the colour preferences of birds in the wild (Duan *et al.* 2014). Further, the selection of fruits with birds may be driven by factors other than colour, behaviours such as nutritional contents and secondary compounds also influence bird food preference (Valido *et al.* 2011). Frugivores can also benefit from the invasion of exotic fruit producing species and can be vectors of exotic invasion by dispersing non-native seeds.

Seed dispersal is the movement of seeds away from the parent plant, even though moreover changes to germination caused by the passageway of a seed through the digestive tract of a vertebrate such as a bird. Birds are expected as the main dispersal agent of many invasive plant species. Many plant species depend on animals for seed dispersal. Ingestion of seeds by vertebrate dispersers may either positively or negatively affect seed germination, or have no apparent effect. The effect of gastrointestinal tract ingestion by frugivores on the changes in seed traits, germination characteristics, and seedling establishment are important factors influencing successful recruitment and species diversity. Animals and birds are dispersing plant seeds in several ways and most of vertebrates ingestion are important for the seed dispersal (Travaset *et al.* 2014). Many plants disperse their seeds by birds. Frugivores birds are eating fresh and dry fruit in different dispersal methods. Successful dispersal can contribute to successful renewal and renovation as well as population spread and preservation of hereditary connectivity.

The aims of this study were: to find out the extent of visits made by various bird species in selected plant species; to examine fruit handling methods by various bird species; to conclude plant-bird interactions in the study area; to find out what are the plant species preferred by the avian community.

## 2. Materials and Methods

### 2.1. Study area

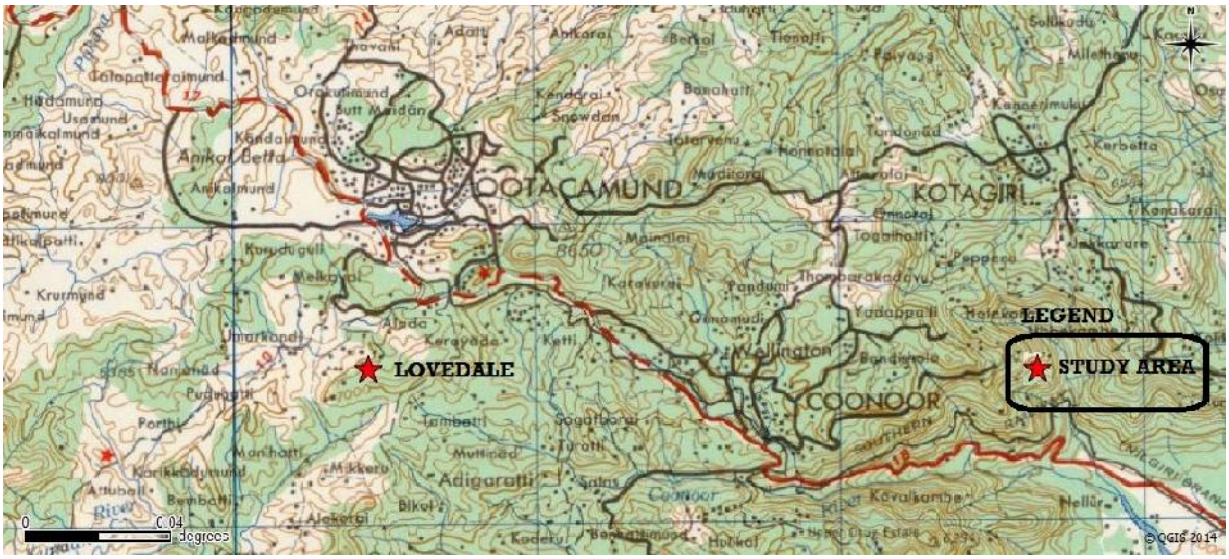


**Fig. 1.** Geographical location of the study area.

This study was conducted in Lovedale area, Nilgiri District, located between 11º11'–11º42'N and 76º14'–77º01'E in the state of Tamil Nadu, South India. It is bounded to the west by Kerala, to the north by Karnataka and to the South east Coimbatore District of Tamil Nadu (Fig. 1). A detailed survey was carried out on the upper plateau of the Nilgiri hills where biotic pressure is very high. The average elevation of the hill range is 1800m. The slope is gentle to very steep, varying from the 5º at the valley bottom to nearly 90º near the hilltops. Champion & Seth (1968) classified this as Southern Montane Wet Temperate Forest. Monthly mean temperature of the Upper Nilgiris during this study varied from 15º to 26º C. The average annual rainfall is 1900–2000 mm and the climate is very equable with an average maximum temperature of 23.3ºC and average minimum 7.2ºC. There is some frost in high areas from December to January. The mammal species found in the shola forest are Leopard *Panthera pardus*, Gaur *Bos gaurus*, Sambar deer *Cervus unicolor*, Barking deer *Muntiacus muntjak*, Wild boar *Sus scrofa*, Nilgiri Langur *Presbytis johni*, Porcupine *Hystrix indica*, etc. Many species of birds, reptiles and amphibians are also seen in the study area.

## 2.2. Vegetation type

The natural vegetation of the plateau consists of vast stretches of grassland interspersed with numerous isolated, compact, sharply defined tropical montane woodlands. These tropical montane woodlands are locally known as sholas, a term derived from the Tamil word "solai", which etymologically means a tropical rain forest. It is currently thought that the tropical rain forest altered as it extended upwards into the temperate grassland areas (Noble 2000). Paulraj (2000) has reported about 180 shola forest patches in the Upper Nilgiris. The report concluded that among the sholas, 107 were found low level of biotic pressure, 58 with medium level of pressure, 13 with high levels of pressure and 2 with very high levels of biotic pressures. The sholas are found along the valleys and folds of the hills while the grasslands are found on the hill slopes. In the Nilgiri Plateau, most of the grasslands are now found only on the western part of the plateau. Sholas belongs to the Southern mountain wet temperature forest type as per the classification of Champion & Seth (1968). Evergreen forests without conifers are found in the Nilgiris, Anamalai and Thirunelvelli Hills of South Indian type is confined to the sheltered valleys of Nilgiris and locally called Sholas (James 1978).

In study area dominant trees are *Eucalyptus globulus, Eucalyptus citriodora, Cupressus* sp., *Araucaria bidwillii, Salix babylonica, Jacaranda mimosifolia, Callistemon lanceolatus*, etc. The shrub species are *Abutilon indicum, Streptosolen jamesonii, Fuchsia hybrida, Achyranthes aspera, Bidens pilosa* and *Primula obconica*, etc. The fern species are *Alsophila australis, Davallia elegans, Selaginella emmeliana* and, *Adiantum gracillimum* etc. The cactus species are *Aporocactus flagelliformis,*

*Epiphyllum hybridum, Echinocactus grusonii* and *Opuntia ficus indica*, etc. The exotic plant species are *Lantana camara, Phytolacca americana, Rubus ellipticus, Rubus niveus, Cestrum aurantiacum, Solanum mauritianum*, etc.

**2.3. Feeding observation**

Plant species with their ripen condition was selected to record the feeding habits and plant-bird interaction in the study area. Observation was made using a binocular in a safer distance in which the activity of the birds should not be disturbed. Birds were identified using the field guide, Ali (2002). Two hours a day in the morning and evening were spent to make observation of feeding habits of birds and altogether a total of 100 hours were spent for the two-hour data collection. We recorded the time of stay in the tree, the number of fruits eaten, and fruit handling behaviour, i.e., whether the animal swallowed the whole fruit, dropped or spit parts of the fruit, pecked on them, or carried them away in the beak (Howe 1997). Birds which ingest the whole fruit (pulp as well as seeds) are considered as legitimate seed disperser. Birds which eat only the pulp or seed are considered as pulp and seed predators respectively.

**2.4. Bird droppings**

The field study was carried out between January and August 2014 in Upper Nilgiris. A total of two hundred bird droppings were collected through direct observation. During the study period two hundred bird droppings were collected from the study area belonging to four abundant bird species and five plant species were identified. The seed droppings were collected under the nests ($N$=109) followed by under the trees ($N$=77) and few ($N$=14) were collected in other places such as human trails and paths. Bird droppings were identified based on their shape and colour and were different in size. The droppings were washed with clear water to segregate the undigested seeds to find out the plant species fed by the birds. Fine sieved filters were used to clean the droppings. The filtered seeds were dried with blotting paper and segregated species wise. The filtered seeds were identified based on the shape and colour, and compare to the natural seeds. Five plant species of fruit trees were observed in the bird dropping collection of the study area. The plant species were identified using the Flora of the Presidency of Madras (Gamble 1935). Comparison was made from the seeds both in the droppings and the collection in the wild ones.

**2.5. Statistical analysis**

Mean (M) Standard deviation (SD) and Standard Error (SE) was calculated to the bird droppings as well as One-way ANOVA was performing for visiting and fruit eaten by birds in the plant species. Statistical analyses were performed Graph Pad Prism 5 statistical computer software.

**3. Results**

**3.1. Feeding observation**

Totally 17 bird species belonging to 13 families and three orders were recorded and most of the birds were feeding on five exotic plant species, namely *Solanum mauritianum*, *Rubus niveus*, *Cestrum aurantiacum*, *Rubus ellipticus* and *Phytolacca americana.* Most of the bird species were interacted mainly with *Cestrum auranticaum.* Sixteen species of birds has interacted this plant.

A total of 16 bird species were interacted with *Cestrum auranticaum* plant. The Oriental Whiteeye was the most attracted bird species with the total visits of 58 times, out of which 28 visits. This species fed 36 fruits with an average of 1.28 fruits per visit followed by 42 visits made by the Red-whisked Bulbul, of which 31 times it was fed the fruits with an average of 1.77 fruit per visit. Thirty six visits were made by the Jungle Myna, of which 50 fruits were eaten within 19 visits with an average of 2.63 per visit. On the other hand, the least number of visits ($N$=1) was made by the Grey-headed Canary Flycatcher and Red-vented Bulbul with the evidence of just one fruit eaten in one visit. The One-way ANOVA showed that visiting and fruit eaten by birds was not significant in *Cestrum auranticaum* ($F$=1.758, $df$=1, $P$=0.1949) (Tables 1,6).

A total of 8 bird species were interacted with *Phytolacca americana*. The Jungle Myna was the most attracted bird species with a total of 39 visits, out of which the bird has eaten 64 fruits in 31 visits with the average 2.06 fruit per visit. Followed by 12 visits were made by Nilgiri Wood Pigeon of which within 6 visits 14 fruits were

eaten with an average of 2.33 fruits per visit, 6 visits were made by Pied Bush Chat of which in 4 visits five fruits were eaten with an average of 1.25 fruits per visit. On the other hand less number of bird species were recorded was Nilgiri Laughing Thursh with a total of 2 visits, within that two fruits were eaten. On the contrary 27 visits were made by Large-billed Crow, 12 visits were made by Eurasian Blackbird but those two birds were not eaten fruits in *Phytolacca americana*. According to One-way ANOVA was shows visiting and fruit eaten by birds was not significant in *Phytolacca americana* plant species ($F$=1.378, $df$=1, $P$=0.2601) (Tables 2,6).

A total of 15 bird species interacted with *Rubus ellipticus*. The Red whiskered Bulbul was most attracted bird species with the total of 51 visits. Out of which 28 visits 43 fruits were eaten with an average of 1.54 fruit per visit. Followed by 42 visits were made by Oriental white eye of which along with 32 visit the bird was eaten 13 fruits and the average fruit eaten was 0.41 per visit. Jungle Myna made 23 visits of which 17 visits the bird was eaten 30 fruits and the average fruit eaten was 1.73 per visit. The least number of visit was made by Great Tit, totally 2 visit were recorded of which one visit the bird eaten one fruit and the average fruit eaten was 1 per visit. According to One-way ANOVA visiting and fruit eaten by birds was not significant in *Rubus ellipticus* plant species ($F$=1.353, $df$=1, $P$=0.2546) (Tables 3, 6).

Seventeen bird species were interacted with *Rubus niveus*. The results revealed that totally seventeen bird species interacted by this plant. The Red-whiskered Bulbul was most attracted bird species with the total of 48 visits, of which 36 visits 50 fruits were eaten by this bird with an average of 1.39 fruits per visit. Followed by 36 visits were made by Oriental Whiteeye, out of which 25 visits 11 fruits were the bird eaten with the average of 0.44 fruit per visit, 23 visits were made by Nilgiri Laughing Thrush, of which 9 visits 21 fruits were eaten by the bird with the average of 2.33 fruit per visit. On the other hand just one visit was made by Malabar Parakeet and Grey-headed Canary Flycatcher intake was one fruit. According to One-way ANOVA visiting and fruit eaten by birds was not significant in *Rubus niveus* plant species ($F$=1.314, $df$=1 $P$=0.2602) (Tables 4,6).

The results revealed that total of seventeen bird species were interacted with *Solanum marutianum*. The Red-whiskered Bulbul was mostly recorded birds species with the total of 52 visits, of which 35 visits 28 fruits were eaten by this bird with an average of 0.8 fruit per visit. Followed by 25 visits were made by Oriental white eye of which 13 visits 4 fruits were eaten by the bird with an average of 0.31 fruits per visit, 24 visits were made by Tailor bird of which 13 visits 4 fruits were eaten by the bird with an average of 0.31 fruits per visit. On the other hand just one visit was made by Malabar Parakeet and Red-vented Bulbul eaten one fruit. According to One-way ANOVA was shows visiting and fruit eaten by birds was not significant in the plant species ($F$=2.095, $df$ =1, $P$=0.1575) (Tables 5–6).

### 3.2. Droppings

All seeds were belonged to exotic plant species, namely *Pytolacca americana, Cestrum auruantiacum, Solanum mauritianum, Rubus niveus* and *Rubus ellipticus* Vitousek (1996). Although 109 droppings were collected under nests, most of them were under *Cestrum aurantiacum* plant species ($N$=32) followed by 21 droppings under *Rubus ellipticus* and 20 droppings under *Phytolacca americana*. On the contrary, most of the droppings were collected under the tree species *Phytolacca americana* ($N$=23) followed by *Cestrum aurantiacum* ($N$=20) and *Rubus ellipticus* ($N$=15).

The high variations were seen in the Jungle Myna droppings where *Solanum marutianum* seeds were seen high in number in the droppings (22.23±11.45, n=978). On the other hand the lowest number of seeds belonged to *Cestrum aurantiacum* (4.50±2.44, n=63) followed by in Red-whiskered Bulbul droppings *Solanum mauritianum* (19.57±9.08, n=548). The least number of seeds were found to be *Cestrum aurantiacum* (4.60±2.22, n=46). In the Pied Bushchat dropping, *Rubus ellipticus* seeds were recorded in highest numbers (13.78±7.60, n=124), the lowest number of seeds belonged to the *Phytolacca americana* (8.50±2.12, n=17).

In Oriental Whiteeye seeds of *Solanum mauritianum* were seen in high numbers 14.3±5.89 (n=286) and *Cestrum aurantiacum* in low number 4.67±1.53 (n=14) (Table 7).

**Table 1.** Results of bird feeding observation in Nilgiri District (*Cestrum aurantiacum*).

| Species | Scientific name | No. of visits | No. of fruits eaten | Average No. of fruit eaten per visit |
|---|---|---|---|---|
| Jungle Babbler | *Turdoides striata* | 4 | 5 | 1.25 |
| Pied Bush Chat | *Saxicola caprata* | 11 | 6 | 0.55 |
| Jungle Crow | *Corvus macrorhynchos* | 3 | 2 | 0.66 |
| Eurasian Blackbird | *Turdus merula* | 0 | 0 | 0 |
| White-throated or browed Fantail | *Rhipidura albicollis* | 4 | 2 | 0.5 |
| Grey-headed Canary Flycatcher | *Culicicapa ceylonensis* | 1 | 1 | 1 |
| Great Tit | *Parus major* | 4 | 3 | 0.75 |
| Jungle Myna | *Acridotheres fuscus* | 19 | 50 | 2.63 |
| Nilgiri Flycatcher | *Eumyias albicaudata* | 3 | 1 | 0.33 |
| Nilgiri Laughing Thrush | *Garrulax leucolophus* | 11 | 18 | 1.63 |
| Nilgiri Wood Pigeon | *Columba religiosa* | 8 | 15 | 1.88 |
| Oriental Whiteeye | *Zosterops palpebrosus* | 28 | 36 | 1.28 |
| Red-vented Bulbul | *Pycnonottus cafer* | 1 | 1 | 1 |
| Red-whiskered Bulbul | *Pycnonottus jocosus* | 31 | 55 | 1.77 |
| House Sparrow | *Passer domesticus* | 4 | 3 | 0.75 |
| Tailorbird | *Orthotomus sutorius* | 6 | 3 | 0.5 |

**Table 2.** Results of bird feeding observation in Nilgiri District (*Phytolacca americana*)

| Species | Scientific name | No. of visits | No. of fruits eaten | Average No. of fruit eaten per visit |
|---|---|---|---|---|
| Pied Bush Chat | *Saxicola caprata* | 4 | 5 | 1.25 |
| Jungle Crow | *Corvus macrorhynchos* | 0 | 0 | 0 |
| Eurasian Blackbird | *Turdus merula* | 0 | 0 | 0 |
| Jungle Myna | *Acridotheres fuscus* | 31 | 64 | 2.06 |
| Nilgiri Laughing Thrush | *Garrulax leucolophus* | 2 | 2 | 1 |
| Nilgiri Wood Pigeon | *Columba religiosa* | 6 | 14 | 2.33 |
| Red-whiskered Bulbul | *Pycnonottus jocosus* | 4 | 6 | 1.5 |
| House Sparrow | *Passer domesticus* | 1 | 2 | 2 |

**Table 3.** Results of bird feeding observation in Nilgiri District (*Rubus ellipticus*).

| Species | Scientific name | No. of visits | No. of fruits eaten | Average No. of fruit eaten per visit |
|---|---|---|---|---|
| Jungle Babbler | *Turdoides striata* | 2 | 4 | 2 |
| Pied Bush Chat | *Saxicola caprata* | 11 | 8 | 0.73 |
| Jungle Crow | *Corvus macrorhynchos* | 0 | 0 | 0 |
| Eurasian Blackbird | *Turdus merula* | 1 | 2 | 2 |
| White-throated Fantail | *Rhipidura albicollis* | 0 | 0 | 0 |
| Grey-headed Canary Flycatcher | *Culicicapa ceylonensis* | 0 | 0 | 0 |
| Great Tit | *Parus major* | 1 | 1 | 1 |
| Jungle Myna | *Acridotheres fuscus* | 17 | 30 | 1.76 |
| Nilgiri Flycatcher | *Eumyias albicaudata* | 3 | 2 | 0.67 |
| Nilgiri Laughing Thrush | *Garrulax leucolophus* | 15 | 32 | 2.13 |
| Nilgiri Wood Pigeon | *Columba religiosa* | 10 | 21 | 2.1 |
| Oriental Whiteeye | *Zosterops palpebrosus* | 32 | 13 | 0.41 |
| Red-whiskered Bulbul | *Pycnonottus jocosus* | 28 | 43 | 1.54 |
| House Sparrow | *Passer domesticus* | 5 | 4 | 1.25 |
| Tailorbird | *Orthotomus sutorius* | 10 | 6 | 0.6 |

**Table 4**. Results of bird feeding observation in Nilgiri District (*Rubus niveus*).

| Species | Scientific name | No. of visits | No. of fruits eaten | Average No. of fruit eaten per visit |
|---|---|---|---|---|
| Jungle Babbler | *Turdoides striata* | 3 | 7 | 2.33 |
| Pied Bush chat | *Saxicola caprata* | 11 | 6 | 0.55 |
| Jungle Crow | *Corvus macrorhynchos* | 1 | 2 | 2 |
| Eurasian Blackbird | *Turdus merula* | 1 | 2 | 2 |
| White-throated Fantail | *Rhipidura albicollis* | 0 | 0 | 0 |
| Grey-headed Canary Flycatcher | *Culicicapa ceylonensis* | 1 | 1 | 1 |
| Great Tit | *Parus major* | 7 | 3 | 0.43 |
| Jungle Myna | *Acridotheres fuscus* | 12 | 25 | 2.08 |
| Nilgiri Flycatcher | *Eumyias albicaudata* | 4 | 4 | 1 |
| Nilgiri Laughing Thrush | *Garrulax leucolophus* | 9 | 21 | 2.33 |
| Nilgiri Wood Pigeon | *Columba religiosa* | 5 | 11 | 2.2 |
| Oriental Whiteeye | *Zosterops palpebrosus* | 25 | 11 | 0.44 |
| Malabar Parakeet | *Psittacula columboides* | 1 | 1 | 1 |
| Red-vented Bulbul | *Pycnonottus cafer* | 0 | 0 | 0 |
| Red-whiskered Bulbul | *Pycnonottus jocosus* | 36 | 50 | 1.39 |
| House Sparrow | *Passer domesticus* | 5 | 5 | 1 |
| Tailorbird | *Orthotomus sutorius* | 6 | 3 | 0.5 |

**Table 5**. Results of bird feeding observation in Nilgiri District (*Solanum marutianum*).

| Species | Scientific name | No. of visits | No. of fruits eaten | Average No. of fruit eaten per visit |
|---|---|---|---|---|
| Jungle Babbler | *Turdoides striata* | 4 | 5 | 1.25 |
| Pied Bush Chat | *Saxicola caprata* | 6 | 3 | 0.5 |
| Jungle Crow | *Corvus macrorhynchos* | 4 | 6 | 1.5 |
| Eurasian Blackbird | *Turdus merula* | 2 | 3 | 1.5 |
| White-throated Fantail | *Rhipidura albicollis* | 1 | 1 | 1 |
| Grey-headed Canary Flycatcher | *Culicicapa ceylonensis* | 1 | 1 | 1 |
| Great Tit | *Parus major* | 4 | 3 | 0.75 |
| Jungle Myna | *Acridotheres fuscus* | 11 | 8 | 0.73 |
| Nilgiri Flycatcher | *Eumyias albicaudata* | 8 | 5 | 0.63 |
| Nilgiri Laughing Thrush | *Garrulax leucolophus* | 9 | 11 | 1.22 |
| Nilgiri Wood Pigeon | *Columba religiosa* | 9 | 7 | 0.78 |
| Oriental Whiteeye | *Zosterops palpebrosus* | 13 | 4 | 0.31 |
| Malabar Parakeet | *Psittacula columboides* | 1 | 1 | 1 |
| Red-vented Bulbul | *Pycnonottus cafer* | 1 | 1 | 1 |
| Red-whiskered Bulbul | *Pycnonottus jocosus* | 35 | 28 | 0.8 |
| House Sparrow | *Passer domesticus* | 4 | 3 | 0.75 |
| Tailorbird | *Orthotomus sutorius* | 13 | 4 | 0.31 |

**Table 6.** Statistical analysis of feeding observation on different plant species.

| Plant species | Common name | No. of bird species | No. of visits | *F* | *P*-value |
|---|---|---|---|---|---|
| *Cestrum aurantiacum* | Orange Cestrum | 16 | 239 | 1.758 | 0.1949 |
| *Phytolacca americana* | American pokeweed | 8 | 191 | 1.378 | 0.2601 |
| *Rubus niveus* | Mysore raspberry | 17 | 215 | 1.314 | 0.2602 |
| *Rubus ellipticus* | Yellow Himalayan raspberry | 15 | 226 | 1.353 | 0.2546 |
| *Solanum marutianum* | Tobacco weed | 17 | 240 | 2.095 | 0.1575 |

**Table 7.** Bird species dropping (± SD = Standard deviation, SE = Standard Error in parenthesis) versus seeds, Frequency (F), Number of bird droppings (n).

| Bird species | Total No. of droppings | F | *Cestrum aurantiacum* | F | *Pytolacca americana* | F | *Rubus ellipticus* | F | *Rubus niveus* | F | *Solanum mauritianum* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jungle Myna | 73 | 14 | 4.50±2.44(0.65) (n=63) | 15 | 9.13±4.29(1.11) (n=137) | 29 | 18.17±12.42(2.31) (n=527) | 23 | 16.65±9.27(1.93) (n=383) | 44 | 22.23±11.45(1.73) (n=978) |
| Oriental Whiteeye | 39 | 3 | 4.67±1.53(0.88) (n=14) | 3 | 7±2(1.15) (n=21) | 20 | 11.9±4.99(1.12) (n=238) | 11 | 13.73±5.18(1.56) (n=151) | 20 | 14.3±5.89(1.32) (n=286) |
| Pied Bush Chat | 20 | 2 | 5±2.83(2.00) (n=10) | 2 | 8.50±2.12(1.50) (n=17) | 9 | 13.78±7.60(2.53) (n=124) | 8 | 12±6.99(2.47) (n=96) | 13 | 13.92±6.16(1.71) (n=181) |
| Red-whiskered Bulbul | 68 | 10 | 4.60±2.22(0.70) (n=46) | 8 | 7.38±2.97(1.05) (n=59) | 27 | 17.96±8.63(1.66) (n=485) | 17 | 17.35±5.41(1.31) (n=295) | 28 | 19.57±9.08(1.72) (n=548) |

## 4. Discussion

Although 17 bird species were recorded for feeding on fruits in this present study, four dominant bird species, namely Red-whiskered Bulbul, Oriental Whiteeye and Jungle Myna were predominantly interacted with five exotic plant species in the degraded shola forest patch of Upper Nilgiris. Most of the birds depend on fruits of these five plants as their diet, predominantly Passeriformes. Our study result showed that *Solanum mauritianum*, *Rubus niveus*, *Cestrum aurantiacum* and *Rubus ellipticus* were most attracted plant species by bird communities. On the other hand, *Phytolacca americana* was recorded as the less attracted plant species in the study area. Generally the fruit eating birds swallow the entire fruit when they feed on them. Therefore small seeded fruits are very much attracted than large seeded fruits by the bird community. Terborgh & Diamond (1970) stated that the attraction of the bird communities was related to small size of fruits, which were attracted more bird species than large size of fruits. Although the fruit size of *Phytolacca americana* is smaller in size but the seed size is bigger than the other seeds due to less fleshy (berry) content. Generally, the fruit eating birds swallow the entire fruit when they feed on them. Therefore, small seeded fruits are very much attracted than large seeded fruits by the bird community. Our study finding also corroborates with Terborgh & Diamond (1970) by the evidence of less attraction *Phytolacca americana* fruit because of its large size of seeds and less content of fleshy than other plant fruits. Dispersal may also allow a seed to spread its species into new habitats. Finally, some types of dispersal may position a seed to spread its species into new habitats and some types of dispersal may position a seed in the precise site required for successful germination and seedling establishment. Vertebrate animals are important dispersal agents and among them birds are perhaps most commonly associated with spreading of seeds into new habitats.

Generally, the frugivory birds interact with the fruiting plants and spend more time on them for feeding of fruits. According to Ali (1931), the Red-whiskered Bulbul is a perfect frugivoroes bird and it target fruiting plant species to feed on fruits in the environment. Similarly, the Oriental Whiteeye was recently described as frugivore bird by Palita *et al*.

(2011) and the Jungle Myna is also a frugivore bird in nature (Balasubramanian 1998).

The efficient frugivore bird species based on their fruit eating intensities and thus resulted in proliferation of exotic plants into native vegetation to become invasive alien species in the study area. The droppings analysis found that all seeds were belonged to exotic plant species, namely *Phytolacca americana, Cestrum aurantiacum, Solanum mauritianum, Rubus niveus* and *Rubus ellipticus.* Thereby plant-bird interaction play vital role on vegetation quality. Our study found that birds were eating more on fruits of *Solanum maruritianum, Rubus ellipticus* and *Rubus niveus,* based on the evidence of their droppings. Among the bird droppings, the Jungle Myna and Red-whiskered Bulbul droppings were high in the study area. Studies by Balasubramanian & Bole (1993); Balasubramanian (2003) and Balasubramanian *et al.* (2011) stated that the Jungle Myna is naturally frugivore bird. Balasubramanian & Maheswaran (2003) and Spotswood (2009) found that the Red-whiskered Bulbul is naturally an effective frugivorous bird in scrub jungles, tropical dry evergreen, dry mixed deciduous and dry deciduous forest in Asia, Africa and India.

The study area in shola forest was degraded. Most of the area is occupied with exotic plants, namely *Cestrum aurantiacum, Pytolacca americana, Rubus ellipticus, Rubus niveus* and *Solanum mauritianum*. The five plants were fruiting and flowering throughout the year. At the same time, the native plants fruit yearly. That is why birds are only attracted by the exotic plants. Therefore, massive plantation by native plant species and gradual removal of exotic plants may be implemented. The eradication of exotic plants should be done before the plant get fruits. Sudden eradication may affect the effective frugivorous bird populations. Native plant fruiting season was totally different with exotic plant fruiting season. The reproduction season of native plants was yearly or once in six months while the reproduction season of exotic plants was throughout the year. Sudden eradication may affect the population of effective frugivorous bird populations.

The preference of feeding seeds of exotic plants would further increase weed proliferation into natural areas. This is considered as a negative impact of the bird community and the plant-bird interaction therefore is crucial for habitat alteration. Thus, these study emphases that seed dispersal by avian community is most critical in habitat management.

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