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SPECIES DIVERSITY, ABUNDANCE AND SOME ASPECTS OF THE ECOLOGY OF BIRDS IN SELECTED HABITATS IN THE HILL REGION OF SRI LANKA

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ABSTRACT

The central hill zone of Sri Lanka represents one of the areas rich in bird life, in terms of both species and habitat diversity. The present study was carried out in six habitat types in a selected area in the central hill zone, consisting of primary montane forests, secondary montane forests, open scrub, grasslands, grassland-forest interface and home gardens, from February to May 2003.

Point counts (Variable Circular Plot Method or VCPM) used in conjunction with BIODIVERSITY PRO and DISTANCE software indicate that primary montane forests have the highest bird species diversity [with a Shannon Index (Log Base 10) of 1.218], followed by grassland-forest interface (1.216). Home garden habitat had the lowest bird species diversity (with a Shannon Index [Log Base 10] of 1.142). The species evenness index used (Shannon Evenness) indicated that species evenness is highest in open scrub habitat (with an index value of 0.971). This was also found to be indicative from the dominance index used (Berger-Parker Index, with an index value of 0.125).

In terms of similarity, the primary and secondary montane forests ranked together as habitats in which the bird species composition was most similar. In terms of habitat preferences, it was found that a considerable number of bird species preferred primary montane forests. Furthermore, there was a marked preference by frugivores and nectarivores for the primary montane forests. Studies on activities of birds indicate that birds are most active during the early and late hours of the day.

Estimates of density from DISTANCE software indicate that black crow has the highest density in the study area (154.17 individuals per km^2) followed by grey tit (117.40), common tailorbird (111.42) and Sri Lanka white-eye (105.84), the last of which is an endemic species.

Key Words
Hill birds, diversity indices, habitats, point counts

INTRODUCTION

The hill zone of Sri Lanka and the study site

Sri Lanka is situated between longitudes 79° 39' E and 81° 53' E and latitudes 5° 54' N and 9° 52' N, with a maximum north-south length of about 435 km and an east-west width of about 225 km and a surface area of some 65,000 km^2. The coastal areas are mainly low-lying, with many lagoons and wetland areas, and the northern half of the island is mostly flat, intersected by rivers with a number of reservoirs known as tanks. The south-central region of the island is mountainous and has an elevation ranging from 900 m to 2440 m, with the highest point in Mount Pidurutalagala, reaching 2484 m. This is surrounded by an upland belt of 300 – 900 m elevation.

Three subdivisions of the wet zone based on elevation are usually recognized. These are the lowlands, medium hills and upper highlands. The medium hills and upper highlands can be considered as the hill zone. The temperature of the hill zone varies greatly and sharp frosts are frequent in the highest altitudes during December and January. The distribution of plant and animal life is profoundly influenced by this pattern of climate and elevation. Therefore, as a result of this pattern of climate and elevation, there are three types of vegetation in the three subdivisions of the wet zone. They are wet evergreen forests or rain forests in the lowlands and adjacent hills, lower mountain forests on the lower slopes of mountains between 1000 m and 1500 m and mountain forests or montane wet evergreen forests above 1500 m (Ashton *et al.*, 1997).

The dominant tree species in montane wet evergreen forests are *Callophyllum walkeri* (Keena), *Syzygium revolutus* (Dambu), *Symplocos spicata, Neolitsea fuscata* (Dawul Kurundu), *Cinnamomum ovalifolium* (Kurundu),

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Litsea ovalifolia, and *Actinodaphne speciosa*. The understorey of these forests is dominated by *Strobilanthes* spp. (Nelu). A luxuriant growth of bryophytes, numerous epiphytic orchids and the lichen *Usnea barbata* adorn these trees. About 40% of the tree species are endemic to Sri Lanka. The non-forest vegetation types in the hill zone are mostly grasslands, found in small pockets. The grasslands of the Horton Plains, Moon Plains, Ambewela, and Nuwara Eliya are known as wet patanas and are interspersed with mountain forests (Ashton *et al.*, 1997).

Birds of Sri Lanka

At least 236 species of birds are breeding residents in Sri Lanka, and a further 189 species are non-breeding visitors to the island (Wijesinghe, 1994). Of the resident species, 23 species are endemic to Sri Lanka (Kotagama, 2000; Kotagama and Jinasena, 2000; Kotagama and Wijeyasinghe, 1998; Inskipp *et al.*, 1996; Santiapillai and Wijesundara, 2002).

Birds of the Hill Zone of Sri Lanka

The present study concerns with the avifauna of the upper highlands, where montane wet evergreen forests are the dominant type of vegetation.

As a result of the overall patterns of altitude, vegetation, and rainfall, the hill zone harbors a characteristic avifauna. Some of the species occurring in this zone occur nowhere else in Sri Lanka. These include the Sri Lanka Wood Pigeon (*Columba torringtoni*), Yellow-eared Bulbul (*Pycnonotus penicillatus*), Sri Lanka Whistling Thrush or Arrenga (*Myophonus blighi*), Sri Lanka Bush-Warbler (*Bradypterus palliseri*), Dusky-blue Flycatcher (*Eumyias sordida*), and Sri Lanka White-Eye (*Zosterops ceylonensis*). Phillips (1955) records 133 species of birds (both resident and migrant) from the Nuwara Eliya District and the upper highlands. Phillips (1955) further states that 22 species are confined to the hill zone and another 12 are common to the hill zone and the wet zone. Recent records of the Ceylon Bird Club[1] indicate that at least 60 species are present in Nuwara Eliya and adjacent areas.

Kelaart (1852) was one of the first to publish on the hill birds of Sri Lanka. Kelaart (1852) devotes a full chapter in his book to the natural history of Nuwara Eliya. Here he describes the avifauna of Nuwara Eliya and gives a list of bird species known to occur at Nuwara Eliya at his time, numbering 50.

The more recent work included those of Phillips (1955) and Wickramanayake (1977). Phillips (1955) was the first to consider specifically the birds of Sri Lanka's hill zone in detail. Phillips (1955) gives a comprehensive introduction to the birds of the upper highlands of Sri Lanka, including a list of all the birds recorded from Nuwara Eliya District to that date. Wickramanayake (1977) devotes a chapter in his book to the birds of the hill zone of Sri Lanka.

Recent workers on the birds of Sri Lanka's hill zone include Karunaratna (1986), Makuloluwa *et al.* (1997), Esufali (1998), Hitinayake *et al.* (1999), Wijesundara and Santiapillai (2000; 2001), Dharmasena *et al.* (2001) and Santiapillai and Wijesundara (2001). Karunaratna (1986) devotes a chapter in his book to the birds of the Udawattakele Forest Reserve, Kandy, in the mid-elevations of Sri Lanka, and includes a list of birds seen in the reserve. Hitinayake *et al.* (1999) provide a list of birds seen in the Kandy Lake and its environs, while Dharmasena *et al.* (2001) note the high avifaunal diversity in the Dunumadalawa (or Wakarawatta) Forest Reserve, which is a watershed forest within the Kandy city limits, at an elevation between 550 and 980m above sea level.

Makuloluwa *et al.* (1997) have studied the diversity and aspects of the ecology of the birds in the mid-elevations of Sri Lanka, while Wijesundara and Santiapillai (2002) investigated the diversity of the avifauna of a selected area in the mid-elevations, based on their previous work (Wijesundara and Santiapillai, 2002) and deals with a review of information on the ecology and status of the avifauna in the same area, while the work by Esufali (1998) deals with aspects of the ecology of the birds in the Knuckles Mountain Range, Sri Lanka.

In addition, Ceylon Bird Club Notes, the official publication of the Ceylon Bird Club, contain valuable information on the avifauna of Nuwara Eliya area. Of these only Esufali (1998) and Wijesundara and Santiapillai (2001) attempt to assess the bird composition in terms of diversity indices and/or the rank-abundance model. In addition, Makuloluwa *et al.* (1997)

[1] **Ceylon Bird Club Notes** 1993 – 2000

assess the composition of bird communities according to their feeding guilds, and the habitat preferences of birds. There is very little scientific work available on hill bird communities in Sri Lanka. The present study, therefore, was conducted to explore the composition of bird communities in a selected area of the hill zone of Sri Lanka.

MATERIALS AND METHODS

A pair of Vivitar 8 x 40 wide-angle binoculars was used to observe the birds and Harrison and Worfolk (1999), Grimmett *et al.* (1998), Ali and Ripley (1978 – 99), Henry (1971), Wijeyaratne *et al.* (2000), and Kazmierczak and van Perlo (2000) were referred for identification. The data are based on point counts (Variable Circular Plot Method or VCPM) done on fixed route transects located in selected areas. The methodology of point counts was according to Sutherland (1996), Marsden (1999), Blondel *et al.* (1981), Bibby *et al.* (1998), Buckland *et al.* (1993), Hamel *et al.* (1996) and Johnson (1995). The sampling areas represented six habitat types *viz.* primary montane forest, secondary montane forest, open scrub, grassland, home garden, and grassland-forest interface. In each of these study sites, at least two point counts were made at each of the sampling stations within each square kilometer of habitat on every visit.

Two visits were made to each sampling station per week during the study period. Counting stations were marked with colored tape. In the study area (Fig. 1), approximately 54 % of the habitat area was primary montane forests, 18 % was secondary montane forests, 11 % was grasslands, 3 per cent was open scrub, 4.5 % was grassland-forest interfaces, and 9 % was home gardens. The total area of these habitats was approximately 110 km^2. Roughly 50 per cent of the area of each habitat type was sampled. In forest, one station was separated from the next station by a distance of about 500 paces (approximately 250 m), whereas in more open habitats this distance was 1000 paces (approximately 500 m). As most transect routes followed existing paths or watercourses, 250 m and 500 m were kept as the minimum distances between two stations as far as possible. This was done in an attempt to reduce bias due to surveying along non-random features such as paths.Data were collected from the beginning of February to the end of May 2003, in Nuwara Eliya (including its urban areas) and adjacent areas including Galway's Land Sanctuary, Pidurutalagala Forest Reserve, Kikilimana Proposed Forest Reserve, Shanthipura (highest village in Sri Lanka), Kandapola-Seetha Eliya Forest Reserve, Bomuralla, Single Tree Hill (One Tree Hill), Nanu Oya Forest, Hakgala Strict Natural Reserve (areas adjoining Hakgala Botanic Gardens, Seetha Eliya section, and Ambewela section), and Ambewela cattle farm (Fig. 1) All detectable birds were recorded from each station. When approaching a counting station, if any birds were disturbed (flushed) from near the plot, these were recorded as being present and the distance from the counting point to the bird's take-off point was estimated. Before beginning to count at each station, at least two minutes were spent without counting in order to reduce the effect of any disturbance on counting.

Counts were made between 0630 h and 1830 h each day, only in the absence of rain or heavy mist. Peak counting hours were between 0630 h – 0930 h and 1530 h – 1830 h. Each count lasted for about 20 minutes, with the data separable into two consecutive 10-minute periods.All birds seen and heard were recorded and the actual distance (radial distance), to the nearest meter, from the counting point to the bird was estimated. For groups of birds, the distance to the "center of gravity" of the group was estimated. To minimize errors in distance estimation, some self-training was undertaken by estimating the distance to certain objects and then actually measuring the distance to that object, using a measuring tape, before data collection was started. This self-training also included measuring of linear distances to certain points in the canopy of trees from a certain point on the ground, away from the tree, as explained in Fig. 2. For measuring the angle, a clinometer was used. The method of detection was recorded as "seen" or "heard". The number of individuals in each encounter was recorded, where possible. Also, activities of the bird (e.g. preening, perching, foraging, feeding, singing etc.) were recorded at each station. Activities of most commonly encountered bird species were graphically plotted against time of day to determine the time of day the birds are most active.

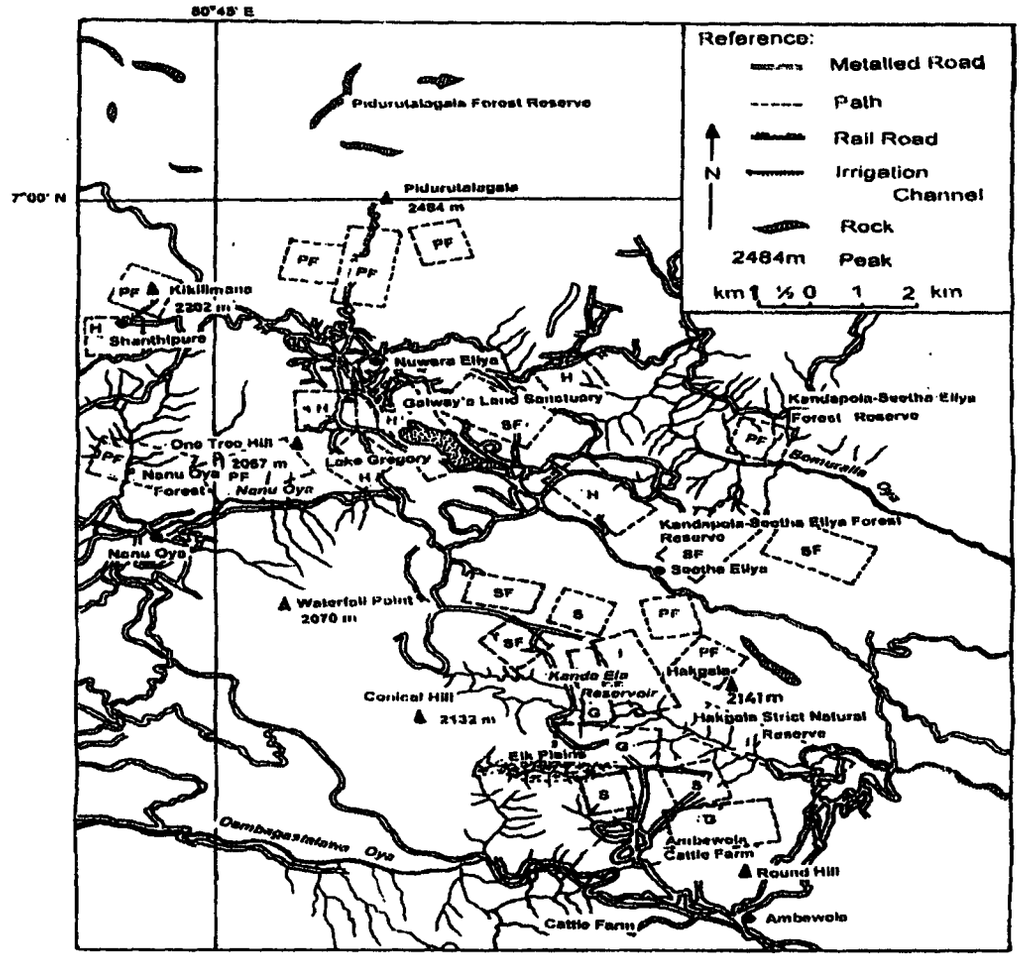

Figure 1. Map of the study area showing the locations of study sites (PF = Primary Montane Forest; SF = Secondary Montane Forest; G = Grassland; S = Open Scrub; I = Grassland-Forest Interface; H = Home Garden).

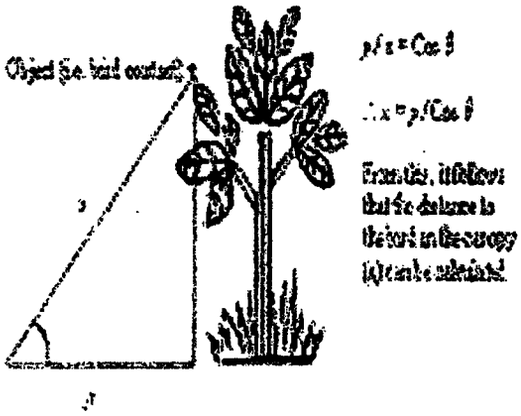

Fig 2. Calculating actual distance to the bird seen using a clinometer

Number of individuals of each commonly encountered species observed in each habitat was graphically plotted against habitat to determine the habitat preferences of each species.

Bird species diversity in each habitat and sampling station was measured using BIODIVERSITY PRO software (McAleece *et al.*, 1997). Using this software, diversity indices (such as Shannon and Berger-Parker) were calculated for each habitat. Also, Rank-Abundance plots for each habitat type and similarity dendrogram for these habitats were generated using this software.

Shannon Index, $H' = -\Sigma p_i \ln p_i$, where p_i is the proportion of individuals found in the i^{th} species in the sample (Magurran, 1988), was used as a measure of bird species diversity in each habitat. Another equation can be derived from this: $N_1 = e^{H'}$ where, $e = 2.7182$, H' = Shannon Index, and N_1 = The number of equally common species that would produce the same diversity as H'. $\therefore N_1 = 2.7182 \ln H'$ This means, after finding *equally common* N_1 number of species, a new species can be encountered.

The Maximum Shannon Diversity (in a situation where all species were equally abundant) for each habitat type can be estimated using the equation, $H_{max} = \ln S$, where S is the number of species in the respective habitat. From these data (the Shannon Index [H'] and Maximum Shannon Diversity [H_{Max}]) the Shannon Evenness (E) can be obtained using the equation$E = H'/H_{Max} = H'/\ln S$, because the ratio of observed diversity (H') to maximum diversity (H_{Max}) can be taken as a measure of evenness (E) (Magurran, 1988).

The Berger-Parker Index (d) was used as a measure of dominance in each habitat type. It is calculated using the formula $d = N_{max}/N$, where N_{max} is the number of individuals in the most abundant species and N is the total number of individuals. In this measure, as d increases, diversity decreases (and dominance increases) and therefore the Berger-Parker Index is usually expressed as 1/d so that an increase in the value of the index accompanies an increase in diversity and a reduction in dominance. Rank/Abundance plots for each habitat type were used as a method of presenting species abundance data. In these graphs the abundance of each species is plotted against the species' rank, in an order from the most abundant to least abundant species. β diversity, which is a measure of how different (or similar) a range of habitats or samples are in terms of the variety (and sometimes the abundance) of species found in them, was measured by using cluster analysis. According to Magurran (1988), when there are a number of sites in the investigation, a good representation of β diversity can be obtained through cluster analysis. \Cluster analysis starts with a matrix giving the similarity between each pair of sites. The two most similar sites in this matrix are combined to form a single cluster. The analysis proceeds by successively clustering similar sites until all are combined in a single dendrogram.

Estimates of density for commonly encountered species were calculated. For estimating bird densities, data were analyzed using DISTANCE software (Thomas *et. al.* 1998). VCPM, when used in conjunction with DISTANCE software, allow estimation of actual animal density by using the fall-off in probability (g) of animal detection over increasing distances (y) from the recorder, where the probability of animal detection at y = 0 is usually assumed to be certain [g(0) = 1] (Marsden, 1999).

Besides the assumption that g(0) = 1 or at least is known, there are three more (main) assumptions of distance sampling (Buckland *et al.*, 1993), (i). Animals are detected prior to natural movement or movement in response to the recorder; (ii). Distances to animal contacts are known accurately; (iii). Sampling points or lines are randomly positioned, or a grid of points/lines is randomly placed. Actual distances (radial distances) r were measured from the point to each detected object. Suppose the design comprises k points, and distances less than or equal to w are recorded. Then the surveyed area is $a = k\pi w^2$, within which n objects were detected. As for line transect sampling, P_a denote the probability that an object within the surveyed area a is detected with estimate Pa'. The object density (D') can be estimated by $D' = n / k\pi w^2 P_a'$ (Thomas *et al.*, 2002).

RESULTS

The diversity indices, i.e. Shannon and Berger-Parker, are given in Table 1 and Table 2 respectively. The Shannon Diversity Index (H') indicates that primary montane forests in the study area have the highest bird species diversity, whereas the Berger-Parker Index indicates that the open scrub habitat has the lowest dominance and hence the highest evenness. The characteristic patterns of species abundance (rank/abundance plots) and the cluster analysis dendrogram for the six habitat types surveyed are given in Fig. 3 and 4 respectively.

In the present study, the abundance curves of primary montane forests and grassland-forest interfaces show longer tails than those of other habitats. The similarity dendrogram shows that the habitats with lot of tree cover *viz.* primary and secondary montane forests, group together

Table 1
Shannon Index results. (PF = Primary Montane Forest; SF = Secondary Montane Forest; G = Grassland; S = Open Scrub; I = Grassland-Forest Interface; H = Home Garden)

Index	S	G	I	H	PF	SF
Shannon H' Log Base 10.	1.195	1.178	1.216	1.142	1.218	1.153
Shannon H_{max} Log Base 10.	1.230	1.230	1.398	1.342	1.531	1.398
Shannon Evenness (E)	0.971	0.957	0.870	0.851	0.795	0.825

Table 2
Berger-Parker Index results. (PF = Primary Montane Forest; SF = Secondary Montane Forest; G = Grassland; S = Open Scrub; I = Grassland-Forest Interface; H = Home Garden)

Index	S	G	I	H	PF	SF
Berger-Parker Dominance (d)	0.125	0.129	0.191	0.178	0.244	0.244
Berger-Parker Dominance (1/d)	8.000	7.750	5.231	5.625	4.096	4.094
Berger-Parker Dominance (d%)	12.500	12.903	19.118	17.778	24.413	24.427

The habitat preferences of the most common bird species are given in Fig. 5. The present study shows that more bird species prefer the undisturbed primary montane forests (Fig. 6). This shows that insectivores, frugivores, nectarivores, omnivores and seedeaters prefer primary montane forests to a greater extent than other habitats. Fig. 7 to 11 show the activity patterns of some commonly encountered bird species over a 12-hour period. These indicate that, in general, birds are most active during the early and late hours of the day. The highest number of endemic species recorded among habitats has from primary montane forests. According to the density estimates, black crow has the highest density followed by grey tit, common tailorbird, and small flowerpecker (Table 3).

DISCUSSION

Diversity Indices

The Shannon Diversity Index (H') indicates that primary montane forests have the highest bird species diversity (with an index value of 1.218), followed by grassland-forest interface (1.216). Home garden habitat has the lowest bird species diversity, with a Shannon Index of 1.142. This may well be due to the increasing habitat change or pollution in the area. It has been observed previously that house sparrows have declined due to the heavy use of agrochemicals (Gunawardana, 1999).

In the Knuckles or Dumbara mountain range, which is a detached part of the central mountain massif of Sri Lanka (Somasekaram *et al.*, 1997), Esufali (1998) has observed that natural habitats with some disturbance harbored the greatest avifaunal diversity followed closely by the home gardens, which were in this case rich forest analogs. In the present study area, the home gardens are no longer forest analogs but are highly urbanized and perhaps also highly polluted. The high species diversity of primary forests in the tropics is a well-known factor and has been documented previously (Daniels *et al.*, 1991; Daniels *et al.*, 1992; Pramod *et al.*, 1997

Table 3
Estimates of density, from DISTANCE software, of the commonly encountered birds.

Species	Density estimate (Number of individuals per km^2)
Feral Pigeon	40.95
Spotted Dove	77.99
Common Coucal	46.53
Barn Swallow	43.91
Indian Pipit	63.76
Red-vented Bulbul	68.10
Yellow-eared Bulbul	93.01
Black Bulbul	16.58
Oriental Magpie Robin	42.39
Pied Bush chat	90.69
Indian Scimitar Babbler	12.66
Franklin's Prinia	23.60
Common Tailorbird	111.42
Green Tree Warbler	51.75
Large-billed Tree Warbler	39.19
Dusky-blue Flycatcher	87.67
Grey-headed Flycatcher	42.55
Grey Tit	117.40
Small Flowerpecker	64.07
Sri Lanka White-Eye	105.84
House Sparrow	78.92
Common Mynah	80.55
Black Crow	154.17

The grassland-forest interface also has a higher diversity of bird species than other habitats except primary montane forest because it is an ecotone. The tall trees of the primary montane forest gradually become shorter and shorter in the ecotone and finally become the grassland. As a result, the ecotone has both forest and grassland bird species. Therefore there is a high bird species diversity at the ecotone due to the edge effect. Although the species richness is lower in grassland-forest interface (S=25) than in primary montane forest (S=34), the species evenness (measured by Shannon Evenness) is greater (0.870 in grassland-forest interface compared to 0.795 in primary montane forest). Therefore the bird fauna in the grassland-forest interface may have a higher diversity in terms of the proportional abundance of species, as high evenness is conventionally equated with high diversity (Magurran, 1988). The lower species evenness of primary montane forest results in the high proportion of certain widely spread bird species (such as common tailorbird and Sri Lanka white-eye) and the presence of some other species (such as the black crow and common mynah) in very small numbers.

The species evenness is highest in the open scrub habitat because there the species found are represented in more or less similar proportions. Even though according to Magurran (1988) this represents a situation where diversity is very high in terms of proportional abundance (due to the high evenness), this is not a very good habitat for most of the upper hill zone birds. This is indicated clearly by the low species richness (S=17) of this habitat. The grasslands also have a high evenness for the same reason.

Although the grassland and open scrub habitats both have a high evenness (0.957 and 0.971 respectively), the species diversity in these two habitats is very low (with a Shannon Index value of 1.178 and 1.195 respectively). This may be due to frequent disturbance by man as they are often located in areas close to human habitations. For example, most of the open scrub and grassland habitats sampled were situated close to the Ambewela Cattle Farm. There was also frequent cattle grazing in these two habitats. As Daniels *et al.* (1990) report, frequent disturbances can prevent bird communities from establishing in any vegetation type. Daniels *et al.* (1990) further state that 'establishing' need not necessarily mean 'to breed'. A species

finding sufficient food in any habitat eventually becomes dependent on it.

According to the Berger-Parker Index, the open scrub habitat has the lowest dominance (with an index value of 0.125) and hence the highest evenness. This is also clearly indicated by the Shannon Evenness Index (0.971). Both primary and secondary montane forests have a high dominance according to the Berger-Parker Index (with an index value of 0.244 for both). This is due to the large proportion of certain bird species present in these two habitats. In primary montane forests, the common tailorbird is present in far greater proportions than other species whereas in secondary montane forests, the black crow occurs in high proportions.

Species Abundance Curves

In the present study, the abundance curves of primary montane forests and grassland-forest interfaces showed longer tails than those of other habitats. This indicates a higher number of rare species. For instance, the black eagle was recorded only from primary montane forests in the present study and even here it was recorded only once. Esufali (1998) noted a similar phenomenon in the Knuckles mountain range, where the natural forests and patana grasslands showed longer tails on the abundance curves. The black crow appears in the top rank of three of the habitat types studied, namely home gardens, secondary montane forests, and grassland-forest interfaces. Although the black crow appears in the top rank in the secondary montane forests, it ranks 22nd in the primary montane forests. This is a significant observation as it shows that the increase in certain human-associated species such as the black crow is indicative of increased human interference. The secondary montane forests are subject to high human interference. The similarity dendrogram (Fig. 4) shows how similar the habitat types studied are in terms of their avifaunal diversity or how similar the species of birds in the different habitat types studied. The habitats with more tree cover *viz.* primary and secondary montane forests, group together. These are in fact most similar habitats in terms of avifaunal diversity. They share species like the common tailorbird, Sri Lanka white-eye, and small flowerpecker, which are common birds of habitats with numerous woody plant species.

Habitat preferences of birds

The study showed that ore bird species prefer the undisturbed primary montane forests. These forests recorded the highest number of bird species. The preference of birds to heavily forested undisturbed areas has been documented previously (de Zoysa and Raheem, 1990). Some species, such as the black eagle and emerald dove, have been observed only in primary montane forests, whereas certain others such as the oriental magpie robin, common tailorbird, grey tit, and black crow, have been observed in all habitat types studied (Fig. 5). Esufali (1998) noted that large tracts of forest are very important to the birds of prey. Although species such as the common tailorbird and grey tit are observed in all habitat types, there is a marked preference for primary montane forests in both these species. Some species, such as the spotted dove and pied bush chat, which are common urban species, have not been observed in primary montane forests, whereas they are very commonly observed in home gardens. The spotted dove, as Henry (1971) reports, has its main headquarters in the dry jungles of the low country but is gradually extending its range and it frequents both cultivation and more open types of forest. The pied bush chat is purely a hill bird common in open grassy areas but avoiding forest (Henry, 1971). home garden habitat. This indicates that there is less insect diversity and/or abundance in the home garden habitat. Furthermore, the study reveals that insectivores formed the greatest proportion of the feeding guilds in each of the habitat types studied. A similar result has been obtained previously by Esufali (1998) in a study of the avifauna in the Knuckles mountain range. The insectivores are important to the agricultural communities in the area this is true for the present study area too (Esufali 1998).The bird species in each habitat type were characterized based on their food preference (Fig. 6), The results shows that the predominantly insectivorous bird species are found in a greater proportion in the primary montane forests, grassland-forest interface, and secondary montane forests, and the least in the Insectivores showed a marked preference for primary montane forests (e.g. Sri Lanka bush warbler, common tailorbird), frugivores (e.g. yellow-fronted barbet) and nectarivores (e.g. purple sunbird). Primary montane forests and grassland-forest interface are also preferred by carnivores.

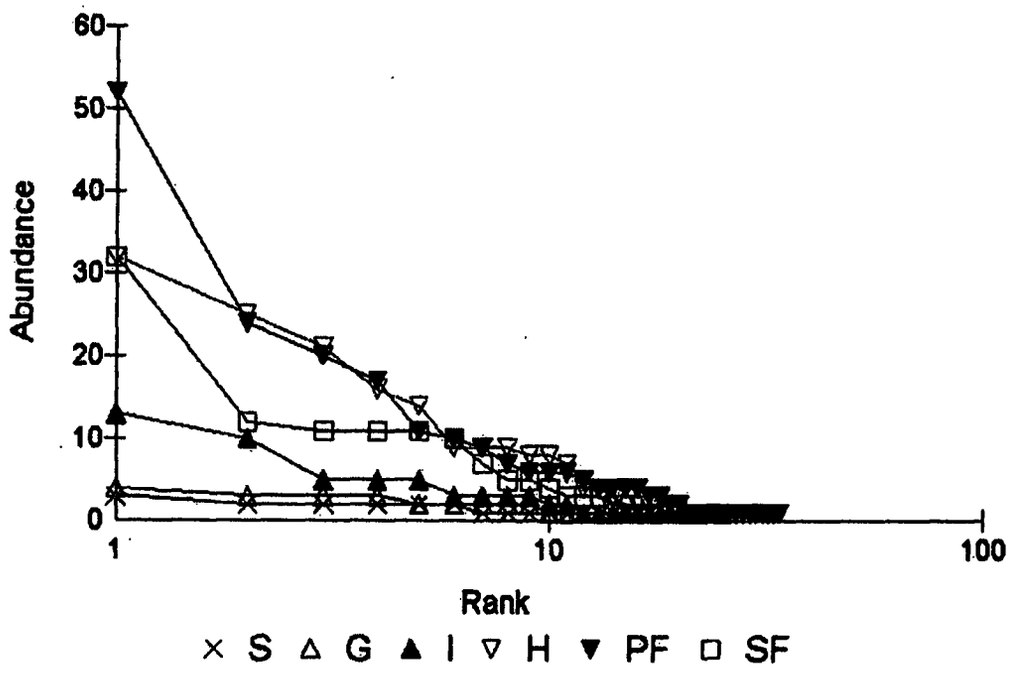

Fig. 3. Abundance plot. Legend: PF = Primary Montane Forest; SF = Secondary Montane Forest; G = Grassland; S = Open Scrub; I = Grassland-Forest Interface; H = Home Garden.

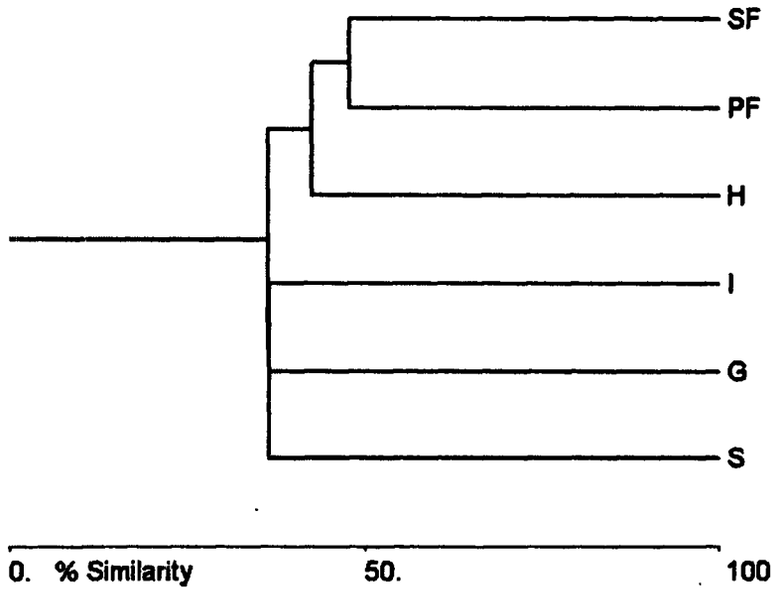

Fig. 4. Extent of similarity between habitats (Bray-Curtis Cluster Analysis Dendrogram [Single Link]). Legend: PF = Primary Montane Forest; SF = Secondary Montane Forest; G = Grassland; S = Open Scrub; I = Grassland-Forest Interface; H = Home Garden.

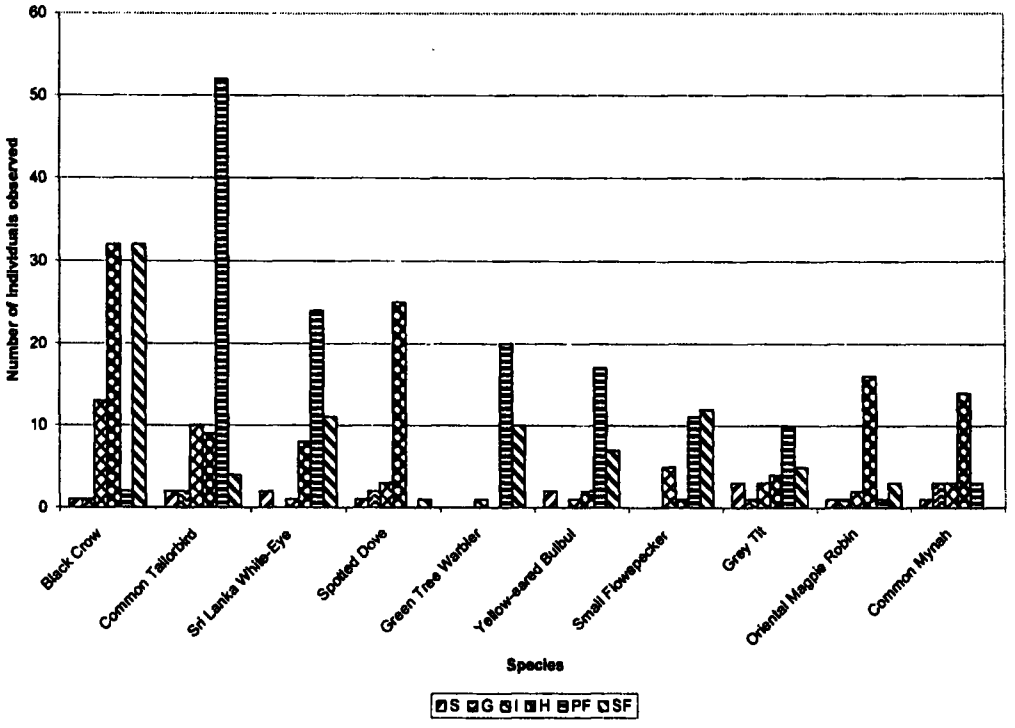

Figure 5. Occurrence of the most common bird species in each habitat type. (PF = Primary Montane Forest; SF = Secondary Montane Forest; G = Grassland; S = Open Scrub; I = Grassland-Forest Interface; H = Home Garden)

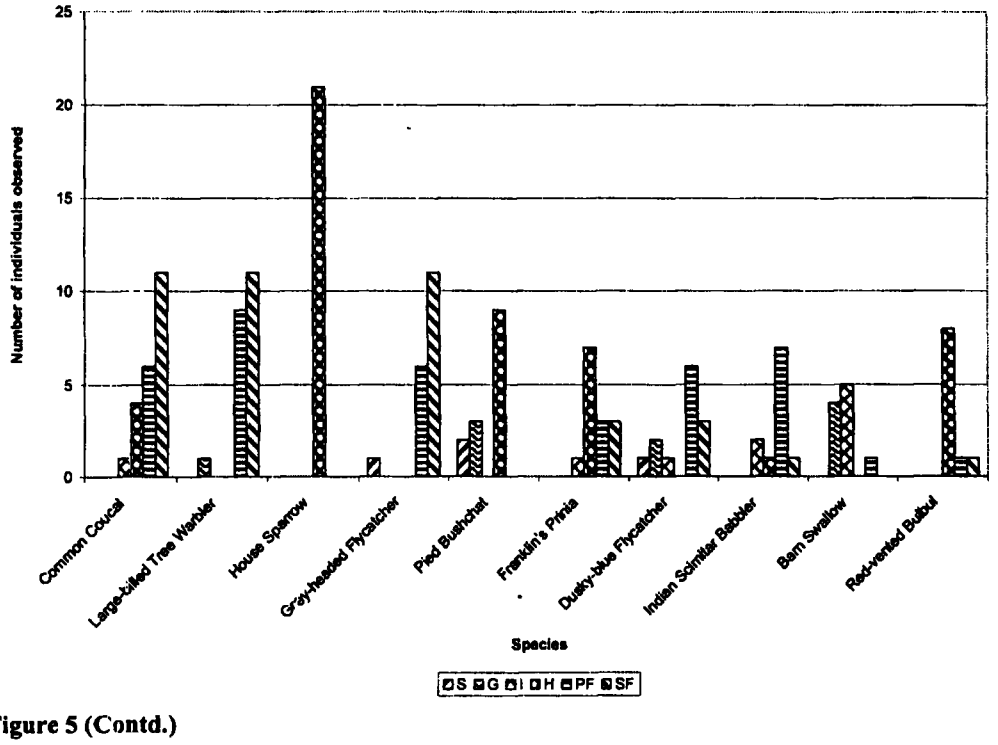

Figure 5 (Contd.)

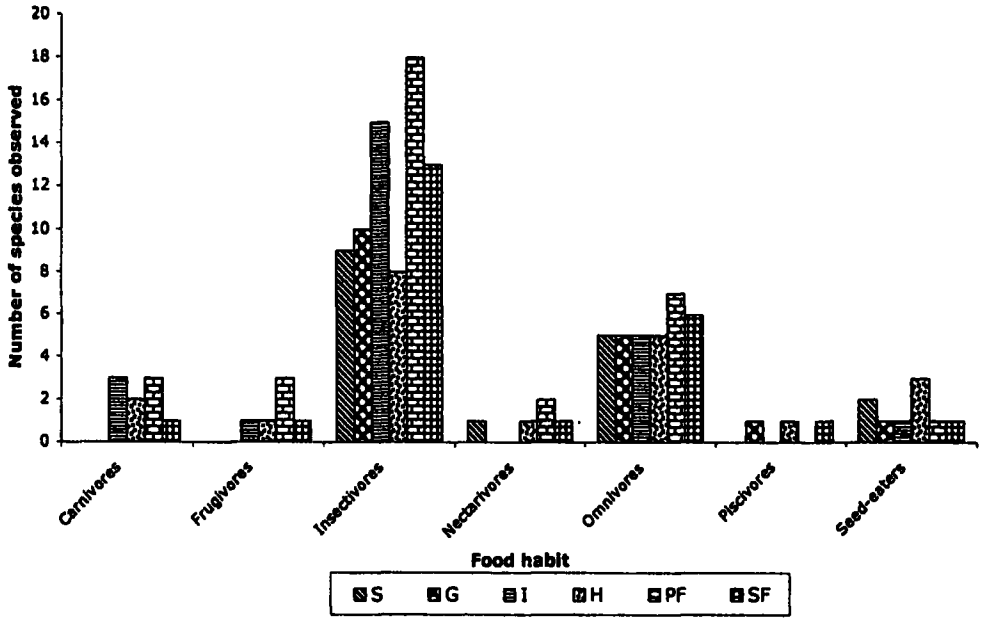

Figure 6. Number of bird species by food habit observed in each habitat. (PF = Primary Montane Forest; SF = Secondary Montane Forest; G = Grassland; S = Open Scrub; I = Grassland-Forest Interface; H = Home Garden)

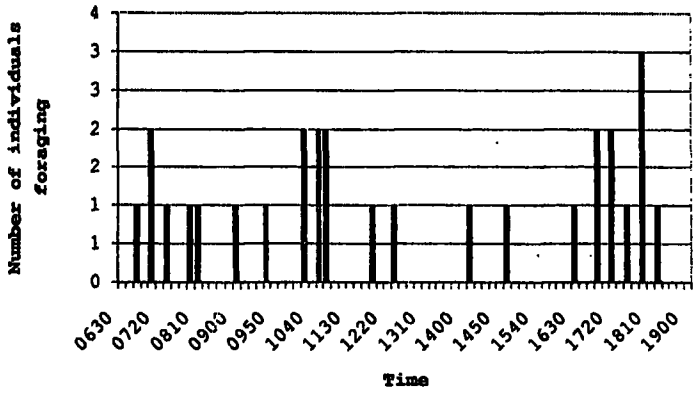

Figure 7. Foraging activity of yellow-eared bulbul through a 12-hour period.

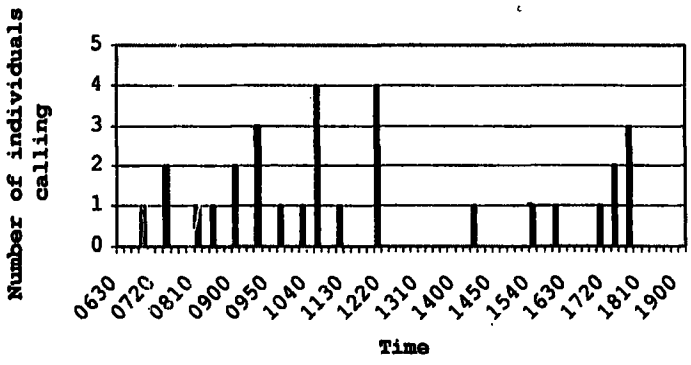

Figure 8. Calling activity of yellow-eared bulbul through a 12-hour period.

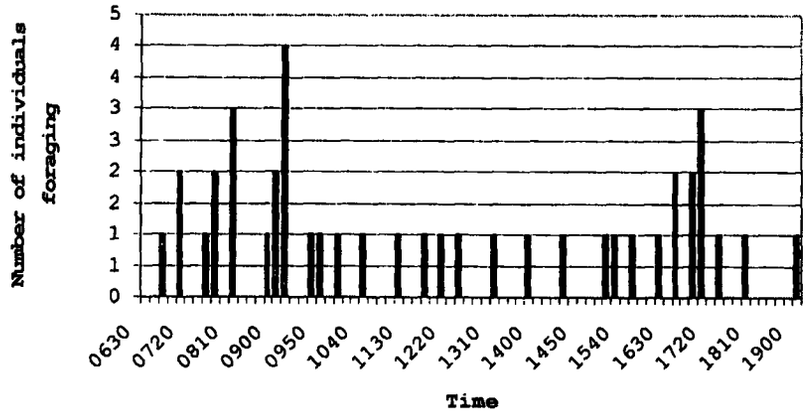

Figure 9. Foraging activity of dusky-blue flycatcher through a 12-hour period.

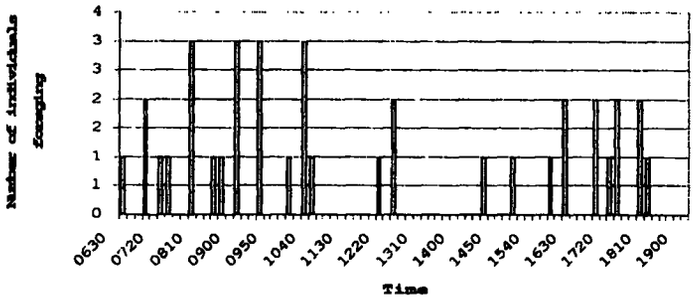

Figure 10. Foraging activity of grey tit through a 12-hour period.

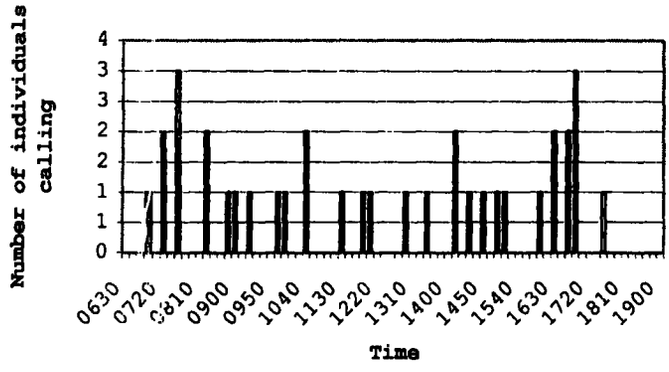

Figure 11. Calling activity of grey tit through a 12-hour period.

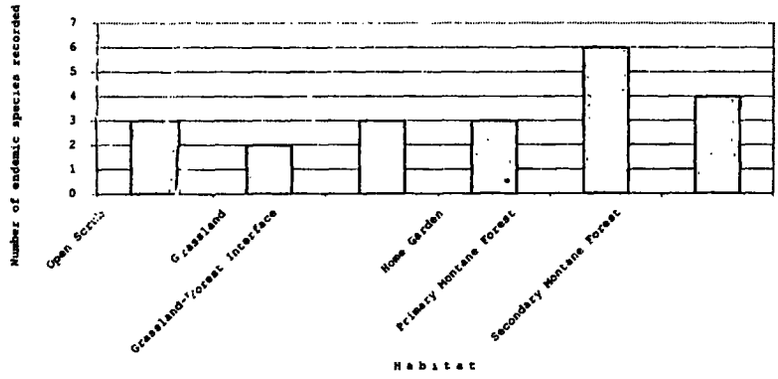

Figure 12. Number of endemic bird species recorded in each habitat

Food preferences of birds

Seedeaters are predominantly found in home garden habitats, followed by open scrub. The preference for evergreen forests by frugivores has been reported previously (Daniels *et al.*, 1990).

Activity patterns of birds

The activity patterns of commonly encountered bird species over a 12-hour period of the day (Fig. 7 to 11) indicated that, in general, birds are most active during the early and late hours of the day. Therefore, for most birds of the present study area, the best time for census from point counts would be the early and late hours of the day. A similar result has been obtained previously by Marsden (1999) for large avian frugivores in Indonesia.

Densities of common bird species

Density estimates were generated from DISTANCE software for the commonly observed species of birds in the study area (Table 3), however these could not be obtained for the more rare species because of the lack of sufficient number of observations on them. Distance software requires a minimum number of observations in order to give a reliable estimate of density.) As the estimates show, black crow has the highest density. This observation is significant because the black crow was unknown in Nuwara Eliya (Henry 1955) However it was steadily extending its range in the higher hills (Henry 1955). According to personal observations, the species is now very common in Nuwara Eliya and it is even seen in Horton Plains, at an elevation of about 2000 m. This increase in numbers no doubt has a negative effect on the endemic species and other hill species, as this crow is a notorious feeder of nestlings. Also, as this crow is commonly associated with man, its increase in Nuwara Eliya and adjacent areas may be indicative of pollution. With the increase of human invasion at Horton Plains, the black crow has also extended its range up there, with the associated pollution.

Endemic bird species

Of the endemic birds recorded in the present study, about 85 per cent are threatened species (IUCN Sri Lanka, 2000). Therefore the present study area can be considered as an important endemic bird area.

Of the six habitat types studied, the endemic bird species are more in the primary montane forests and least in the grasslands (Fig. 12). Grasslands are habitats which are highly disturbed by human activities such as cattle grazing. A similar result has been obtained previously in a study in India (Daniels *at al.*, 1990) and in the Knuckles mountain range in Sri Lanka (Esufali, 1998). The latter study further states that next to undisturbed natural forests, the patana grasslands had the highest percentage endemism of birds in the study area. Nevertheless the present study reveals that grasslands have the least endemism of birds among the habitat types in the study area.

In terms of endemism, the primary montane forests are comparable with the lowland rainforests of Sri Lanka. Both these types of forests have a high percentage of endemic species. For example, Sinharaja, which is the only remaining large tract of lowland rainforest in Sri Lanka, is the only locality where 18 out of 23 bird species endemic to Sri Lanka (78 per cent) may be viewed (de Zoysa and Raheem, 1990). The present study detected 26 per cent of the endemic bird species of Sri Lanka in the primary montane forests.

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Appendix: List of birds recorded during the present study

Order Pelecaniformes
- **Family Phalacrocoracidae**
  - *Phalacrocorax niger* Little Cormorant

Order Ciconiiformes
- **Family Ardeidae**
  - *Ardeola grayii* Indian Pond Heron

Order Falconiformes
- **Family Accipitridae**
  - *Pernis ptilorhynchus* Oriental Honey Buzzard/Crested Honey Buzzard
  - *Elanus caeruleus* Black-winged Kite
  - *Spilornis cheela* Crested Serpent Eagle
  - *Ictinaetus malayensis* Black Eagle

Order Galliformes
- **Family Phasianidae**
  - *Gallus lafayettii* Sri Lanka Jungle Fowl (Endemic Species)

Order Gruiformes
- **Family Turnicidae**
  - *Turnix suscitator* Barred Buttonquail

Order Charadriiformes
- **Family Charadriidae**
  - *Vanellus indicus* Red-wattled Lapwing
- **Family Scolopacidae**
  - *Gallinago stenura* Pintail Snipe (Winter Visitor)

Order Columbiformes
- **Family Columbidae**
  - *Columba livia* Feral Pigeon
  - *Streptopelia chinensis* Spotted Dove
  - *Chalcophaps indica* Emerald Dove

Order Cuculiformes
- **Family Centropodidae**
  - *Centropus sinensis* Common Coucal/Greater Coucal

Order Apodiformes
- **Family Apodidae**
  - *Aerodramus unicolor* Indian Edible-nest Swiftlet

Order Piciformes
- **Family Capitonidae**
  - *Megalaima flavifrons* Yellow-fronted Barbet (Endemic Species)
  - *M. haemacephala* Coppersmith Barbet

Order Passeriformes
- **Family Alaudidae**
  - *Alauda gulgula* Indian Skylark/Oriental Skylark
- **Family Hirundinidae**
  - *Hirundo rustica* Barn Swallow (Winter Visitor)
  - *H. tahitica* Hill Swallow
- **Family Motacillidae**
  - *Motacilla cinerea* Grey Wagtail (Winter Visitor)
  - *Anthus rufulus* Indian Pipit/Paddyfield Pipit
- **Family Campephagidae**
  - *Coracina macei* Large Cuckoo-Shrike
  - *Pericrocotus flammeus* Scarlet Minivet/Orange Minivet
  - *Hemipus picatus* Pied Shrike/Bar-winged Flycatcher Shrike

Family Pycnonotidae

Pycnonotus cafer Red-vented Bulbul
P. penicillatus Yellow-eared Bulbul (Endemic Species)
Hypsipetes leucocephalus Black Bulbul

Family Laniidae

Lanius cristatus Brown Shrike (Winter Visitor)

Family Turdidae

Erithacus brunneus Indian Blue Chat/Indian Blue Robin (Winter Visitor)
Copsychus saularis Oriental Magpie Robin
Saxicola caprata Pied Bush chat
Zoothera spiloptera Spotted-winged Thrush (Endemic Species)
Turdus merula Eurasian Blackbird

Family Timaliidae

Pomatorhinus horsfieldii Indian Scimitar Babbler
Dumetia hyperythra White-throated Babbler/Tawny-bellied Babbler
Rhopocichla atriceps Black-fronted Babbler/Dark-fronted Babbler

Family Sylviidae

Bradypterus palliseri Sri Lanka Bush Warbler (Endemic Species)
Acrocephalus dumetorum Blyth's Reed Warbler (Winter Visitor)
Cisticola juncidis Zitting Cisticola/Streaked Fantail Warbler
Prinia hodgsonii Franklin's Prinia/Grey-breasted Prinia
P. socialis Ashy Prinia
P. subflava White-browed Prinia/Plain Prinia
Orthotomus sutorius Common Tailorbird
Phylloscopus nitidus Green Tree Warbler/Green Leaf Warbler (Winter Visitor)
P. magnirostris Large-billed Tree Warbler/Large-billed Leaf Warbler (Winter Visitor)

Family Muscicapidae

Eumyias sordida Dusky-blue Flycatcher (Endemic Species)
Culicicapa ceylonensis Grey-headed Flycatcher

Family Paridae

Parus major Grey Tit/Great Tit

Family Dicaeidae

Dicaeum erythrorhynchos Small Flowepecker/Tickell's Flowerpecker

Family Nectariniidae

Nectarinia lotenia Loten's Sunbird
N. asiatica Purple Sunbird

Family Zosteropidae

Zosterops ceylonensis Sri Lanka White-Eye (Endemic Species)

Family Estrildidae

Lonchura punctulata Spotted Munia/Scaly-breasted Munia
L. malacca Black-headed Munia

Family Ploceidae

Passer domesticus House Sparrow

Family Sturnidae

Acridotheres tristis Common Mynah

Family Corvidae

Corvus macrorhynchos Black Crow/Jungle Crow