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Impact of Anthropogenic Land Alterations on Bird Diversity, Abundance and Feeding Guild in Nilgiri District

RAJESH RAMNARAYAN*[1] AND K. SHANTHI[2]

[1] *Department of Environmental Science, Bharathiar University, Coimbatore, Tamilnadu, India.*
[2] *Department of Environmental Science, PSG College of Arts and Science, Coimbatore 641014. India.*
Email IDs: [1] rramnarayan@yahoo.co.in; [2] shanthivis@gmail.com.
*Corresponding Author.

ABSTRACT

In this study, avian data was collected using Line transect method in anthropogenically altered landscapes of Nilgiris district. A total of 108 species of birds were observed in the eight sampling locations. The total number of birds recorded stood at 14212 and the total number of observations at 8771. The number of resident bird species stood at 95. The species count for winter migrants and passage visitor stood at 12 and 1 respectively. Number of Endemic species observed was 8.

Under the category of well wooded area: tea estate in Kunjapanai and Catherine with diversified shade trees; and SIMS park (botanical garden) were chosen. Under the category of tea monoculture area (under monotypic shade tree of *Grevillea robusta*) locations of Mullur, Dolphin Nose and Attadi tea estate were included. Residential area of Brookland (Coonoor taluk) and Commercial area of Coonoor town were chosen under the urban area category. Avian data was analysed both under both landscape level and at patch level. The objective of this study is to ascertain the status of bird richness and abundance in these varying landscapes.

The number of species recorded in landscape categories of well-wooded area, tea monoculture area and urban area stood at 103, 60 and 34 species respectively. At patch level, Kunjapani, Catherine and SIMS park had higher bird richness and abundance when compared with the three areas of tea planation under monotypic shade of *Grevillea robusta*. The Coonoor town area had the lowest species count but had the highest bird abundance. Attadi tea estate (tea monoculture area) had the lowest bird abundance. Tea gardens under the monotypic shade tree of Silver Oak support few bird species, and with low abundance. Conversion of these areas into urban areas will only serve to increase the abundance of a handful of omnivores.

Key Words: Nilgiri Biosphere; Monoculture; Urbanisation; Frugivore; Insectivore; Omnivore;

INTRODUCTION

Nilgiris District has been carved out of the Nilgiri hill range of the Western Ghats, which is a global biodiversity hotspot (Myers et al. 2000, Das et al. 2006). The Nilgiri Biosphere Reserve (NBR), the first biosphere reserve in India, was created within this hill range in 1986. All forest areas in Nilgiris District fall under NBR. The biodiversity of Nilgiris District can be considered synonymous with the biodiversity of NBR and has been treated as such in this document; also, the district plays a crucial and pivotal role in the success of the NBR.

Although the district has a sizable green cover, the enormous loss of forest due to anthropogenic activities in the last 200 years has been phenomenal. The quality of forest areas has also suffered. The dense forest area of Nilgiris District decreased from 783.26 km^2 to 293.48 km^2 between 1973 and 1995, while in the corresponding period, open and degraded forest areas increased from 798.25 km^2 to 921.26 km^2 (Jha et al. 2000).

The loss of forest area in NBR between 1920 and 2012 was 1423.60 km^2 (24.50%) and between 1973 and 2012, 61.50 km^2. Since 1999, the forest cover has shown no negative change, indicating management effectiveness since the formation of NBR (Satish et al. 2014).

Major loss of forest area occurred after Independence, because of development of physical infrastructure, dam construction and population growth (Reddy et al. 2013). The plantation industry, which was earning precious foreign currency, was encouraged during the immediate period after Independence. The area under tea plantation rose from 9,000 ha in 1950 to 55,779 ha in 2015 (District Statistical Handbook. The Nilgiri District, 2015-16). With the state supporting the tea planters during the lean years (when the international price of tea dropped) with subsidies, tea cultivation became an indispensable livelihood for the local denizens, turning agriculture in the Nilgiris into a monoculture of tea plantation.

With tea plantation came in immigrants, settlements and urbanization. It may be noted that the Western Ghats ecosystems have the highest population density among all the hotspot biodiversity areas in the world (Cincotta et al. 2000, Shi, et al. 2005). Plantation and tourism activities attracted a large number of immigrants from the plains. Since Independence, the growth rate of the population of Nilgiris District has been well above that of Tamil Nadu. The district has a population of 735,000 (2011 census), and the level of urbanization stands at 59% (Tamil Nadu average, 43.86%). (Urban scenario, Tamil Nadu, based on 2001 Census).

Protected areas cover about 12% of the earth's surface (Chape et al. 2005). Protection has proved to an effective way to conserve biodiversity (Teborgh et al. 2002).Such in-situ protection by itself may be enough to protect tropical biodiversity in the long term (Rosenzweig 2003). Among the other alternatives, human-influenced landscapes of agro-forestry, especially in the tropics, have always had an appeal for biodiversity conservationists (Chazdon et al. 2009). Agro-forestry commodity production systems—in particular, those tree-covered, intensively used landscapes of coffee, rubber, arecnut and cacao—can create and maintain habitat and support native species (Bhagwat et al. 2008). The dynamics of such agro-forestry systems sustain biodiversity but are not fully understood. This paucity of knowledge reflects an overall lack of research and also indicates lack of research focus on anthropogenic environments (Rickeet and Lonsdorf 2013).

Agro-plantations of cardamom and coffee have been reasonably well researched from the point of view of avian biodiversity. Often, coffee and cardamom are grown under the shade of native trees, and such environments have often housed higher levels of biodiversity (Raman and Sukumar 2002, Raman 2006, Anand et al. 2008). Tea plantations account for more than 70% of the cultivated land in Nilgiris District, and there is sparse literature on the same. These are considered as monocultures with little shade; tea is cropped at around a metre's height from ground level, and only vegetative growth is encouraged. Generally, native trees are not used for shade, and the preferred single alien species of tree is the Silver Oak (*Grevillea robusta*). Tea growing in the tropical humid slopes of mountains areas attracts a lot of pests, and erosion during the monsoon causes the soil nutrients to wash away, hence these plantations require use of pesticide and fertilizer. It is generally considered that biodiversity would be affected adversely by such intensely managed agro-systems.

However, all tea in the Nilgiris is not grown with Silver Oak as the shade tree. There are several estates which use diverse trees, both native and alien, as shade trees, and the avian biodiversity of such plantations needs to be studied to know what, at a minimum, can be done to improve biodiversity in such intense plantations. The importance of such a study in an urban landscape lies in the fact that while there is limited scope for further large-scale expansion of tea plantations in Nilgiri district, the area under urbanization is fast expanding. Such a study, if pooled with similar studies from other tropical tea-growing countries like Sri Lanka, Kenya, Tanzania, etc., can lead to a vast body of knowledge, enabling extraction of valuable insights for avian conservation. Since there is no exclusive research on tea plantations (of various kinds and intensity) and urbanization in the Nilgiris, which is a crucial and pivotal area of the NBR, it was decided to examine the avian data in the anthropogenically altered landscapes in this area.It is hypothesized that there would not be any significant difference in bird richness and abundance in these different landscapes.

STUDY AREA

The Nilgiris District is the smallest district in the Indian state of Tamil Nadu and has an area of 2545 km^2; its co-ordinates are 11°12' to 11°37' North and 76°30' to 76°55' East. The district is basically hilly, and has an elevation of 1000 MSL to 2600 MSL, with a 56% green cover, against the state average of 17.5%. The mean minimum temperature was 5°C and mean maximum was 26°C during 2015-16. The total rainfall during 2015-16 was 1357.70 mm.

The Kunjapanai tea estate had a well-developed canopy structure of diversified trees: they included *Grevillea robusta, Erythrina sp., Mangifera indica*, *Ceiba pentandra, Artocarpus heterophyllus, Gliricidia sepium, Dalbergia latifolia and Ficus religiosa.* Additionally, many *Piper nigrum* vines were present on *Grevillea robusta.* A similar pattern could be observed in the Catherine area: here the shade trees included *Erythrina sp., Mangeifera indica, Artocarpus heterophyllus, Psidium guajava, Ficus sp., Grevillea robusta, Vernonia arborea, Albizia sp., Mallotus tetracoccus*, *Lingustrum perrottetii,Citrus X sinensis and Syzygium sp*. Large-scale growth of *Lantana camera* was observed.SIMS Park, being a botanical garden, has 1,200 species of plants representing 86 families; its multi-layered canopy consists of gigantic trees, followed by small trees, shrubs and sub-shrubs, along with freely flourishing undergrowth at various locations.

In the case of Mullur, the dominant shade tree was *Grevillea robusta*, but some fruit-bearing trees like *Psidium guajava, Artocarpus heterophyllus,*and *Syzygium sp.* were also present. Additionally, *Piper nigrum* vines were present on *Grevillea robusta.* In the Dolphin's Nose tea estate, *Grevillea robusta* was the dominant tree; a few ornamental trees like *Callistemon sp*. *Jacaranda mimosifolia, Euphorbia pulcherrima* and *ficus sp*. in the temple complex were also seen. Although the Attadi tea estate had the shade tree *Grevillea robusta* dominating, the growth of these trees was stunted in most places, several of them being reduced to dead stumps. Attadi tea estate had the least shade and canopy cover. A few *Acacia mearnsii* (black wattle) were present in the estate.

The Brookland location contains a posh urban area with many house gardens and a few tea estates under the shade of *Grevillea robusta*. The landscape had prominent built-up areas. Most of the trees found here were ornamental: *Callistemon* sp., *Jacaranda mimosifolia, Euphorbia pulcherrima, Araucaria* sp., *Grevillea robusta, Prunus cerasoides, Pine* sp. *and Cupressus* sp. This area had a dense growth of Lantana *camera.* Most households had large gardens with ornamental plants, mostly of non-native origin. The Town area had very few trees and was characterized by large contiguous built-up areas (used mainly for commercial purposes) without any shade. The trees here were *Callistemon sp., Jacaranda mimosifilia* and *Prunus cerasoides*.

Many locations under this study are undergoing rapid change in landscape character. For example, the remaining tea estates in Brookland are being developed into residential localities. Kunjapani estate has changed hands, and it is not sure if the new management will intensify plantation (which means removing the large shade trees). Efforts are on to convert Attadi tea estate into a residential area. The Catherine area, being close to Catherine falls (a tourist spot), is witnessing large-scale diversion of tea estates into tourism-related structures.

METHODOLOGY

The line transect method was chosen, as the sampling units were of open nature (Bibby et al. 1998). All transects were completed at an even pace. Avian data was collected between January 2016 and December 2016. Twenty one-hour readings were taken in each of the locations. All readings were taken between 06:45 and 11:30 hours and 15:30 and 17:00 hours. A total of 160 samples was taken across eight locations. Swallows and swifts were not considered in the counts. Opportunist sightings were not included. The field guides by Krys Kazmierczak (2000) and Richard Grimmett et al. (2016), were used for reference. Although Indian birds have mixed food habitats, a simplified food guild, based on the predominant food habits of each bird species, was followed in this study. For classification into feeding guilds, Ali & Ripley (1987) was referred. A pair of Nikon 10*42 resolution binoculars was used for identifying birds as depicted in Table 1.

Data Analysis

Analysis of bird data was undertaken on both landscape and patch basis. Under the landscape category, the data for P1, P2 and P3 were analysed as a single unit, referred to as 'well wooded' (hereafter referred as WW). The locations P4, P5 and P6 were analysed as a single unit, referred to as 'tea monoculture' areas (hereafter referred to as TM). The locations P7 and P8 were analysed as a single unit referred to as 'urban area' (hereafter referred to as UR). Under patch analysis, each of the eight locations was analysed separately.

The line transects for SIMS Park started from the SIMS Park gate, which is located 2.60 km from Coonoor railway station. The line transects for Town, Brooks and Attadi where 250 m, 600 m and 1 km away from the line transect of SIMS (start point). The maximum altitude variation between these sites was minimal, at 126 MSL. Considering the physiognomic similarity of altitude and

Table 1. Description of sample locations

Patch No.	Location of Patch	Av. altitude (m)	Main attribute	Description	GPS co-ordinate of Start Point
P1	Kunjapanai	1014	Tea plantation	Well wooded diversified shade trees. Sparse build-up area.	11° 21' 52.47"N 76° 55' 56.20"E
P2	Catherine	1488	Tea plantation	Well-wooded diversified shade trees. Minimal build-up area.	11° 23' 06.251"N 76° 51' 51.635"E
P3	SIMS Park	1830	Botanical Garden	Well wooded with diverse trees. Minimal build-up area	11° 21' 20.75"N 76° 48' 01.97"E
P4	Mullur	1239	Tea plantation	Silver Oak as dominant shade tree. Sparse build-up area	11° 21'52.463"N 76° 54' 15.265"E
P5	Dolphin Nose	1660	Tea plantation	Silver oak as dominant shade tree. Sparse build-up area.	11° 21' 55.498"N 76° 51' 15.008"E
P6	Attadi	1912	Tea plantation.	Silver Oak as dominant shade tree. Tea estate with minimal shade, Sparse build-up area.	11° 21' 37.44"N 76° 48' 30.77"E
P7	Brookland	1807	Residential	Urbanised areas: significant build-up area, with some tea estates and house gardens.	11° 21' 25.24"N 76° 48' 18.40"E
P8	Coonoor Town	1786	Urban area	Significant build up area with commercial activities.	11° 21' 12.221"N 76° 48' 01.432"E

spatial proximity of these sites, this subset of landscape patches is further analysed under the name 'Coonoor complex'.

The Shannon diversity index (Shannon and Weaver 1949) was used to calculate the alpha diversity of bird species in all patches. Rarefaction analysis was performed for each site (Krebs 1989). Non-parametric test of ANOSIM and SIMPER analysis was performed on data (Clarke 1993) using PAST Version 3.13 software (Hammer et al. 2001). The same software was used to calculate the Jaccard similarity and distance indices. For application of Multivariate statistical analysis and interpretation, Jim Fowler et al (2009) was referred.

RESULTS

The number of species in each of the landscape areas differed significantly. WW areas had the maximum number of species (103), followed by TM and UR areas with 60 and 34 species, respectively (Figure 1). UR areas shared 29 and 31 species with TM and WW areas, respectively. TM shared 58 out of its 60 species with WW areas; 29 species were common to all the three landscapes as shown in Figure 2.

P1, P2, and P3 patches had higher species richness, at 73, 58 and 54 species, respectively. The figures for P4, P5 and P6 were 49, 35 and 23, respectively. P7 and P8 had 32 and 20 species, respectively (Figure 3).

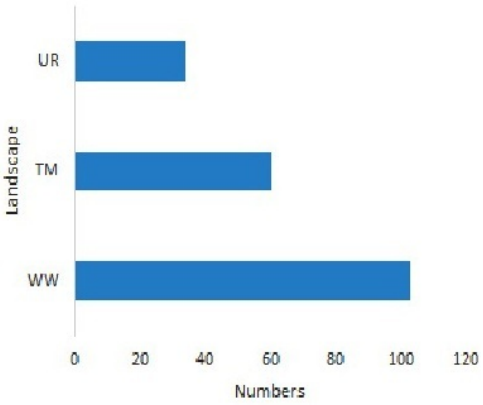

Figure 1. Species richness-landscape level

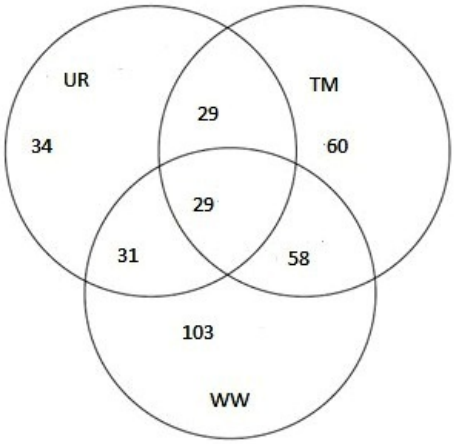

Figure 2. Venn Diagram of bird species-landscape level

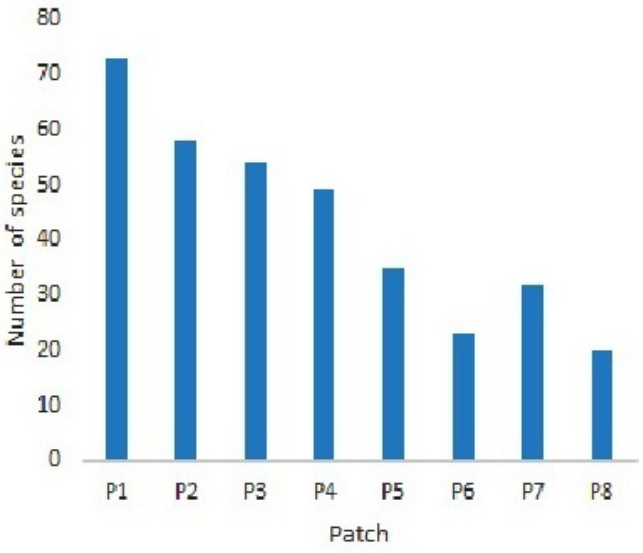

Figure 3. Number of species richness-patch level

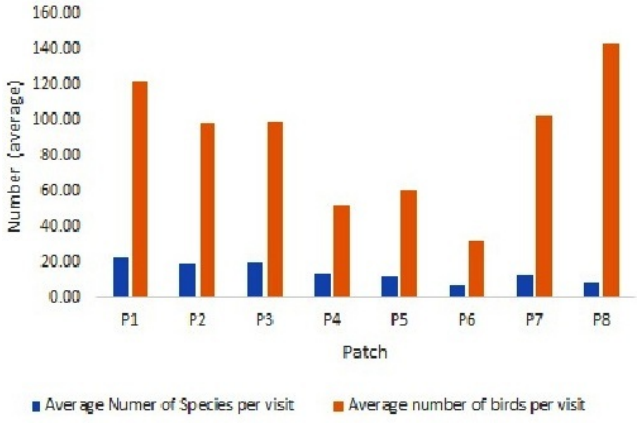

Figure 4. Mean number of species and mean number of birds per visit

The Town and Brooks areas had lower numbers of species but supported a large number of birds. The town area supported the maximum number of birds. P1, P2 and P3 fared well on both parameters. Species richness for P4 was high but bird abundance was lower than in the previous three areas. Bird abundance was lower in locations P5 and P6 too. P6 had the lowest score on both parameters as in figure 4.

P1 had the highest Shannon-Weaver value, at 2.95. P3, P4 and P2 had values of 2.83, 2.81 and 2.65, respectively. The Shannon values for P5 and P7 were lower, at 2.47 and 2.28, respectively. P6 and P8 had the lowest values, at 1.67 each (Figure 5).

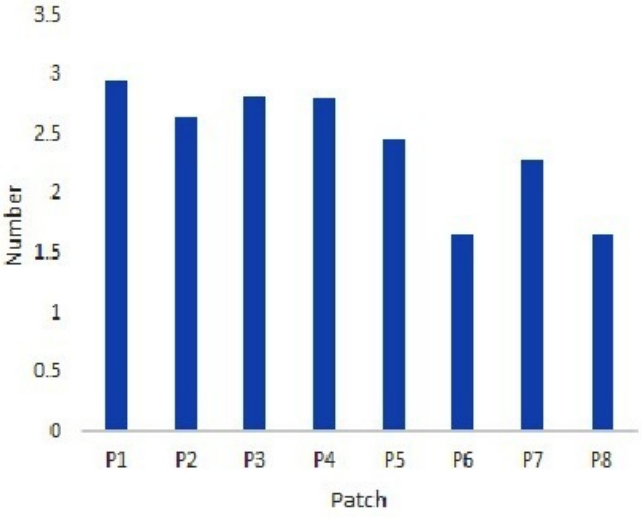

Figure 5. Shannon index of biodiversity

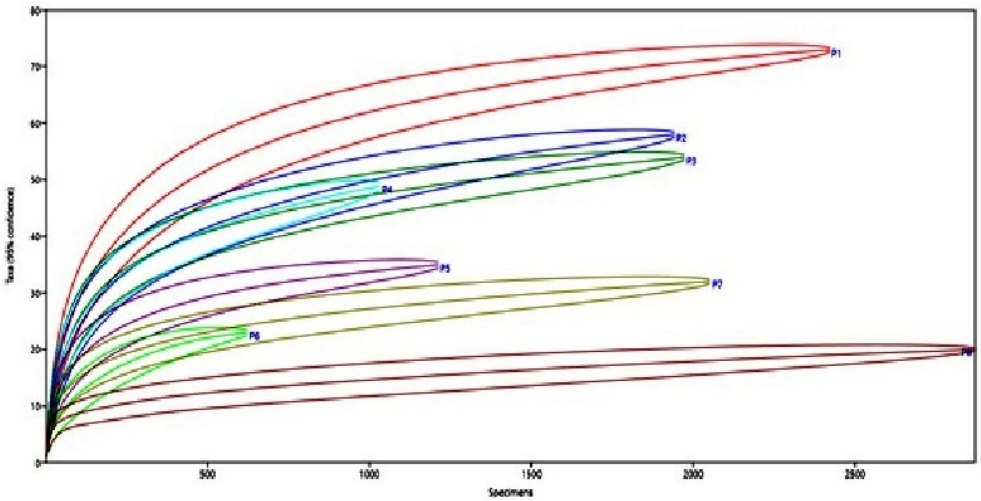

Figure 6. Individual rarefaction curves

The rarefaction curves for P1, P2, P3 and P4 were steeper than for the locations of P5, P7 and P6. The corresponding curves for both P7 and P8 showed early tendency to flatten (Figure 6).

The R value of one-way ANOSIM (Bray-Curtis) similarity index for grouped abundance samples stood at 0.7959 ($P< 0.001$), indicating a high level of dissimilarity between the grouped samples. The Jaccard similarity and distance indices landscape wise comparison indicated large dissimilarity between UR and WW at 0.29. The comparative figures between TM and WW stood at 0.55and that between TM and UR stood at 0.44.

At patch level, the maximum dissimilarity was seen between P1 and P8, at 0.21; next between P2 and P8, at 0.24, then between P1 and P6, at 0.25. In relative terms, P6 had more similarity with P7, P5 and P8. The urban landscapes of P8 and P7 were closer to each other, at 0.53 as depicted in Table 2.

Species richness and abundance were higher for resident and winter migrants in the locations of P1, P2 and P3 and P4. Bird abundance was low in P6, P5 and P4 in both categories. P7 and P8 area had lower resident species numbers, with high abundances. P6 and P8 were least hospitable towards winter migrants. A lone passage visitor was found in P1 as depicted in Table 3.

Table 2. The Jaccard similarity and distance indices at patch level

P1	P2	P3	P4	P5	P6	P7	P8
P1	0.42	0.41	0.49	0.29	0.25	0.28	0.21
P2		0.37	0.55	0.48	0.33	0.36	0.24
P3			0.39	0.29	0.28	0.41	0.30
P4				0.45	0.38	0.42	0.28
P5					0.45	0.49	0.41
P6						0.53	0.43
P7							0.53

Table 3. Patch-wise number of Resident species, Winter migaratory species and Passage visitor species

	P1	P2	P3	P4	P5	P6	P7	P8
Resident spedies	63	49	45	42	30	20	27	19
Resident species total	2285	1857	1820	971	1171	617	2010	2867
Winter migrants.	9	9	9	7	5	3	5	1
Winter migrants total	143	95	160	76	51	16	51	13
Passage visitors	1	0	0	0	0	0	0	0
Passage visitors total	2	0	0	0	0	0	0	0

Table 4. Endemic and IUCN red list species in different patches

	P1	P2	P3	P4	P5	P6	P7	P8
Endemic species no.	2	5	6	2	1	1	1	1
Endemics total	65	83	149	39	16	2	1	1
IUCN* Status NT/VU Species.	0	2	3	0	0	0	0	0
IUCN * Status NT/VU total	0	6	47	0	0	0	0	0

The maximum number of endemic species and their abundance was found in P3, followed by P2, P1 and P4. Only one endemic species each was recorded in P6, P7, P5 and P8. The species in the IUCN red-list were recorded only from P3 and P2 as shown in Table 4.

The number of frugivore species in the WW areas of P1, P2 and P3 stood at 13, 14 and 12, respectively. The TM areas had much lower recordings, except for P4 wherein the figure stood at 12 species: P5 and P6 recorded 6 and 2 species, respectively. For UR areas, the figures were low, with P7 and P8 accounting for 6 and 4 species, respectively. The insectivore species number peaked for P1, at 46 species, followed by similar areas of P2 and P3, at 30 and 32 species, respectively. Among the TM areas, P4 fared better, at 25 species, while the same for P5 and P6 stood at 17 and 12 species, respectively. In UR areas, P7 netted 16 species, while the value for P8 stood the lowest, at 7 species. Five omnivore species were seen in the UR areas of P7 and P8. P2 and P5 had 4 species each, while P1, P4 and P3 had 3 species each. P6 had the least number of omnivores, at 2 species. P1 recorded 3 nectarivore species. All other locations recorded 2 species of nectarivores each. UR areas had low carnivore and granivore species richness (Figure 7).

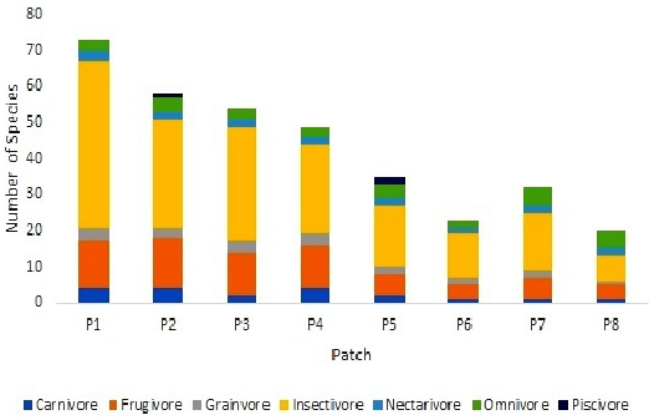

Figure 7. Feeding guild-number of bird species

The abundance of frugivores, insectivores, nectarivores and granivores was high in P1, P2 and P3 locations. Omnivore abundance was low in these areas. In general, P4, P5 and P6 had low bird abundance for all feeding guilds. In P7 and P8, the abundance of frugivores, insectivores and nectarivores was even lower, but the abundance of omnivores was substantially higher (Figure 8).

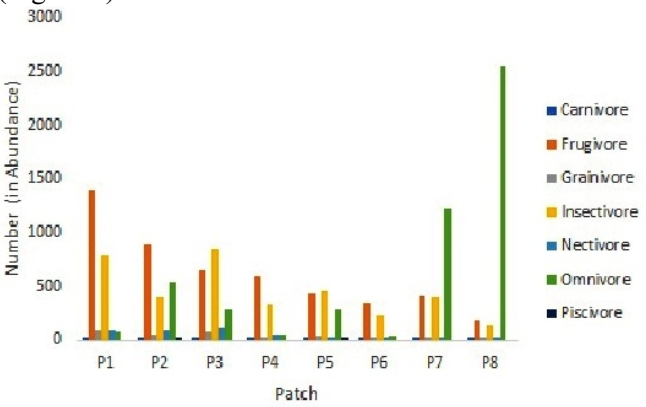

Figure 8. Feeding guild-abundance of birds

DISCUSSION

P1 and P2 patches, with their diversified canopy of trees, had higher bird richness and abundance than the TM patches of P4, P5 and P6. In P1, the en masse flowering of several giant *Ceiba pentandra* trees attracted several birds. This, along with presence of fruiting trees and nectar yielding trees like *Erythrinasp*. ensured diverse foraging options for birds. The micro-habitats provided by *Denrophthoe sp*. (parasitic plant) on *Dalbergia latifolia* and *Piper nigrum* vines on *Grevillea robusta* were also utilized by birds (especially small birds) for hiding and nesting purposes. Similar diversified tree canopy was observed in P2. The perennial flowering and fruiting of *Lantana camera* clumps, along with abundant presence of *Dendrophthoe sp*. on abandoned *Citrus X sinensis* trees, ensured higher bird counts here. Large-scale fruiting of *Syzygium sp* was also observed. P3, being a botanical garden, with 1,200 species of plants representing 86 families, its multi-layered canopy consisting of gigantic trees, followed by small trees, shrubs and sub-shrubs, along with freely flourishing undergrowth, ensured several micro-habitats for birds. In general, WW areas had higher bird richness and abundance. A similar trend was noticed in tea plantations in well-wooded diversified canopy areas.

In the case of P4, the dominant shade tree was *Grevillea robusta*, but the presence of a few fruit-bearing trees and the micro-habitats provided by the *Piper nigrum* vines on *Grevillea robusta* assured higher bird counts here than in other TM areas. Both P5 and P6 were typical monoculture tea estates, with *Grevillea robusta* as the dominant tree. However, in P6, most of the

Grevillea robusta were stunted in growth, several of them being reduced to dead stumps. L6 tea estate had the least shade and canopy cover. TM areas in general had very low bird abundance. P6 had the lowest abundance among all the eight sampling areas.

Tea, *Camellia sinensis,* is generally planted in the Nilgiris under the canopy of the monotypic shade tree of Silver Oak, *Grevillea robusta*. Tea bushes are kept pruned at a height of 1 metre, the next canopy level being occupied by *Grevillea robusta*. Compared with the erstwhile diverse multi-canopy forest areas, these plantation habitats offer little in terms of shade and micro-habitats. Tea plantations are a poor habitat for rainforest birds because of fallouts and fragmentation in landscapes (Raman 2006).

Bird richness in P7 was higher than in P8 because of the presence of various ornamental trees and shrubs (mostly non-native) in the household gardens. The P8 area had the lowest species richness count among all the samplings sites but had the highest levels of abundance. UR areas in general supported greater abundance, especially when compared with the TM areas.

The presence of semi-open dump yards and liberal food handouts from temples and houses in the urban areas enabled omnivores like *Passer domesticus*, *Columba livia*, *Acridotheres fuscus, Corvus splendens* and *Corvus culminates* to thrive. In mountainous areas like the Nilgiris, building side-walls are secured with rock slabs, and a gap is provided between the slabs for rainwater to drain away. These gaps are utilized by birds for nest building. The larger-sized gaps are used by *Columba livia*, and the smaller-sized gaps by both *Passer domesticus* and *Acridotheres fuscus* for nesting. The large numbers of the old type of tiled buildings and houses provided additional nesting opportunities for both *Passer domesticus* and *Columba livia*. These five omnivores contributed as much as 59.15% and 88.89% to bird abundance in the P7 and P8 locations, respectively.

The Coonoor Complex

The transects in the four locations of P3, P6, P7 and P8 in the Coonoor complex were close to each other, with minimal differences in altitude. Significant differences in bird composition were seen in these four areas. Both *Columba livia* and *Acridotheres fuscus*, which were abundant in P7 and P8, were not recorded in P3 (the transects of P8 and P3 were separated by 250 m). *Passer domesticus,* ranked number one in terms of abundance in the P8 and P7 locations, was not recorded in P6 (within 1 km of these areas). Similarly, *Columba livia* and *Acridotheres fuscus* were not recorded either in P6. Abundance of *Corvus culminates* and *Corvus splendens* at P7 was recordedat 180 and 134, respectively; the corresponding figures for P8 stood at 69 and 355. Most of the birds seen in P3 were not recorded in the other Coonoor complex locations. For example, the endemic birds and the birds listed under the IUCN threat categories observed in P3 were never found in the other Coonoor complex locations.

Birds seem to be micro-fine-tuned to their preferred habitat and see no reason to venture out into other locations. It was found recently that the geographical range of 17 of the 18 Western Ghats endemic birds was overestimated (Ramesh et al. 2017). The report further indicates that since the International Union for Conservation of (IUCN) red-list relies mostly on accuracy of geographic range, as many as 10 endemic species will probably require up-listing of their IUCN threat status. *Ficedula nigrorufa* wasrepeatedly sighted at the same locations in the P3 transec*t.* Anthropogenic land alterations have driven these birds into islands of preferred habitats. These birds may become susceptible to disease because of in-breeding (Robin et al. 2015).

Feeding Guilds

As many as 64 insectivore bird species were recorded in the entire study, accounting for 59% of the birds observed. The insectivore and frugivore species richness declined with intensification of land use. The insectivore species number was highest for P1, at 46 species, followed by similar areas of P2 and P3, at 30 and 32 species, respectively. Among the TM areas, P4 fared better than the others, at 25 species, while the counts for P7 and P5 stood at 17 and 12, respectively. Among the UR areas, P7 netted 16 species, while the count for the P8 area stood the lowest, at 7 species. With intensification of land use, a prominent decline in insectivore richness was found. In general, frugivores and insectivores are more vulnerable to extinction from degradation and loss of forests (Castelletta et al. 2000). The maximum number of omnivore species was seen in the urban areas of P7 and P8, at 5 species each. P2 and P5 had 4 species each, while P1, P4 and P3 had 3 species each. P6 had the least number of omnivores, at 2 species. This is in broad agreement with the view that omnivores are less affected by fragmentation than insectivores because of their broader dietary range (Sekercioglu et al.

2002). P1 recorded three nectarivore species, while all other locations recorded only two each.

Abundance of frugivores was highest in the WW areas of P1, P2 and P3. The abundance in P4, P5 and P6 was lower. In the case of the urban patches of P7 and P8, the figures plummeted sharply. Insectivore abundance was highest in P3 and P1, followed by P5, P2, P7 and P4. The TM area of P6 and urban town area of P8 had the lowest figures. The omnivore population was sharply higher in both the urban sampling areas of P8 and P7, accounting for as much as 89% and 59% of bird abundance here, respectively. Granivore abundance was higher in the WW areas. Species richness and abundance of carnivores were found to be minimal in urban landscapes.

Winter Migratory and Passage Visitors

Phylloscopus trochiloides was present in all locations and accounted for as much 49% of the total winter migrant recordings. Except for the P8 region, *Acrocephalus dumetorum* was present in all locations and accounted for another 13% of the winter migrant recordings. *Dicrurus leucophaeus* had its presence in all the WW areas and in P4 but was absent in the other TM and UR areas; it accounted for 11% of the total. *Motacilla cinerea,* accounted for 8% of the winter migrant count and was seen in four locations, with maximum recordings from P3. *Larvivora brunnea* was recorded only in P3 and P1. *Geokichla wardii,* a passage migrant, was recorded in P1. TM and UR areas showed little hospitality towards migratory birds.

Endemic Bird and Birds in the IUCN Threat List

Among the Western Ghats endemic birds, *Letocoma minima* was seen in all locations. *Tephrodornis fuscus* preferred lower altitudes; hence, only a few birds were recorded in P3. The P3 location had the highest number of endemic birds. Six species were recorded: *Letocoma minima,Pisttacula columboides*, *Ficedula nigrorufa*, Eumyias *albicaudatus*, *Columbia elphinstonii* and *Cyronis pallidipes*. The P2 site had five endemic birds to its credit. *Pycnonatus procephalus* and *Turdoides subrufa* were seen in only in P2, among the sites surveyed. The other birds recorded at P2 were *Eumyias albicaudatus, Letocoma minima* and *Pisttacula columboides*. The TM and UR areas extended little hospitality towards endemics. Three IUCN red-listed birds—*Ficedula nigrorufa*, *Eumyias albicaudatus* and *Columbia elphinstonii*—wererecorded in P3. P2 accounted for two: *Pycnonatus procephalus* and *Eumyias albicaudatus*. Birds under the IUCN red-list category accounted for only 0.37% of the total bird recordings.

Dominant Species and SIMPER Analysis

The output from SIMPER analysis indicates that the five omnivores, *Passer domesticus*, *Columba livia*, *Acridotheres fuscus, Cornus splendens,* and *Corvus culminates,* cumulatively contributed to 39.19% of the total dissimilarity among the eight different sites. If *Pycnonotus cafer* is included, then six birds account for 52.07% of the dissimilarity among the sites. Out of the total of 108 species recorded in the study, 64, or 59%, belonged to the insectivore category, their cumulative contribution to dissimilarity being only 28.32%. This indicates the low abundance of insectivores.

Up to the 80th percentile point of cumulative dissimilarity in the SIMPER analysis, only one endemic bird figured: *Leptocoma minima*, accounting for 1.76%. Similarly, only one winter migrant, *Phylloscopus trochiloides*, featured within the 80th percentile, with a score of 2.21%. The contribution of the eight endemics to the cumulative dissimilarity stood at 3.60%, and that of birds in the IUCN red-list category at 0.56%, in the study area.

CONCLUSION

Tea monoculture areas supported low species richness and abundance. In general, well wooded areas with diversified canopy (even in tea plantations) supported higher species richness and abundance. Urban landscapes supported a large abundance of a few species of birds. Both insectivore and frugivore species were sensitive to anthropogenic landscape alterations, while omnivores were much less effected.

Since all forest areas in Nilgiri District fall under NBR, further land conversion to plantations is unlikely. However, conversion of existing tea plantation areas into built-up spaces, both for residential and tourism-related activities, is taking place in many areas. Since land prices have escalated, future dwellings are unlikely to have substantial house garden areas. This does not augur well for the remaining few birds in this region. Tea gardens under the monotypic shade tree of Silver Oak support few bird species, and with low abundance.

Conversion of these areas into built-up areas will only serve to increase the abundance of a few omnivores.

The economics of tea plantation demand a double-canopy structure; the only viable option left to attract birds to these areas, then, is to increase the diversity of shade trees. On this front, extensive research on possible replacement or partial replacement of the Silver Oak, *Grevillea Robusta,* needs to be undertaken. Notably, in Bangladesh and in the sub-Himalayan areas, tea is mostly grown undershade of *Albizzia sp.* In Sri Lanka, which is much closer to the Western Ghats, a combination of *Grevillea robusta, Calliandra calothrysus, Erythrina lithosperma, Acacia sp, Albizia sp and Gliricida sepium* has been recommended (different combinations for different altitudes) by The Tea Research Institute of Sri Lanka, circular 2003. In the Nilgiris, *Grevillea robusta* is the recommended shade tree (recommended by UPASI Tea Research Foundation). *Erythrina indica* holds promise but has low timber value than *Grevillea robusta*. The ease of coppicing or removal ofshade tree species also depend on the complicated provisions of the Tamil Nadu Hill Area (Preservation of Trees) Act, 1955. Finding an economically viable model, considering these limitations, is difficult. Moreover, it is too far-fetched to imagine that the forest researchers, planters and lawmakers would work in unison for the betterment of avian diversity.

One silver lining is that large tea estates in the Nilgiris are now sensitive to biodiversity issues; fragmented forests inside estates are being preserved, and even bird-biodiversity records are being maintained. The government could encourage tea planters to take up organic farming, as ensuing certifications, such as Rainforest Alliance eco-certification, would ensure that native shade trees are present. Recently, the Government of India has initiated steps to promote organic farming in north-east region of India. A similar move to promote organic farming in vital districts falling under international biosphere areas in India would augur well for biodiversity.

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Common Name	Scientific name	P1	P2	P3	P4	P5	P6	P7	P8	IUCN 2016	Migratory status	Endemic	Feeding Guild
Ashy Drongo	*Dicrurus leucophaeus* Vieillot, 1817	13	9	28	16	0	0	0	0	LC	WV		I
Ashy Prinia	*Prinia socialis* Sykes, 1832	0	7	0	20	18	39	25	0	LC	R		I
Ashy Woodswallow	*Artamus fuscus* Vieillot, 1817	6	1	0	2	6	0	0	0	LC	R		I
Asian Fairy Bluebird	*Irena puella* (Latham, 1790)	11	2	0	8	0	0	0	0	LC	R		F
Banded Bay Cuckoo	*Cacomantis sonneratii* (Latham, 1790)	2	0	0	0	0	0	0	0	LC	R		I
Bar-Winged Flycatcher-Shrike	*Hemipus picatus* (Sykes, 1832)	13	0	15	1	0	1	0	0	LC	R		I
Bay-Backed Shrike	*Lanius vittatus* Valenciennes, 1826	0	1	0	0	1	0	0	0	LC	R		I
Black Drongo	*Dicrurus macrocercus* Vieillot, 1817	31	0	3	0	0	0	0	0	LC	R		I
Black Eagle	*Ictinaetus malaiensis* (Temminck, 1822)	3	0	0	3	2	0	1	0	LC	R		C
Black-And-Orange Flycatcher	*Ficedula nigrorufa* (Jerdon, 1839)	0	0	19	0	0	0	0	0	NT	R	E	I
Black-Headed Cuckooshrike	*Lalage melanoptera* (Rüppell, 1839)	2	0	0	0	0	0	0	0	LC	R		I
Black-Hooded Oriole	*Oriolus xanthornus* (Linnaeus, 1758)	3	0	0	0	0	0	0	0	LC	R		I
Black-Naped Monarch	*Hypothymis azurea* (Boddaert, 1783)	2	0	0	0	0	0	0	0	LC	R		I
Black-Rumped Flameback	*Dinopium benghalense* (Linnaeus, 1758)	4	0	0	0	0	0	0	0	LC	R		I
Black-Throated Munia	*Lonchura kelaarti* (Jerdon, 1863)	2	0	15	2	0	0	0	0	LC	R		G
Black-Winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	0	1	0	3	0	0	0	0	LC	R		C
Blue Rock Thrush	*Monticola solitarius* (Linnaeus, 1758)	0	1	0	11	4	0	0	0	LC	WV		I
Blue-Capped Rock Thrush	*Monticola cinclorhyncha* (Vigors, 1832)	2	0	1	0	0	0	0	0	LC	WV		I
Blyth's Reed Warbler	*Acrocephalus dumetorum* Blyth, 1849	15	13	20	6	17	2	14	0	LC	WV		I
Bonelli's Eagle	*Aquila fasciata* (Vieillot, 1822)	0	2	0	0	0	0	0	0	LC	R		C
Brahminy Kite	*Haliastur indus* (Boddaert, 1783)	0	1	0	0	0	1	0	0	LC	R		C
Bronzed Drongo	*Dicrurus aeneus* Vieillot, 1817	11	0	0	0	0	0	0	0	LC	R		I
Brown Shrike	*Lanius cristatus* Linnaeus, 1758	11	3	1	0	0	0	0	0	LC	WV		I
Brown-Breasted Flycatcher	*Muscicapa muttui* (Layard, 1854)	4	0	1	0	0	0	0	0	LC	WV		I
Brown-Capped Pygmy Woodpecker	*Picoides nanus* (Vigors, 1832)	3	1	4	0	0	0	0	0	LC	R		I
Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	0	1	0	0	0	0	0	0	LC	R		I
Chestnut-Headed Bee-Eater	*Merops leschenaulti* Vieillot, 1817	112	10	0	44	1	0	0	0	LC	R		I
Cinereous Tit	*Parus cinereus* Vieillot, 1818	1	0	76	1	2	2	7	1	LC	R		I
Common Goldenback	*Dinopium javanense* (Ljungh, 1797)	14	0	3	0	0	0	1	0	LC	R		I
Common Hoopoe	*Upupa epops* Linnaeus, 1758	5	11	5	0	0	0	2	1	LC	R		I
Common Iora	*Aegithina tiphia* (Linnaeus, 1758)	6	8	0	1	0	0	0	0	LC	R		I
Common Kestral	*Falco tinnunculus* Linnaeus, 1758	0	0	0	0	1	0	0	0	LC	R		C
Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	0	0	0	0	1	0	0	0	LC	R		P
Common Pigeon	*Columba livia* Gmelin, 1789	0	0	0	0	0	0	303	841	LC	R		O
Common Rosefinch	*Carpodacus erythrinus* (Pallas, 1770)	15	2	1	6	0	0	1	0	LC	WV		F
Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	36	0	1	9	0	0	0	0	LC	R		I
Common Woodshrike	*Tephrodornis pondicerianus* (Gmelin, 1789)	1	0	0	0	0	0	0	0	LC	R		I
Coppersmith Barbet	*Psilopogon haemacephalus* (Müller, 1776)	17	3	0	0	0	0	0	0	LC	R		F
Crested Goshawk	*Accipiter trivirgatus* (Temminck, 1824)	2	0	1	7	0	0	0	0	LC	R		C
Crested Treeswift	*Hemiprocne coronata* (Tickell, 1833)	85	0	0	0	0	0	0	0	LC	R		I
Crimson-Backed Sunbird	*Leptocoma minima* (Sykes, 1832)	8	33	98	11	16	2	1	1	LC	R	E	N
Emerald Dove	*Chalcophaps indica* (Linnaeus, 1758)	0	0	2	0	0	0	0	0	LC	R		F
Golden-Fronted Leafbird	*Chloropsis aurifrons* (Temminck, 1829)	28	6	0	5	0	0	0	0	LC	R		I
Greater Coucal	*Centropus sinensis* (Stephens, 1815)	2	1	0	1	0	0	0	0	LC	R		I
Greater Racket-Tailed Drongo	*Dicrurus paradiseus* (Linnaeus, 1766)	1	0	0	0	0	0	0	0	LC	R		I
Green Bee-Eater	*Merops orientalis* Latham, 1802	1	0	0	0	0	0	0	0	LC	R		I
Greenish Warbler	*Phylloscopus trochiloides* (Sundevall, 1837)	73	40	69	35	26	13	28	13	LC	WV		I
Grey Junglefowl	*Gallus sonneratii* Temminck, 1813	9	7	0	12	3	2	0	0	LC	R		G
Grey Wagtail	*Motacilla cinerea* Tunstall, 1771	0	9	34	0	5	0	1	0	LC	WV		I
Grey-Breasted Prinia	*Prinia hodgsonii* Blyth, 1844	10	0	0	2	0	0	0	0	LC	R		I
Grey-Headed Bulbul	*Pycnonotus priocephalus* (Jerdon, 1839)	0	4	0	0	0	0	0	0	NT	R	E	F
Grey-Headed Canary Flycatcher	*Culicicapa ceylonensis* (Swainson, 1820)	0	0	37	0	0	0	0	0	LC	R		I
House Crow	*Corvus splendens* Vieillot, 1817	3	27	1	0	1	2	69	355	LC	R		O

House Sparrow	*Passer domesticus* (Linnaeus, 1758)	0	252	207	3	138	0	542	1094	LC	R		O
Indian Blackbird	*Turdus simillimus* Jerdon, 1839	1	1	15	0	6	0	5	0	LC	R		I
Indian Blue Robin	*Larvivora brunnea* Hodgson, 1837	1	0	5	0	0	0	0	0	LC	WV		I
Indian Golden Oriole	*Oriolus kundoo* Sykes, 1832	9	2	0	1	0	0	0	0	LC	WV		I
Indian Jungle Crow	*Corvus culminatus* Sykes,1832	6	16	83	10	17	37	180	134	LC	R		O
Indian Pond Heron	*Ardeola grayii* (Sykes, 1832	0	4	2	1	0	0	1	0	LC	R		I
Indian Scimitar Babbler	*Pomatorhinus horsfieldii* Sykes, 1832	7	2	3	1	0	5	3	0	LC	R		I
Indian Yellow Tit	*Machlolophus aplonotus*(Blyth, 1847)	0	0	5	0	0	0	0	0	LC	R		I
Jungle Babbler	*Turdoides striata* (Dumont, 1823)	50	36	0	26	107	5	45	0	LC	R		I
Jungle Myna	*Acridotheres fuscus* (Wagler,1827)	60	235	0	39	130	0	125	136	LC	R		O
Legge's Hawk-Eagle	*Nisaetus kelaarti* Legge, 1878	1	0	0	0	0	0	0	0	LC	R		C
Lesser Yellownape	*Picus chlorolophus* Vieillot, 1818	1	2	0	0	0	0	0	0	LC	R		I
Long-Tailed Shrike	*Lanius schach* Linnaeus, 1758	0	16	0	1	6	1	7	0	LC	WV		I
Malabar Parakeet	*Psittacula columboides* (Vigors, 1830)	57	27	3	28	0	0	0	0	LC	R	E	F
Malabar Woodshrike	*Tephrodornis sylvicola* Jerdon, 1839	3	0	0	0	0	0	0	0	LC	R		I
Nilgiri Flowerpecker	*Dicaeum concolor* Jerdon, 1840	20	59	1	5	52	0	0	0	LC	R		F
Nilgiri Flycatcher	*Eumyias albicaudatus* Jerdon, 1840	0	2	19	0	0	0	0	0	NT	R	E	I
Nilgiri Wood Pigeon	*Columba elphinstonii* (Sykes, 1833)	0	0	9	0	0	0	0	0	VU	R	E	F
Orange Minivet	*Pericrocotus flammeus* (Forster, 1781)	65	0	0	12	0	0	0	0	LC	R		I
Oriental Honey-Buzzard	*Pernis ptilorhynchus* (Temminck, 1821)	0	2	1	6	0	0	0	0	LC	R		C
Oriental Magpie Robin	*Copsychus saularis* (Linnaeus, 1758)	27	28	32	33	13	0	0	1	LC	R		I
Oriental White-Eye	*Zosterops palpebrosus* (Temminck, 1824)	95	122	319	92	170	103	188	100	LC	R		I
Painted Bush Quail	*Perdicula erythrorhyncha* (Sykes, 1832)	0	0	0	0	0	0	2	0	LC	R		G
Pied Bushchat	*Saxicola caprata* (Linnaeus, 1766)	3	29	27	1	59	56	59	14	LC	R		I
Pied Thrush	*Geokichla wardii* (Blyth, 1842)	2	0	0	0	0	0	0	0	LC	PA		I
Pin-Striped Tit Babbler	*Macronous gularis* (Horsfield, 1822)	0	0	1	0	0	0	0	0	LC	R		I
Puff-Throated Babbler	*Pellorneum ruficeps* Swainson, 1832	9	0	3	0	0	0	0	0	LC	R		I
Purple Sunbird	*Cinnyris asiaticus* (Latham, 1790)	3	0	0	0	0	0	0	0	LC	R		N
Purple-Rumped Sunbird	*Leptocoma zeylonica* (Linnaeus, 1766)	75	49	16	30	3	3	9	2	LC	R		N
Red Spurfowl	*Galloperdix spadicea* (Gmelin, 1789)	3	2	0	0	0	0	0	0	LC	R		F
Red-Vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	218	75	11	74	39	5	38	14	LC	R		F
Red-Whiskered Bulbul	*Pycnonotus jocosus* (Linnaeus, 1758)	780	628	493	317	334	335	367	163	LC	R		F
Rose-Ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	5	0	6	1	3	0	1	1	LC	R		F
Rufous Babbler	*Turdoides subrufa* Jerdon,1839	0	17	0	0	0	0	0	0	LC	R	E	I
Scaly-Breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)	0	0	27	0	0	0	0	0	LC	R		G
Shaheen Falcon	*Falco peregrinus peregrinator* Sundevall, 1837	0	0	0	0	0	0	0	1	LC	R		C
Shikra	*Accipiter badius* (Gmelin, 1788)	1	0	0	0	0	0	0	0	LC	R		C
Small Minivet	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	1	0	0	0	0	0	0	0	LC	R		I
Southern Hill Myna	*Gracula indica* (Cuvier, 1829)	53	0	0	52	0	0	0	0	LC	R		F
Spotted Dove	*Spilopelia chinensis* (Scopoli, 1786)	55	29	32	2	26	10	18	2	LC	R		G
Square-Tailed Bulbul	*Hypsipetes ganeesa* Sykes, 1832	0	1	48	0	4	0	0	0	LC	R		F
Streak-Throated Woodpecker	*Picus xanthopygaeus* (Gray & Gray, 1846)	5	11	0	5	2	2	0	0	LC	R		I
Tawny-Bellied Blabbler	*Dumetia hyperythra* (Franklin, 1831)	5	0	0	0	0	0	0	0	LC	R		I
Tickell's Blue Flycatcher	*Cyornis tickelliae* Blyth, 1843	0	0	28	2	0	0	2	0	LC	R		I
Tricoloured Munia	*Lonchura malacca* (Linnaeus, 1766)	22	4	0	0	0	0	0	0	LC	R		G
Velvet-Fronted Nuthatch	*Sitta frontalis* Swainson, 1820	9	0	14	0	0	0	0	0	LC	R		I
Vernal Hanging Parrot	*Loriculus vernalis* (Sparrman, 1787)	97	23	17	34	0	2	2	0	LC	R		F
White-Bellied Blue Flycatcher	*Cyornis pallidipes* (Jerdon, 1840)	0	0	1	0	0	0	0	0	LC	R	E	I
White-Breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	0	1	0	0	6	0	0	0	LC	R		I
White-Browed Bulbul	*Pycnonotus luteolus* (Lesson, 1841)	0	2	0	2	0	0	0	0	LC	R		F
White-Browed Wagtail	*Motacilla maderaspatensis* Gmelin, 1789	0	0	5	0	0	0	0	0	LC	R		I
White-Cheeked Barbet	*Psilopogon viridis* (Boddaert, 1783)	101	51	57	62	9	3	7	2	LC	R		F
White-Spotted Fantail	*Rhipidura albogularis* (Lesson, 1832)	0	0	49	0	0	2	7	4	LC	R		I
White-Throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	0	6	0	0	1	0	0	0	LC	R		P
Yellow-Browed Bulbul	*Acritillas indica* (Jerdon, 1839)	13	14	6	1	0	0	0	0	LC	R		F
Total number of birds		2430	1952	1980	1047	1229		633	2061	2880			
Number of species		73	58	54	49	35	23	32	20				

IUCN - International Union for Conservation of Nature : LC- Least Concern; NT- Near Threatened; VU- Vulnerable; E- Endemic to Western Ghats ;

R- Resident; WV- Winter visitor; PA- Passage visitor; I - Insectivore; F- Frugivore; G- Granivore; C- Carnivore; N- Nectivore; O- Omnivore; P- Piscivore.