Diversity and adundance of avifauna in terrestrial habitats of Ludhiana district in Punjab, India

India harbours 7–8% of the recorded species of the world and hence, is among the 17 mega diverse countries with four biodiversity hotspots, i.e., Western Ghats, Himalayas, Indo-Burma region, and Sundaland. Out of total animal species, bird species in India makes over 13% of the world's bird diversity with 1,300 known bird species (Grimmett & Inskipp 2010).

In Punjab, the avian fauna is represented by 428 known species (Edake 2015). The scrutiny of relevant literature revealed that though a number of workers compiled their work on avian fauna but no consolidated work has been attempted to document the terrestrial bird species especially after the green revolution in Punjab in general and district Ludhiana in particular except some scattered works by Whistler (1919), Dhindsa et al. (1988), Kler (2006, 2009), Kler & Kumar (2015a,b). It seems important to conduct fresh surveys to document the bird diversity of district as well as state as deforestation occurred widely for the expansion of agricultural fields in and after 1960s and the intensification of agriculture created extensive homogenous agricultural areas. This destruction and deterioration of habitats resulted in loss and decline in number of bird species from the State; however, some species also became more adapted to the changed ecological conditions. Hence, an attempt has been made to study the avian diversity of terrestrial habitats in district

Ludhiana located in the Malwa region of Punjab.

Monthly surveys have been conducted to document avian diversity of agricultural habitats and forest habitats in study area during the span of four years from May 2016 to April 2020. To conduct these surveys, four sites were selected from agricultural habitats and two sites from forest habitats. The study sites were identified on the basis of vegetation cover, anthropogenic activities and lack of information about avian diversity prevailing in those areas.

Agricultural habitat: The main crops sown in the area includes wheat, maize, rice, barley, sugarcane, potato etc. in different seasons. Four line transects were selected in the agricultural sites in the study area.

Site-1 (S1) Lalheri to Majra line transect: This site is permanent narrow path starting from village Lalheri to village Majra falling in Khanna tehsil of the district. It is located 12 km towards east from Khanna between 30.71°N & 76.24°E. The line transect is marked by the presence of agricultural fields.

ii. Site-2 (S2) Seh to Majra line transect: The site also includes agricultural fields around the line transect. The area falls under Samrala tehsil of district Ludhiana. The site is located 9 km from Samrala between 30.76°N & 76.23°E.

iii. Site-3 (S3) Malakpur line transect: The line transect is also a straight path along agricultural fields of village Malakpur. This village falls under Payal tehsil of district. It is located 18 km away from Payal between 30.56°N & 76.10°E.

iv. Site-4 (S4) Chuhrpur line transect: The village Chuhrpur falls under Ludhiana West tehsil and shares its boundaries with Ludhiana city. It is located 11 km towards east from Ludhiana city between 30.94°N & 75.79°E.

Forest habitat: The selected forest region falls in village Mattewara of Ludhiana East tehsil. The main plantation in this forest includes *Eucalyptus* sp. Two sites, i.e., Site 1 (S5) and Site 2 (S6) were selected in this forest area for the present studies.

Site 1: It is located between 30.99°N & 75.97°E. **Site 2:** It is located between 30.99°N & 75.96°E.

The bird diversity was explored using line transect method (Buckland et al. 2001). All birds seen, heard or in flight are recorded. The collected data including species name, number of individuals and habitat type was recorded in the field diary. Olympus 10X50 DPS binoculars were used to avoid disturbance to the birds. Field photography was done with the help of a DSLR camera Canon 60d. Various field guides (Ali & Ripley 1987; Ali 2002; Grimmett & Inskipp 2010; Grimmett et al. 2011) have been used to identify the bird species and not even a single species of bird was captured or killed during this investigation. The conservation status of bird species has been assigned as per IUCN Red List status 2020.

The following statistical indices were used to measure species diversity in a community. These indices are also important to describe rarity and commonness of different species in a given community and act as vital tool for biologists to understand community structures (Anthal 2017).

(i) Shannon-Wiener diversity index (H'): This is an important diversity index to account the number of individuals and number of taxa of a community. It varies from 0 to higher values depending on number of present taxa. The formula for Shannon's index is:

 $H' = -[\Sigma Pi lnPi]$

where H' = Shannon's diversity index, Pi = Relative abundance, InPi = Natural logarithm of this proportion

(ii) Margalef's species richness index (Margalef 1958): This index is used to calculate the species richness, i.e., the number of species present in a particular habitat.

Rmf(d') = S-1/ln(N)

where S = Total number of species, In = Natural log, N = Total number of individuals in the sample

(iii) Pielou's evenness index (Pielou 1969): It is used to calculate evenness which indicates relative abundance or proportion of individuals among the species.

$$E = H'/In S$$

where H' = Index of diversity of Shannon-Wiener, In = Natural log, S = Total number of species

(iv) Berger-Parker index of dominance (Berger & Parker 1970): It is used to calculate the number of individuals of dominant taxon relative to the total number of individuals of a community. The

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formula is given below. d = Nmax/N where d = Berger-Parker index, Nmax = Number

of individuals in the most abundant species, N = Total number of individuals in a community.

During present studies, a total of 96 species referable to 14 orders and 39 families from the terrestrial habitats including agricultural and forest line transects has been recorded (Table 1). Order Passeriformes is found to have maximum number of species, i.e., 54 species belonging to 18 families. Out of 96 species, one species, i.e., Alexandrine Parakeet Palaeornis eupatria belongs to 'Near Threatened' category where as the remaining 95 species belong to 'Least Concern' category. Other studies in the region are of Whistler (1919), Dhindsa et al. (1988), Kler (2006), Kler (2009), Kler & Kumar (2015a,b). Similar studies conducted in other states of India found 117 species of terrestrial birds from northern Bengal (Roy et al. 2012), 41 species of birds from Chandertal Wildlife Sanctuary-cum-wetland in Trans-Himalayan cold desert region of Himachal Pradesh (Rana et al. 2014), 104 species from Telangana (Narayana et al. 2015), 139 species from Uttar Pradesh (Yashmita-Ulman & Singh 2021), and 63 species from Maharashtra (Khabade et al. 2022).

The collected data subjected to Shannon diversity index showed that all the study sites were highly diverse and the values are summarized in Table 2. On comparison of the diversity index of all the study sites, it has been found that site 3 (3.638) is highly diverse followed by site 1 (3.512), site 4 (3.431), site 2 (3.375), site 6 (3.229) and site 5 (3.098).

Similarly, the values of Margalef's Richness Index showed that site 1 (7.495) have more number of species than site 2 (6.591) followed by site 4 (5.887), site 3 (5.279), site 5 (5.078) and site 6 (4.789) possess least number of species. Hence, it is observed in the present study that agricultural habitat have more number of species as compared to forest habitat (Table 1). It has been concluded that the agricultural habitats in the study area form agricultural mosaics with combination of natural vegetations, various cropping patterns, irrigated fields and rural residential areas and thus provide number of nesting, feeding and roosting sites and ultimately harbour abundant avian diversity. After Green Revolution, the conversion of forest lands or woody patches into agricultural areas ultimately affected the avian species in the district which prefers forest or undisturbed woody areas. The area under forest cover in district as well as in state is reduced to less than 5%. Moreover, the work of highway building project also affected the presence of different bird species at transect sites 5 and 6 of Mattewara forest in the study area. On the basis Pielou's evenness index, it is found that all the study sites possess an even distribution and dispersal of species. All the values are near 1 i.e., site 3 (0.916) followed by site 4 (0.845), site 6 (0.821), site 1 (0.816) and site 2 and site 5 (0.805) each. As per Berger-Parker index the results showed that site 5 (0.121) has higher index of dominance as compared to site 2 (0.085), site 6 (0.077), site 1 (0.075), site 4 (0.074) and site 3 (0.069).

While surveying to explore the avian diversity in the study area, number of threats causing

Table 1: Distribution of recorded avian species in studied sites.

	Common name	Scientific name	IUCN List	IUCN Agriculatual List Habitats			Forest Habitats		
			status 2020	S1 S2 S3 S4			S5	S6	
1.	Indian Pond Heron	Ardeola grayii (Sykes, 1832)	LC	+	+	+	+	+	+
2.	Black-crowned Night Heron	Nycticorax nycticorax (Linnaeus,1758)	LC	+	+	+	+	-	-
3.	Cattle Egret	Bubulcus ibis (Linnaeus,1758)	LC	+	+	+	+	+	+
4.	Intermediate Egret	Ardea intermedia Wagler, 1829	LC	+	-	-	+	-	-
5.	Little Egret	<i>Egretta garzetta</i> (Linnaeus, 1766)	LC	-	+	-	-	-	-
6.	Red-naped Ibis	Pseudibis papillosa (Temminck, 1824)	LC	+	+	+	+	-	-
7.	Spot-billed Duck	Anas poecilorhyncha Forster, 1781	LC	+	+	+	+	-	-
8.	Lesser Whistling Duck	Dendrocygna javanica (Horsfield, 1821)	LC	+	+	+	+	-	-
9.	Black-winged Kite	Elanus caeruleus (Desfontaines, 1789)	LC	+	-	-	+	-	-
10.	Black Kite	Milvus migrans (Boddaert, 1783)	LC	+	+	+	+	+	+
11.	Shikra	Accipiter badius (Gmelin, 1788)	LC	-	+	+	-	+	+
12.	White-eyed Buzzard	Butastur teesa (Franklin, 1831)	LC	-	-	-	-	-	+
13.	Grey Francolin	Francolinus pondicerianus (Gmelin, 1789)	LC	+	+	+	+	+	+
14.	Indian Peafowl	Pavo cristatus Linnaeus, 1758	LC	+	+	-	-	+	+
15.	White-breasted Waterhen	Amaurornis phoenicurus (Pennant, 1769)	LC	+ + + +		-	-		
16.	Black-winged Stilt	Himantopus himantopus (Linnaeus, 1758)	LC + + +		+	+	+		
17.	Red-wattled Lapwing	Vanellus indicus (Boddaert, 1783)	LC + + + +		+	+	+		
18.	Ruff	Calidris pugnax (Linnaeus, 1758)	LC - +		-	-	-		
19.	Common Snipe	Gallinago gallinago (Linnaeus, 1758)	LC +		-	-	-		
20.	Green Sandpiper	Tringa ochropus Linnaeus, 1758	LC	-	-	-	-	+	+
21.	Rock Pigeon	Columba livia Gmelin, 1789	LC	+	+	+	+	+	+
22.	Yellow-footed Green Pigeon	Treron phoenicopterus (Latham, 1790)	LC + +		+	+			
23.	Eurasian Collared Dove	Streptopelia decaocto (Frivaldszky, 1838)	LC + + + +		+	+			
24.	Spotted Dove	Spilopelia chinensis (Scopoli, 1786)	LC	-	-	-	-	+	+
25.	Laughing Dove	Spilopelia senegalensis (Linnaeus, 1766)	LC	+	-	+	+	-	-
26.	Alexandrine Parakeet	Palaeornis eupatria (Linnaeus, 1766)	NT	+	-	-	-	+	+
27.	Rose-ringed Parakeet	Alexandrinus krameri (Scopoli, 1769)	LC	+	+	+	+	+	+
28.	Greater Coucal	Centropus sinensis (Stephens, 1815)	LC	+	+	+	+	+	+
29.	Asian Koel	Eudynamys scolopaceus (Linnaeus, 1758)	LC	+	+	+	+	+	+
30.	Common Barn Owl	Tyto alba (Scopoli, 1769)	LC	+	-	-	-	-	-
31.	Spotted Owlet	thene brama (Temminck, 1821) LC - + +		-	+	+			
32.	Indian Grey Hornbill	Ocyceros birostris (Scopoli, 1786) LC + - +		+	+	+			
33.	Common Hoopoe	Upupa epops Linnaeus, 1758	LC + + - +		+	-	-		
34.	White-breasted Kingfisher	Halcyon smyrnensis (Linnaeus, 1758)	LC	LC + + + +		-	-		
35.	Pied Kingfisher	Ceryle rudis (Linnaeus, 1758)	LC	+		-	-		
36.	Green Bee-eater	Merops orientalis Latham, 1802	LC	+	+	+	+	+	+
37.	Indian Roller	Coracias benghalensis (Linnaeus, 1758)	LC	+	-	-	+	+	+
38.	Coppersmith Barbet	Psilopogon haemacephalus (Müller, 1776)	LC	-	+	+	-	+	+

	Common name	Scientific name	IUCN	Agriculatual Habitats			Forest		
			status				Нар		
			2020	51	52	55	54	55	30
39.	Brown-headed Barbet	Psilopogon zeylanicus (Gmelin, 1788)	LC	-	+	+	-	+	+
40.	Eurasian Wryneck	Jynx torquilla Linnaeus, 1758	LC	+	-	-	-	-	-
41.	Black-rumped Flameback	Dinopium benghalense (Linnaeus, 1758)	LC	-	-	-	-	+	+
42.	Brown-capped Pygmy Woodpecker	Picoides nanus (Vigors, 1832)	LC	-			+	+	
43.	Wire-tailed Swallow	Hirundo smithii Leach, 1818	LC	+	+	+	+	-	-
44.	Barn Swallow	Hirundo rustica Linnaeus, 1758	LC	+	+	-	+	-	-
45.	Streak-throated Swallow	Petrochelidon fluvicola (Blyth, 1855)	LC	+	+	-	-	-	-
46.	Tree Pipit	Anthus trivialis (Linnaeus, 1758)	LC	+	+	-	-	-	-
47.	Paddyfield Pipit	Anthus rufulus Vieillot, 1818	LC	+	-	+	+	-	-
48.	Yellow Wagtail	<i>Motacilla flava</i> Linnaeus, 1758	LC	+	+	+	+	-	-
49.	Citrine Wagtail	Motacilla citreola Pallas, 1776	LC	+	+	-	+	-	-
50.	White-browed Wagtail	Motacilla maderaspatensis Gmelin, 1789	LC	+	+	-	-	-	-
51.	White Wagtail	Motacilla alba Linnaeus, 1758	LC	+	+	+	+	-	-
52.	Red-vented Bulbul	Pycnonotus cafer (Linnaeus, 1766)	LC	+	+	+	+	+	+
53.	Common Chiffchaff	Phylloscopus collybita (Vieillot, 1817)	LC	+	+	-	-	-	-
54.	Grey-hooded Warbler	Phylloscopus xanthoschistos (Gray, 1846)	LC	LC -		-	-	-	+
55.	Sulphur-bellied Warbler	Phylloscopus griseolus Blyth, 1847	LC	+	-	-	-	-	+
56.	Hume's Leaf Warbler	Phylloscopus humei (Brooks, 1878)	LC	-	-	-	-	-	+
57.	Bay-backed Shrike	Lanius vittatus Valenciennes, 1826	LC	-	-	-	-	+	+
58.	Long-tailed Shrike	Lanius schach Linnaeus, 1758	LC	+	+	+	+	+	+
59.	Rufous-tailed Shrike	Lanius isabellinus Ehrenberg, 1833	LC	+	-	-	+	-	-
60.	Oriental Magpie Robin	Copsychus saularis (Linnaeus, 1758)	LC	LC + - + +		+	+	+	
61.	Indian Robin	Saxicoloides fulicatus (Linnaeus, 1766)	LC	+ - + +		+	+		
62.	Red-breasted Flycatcher	Ficedula parva (Bechstein, 1792)	LC	- +		-	-		
63.	Bluethroat	Cyanecula svecica (Linnaeus, 1758)	LC	+	+	+	+	-	-
64.	Black Redstart	Phoenicurus ochruros (Gmelin, 1774)	LC	-	-	+	-	+	+
65.	Pied Bushchat	Saxicola caprata (Linnaeus, 1766)	LC	+	+	+	+	+	+
66.	Common Stonechat	Saxicola torquatus (Linnaeus, 1766)	LC	+	+	+	+	-	-
67.	Brown Rock Chat	Oenanthe fusca (Blyth, 1851)	LC	+ + + +		-	-		
68.	Jungle Babbler	Turdoides striata (Dumont, 1823)	LC	+	-	+	-	+	+
69.	Common Babbler	Argya caudata (Dumont, 1823)	LC +		-	-			
70.	Rufous-fronted Prinia	Prinia buchanani Blyth, 1844	LC	LC + + - +		-	-		
71.	Yellow-bellied Prinia	Prinia flaviventris (Delessert, 1840)	LC +		-	-			
72.	Ashy Prinia	Prinia socialis Sykes, 1832	LC + + - +		-	-			
73.	Plain Prinia	Prinia inornata Sykes, 1832	LC	+ + + +		+	+		
74.	Common Tailorbird	Orthotomus sutorius (Pennant, 1769)	LC	+ + + +		+	+		
75.	Zitting Cisticola	Cisticola juncidis (Rafinesque, 1810)	LC	+ + + +		+	+		
76.	Purple Sunbird	Cinnyris asiaticus (Latham, 1790)	LC	+ + + +		+	+		
77.	Indian Silverbill	Euodice malabarica (Linnaeus, 1758)	LC	+	+	+	+	-	-
78.	Scaly-breasted Munia	Lonchura punctulata (Linnaeus, 1758)	LC	+	+	+	+	-	-

	Common name	Common name Scientific name		Agriculatual Habitats				Forest Habitats	
			status 2020	S1	S2	S 3	S4	S5	S 6
79.	House Sparrow	Passer domesticus (Linnaeus, 1758)	LC	+ + + +		+	+		
80.	Sind Sparrow	Passer pyrrhonotus Blyth, 1844	LC	+	+ + + +		-	-	
81.	Chestnut-shouldered Petronia	Gymnoris xanthocollis (Burton, 1838)	LC				+	+	
82.	Streaked Weaver	Ploceus manyar (Horsfield, 1821)	LC	- +				-	-
83.	Baya Weaver	Ploceus philippinus (Linnaeus, 1766)	LC	+	+	+	+	-	-
84.	Common Starling	Sturnus vulgaris Linnaeus, 1758	LC	+	+	-	-	-	-
85.	Asian Pied Starling	Gracupica contra (Linnaeus, 1758)	LC	+	+	+	+	+	+
86.	Brahminy Starling	Sturnia pagodarum (Gmelin, 1789)	LC	+	-	-	-	-	-
87.	Common Myna	Acridotheres tristis (Linnaeus, 1766)	LC	+	+	+	+	+	+
88.	Bank Myna	Acridotheres ginginianus (Latham, 1790)	LC	+	+	+	+	+	+
89.	Eurasian Golden Oriole	Oriolus oriolus (Linnaeus, 1758)	LC	+	+	-	+	-	-
90.	Black Drongo	Dicrurus macrocercus Vieillot, 1817	LC	+	+	+	+	+	+
91.	Rufous Treepie	Dendrocitta vagabunda (Latham, 1790)	LC	+	+	+	+	+	+
92.	Large-billed Crow	Corvus macrorhynchos Wagler, 1827	LC	-	-	-	-	+	+
93.	House Crow	Corvus splendens Vieillot, 1817	LC	+	+	+	+	+	+
94.	Red-headed Bunting	Emberiza bruniceps Brandt, 1841	LC	+	+	-	-	-	-
95.	Ashy-crowned Sparrow Lark	Eremopterix griseus (Scopoli, 1786) LC		-	-	-	-	+	+
96.	Crested Lark	Galerida cristata (Linnaeus, 1758)	LC	-	+	-	-	-	-
	Total			74	66	53	58	47	51
Recorded (+) Not Recorded (-)									



Species diversity, evenness, richness and dominance in study sites during year May 2016 to April 2020.

loss of bird species has been observed. These threats are mainly anthropogenic such as deforestation, extensive agriculture, excessive use of pesticides, stubble burning, deterioration of natural habitats, pollution and urbanization etc. Jerath et al. (2014) also concluded that the factors such as increased urbanization, change in land use pattern, degradation of natural habitats and pollution, increased demand of timber, deforestation, invasive alien species, poaching, illegal trade of wildlife products, forest fires and encroachments, soil erosion in Shivalik tracts are affecting the forests and wildlife in Punjab. Many studies in other parts of

Diversity Indices	Study sites					
	S1	S2	S3	S4	S5	S6
Species number (N)	74	66	53	58	47	51
Shannon diversity Index	3.512	3.375	3.638	3.431	3.098	3.229
Pielou's evenness index	0.816	0.805	0.916	0.845	0.805	0.821
Margalef's Richness Index	7.495	6.591	5.279	5.887	4.789	5.078
Berger-Parker index	0.075	0.085	0.069	0.074	0.121	0.077

Table 2: Avian diversity and richness at agricultural and forest transect sites in district Ludhiana, Punjab.

the world also observed the modern agriculture as one of the main threats for biological diversity and considered its effect comparable to extensive climate changes (Donald et al. 2002; Donald et al. 2006; Wretenberg et al. 2006). Other workers correlated the decrease in bird populations in Western and Northern Europe with extensive changes in land use and landscape structure (Chamberlain & Fuller 2000; Fuller et al. 1995; Virkkala et al. 2004).

Keeping in mind, various threats to birdlife in the study area, it is need of the hour to initiate suitable steps. As most of the bird species are dependent on native plants for feeding, roosting and nesting. Hence, the plantation of native plants should be encouraged in the region. To increase population of uncommon or rare bird species in the district such as Alexandrine Parakeet, Common Barn Owl, Golden Oriole and Chestnut-shouldered Petronia, it is recommended that different plants associated/ preferred by such species must be grown to provide them favourable foraging, roosting and nesting sites. Environmental awareness and educational programmes are also recommended to educate local people of the state about importance of different bird species and the plants associated with them.

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Sandeep Kaur Thind¹, Charn Kumar² & Amritpal Singh Kaleka³

 ^{1&3} Department of Zoology and Environmental Sciences, Punjabi University, Patiala, Punjab 147002, India.
 ² Department of Biology, A.S. College, Khanna, Ludhiana, Punjab 141401, India.

Email: ³apskaleka@gmail.com (corresponding author)

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