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Avifaunal Diversity in Kolkata and Its Urban Extensions: A Cross-Sectional Study

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ABSTRACT

Kolkata Metropolis is one of the largest urban settlements in South-eastern Asia at the lower Gangatic planes. With a history of 350 years of urban development, the city witnessed rapid extension of its urban boundaries for last couple of decades. In this study, we documented and compared the avifauna diversity of core urban settlements and its expanding peripheral sub-urban regions through cross-sectional sampling, listing, ranking, plotting and diversity indexing. About 140 species of birds were found in the area within the study period. The urban core showed lower diversity than peripheral sub-urban regions. Diversity pattern showed that sub-urban avifauna community contained high number of rarer species than core urban Kolkata. Notably, avifauna community in urban core is indicating a more stable community structure in comparison to its sub-urban counterpart. So with higher diversity, the outer Kolkata possesses more fragile avifauna community. These findings indicated that the shock of urbanization of distant past might have recovered by avifauna community of Kolkata and adjusted to a lesser diversity, but avifauna of its sub-urban fringes are now in more susceptible state.

Key Words: Avifauna, Kolkata, Diversity, Community

INTRODUCTION

Diversity of fauna is one of the most important ecological indicators to evaluate the quality of habitats or more precisely Health of the Ecosystem (EHA) (Jørgensen et al. 2011). Among them Avifauna are highly mobile species capable to appear or disperse in any location in quick succession. Therefore they are considered as the quick responders to any of the environmental or anthropogenic perturbation in an area. In general, the class AVES contain more species distributed over nearly the entire Earth than other class of Vertebrates and possess about 9930 species worldwide (Collar et al. 1997). The Indian subcontinent with diverse environmental conditions, wide altitudinal differences, varied climate, vegetation and habitat diversity and geographical position cater over 1300 species of birds with about 80 endemic species (Grimmett et al. 2011). However, with the rapidly growing population of India and anthropogenic interventions in fastr pace of urbanization and expansion of human habitat the birds here facing an unprecedented pressure of habitat loss throughout the country.

The state of West Bengal, situated at the eastern part of the country shows a major diversity of birds consisting of about 800 species of varied types despite its relatively smaller size, mostly because of its stretched geographic existence from the Bay of Bengal to the Himalayan mountain tops containing wide habitat and vegetation diversity (Home A, 2006). Kolkata is the capital of the state which has a history of urbanization in the bank of lower gangetic planes for around 350 years from the time of British colonial rules in India. Kolkata metropolis is an important socio-economic city and one of the highest population dense areas of India which is rapidly going under a phase of urban extension of its periphery in last 15-20 years. Where Kolkata Municipal Corporation (KMC) directly controls 205 Km^2 areas, satellite townships like Salt-lake and newly added Rajarhat-Newtown comprise another 50 Km^2 (Haque et al, 2019). However, the total urban and semi-urban belt adjoining Kolkata metropolis known as greater Kolkata is spread over 1,800 sq. km. and comprises of, (i) the conurbation area, stretching in a linear manner along the east-west bank of Hooghly river

and (ii) the rural/semi-urban areas lying as a ring around the conurbation area (Comprehensive Mobility Plan, 2008), and consists of about 14.85 million population (www.worldpopulationreview.com). Though different areas have varied population density, the core Kolkata possesses an incredible density of 26,000 people/Km^2. The diversity of avifauna in such a region is expected to be much less due to massive anthropogenic interventions. At the same time, the avifauna found frequent in this region will be considered as the adaptive ones with urbanization and suitable candidates for the region in this Anthropocene era (Richard M, 2015).

The primary aim of our study was to find the avifauna diversity in this vast area of Kolkata metropolis and compare such diversity with the highly urbanized inner core and peripheral urban to semi-urban landscapes. With the cross-sectional sampling approach a rough estimation of distributional abundance of the identified avifauna species had been done to get an estimation of avifauna community structure in urban core and peripheral urban to semi-urban areas and converting landforms of the region.

STUDY AREAS

Our study areas are primarily the 'Greater Kolkata', which includes the jurisdiction of Kolkata Municipal Corporation (KMC), satellite townships of Salt Lake and Rajarhat-Newtown and peripheral municipal areas comprising about 1800 Km^2 as mentioned previously. These areas are divided into two categories – (i) Urban, by definition, is a human settlement with high population density and infrastructure of built environment; and (ii) Sub-urban, that is a mixed-use or residential area, existing either as part of a city or urban area or as a separate residential community within commuting distance of a city surrounded by rural belts.

Four spots from each category were selected for their characteristic availability of birds in 'urban refuges' or parks or open landscapes or river banks within this region. They are as follows –

In Urban Areas –

a) Chintamoni Kar Bird Sanctuary (CKBS) [22.4293° N, 88.4007° E] is located in southern border of KMC area in Narendrapur, South 24, of only 17 acres, originally given the status of sanctuary in 1982.
b) Shyamkhola [22.4249° N, 88.3896° E] in South 24 Pargans is a rural pocket at southern extreme of Kolkata metropolis with stretches of wetlands, farmlands and natural vegetation catering local birds, passers and migrants.
c) Rabindra Sarobar lake [22.5121° N, 88.3637° E] and adjoining park of about 73 acres with sufficient vegetation within the densely populated core of Kolkata city surrounded by residential and commercial settlements.
d) Maidan [22.5448° N, 88.3426° E] is over 100 acres of open land with crosscutting roads lined by large trees and monumental architecture including Victoria Memorial Hall and almost at the centre of Kolkata city.

In Sub-urban Areas –

a) Rajarhat Wetlands with several lakes and grasslands adjacent to the newly built satellite township of Kolkata. The site was around Kadampur village [22.5754° N, 88.4798° E] in within this area.
b) Boshipota village in Serampur-Uttarpara [22.7541° N, 88.3389° E] block at the west side of Hoogly River (lower part of Ganges) with stretches of cultivable lands around.
c) Barrackpore (industrial) belt in the east side of Hoogly river, which has many commercial lands, either active or abandon and few cultivable areas and lowlands stretching from Icchapore [22.8010° N, 88.3699° E] to Belgharia [22.6670° N, 88.3796° E]. Several spots of the area had been visited with the observation made along the river banks.
d) Halisahar [22.9295° N, 88.4249° E], at the northern extreme of sub-urban periphery of greater Kolkata having low grassy wetlands.

METHODS

Data Collection and Documentation

Observations in this cross-sectional study had been made for the period of November, 2018 to April, 2019 within the areas mentioned. Timings of observations were from 7 am to 10:30 am in the morning and 3 pm to 5:30 pm in the afternoon. Each spots were visited thrice during the period of study and sampling were done by point and line transact methods. Line transact were found most effective per unit effort of data collection and each sampling areas were traversed with at least 9 line transacts of 100 m each (Soka et al. 2013). As Barrackpore belt is a large stretch of urban to semi-urban area where 4 spots were visited separately with portions of river banks, each visited at least twice during that period. Detecting and identifying birds were by manual entry and camera capture and identified using standard

field guides on birds of Indian subcontinent (Grimmett et al, 2011, Ali S, 2002).

Data Analysis and Classification

The abundance of birds was calculated on the cumulative observation number of each bird species during the study period in the above mentioned observation spots of two zones. The frequencies of abundance or relative abundance were calculated for each species against the total observation and the ranking of abundance were done on such relative abundance values.

$$\text{Relative Abundance of } i^{\text{th}} \text{ species } (p_i) = \frac{\text{Numbers of individuals in } i^{\text{th}} \text{ species}}{\text{Total number of individuals of all species (N)}}$$

After ranking the species they were classified as per their availability or relative abundance into a four grading system, namely, –

i) Highly Frequent, where $(p_i) \geq 0.02$
ii) Frequent, where $(p_i) < 0.02$ to ≥ 0.005
iii) Rare, where $(p_i) < 0.005$ to ≥ 0.001
iv) Very rare, where $(p_i) < 0.001$

Community Analysis of Avifauna in Two Zones

Whittaker Plot or rank abundance curve was used to analyse the avifauna community with the depiction of species richness and evenness (Whittaker, 1965; Rajashekara and Venkatesham, 2017). Bird diversity and community was analysed by Shannon's Diversity Index (H_S) which indicated that whether the communities were natural or not and where they were positioned in the natural range of community values (Shannon, 1948; Krebs, 1989; Sax, 2002). This index also emphasised on rare objects, hence reflects the weightage of both dominant and rare species in the index value to analyse any community.

$$H_S = -\sum p_i (ln\, p_i) \quad {}^{i=1}_{S}$$

Where, p_i = Relative Abundance of i^{th} species,
ln = Natural logarithm
S = Species richness or total number of species in community

The Shannon's Equitability (E_H) of such community has been calculated as H_S/H_{max} i.e., $H_S/ln(S)$, depicting the evenness of individuals among species in the community had been calculated for these two community.

The values of Shannon's Index (H_S) and Equitability (E_H) of both the zones were compared and analysed with Whittaker Plots.

RESULTS

Avifauna Diversity and Abundance

The observations on avifauna diversity of both urban and sub-urban regions found 121 species of birds in the outer periphery of Kolkata where the urban core regions documented 73 species during this short period of study. Overall, around 140 species were observed in both the regions during the period. Importantly, the number of highly frequent species with relative abundance $(p_i) \geq 0.02$, was only 9 in sub-urban zones where there were 12 such highly frequent species observed in urban Kolkata, though the species richness was high in outer sub-urban zone. However, most of the highly frequent species are common in both the region among which Common Myna and House Crow are super-dominant in both zones. As per the defined scale there were 32 frequent species in sub-urban zone and 15 frequent species found in urban Kolkata; 48 rare species in sub-urban and 25 rare species in urban Kolkata; and 32 species were very rare in sub-urban Kolkata in contrast to 21 species in its urban counterpart. The list of avifauna observed in the study has been tabulated in Table 1 and Table 2 with their relative abundance values and classification. Photographs of birds taken from sites of observation has been shown in Figure 1 with a classification of per their abundance (such classification in Figure – 1 may not synchronize exactly with Tables as the figure plate with birds' photographs include both the zones within the same plate).

Community Analysis

Whittaker Plot depicting the Rank Abundance of avifauna community of urban and sub-urban Kolkata has been plotted in Figure 2a and b. Both the plots are showing a highly concave nature with a very sharp peak and a flattened long tail with shorter intermediate curvature. Therefore, both the plots are indicating for very few highly dominating species and a large number of rarer species with some intermediate species distribution in-between. In both cases first couple of species disastrously breaks the evenness of the community where the long tail shows high evenness. From Figure 2a it is clearly seen that the tail of the curve comprising of rare species are much longer that its counterpart shown in Figure 2b. Hence, sub-urban area was visited by higher number of species with very low abundance. The Shannon's index (H_S) values calculated for both communities in Table 1 and 2 are 3.441186655 and 3.020723075 for sub-urban and urban Kolkata respectively. The values show that both the communities were within the range of natural

Table 1: Avifauna Community Diversity in Sub-urban Areas around Kolkata Metropolis

Sl. No.	Order	Name	Scientific Name	Abundance	Frequency	Comment	$p_i \ln p_i$
1	Passeriformes	Common myna	*Eudynamys scolopaceus*	500	0.282007896	Highly frequent	-0.356971294
2	Passeriformes	House crow	*Milvus migrans*	100	0.056401579	Highly frequent	-0.162169098
3	Psittaciformes	Rose ringed paraket	*Corvus splendens*	86	0.048505358	Highly frequent	-0.146781143
4	Columbiformes	Rock pegion	*Pycnonotus cafer*	80	0.045121263	Highly frequent	-0.139803797
5	Passeriformes	Asian pied starling	*Streptopelia orientalis*	60	0.033840948	Highly frequent	-0.114588283
6	Passeriformes	Jungle babbler	*Microcarbo niger*	55	0.031020869	Highly frequent	-0.107738428
7	Passeriformes	Red vented bulbul	*Acridotheres tristis*	50	0.02820079	Highly frequent	-0.100631848
8	Passeriformes	Black drongo	*Gracupica contra*	40	0.022560632	Highly frequent	-0.085539738
9	Suliformes	Little cormorant	*Megalaima asiatica*	37	0.020868584	Highly frequent	-0.080751203
10	Coraciiformes	Green bee eater	*Psittacula krameri*	35	0.019740553	Frequent	-0.077483254
11	Passeriformes	Red whiskered bulbul	*Turdoides striata*	35	0.019740553	Frequent	-0.077483254
12	*Pelecaniformes*	Cattle egret	*Bubulcus ibis*	32	0.018048505	Frequent	-0.072459196
13	*Pelecaniformes*	Pegion	*Columba livia*	32	0.018048505	Frequent	-0.072459196
14	Ciconiiformes	Asian openbill stork	*Anastomus oscitans*	30	0.016920474	Frequent	-0.069022521
15	Passeriformes	Black hooded oriole	*Spilopelia chinensis*	25	0.014100395	Frequent	-0.060089573
16	Coraciiformes	White breasted kingfisher	*Merops orientalis*	22	0.012408347	Frequent	-0.054465023
17	*Columbiformes*	Spotted dove	*Oriolus xanthornus*	20	0.011280316	Frequent	-0.050588788
18	Pelecaniformes	Indian pond heron	*Dicrurus macrocercus*	20	0.011280316	Frequent	-0.050588788
19	Passeriformes	Barn swallow	*Hirundo rustica*	20	0.011280316	Frequent	-0.050588788
20	Passeriformes	Plain prinia	*Prinia inornata*	18	0.010152284	Frequent	-0.046599558
21	Passeriformes	Oriental magpie robin	*Dendrocitta vagabunda*	16	0.009024253	Frequent	-0.042484735
22	Charadriiformes.	Bronze winged jacana	*Metopidius indicus*	15	0.008460237	Frequent	-0.04037545
23	Charadriiformes	Red watted lapwing	*Vanellus indicus*	15	0.008460237	Frequent	-0.04037545
24	Piciformes	Blue throated barbet	*Orthotomus sutorius*	14	0.007896221	Frequent	-0.038228535
25	Passeriformes	Rofos treepie	*Copsychus saularis*	14	0.007896221	Frequent	-0.038228535
26	Passeriformes	House sparrow	*Passer domesticus*	13	0.007332205	Frequent	-0.0360413
27	Passeriformes	Common tailorbird	*Acridotheres fuscus*	12	0.00676819	Frequent	-0.033810639
28	Passeriformes	Black headed benting	*Emberiza melanocephala*	12	0.00676819	Frequent	-0.033810639
29	Anseriformes	Mallard	*Anas platyrhynchos*	12	0.00676819	Frequent	-0.033810639
30	Passeriformes	Jungle myna	*Acridotheres fuscus*	11	0.006204174	Frequent	-0.031532919
31	*Cuculiformes*	Greater caucal	*Ardeola grayii*	10	0.005640158	Frequent	-0.029203854
32	Passeriformes	Purple sunbird	*Halcyon smyrnensis*	10	0.005640158	Frequent	-0.029203854
33	Cuculiformes	Asian koel	*Eudynamys scolopaceus*	10	0.005640158	Frequent	-0.029203854
34	Accipitriformes	Black kite	*Milvus migrans*	10	0.005640158	Frequent	-0.029203854
35	Passeriformes	Yellow headed benting	*Teretistris fernandinae*	10	0.005640158	Frequent	-0.029203854
36	Charadriiformes	Pheasent tailed jacana	*Hydrophasianus chirurgus*	10	0.005640158	Frequent	-0.029203854
37	Passeriformes	Bank myna	*Acridotheres ginginianus*	10	0.005640158	Frequent	-0.029203854
38	Passeriformes	Baya weaver	*Ploceus philippinus*	10	0.005640158	Frequent	-0.029203854
39	Piciformes	Black rumped flameback	*Dinopium benghalense*	10	0.005640158	Frequent	-0.029203854
40	*Piciformes*	Lineated barbet	*Megalaima lineata*	9	0.005076142	Frequent	-0.026818292
41	Passeriformes	House sparrow	*Passer domesticus*	9	0.005076142	Frequent	-0.026818292
42	Passeriformes	White rumped munia	*Lonchura striata*	8	0.004512126	Rare	-0.024369933
43	Passeriformes	Tri coloured munia	*Lonchura malacca*	8	0.004512126	Rare	-0.024369933
44	Passeriformes	Purple rumped sunbird	*Leptocoma zeylonica*	8	0.004512126	Rare	-0.024369933
45	Passeriformes	Long tailed shrike	*Lanius schach*	8	0.004512126	Rare	-0.024369933
46	Podicipediformes	Little grabe	*Tachybaptus ruficollis*	7	0.003948111	Rare	-0.021850892
47	Passeriformes	Indian silverbill	*Euodice malabarica*	7	0.003948111	Rare	-0.021850892
48	Passeriformes	Cheastnut tailed starling	*Sturnia malabarica*	7	0.003948111	Rare	-0.021850892
49	Passeriformes	Large billed crow	*Corvus macrorhynchos*	7	0.003948111	Rare	-0.021850892
50	Passeriformes	Straited grassbird	*Megalurus palustris*	6	0.003384095	Rare	-0.019250996

51	Passeriformes	Paddy field pipet	*Anthus rufulus*	6	0.003384095	Rare	-0.019250996
52	Caprimulgiformis	Asian palm swift	*Amaurornis phoenicurus*	6	0.003384095	Rare	-0.019250996
53	Passeriformes	Scaly breasted munia	*Lonchura punctulata*	5	0.002820079	Rare	-0.016556657
54	Passeriformes	Bengal bushlark	*Mirafra assamica*	5	0.002820079	Rare	-0.016556657
55	Strigiformes	Spotted owlet	*Athene brama*	5	0.002820079	Rare	-0.016556657
56	Piciformes.	Coppersmith barbet	*Megalaima haemacephala*	5	0.002820079	Rare	-0.016556657
57	Passeriformes	White wagtail	*Motacilla alba*	5	0.002820079	Rare	-0.016556657
58	Bucerotiformes	Common hoopoe	*Upupa epops*	5	0.002820079	Rare	-0.016556657
59	Passeriformes	Brown shrike	*Lanius cristatus*	5	0.002820079	Rare	-0.016556657
60	Passeriformes	Yellow wagtail	*Motacilla flava*	4	0.002256063	Rare	-0.01374875
61	Passeriformes	Zilting cisticola	*Cisticola juncidis*	4	0.002256063	Rare	-0.01374875
62	Passeriformes	White rumped munia	*Lonchura striata*	4	0.002256063	Rare	-0.01374875
63	Columbiformes	Eurasian collered dove	*Streptopelia decaocto*	3	0.001692047	Rare	-0.010798333
64	Falconiformes	Peregrine falcon	*Falco peregrinus*	3	0.001692047	Rare	-0.010798333
65	Pelecaniformes	Yellow bittern	*Ixobrychus sinensis*	3	0.001692047	Rare	-0.010798333
66	Passeriformes	Citrine wagtail	*Motacilla citreola*	3	0.001692047	Rare	-0.010798333
67	Ciconiiformes	Wally necked strok	*Ciconia episcopus*	3	0.001692047	Rare	-0.010798333
68	Coraciiformes	Indo chinise roller	*Corvus benghalensis*	3	0.001692047	Rare	-0.010798333
69	Columbiformes	Yellow footed green pegion	*Treron phoenicoptera*	3	0.001692047	Rare	-0.010798333
70	Pelecaniformes	Little egret	*Egretta garzetta*	3	0.001692047	Rare	-0.010798333
71	*Piciformes*	Fulvous brested woodpecker	*Dendrocopos macei*	3	0.001692047	Rare	-0.010798333
72	Passeriformes	Orange headed thrush	*Geokichla citrina*	3	0.001692047	Rare	-0.010798333
73	Passeriformes	Asian brown flycatcher	*Muscicapa latirostris*	3	0.001692047	Rare	-0.010798333
74	Coraciiformes	Common kingfisher	*Alcedo atthis*	3	0.001692047	Rare	-0.010798333
75	Passeriformes	Blyth reed wabbler	*Acrocephalus dumetorum*	2	0.001128032	Rare	-0.00765627
76	Accipitriformes	Shikra	*Accipiter badius*	2	0.001128032	Rare	-0.00765627
77	*Piciformes*	Eurasian wryneek	*Jynx torquilla*	2	0.001128032	Rare	-0.00765627
78	Passeriformes	Red avadavat	*Amandava amandava*	2	0.001128032	Rare	-0.00765627
79	Coraciiformes	Indian roller	*Coracias benghalensis*	2	0.001128032	Rare	-0.00765627
80	Passeriformes	Siberian stone chat	*Saxicola maurus*	2	0.001128032	Rare	-0.00765627
81	Passeriformes	Blue throat	*Luscinia svecica*	2	0.001128032	Rare	-0.00765627
82	Passeriformes.	Oriental white eye	*Zosterops palpebrosus*	2	0.001128032	Rare	-0.00765627
83	Charadriiformes	Common sandpiper	*Actitis hypoleucos*	2	0.001128032	Rare	-0.00765627
84	Cuculiformes	Common hawk cuckoo	*Hierococcyx varius*	2	0.001128032	Rare	-0.00765627
85	Passeriformes	Black naped oriole	*Oriolus chinensis*	2	0.001128032	Rare	-0.00765627
86	Passeriformes	Taiga fly catcher	*Ficedula albicilla*	2	0.001128032	Rare	-0.00765627
87	Passeriformes	Black red start	*Phoenicurus ochruros*	2	0.001128032	Rare	-0.00765627
88	Passeriformes	Little spiderhunter	*Arachnothera longirostra*	2	0.001128032	Rare	-0.00765627
89	Passeriformes	Indian paradise flycatcher	*Terpsiphone paradisi*	2	0.001128032	Rare	-0.00765627
90	Cuculiformes	Plantitive cuckoo	*Cacomantis merulinus*	1	0.000564016	Very Rare	-0.004219081
91	Anseriformes	Cotton pygmy goose	*Nettapus coromandelianus*	1	0.000564016	Very Rare	-0.004219081
92	Passeriformes	Olive backed pipet	*Anthus hodgsoni*	1	0.000564016	Very Rare	-0.004219081
93	Passeriformes	Oriental skylark	*Alauda gulgula*	1	0.000564016	Very Rare	-0.004219081
94	*Pelecaniformes*	Black headed ibis	*Threskiornis melanocephalus*	1	0.000564016	Very Rare	-0.004219081
95	*Accipitriformes*	*Pied harrier*	*Circus melanoleucos*	1	0.000564016	Very Rare	-0.004219081
96	Anseriformis	Gangarey	*Anas galericulata*	1	0.000564016	Very Rare	-0.004219081
97	Passeriformes	Ashy prinia	*Prinia socialis*	1	0.000564016	Very Rare	-0.004219081
98	Passeriformes	Ashy crowened sparrow lark	*Eremopterix griseus*	1	0.000564016	Very Rare	-0.004219081
99	Passeriformes	Common babbler	*Turdoides caudata*	1	0.000564016	Very Rare	-0.004219081
100	*Accipitriformes*	Oriental honey	*Pernis ptilorhynchus*	1	0.000564016	Very Rare	-0.004219081
101	Charadriiformes	Common snipe	*Gallinago gallinago*	1	0.000564016	Very Rare	-0.004219081

102	Passeriformes	Crested bunting	*Melophus lathami*	1	0.000564016	Very Rare	-0.004219081
103	Passeriformes	Pale billed flower peaker	*Dicaeum erythrorhynchos*	1	0.000564016	Very Rare	-0.004219081
104	Coraciiformes	Stork billed kingfisher	*Pelargopsis capensis*	1	0.000564016	Very Rare	-0.004219081
105	Passeriformes	Common iora	*Aegithina tiphia*	1	0.000564016	Very Rare	-0.004219081
106	Passeriformes	Indian golden oriole	*Oriolus kundoo*	1	0.000564016	Very Rare	-0.004219081
107	Passeriformes	Grey backed shrike	*Lanius tephronotus*	1	0.000564016	Very Rare	-0.004219081
108	Passeriformes	Scarlet backed flowerpecker	*Dicaeum cruentatum*	1	0.000564016	Very Rare	-0.004219081
109	Ciconiiformes	Painted stork	*Mycteria leucocephala*	1	0.000564016	Very Rare	-0.004219081
110	Passeriformes	Cinerous tit	*Parus cinereus*	1	0.000564016	Very Rare	-0.004219081
111	*Piciformes*	Greater flameback	*Chrysocolaptes guttacristatus*	1	0.000564016	Very Rare	-0.004219081
112	*Piciformes*	Lesser flameback	*Dinopium benghalense*	1	0.000564016	Very Rare	-0.004219081
113	Passeriformes	Racket tailed drongo	*Dicrurus paradiseus*	1	0.000564016	Very Rare	-0.004219081
114	*Gruiformes*	White brested waterhen	*Amaurornis phoenicurus*	1	0.000564016	Very Rare	-0.004219081
115	Charadriiformes	Oriental patincole	*Glareola maldivarum*	1	0.000564016	Very Rare	-0.004219081
116	*Gruiformes*	Purple swarphen	*Porphyrio porphyrio*	1	0.000564016	Very Rare	-0.004219081
117	Anseriformes	Northern shoveler	*Anas clypeata*	1	0.000564016	Very Rare	-0.004219081
118	Charadriiformes	Wood sandpiper	*Tringa glareola*	1	0.000564016	Very Rare	-0.004219081
119	Anseriformes	Ferruginous pochard	*Aythya nyroca*	1	0.000564016	Very Rare	-0.004219081
120	Passeriformes	Common rose finch	*Carpodacus erythrinus*	1	0.000564016	Very Rare	-0.004219081
121	Passeriformes	Streaked weaver	*Ploceus manyar*	1	0.000564016	Very Rare	-0.004219081
			$\sum p_i \ln p_i$				-3.441186655
			Shannon's Diversity Index (H_s)				3.441186655
			Shannon's Equitability Index (E_H)				0.71754315

Table 2: Avifauna Community Diversity within Kolkata Metropolis

Sl. No.	Order	Common Name	Scientific Name	Abundance	Frequency	Comments	$p_i \ln p_i$
1	Passeriformes	Common myna	*Eudynamys scolopaceus*	321	0.312257	Highly Frequent	-0.363444888
2	Passeriformes	House Crow	*Milvus migrans*	75	0.072957	Highly Frequent	-0.19099304
3	Psittaciformes	Rose ringed parakeet	*Corvus splendens*	65	0.06323	Highly Frequent	-0.174576538
4	Columbiformes	Rock pigeon	*Pycnonotus cafer*	54	0.052529	Highly Frequent	-0.154770914
5	Passeriformes	Asian pied starling	*Streptopelia orientalis*	40	0.038911	Highly Frequent	-0.126323717
6	Passeriformes	Jungle babbler	*Microcarbo niger*	40	0.038911	Highly Frequent	-0.126323717
7	Passeriformes	Red vented bulbul	*Acridotheres tristis*	32	0.031128	Highly Frequent	-0.108003189
8	Passeriformes	Black drongo	*Gracupica contra*	30	0.029183	Highly Frequent	-0.103137652
9	Suliformes	Little cormorant	*Megalaima asiatica*	29	0.02821	Highly Frequent	-0.100655502
10	Coraciiformes	Green bee eater	*Psittacula krameri*	26	0.025292	Highly Frequent	-0.09300544
11	Passeriformes	Red whiskered bulbul	*Turdoides striata*	24	0.023346	Highly Frequent	-0.087718617
12	Ciconiiformes	Painted stork	*Mycteria leucocephala*	21	0.020428	Highly Frequent	-0.079482259
13	*Pelecaniformes*	Cattle egret	*Columba livia*	17	0.016537	Frequent	-0.067837337
14	Passeriformes	Black hooded oriole	*Spilopelia chinensis*	18	0.01751	Frequent	-0.070827655
15	Coraciiformes	White breasted kingfisher	*Merops orientalis*	18	0.01751	Frequent	-0.070827655
16	*Columbiformes*	Spotted dove	*Oriolus xanthornus*	16	0.015564	Frequent	-0.064789737
17	Pelecaniformes	Indian pond heron	*Dicrurus macrocercus*	13	0.012646	Frequent	-0.055268259
18	Passeriformes	Oriental magpie robin	*Dendrocitta vagabunda*	12	0.011673	Frequent	-0.051950416
19	Piciformes	Blue throated barbet	*Orthotomus sutorius*	10	0.009728	Frequent	-0.045067362
20	Passeriformes	Rofos treepie	*Copsychus saularis*	10	0.009728	Frequent	-0.045067362
21	Passeriformes	Common tailorbird	*Acridotheres fuscus*	10	0.009728	Frequent	-0.045067362
22	Passeriformes	Jungle myna		10	0.009728	Frequent	-0.045067362
23	*Cuculiformes*	Greater caucal	*Ardeola grayii*	10	0.009728	Frequent	-0.045067362
24	Passeriformes	Purple sunbird	*Halcyon smyrnensis*	10	0.009728	Frequent	-0.045067362

25	Cuculiformes	Asian koel	*Eudynamys scolopaceus*	10	0.009728	Frequent	-0.045067362
26	Accipitriformes	Black kite	*Milvus migrans*	8	0.007782	Frequent	-0.03778894
27	Charadriiformes.	Bronze winged jacana	*Metopidius indicus*	8	0.007782	Frequent	-0.03778894
28	*Gruiformes*	Purple swarphen	*Porphyrio porphyrio*	5	0.004864	Rare	-0.025905149
29	Passeriformes	Purple rumped sunbird	*Leptocoma zeylonica*	5	0.004864	Rare	-0.025905149
30	Passeriformes	House sparrow	*Passer domesticus*	5	0.004864	Rare	-0.025905149
31	Passeriformes	Asian brown flycatcher	*Muscicapa latirostris*	4	0.003891	Rare	-0.021591506
32	*Piciformes*	Lineated barbet	*Megalaima lineata*	4	0.003891	Rare	-0.021591506
33	Strigiformes	Spotted owlet	*Athene brama*	3	0.002918	Rare	-0.017031948
34	Passeriformes	Brown brested flycatcher	*Muscicapa muttui*	3	0.002918	Rare	-0.017031948
35	Passeriformes	Taiga flycatcher	*Ficedula albicilla*	3	0.002918	Rare	-0.017031948
36	Passeriformes	Paddy field pipit	*Anthus rufulus*	3	0.002918	Rare	-0.017031948
37	Piciformes	Lesser flameback	*Dinopium benghalense*	3	0.002918	Rare	-0.017031948
38	Caprimulgiformes	Asian palm swift	*Cypsiurus balasiensis*	3	0.002918	Rare	-0.017031948
39	Ciconiiformes	Asian openbill stork	*Anastomus oscitans*	3	0.002918	Rare	-0.017031948
40	Passeriformes	Indian pitta	*Pitta brachyura*	2	0.001946	Rare	-0.012146892
41	Passeriformes	Orange headed thrush	*Geokichla citrina*	2	0.001946	Rare	-0.012146892
42	Passeriformes	Asian brown flycatcher	*Muscicapa latirostris*	2	0.001946	Rare	-0.012146892
43	Passeriformes	Fire throat	*Luscinia pectardens*	2	0.001946	Rare	-0.012146892
44	Passeriformes	Yellow wagtail	*Motacilla flava*	2	0.001946	Rare	-0.012146892
45	Passeriformes	Cinerous tit	*Parus cinereus*	2	0.001946	Rare	-0.012146892
46	Coraciiformes	Common kingfisher	*Alcedo atthis*	2	0.001946	Rare	-0.012146892
47	*Piciformes*	Coppersmith barbet	*Megalaima haemacephala*	2	0.001946	Rare	-0.012146892
48	Passeriformes	Cheastnut tailed starling	*Sturnia malabarica*	2	0.001946	Rare	-0.012146892
49	Piciformes	Black rumped flameback	*Dinopium benghalense*	2	0.001946	Rare	-0.012146892
50	Passeriformes	Long tailed shrike	*Lanius schach*	2	0.001946	Rare	-0.012146892
51	Anseriformes	Mallard	*Anas platyrhynchos*	2	0.001946	Rare	-0.012146892
52	Columbiformes	Yellow footed green pegion	*Treron phoenicoptera*	2	0.001946	Rare	-0.012146892
53	Passeriformes	Black naped monarch	*Hypothymis azurea*	1	0.000973	Very Rare	-0.006747878
54	Passeriformes	Taiga fly catcher	*Ficedula albicilla*	1	0.000973	Very Rare	-0.006747878
55	Ciconiiformes	Painted stork	*Mycteria leucocephala*	1	0.000973	Very Rare	-0.006747878
56	Passeriformes	White throated fantail	*Rhipidura albicollis*	1	0.000973	Very Rare	-0.006747878
57	Caprimulgiformes	Indian nightjar	*Caprimulgus asiaticus*	1	0.000973	Very Rare	-0.006747878
58	Strigiformes	Brown fish owl	*Bubo zeylonensis*	1	0.000973	Very Rare	-0.006747878
59	Suliformes	Oriental darter	*Anhinga melanogaster*	1	0.000973	Very Rare	-0.006747878
60	Gruiformes	Common moorhen	*Gallinula chloropus*	1	0.000973	Very Rare	-0.006747878
61	Pelecaniformes	Black crowned night heron	*Nycticorax nycticorax*	1	0.000973	Very Rare	-0.006747878
62	Psittaciformes	Alexandrian parakeet	*Psittacula eupatria*	1	0.000973	Very Rare	-0.006747878
63	Gruiformes	Water cock	*Gallicrex cinerea*	1	0.000973	Very Rare	-0.006747878
64	Suliformes	Little cormorant	*Microcarbo niger*	1	0.000973	Very Rare	-0.006747878
65	Passeriformes	Verditter flycatcher	*Eumyias thalassinus*	1	0.000973	Very Rare	-0.006747878
66	Passeriformes.	Blue capped rock thrush	*Monticola cinclorhynchus*	1	0.000973	Very Rare	-0.006747878
67	Passeriformes	Tickele's thrush	*Turdus unicolor*	1	0.000973	Very Rare	-0.006747878
68	Passeriformes	Indian paradise flycatcher	*Terpsiphone paradisi*	1	0.000973	Very Rare	-0.006747878
69	Passeriformes	White throated fantail	*Rhipidura albicollis*	1	0.000973	Very Rare	-0.006747878
70	Passeriformes	Citrine wagtail	*Motacilla citreola*	1	0.000973	Very Rare	-0.006747878
71	Piciformes	Greater flameback	*Chrysocolaptes guttacristatus*	1	0.000973	Very Rare	-0.006747878
72	Passeriformes	Tickel's blue flycatcher	*Cyornis tickelliae*	1	0.000973	Very Rare	-0.006747878
73	Strigiformes	Barn owl	*Tyto alba*	1	0.000973	Very Rare	-0.006747878
						$\sum p_i \ln p_i$	-3.020723075
						Shannon's Diversity Index	3.020723075
						Shannon's Equitability Index (E_H)	0.7040558515

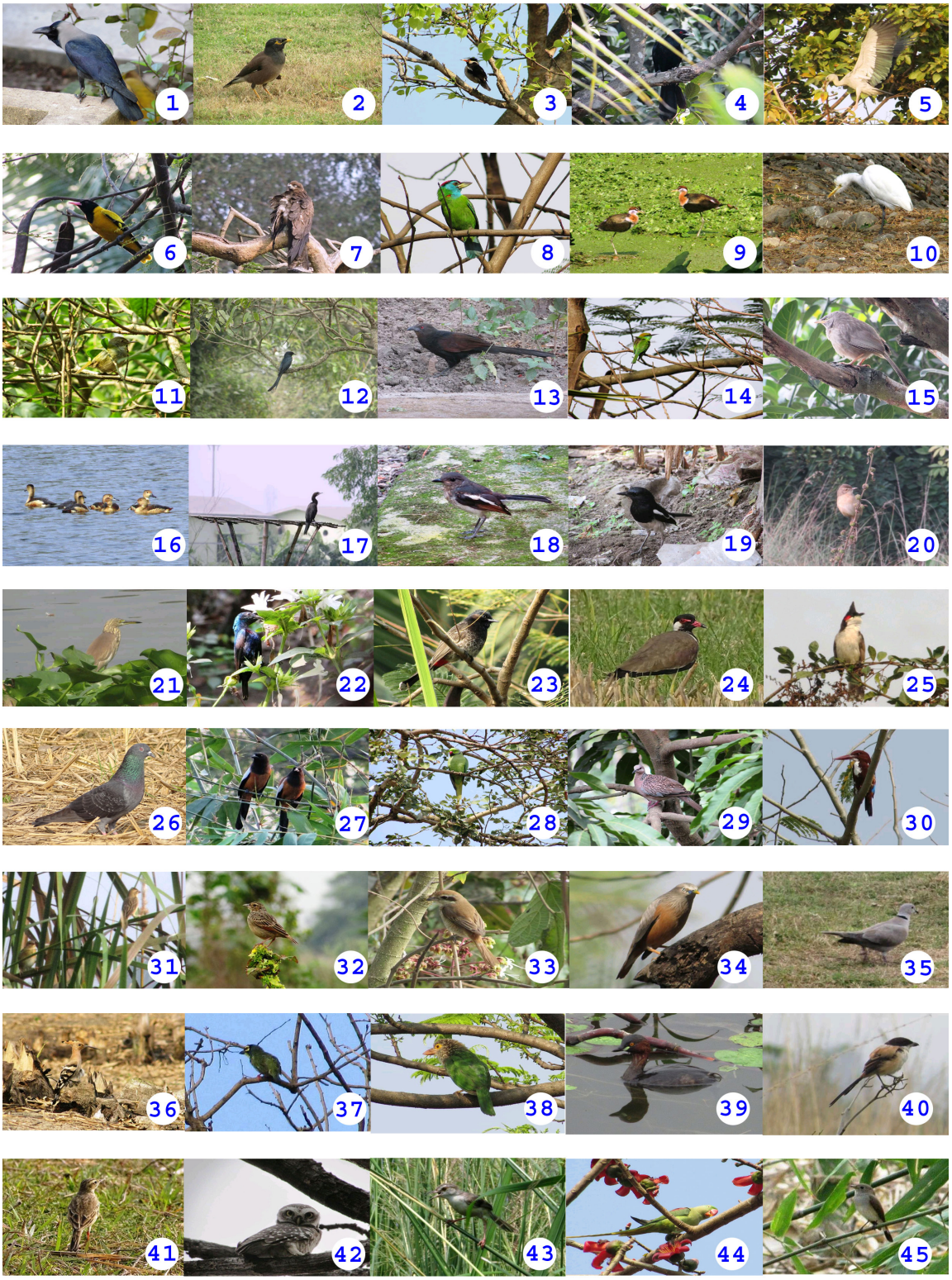

Figure 1. Photographs of different birds taken from the study area during the period of study; numbered and categorized as per availability (selective photograph, sequences and categories are not identical with tables). The birds are – 1. Common Crow, 2. Common Myna, 3. Asian pied starling, 4. Asian koel, 5. Asian open-bill stork, 6. Black headed oriole, 7. Black kite, 8. Blue throated barbet, 9. Bronzed winged jacana, 10. Cattle egret, 11. Common tailorbird, 12. Black drongo, 13. Greater coucal, 14. Green bee-eater, 15. Jungle babbler, 16. Lesser whistling duck, 17. Little cormorant, 18. Oriental magpie robin (female), 19. Oriental magpie robin (male), 20. Plain prinia, 21. Pond heron, 22. Purple sunbird, 23. Red-vented bulbul, 24. Red-wattled lapwing, 25. Red wiskered bulbul, 26. Rock pigeon, 27. Rufus treepie, 28. Rose-ringed parakeet, 29. Spotted dove, 30. Red-breasted kingfisher, 31. Yellow-heated bunting, 32. Bengal bushlark, 33. Brown shrike, 34. Tailed chestnut starling, 35. Collared dove, 36. Common hoopoe, 37. Coppersmith barbet, 38. Lineated barbet, 39. Little grebe, 40. Long-tailed shrike, 41. Paddyfield pipit, 42. Spotted owlet, 43. Striated grassbird, 44. Alexandrian parakeet, 45. Asian brown flycatcher.

01 - 31 - Frequent species
32 - 43 - Moderately frequent species
44 - 65 - Rare species
66 - 80 - Very rare species

Figure 46. Blacknapped oriole, 47. Blue throat, 48. Blyth's reed warbler, 49. Citrine wagtail, 50. Common hawk-cuckoo, 51. Common kingfisher, 52. Common moorhen, 53. Common sandpiper, 54. Fire throat, 55. Fulvous-breasted woodpecker, 56. Indian roller, 57. Little spider-hunter, 58. Night heron, 59. Orange headed thrush, 60. Oriental white eye, 61. Siberian stonechat, 62. Taiga flycatcher, 63. White-rumped munia, 64. Yellow-footed green pigeon, 65. Zitting cisticola, 66. Tickell's blue flycatcher, 67. Cinereous tit, 68. Common snipe, 69. Fantail, 70. Garganey, 71. Greater flame-back woodpecker, 72. Cotton pygmy goose, 73. Indian nightjar, 74. Oriental darter, 75. Painted stroke, 76. Pale billed flower-pecker, 77. Scarlet backed flower-pecker, 78. Stork billed kingfisher, 79. Verditer flycatcher, 80.

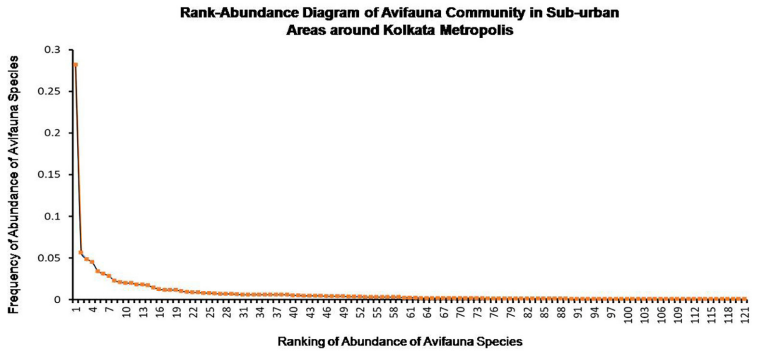

Figure 2. Whittaker Plot or the Rank Abundance diagram of avifauna community in a) sub-urban Kolkata and b) urban Kolkata. Both graphs are showing avifauna diversity number with very few highly dominant species and most others as rare and very rare (see text for details).

community but the index value of sub-urban avifauna community is almost at the boundary or threshold of natural community index value at its higher range (H_S <3.5). But at the same time, the equitability index (E_H) of both the zone are nearly equal with the values 0.71754315 and 0.7040558515 for sub-urban and urban avifauna community respectively. The marginally higher equitability value in sub-urban community despite its higher threshold level value of community index indicates that the very even presence of high number of rarer species contributed for its equitability value.

Discussion

A total of 140 number of avifauna having 18 orders of 53 families were recorded during the study period. Order Passeriformes had the highest number of bird species followed by Columbiformes and Coraciiformes. Family Strigiformes, Psittaciformes, Pelecaniformes had only one species each. Higher relative frequency of some birds could be contributed by high occurrences of these birds in some particular site, though they were not much frequent in all over the range. Such patchy distribution of some birds were observed in some wetlands or grasslands. Most of the birds observed during this study were resident and some were migratory species. Lameed (2011) reported that the species that are winter migrants use wetlands for rest and other activities while waiting for the favorable condition of their home range. Also, higher number of birds in terrestrial habitat may be attributed with having greater resources such as food and nesting sites who are tolerant to anthropogenic perturbation (Remsen and Parker, 1983; Walwert et al. 2004). Such adaptability of some birds has become the key to their success in proximate association with urban landscape. High dominance of common myna and house crow in both the zones might be exemplary evidence in this respect, whereas, house sparrow were found rarer in urban Kolkata in recent times probably due to the loss of their nesting preferences in the present model of modifying urban constructions.

Species richness of different feeding guilds might respond differently to changes in vegetation structure and complexity across tropical ecosystems (Waltert et al. 2005). The rank abundance diagram or Whittaker's plot index indicates that sub-urban region having the higher species diversity than urban region, where several rare species visited in places. As per the

locality feedback, the rare visits of different species were mostly due to their losing habitats for encroaching human activities and settlements. Increasing population, rapid changes in land usages and pollution are complicating the problem at increasing speed.

Petersen and Westmark (2013) reported that bird species richness and diversity within wetlands were positively correlated with percent cover of trees. Bird abundance and varieties rise with increase in food availability. The higher abundance of birds in terrestrial habitat could also be due to the composition of the vegetation that forms the main element of their habitat (Pomara et al. 2012; Chapman and Reich, 2007; Salah and Idris, 2013). The lower number of water birds could be attributed to the destruction of the wetland habitats, due to overgrazing, and cultivation. The reverie vegetation near the lakes were observed to be heavily overgrazed by cattle which use the areas around the lake as feeding areas and vegetation cleared due to cultivation thus interfering with the area which could be used for nesting, feeding, and breeding sites for wetland birds. Degradation of wetlands is the major issue in this area and associated with faster rate of changing the character of lands and lowlands of the region. Areas adjacent to urban Kolkata and newly developing satellite townships like Rajarhat-Newtown, are now major hotspots of loss of habitats to birds (Cox 2012).

Many of the areas and land forms found previously in sub-urban periphery or surrounding village or lowlands and wetlands are now quickly converting the land characters for the expansion of urban settlements. These anthropogenic activities related to transformations of urban settlements are now offering heavy toll to avifauna community. Due to such disturbance of sub-urban areas with rapid habitat loss, many previously native and passage migrants who were much sensitive to environmental disorders were becoming much rarer in these regions. The existence of a longer list of rare and very-rare species in sub-urban Kolkata is indicating to the fact (Table 1 and Figure 1). If we consider the Shannon' Index value of both the communities we found that urban area showed the value more central (~3.02) to the normal community value range, i.e, 1.5 – 3.5. But we found more marginal value far avifauna community of sub-urban areas (~3.44). The observation indicated for a more stable and natural avifauna community in urban area rather than the sub-urban zones. Though urban Kolkata was inhabited and visited by lesser number of bird species, almost $3/5^{th}$ species of birds than the sub-urban Kolkata, but the present avifauna community was found healthier in Kolkata.

These observations can be explained if we look at the population explosion and rapid transformation of lands surrounding the city in suburban belts in last couple of decades (Cox, 2012 and Haque et al, 2019). In comparison, the land use and population growth under the areas of Kolkata Municipal Corporations and allied city areas changed little for last few decades, because the area had reached to its saturation threshold (Cox, 2012). Therefore, the avifauna community in Kolkata core has now obtained a time of few decades to adapt and stabilize in the region amidst the human settlements. We found a larger list of dominant or highly frequent species of birds in Kolkata than the sub-urban regions, who might be considered as the best adapted avifauna with urbanization. Some of them like house crow, common myna, pigeon, Asian pied starling etc. are directly dependent on human habitation, whereas, rose-ringed parakeet, jungle babbler, varieties of bulbul or black drongo are found comfortable with small vegetation areas within the city including kitchen gardens, open spaces or small parks or trees planted for beautification purpose. Most of the rare or very rare birds were found in the abandon lands and vegetation, sanctuary within city or lakes surrounded with trees with an area of 10-20 ha or more, even within a surroundings of busy urban establishments. In contrary, rapid change in sub-urban areas in recent times left no such time or less time to adapt for the birds there. Therefore, many resident species of the region when losing their natural home in quick succession, many visitors or migrants are also losing their resting habitats. So, probably they are facing much higher selection pressure now, which was the case for urban avifauna few decades earlier. Thus many species frequent in those sub-urban periphery couple of decades earlier are now becoming rare and very rare due to the initial impact of urban transformation on their population and did not receive enough time to be resilient or adapted. As an obvious effect the avifauna of those sub-urban areas are now threatened in a more fragile community which may result into loss of biodiversity in near future.

CONCLUSION

This study showed that with less diversity, the avifauna community in the urban core of Kolkata metropolis is more stable and natural, whereas, with higher diversity, the avifauna community in sub-urban region is less stable and possessing a large number of rare and very rare species. More population density and urban structures decreased the diversity in urban Kolkata, but the avifauna acquired better community characteristics with such limited and constrained resources of fixed nature in time. But the avifauna of sub-urban areas, though possess much diversity, are lacking stability probably due to failure of many species to cope with the fast changes of land forms due to expanding urbanization.

Probably, in urban core, different avifauna species are showing tolerance and possibly compromising there niche width to adapt in urban life with human as has been explained in different recent studies in other metropolis of the world (Schilthuizen, 2018). Further investigation is needed in this areas when we will be able to see how several species adapt and may opt for newer speciation by thriving an age of extinction in this Anthropocene era (Monastersky, 2015; Thomas, 2017). However, it has been observed that small patch of natural habitats within the urban areas are capable to support large varieties of avifauna diversity and fragmented stretches of open natural landmasses and water bodies are visited by high number of species varieties from rare to very rare categories. If proper land use planning is keeping such habitats intact to a certain extent and in a well-connected manner within the urban outgrowths, we may hope that not only the avifauna species, but also other sensitive species can be thrived in those inter-connected satellite natural patches within this urban jungle. Thus we can prevent the landslide loss of avifauna diversity in and around Kolkata with an early step in urban planning and development in this extending periphery of the city.

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Author Contributions: S.S contributed in data collection and drafting primary manuscript, A.M contributed in collection and documentation of data and preparation of plates, S.G participated in data analysis and A.G managed the work, edited, finalized and approved the manuscript.

Conflict of interest: We declare that there is no conflict of interest.

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