

Post-monsoon bird assemblages in rural and riverine environments of Northern Howrah, West Bengal, India: A spatio-temporal approach

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Abstract

The primary goal of this study was to evaluate avian assemblages in four different land types (Wetland Associated Bamboo Forest, Agricultural Land, Wetland Associated Agricultural Land and Riverside Agricultural Land) located in a flood prone area of South Bengal during the post monsoon months of 2020. Surveys were conducted for 48 days in a land type and time dependent manner to explore the changes in abundance, dominance, evenness and species richness. A total of 18654 observations belonging to 16 orders, 44 families, 70 genera and 81 species were recorded. Despite having lowest total count and third species rich area, Bamboo Forest emerged as the most diverse area with the highest Shannon index (3.37), Evenness index (0.4616) and lowest dominance index (0.06108). Bamboo forests exhibited the maximum values of Simpson 1-D (0.9389), Brillouin index (3.312), Menhinick Index (1.261), Equitability (0.8134) and alpha diversity (Fisher's alpha 11.74). Having maximum number of species occurrence (69), Riverside agricultural land was found to be the least diverse land type (Shannon index 2.847) showing highest value of dominance (0.1203). December attracted the most diverse (Shannon index 3.474) bird community and October showed the lowest value of Shannon index (2.919) with maximum value of dominance (0.123). We conclude that protection of natural habitats like bamboo forests, wetland and tree cover in small villages and proper management of agricultural lands is necessary for promoting species diversity and evenness in a rural environment.

Keywords: agricultural land; avian assemblages; bamboo forest; riverside; South Bengal

Abbreviations: WABF-Wetland Associated Bamboo Forest; AGL-Agricultural Land; WAAL-Wetland Associated Agricultural Land; RAL-Riverside Agricultural Land; TC-Tree cover; BC-Bamboo cover; SH-Shrub; P-Paddy cover; WC-Wetland cover; FG-Feeding Guild; I-Insectivorous; C-Carnivorous; O-Omnivorous; F-Frugivorous; G-Granivorous; N-Nectarivorous; I/N-Insectivore-Nectivore; I/F-Insectivore-Frugivore; MS-Migratory Status; RS-Resident; LM-Local Migratory; M-Migratory; IS-IUCN Status; LC-Least Concern

Introduction

India is home for 1263 species of birds belonging to 23 orders, 107 families and 498 genera and harbours nearly 12.5% of all birds of the world (Praveen *et al.*, 2016). The avifaunal diversity of West Bengal is very rich

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with 861 species including some extremely rare ones (Rahmani *et al.*, 2016). Knowledge gathered through the study of bird communities can be used as bioindicators to monitor the health of an environment or ecosystem as well as environmental hazards including several pollution events (Padoa-Schioppa *et al.*, 2006; Amat and Green 2010; Martínez, 2012).

Properly managed agricultural lands are important components for biodiversity conservation and are equally important as the forest patches that harbour a large number of species as well as serve as safe corridors for the dispersal of wildlife between patches (Perfecto and Vandermeer, 2002; Norris, 2008; Rodrigues *et al.*, 2013; Deikumah *et al.*, 2017). Agricultural lands with abundant native tree cover exhibit structural heterogeneity and provide habitat and resources for several species (Deikumah *et al.*, 2017). Elucidating the biodiversity at riverine landscapes often reflects the global conservation importance (Ormerod, 1999; Buckton and Ormerod, 2002). Despite several comprehensive studies on diversity, species distribution and ecology of birds in riverine landscapes, still there is lacking of vivid knowledge on global patterns of species richness in riverine landscapes (Buckton and Ormerod, 1997; Buckton and Ormerod, 2002; Buckton and Ormerod, 2008; Sau *et al.*, 2018; Sinha *et al.*, 2019).

A number of previous studies have demonstrated avifaunal assemblages in different types of agricultural lands and suburban landscape of South Bengal (Hossain and Aditya, 2014; Roy *et al.*, 2016; Mukhopadhyay and Mazumdar, 2017; Sau *et al.*, 2018; Mukhopadhyay and Mazumdar, 2019; Chakraborty *et al.*, 2020; Ghosh *et al.*, 2021). However, very few studies (Sau *et al.*, 2018) have conducted the investigation on avifaunal assemblages in river adjoining agricultural lands in South Bengal and further compared the results with other land types located away from the river. Several studies have reported the avifauna from different urban areas of Howrah district. Majumdar *et al.* (1992) have reported 540 species belonging to 210 genera, 60 families and 16 orders from West Bengal including 22 species from Howrah district. However, most of these studies were conducted in the Santragachi Jheel (a lake near Santragachi railway station) of Howrah district. Mazumdar *et al.* (2007) have reported 16 species of waterbirds and Patra *et al.* (2010) have recorded bird 33 species belonging to 8 families and 23 genera in the Santragachi Jheel of Howrah district. A study by Khan (2010) has described temporal changes to the community structure of 15 species of migratory waterbirds in the lake. Biswas and Banerjee (2016) reported a total of 38 species of birds belonging to 23 families under 12 orders and Palit (2018) has identified 25 species of water birds in the same lake of the district. Recently Chakraborty *et al.* (2020) has described assemblages of 43 bird species belonging to 12 orders and 26 families at two urban areas (Liluah and Belur) of Howrah district. A study from 17 freshwater wetlands of rural and urban areas of Howrah has reported 54 species of wetland dependent or wetland associated birds from 14 families (Nandi *et al.*, 1999). Only two species of water birds (*Ardeola grayii* and *Egretta garzetta*) have been described so far from the Udaynarayanpur block of Howrah district (Nandi *et al.*, 1999). To our knowledge, no comprehensive study on avian assemblages has so far been reported from any flood prone rural land type of the Howrah district in South Bengal.

The aim of this study was therefore to explore avian assemblages in four different land types located near riverine landscape in a flood prone block of West Bengal. In this paper, we ask whether diversity of avifauna in the rural environment changes in a land type as well as time dependent manner in the post monsoon season. We further explored changes in abundance, dominance, evenness and species richness under the same conditions.

Materials and Methods

Study area

The study was conducted in four main land cover types (WABF: Wetland Associated Bamboo Forest, AGL: Agricultural Land, WAAL: Wetland Associated Agricultural Land and RAL: Riverside Agricultural Land) located in four villages (Sultanpur, Sitapur, Baira Kurchi and Jangalpara Belgram) of Udaynarayanpur block of Howrah district (Figures 1 and 2). Udaynarayanpur community development block (22°43'01"N 87°58'30"E) is the northernmost part of Howrah district of West Bengal and belongs to the Uluberia subdivision of the district. The block (124.80 km²) is bounded by the Hooghly district on three sides and is located 43 km from the district headquarters. One of the most flood-prone regions of the district, Udaynarayanpur is located in between two rivers, Damodar and Mundeswari and the present study area is located very close to river Damodar. The study area encompasses a number of swampy areas along with ponds, jheels which are dominated by amphibious macrophytes including some family members of Cyperaceae and Gramineae (Nandi *et al.*, 1999).

WABF: These are bamboo-dominated areas present near wetlands of Sultanpur and Baira Kurchi villages in Udaynarayanpur. Besides *Bambusa* sp, some other notable trees of these areas are *Neolamarckia cadamba*, *Cocos nucifera*, *Borassus flabellifer*, *Swietenia mahagoni*, *Monoon longifolium*, *Acacia auriculiformis*, *Areca catechu*, *Artocarpus heterophyllus*, *Mangifera indica*, *Carissa carandas*, *Ficus racemose*, *Psidium guajava*, *Tamarindus indica* etc. Some of the common herbs and shrubs of the area are *Musa* sp, *Curcuma longa*, *Colocasia esculenta*, *Citrus limon*, *Hibiscus* sp, *Tabernaemontana divaricate*, *Clitoria ternatea*, *Impatiens balsamina*, *Jasminum Sambac*, *Mirabilis jalapa*, *Leonurus sibiricus*, *Ixora coccinea* etc.

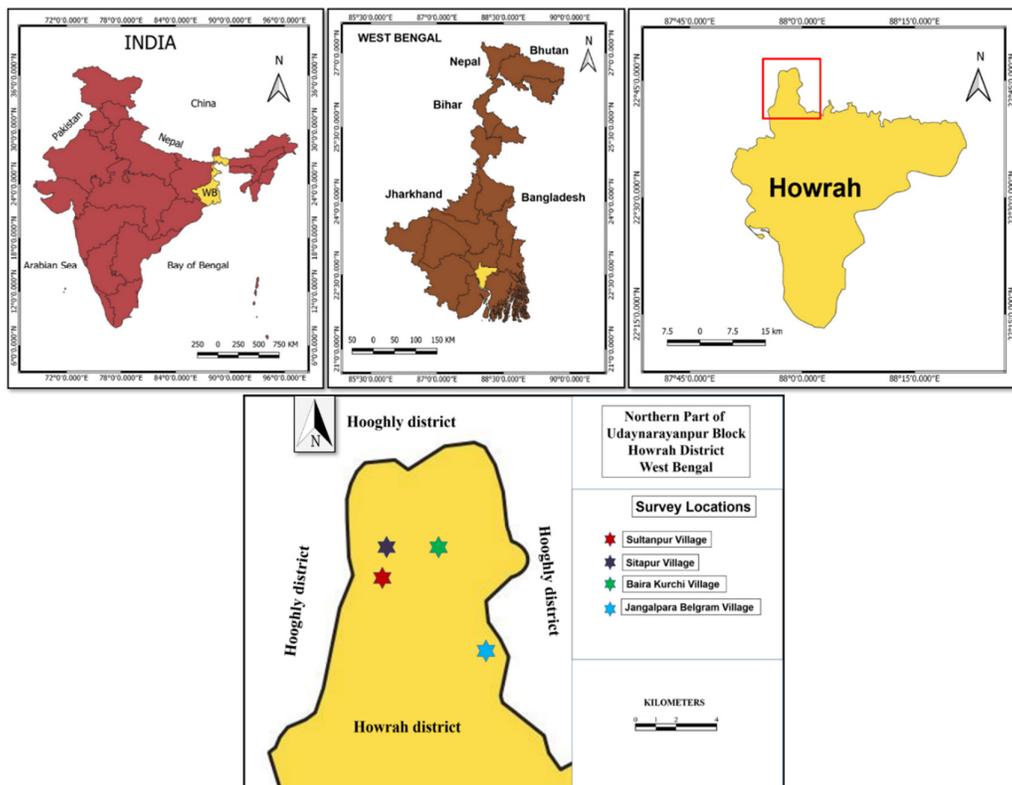


Figure 1. Geographical location of the study area: Four villages in Udaynarayanpur block of Howrah district, West Bengal, India.

(Map data: India from Nayak, 2020 with permission from the publisher; West Bengal, Howrah district and Northern part of Udaynarayanpur block were generated using QGIS).

AGL: These lands of the study area are located in the Sitapur village and dominated by paddy fields interspersed with patchy vegetation including *Musa* sp., *Borassus flabellifer*, *Acacia auriculiformis*, *Moringa oleifera*, *Ocimum gratissimum*, *Parthenium hysterophorus*, *Saccharum spontaneum*, *Vachellia nilotica* etc.

RAL: These are agricultural lands located on the West River bank of the Damodar river in Jangalpara Belgram village. These plots are dominated by paddy fields interspersed with scrubland, tree cover and water bodies. Some of the important tree species of the area are *Areca catechu*, *Albizia lebbek*, *Dalbergia sissoo*, *Ficus racemose*, *Borassus flabellifer*, *Acacia auriculiformis* etc. Further, the river terraces, floodplain of Damodar are also part of this habitat type that harbour a number of fish and invertebrates and attract a variety of birds.

WAAL: These are wetland associated agricultural lands located in flood prone areas of Baira Kurchi and Sultanpur Village. These lands remain submerged for months after the monsoon season and are dominated by paddy fields with several wetland vegetations like *Aeschynomene indica*, *Cyperus* spp, *Ipomoea aquatica*, *Typha elephantina*, *Marsilea quadrifolia*, *Trapa bispinosa* etc. (Nandi *et al.*, 1999).



Figure 2. Land use types of Udaynarayanpur block surveyed in the study. A. An agriculture land (AGL) in Sitapur village B. Damodar river near agricultural lands (RAL) in Jangalpara Belgram village. C. Wetland associated agricultural lands (WAAL) located in flood prone areas of Sitapur village D. Bamboo-dominated areas (WABF) near wetlands of Sultanpur village in Udaynarayanpur

Sampling design

The study was conducted during the post-monsoon months (October, November and December) between 01 October and 31 December 2020. Vegetation and birds were surveyed using a grid-based method as described by Haney *et al.* (2008). Equal number (four per land type) of survey grids (250 m × 250 m) were established in all four land cover types with a total of 16 survey grids (Figure 1; Table 1). Each of these survey grids were subdivided into 25 grid cells each measuring 50m × 50m. A 25 m habitat buffering zone was maintained around each survey grid to reduce the effects of edge. A minimum distance of 500m between two successive survey grids were allocated and the survey of both birds and vegetation data was completed by a single investigator. Each land type (four survey grids) was visited four times a month (once per survey grid) with a total of 12 survey days and all four land types received a total of 48 survey days. Birds were surveyed from dawn to mid-morning during each week of October, November and December using the methods previously

described by Haney *et al.* (2008). All birds detected visually or acoustically were recorded by advancing slowly along the line transect within 25m to the front and on both sides of the line transect. The birds were identified using a binocular and field guides (Ali and Ripley 1987; Grimmett *et al.*, 2015). Bird surveys were avoided during adverse weather conditions such as low cloud, high winds, rainfall fog and strong winds. For vegetation survey (tree with diameter at breast height ≥ 10 cm), ten of the 25 grid cells were randomly selected placing transects (50 m) through the middle of the grids. Five main variables (percentage) viz Tree cover (TC), Bamboo cover (BC), Shrub (SH), Paddy cover (PC) and Wetland cover (WC) were measured in order to elucidate the relationships between bird assemblages and their environment through Canonical correspondence analysis (CCA). We used three 2 x 2 m quadrats for the estimation of vegetation percentage and average values from the three quadrats were used for CCA. Bird species having fewer than 10 observations among all the counts were eliminated from the present study.

Data analysis

Species with less than 10 counts throughout the study were excluded from all our analyses. In order to investigate the relationship among the bird assemblages and habitat variables a CCA was performed. Environmental variables (percentage) were subjected to Z-score transformation and species abundances to square root transformation prior to CCA to normalize distributions. All box plots, individual-based rarefaction curves CCA and calculation of month and land cover -wise diversity and evenness indices were performed using PAST version 4.03 software (Hammer *et al.*, 2001) and other graphical representations of data were generated using Microsoft Office Excel, 2010. To measure any statistically significant differences between the means of plot and sample-wise group data (species richness and species abundance), one-way analysis of variance (ANOVA) was conducted setting Alpha to 0.05. Post-hoc Tukey HSD (honestly significant difference) between pairs or subgroups after a significant ANOVA result, was performed using Tukey HSD calculator (astatsa.com) to identify the variables that differ significantly. The Venn diagrams showing the number of species among different land types and months were generated using online Venn diagram generator of the Bioinformatics and Systems Biology Group of the Department of Plant Systems Biology, Ghent University (<https://bioinformatics.psb.ugent.be/webtools/Venn/>).

Table 1. Location of sampling sites of the study area

Sl No	Location	Site/Grid code	GPS coordinates
1	Sitapur Village	AGL1	22.74510°N, 87.96404°E
2	Sitapur Village	AGL2	22.74532°N, 87.96775°E
3	Sitapur Village	AGL3	22.74162°N, 87.96359°E
4	Sitapur Village	AGL4	22.74101°N, 87.96870°E
5	Jangalpara Belgram Village	RAL1	22.72123°N, 87.98996°E
6	Jangalpara Belgram Village	RAL2	22.71795°N, 87.99181°E
7	Jangalpara Belgram Village	RAL3	22.71454°N, 87.99309°E
8	Jangalpara Belgram Village	RAL4	22.71276°N, 87.99361°E
9	Baira Kurchi Village	WAAL 1	22.74545°N, 87.97367°E
10	Baira Kurchi Village	WAAL 2	22.74577°N, 87.98054°E
11	Sultanpur Village	WAAL 3	22.73481°N, 87.96747°E
12	Sultanpur Village	WAAL 4	22.73434°N, 87.96288°E
13	Sultanpur Village	WABF 1	22.73545°N, 87.96870°E
14	Sultanpur Village	WABF 2	22.73442°N, 87.96704°E
15	Baira Kurchi Village	WABF 3	22.74046°N, 87.98058°E
16	Baira Kurchi Village	WABF 4	22.73995°N, 87.97337°E

AGL = Agricultural land, RAL = Riverside Agricultural land, WAAL = Waterbody Associated Agricultural land, WABF = Waterbody Associated Bamboo Forest.

Table 2. Land type and Month wise diversity indices of all species (pooled samples) studied in Udaynarayanpur, Howrah

Indices	WABF	AGL	RAL	WAAL	OCT	NOV	DEC
Taxa_S	63	61	69	68	74	75	78
Individuals	2498	4688	7251	4217	6030	7646	4978
Dominance_D	0.06108	0.1189	0.1203	0.07608	0.123	0.1048	0.05753
Simpson_1-D	0.9389	0.8811	0.8797	0.9239	0.877	0.8952	0.9425
Shannon_H	3.37	2.869	2.847	3.194	2.919	2.983	3.474
Evenness_e^H/S	0.4616	0.2887	0.2499	0.3585	0.2504	0.2633	0.4138
Brillouin	3.312	2.838	2.824	3.155	2.89	2.959	3.435
Menhinick	1.261	0.8909	0.8103	1.047	0.953	0.8577	1.106
Margalef	7.925	7.098	7.65	8.027	8.386	8.276	9.045
Equitability_J	0.8134	0.6978	0.6725	0.7569	0.6783	0.6909	0.7975
Fisher_alpha	11.74	9.899	10.56	11.51	11.87	11.54	13.13
Berger-Parker	0.1697	0.2929	0.2633	0.208	0.2998	0.2477	0.177
Chao-1	63	61	69	68	74	75	78

The number of common species occurrence among four land types and three months were 49 and 67 respectively (Figure 4A and B). Avian species richness was astonishingly similar between RAL (69) and WAAL (68) and between WABF (63) and AGL (61) (Figure 4A). However, species richness per plot (survey grid) among these four land types were significantly different from each other (Figure 5A). Maximum difference in species richness per plot ($F=9.28$, $p<0.01$) was recorded between AGL and RAL. Month wise data showed similar species richness among all three months (Figure 4B). However, species richness per sample showed significant difference ($F=4.95$, $p<0.01$) between October and December (Figure 5C). We also recorded significant differences in plot wise species abundance with maximum difference ($F= 9.69$, $p<0.01$) between WABF and RAL (Figure 5B). However, sample wise species abundance data showed no significant difference among three months during the study (Figure 5D).

Among these four land types, RAL harboured 10 unique species (*Lonchura striata*, *Plegadis falcinellus*, *Lonchura malacca*, *Dendrocygna javanica*, *Charadrius dubius*, *Anthus rufulus*, *Actitis hypoleucos*, *Ceryle rudis*, *Tringa glareola*, *Motacilla citreola*) and WABF three (*Terpsiphone paradisi*, *Geokichla citrina*, *Dendrocopos mahrattensis*) which were not found in other two land types (Figure 4B).

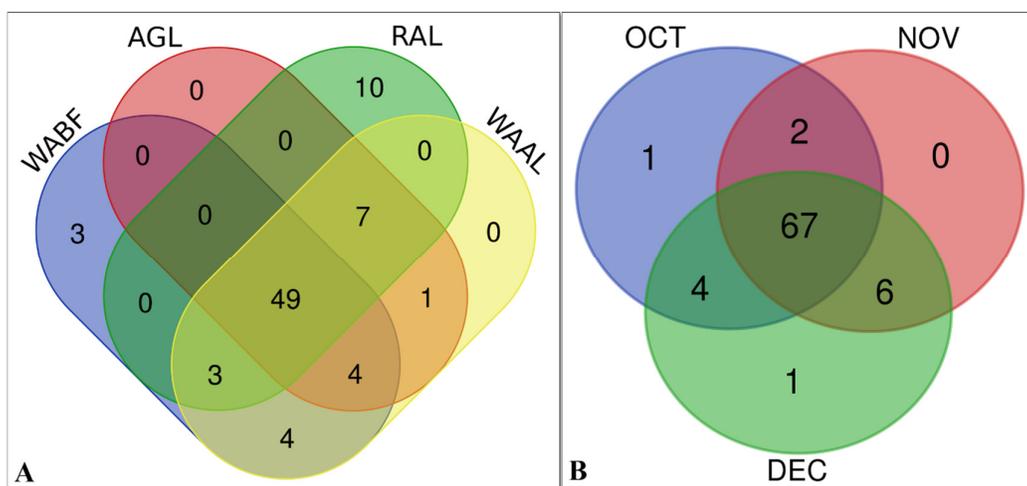


Figure 4. Land type (A) and month (B) wise Venn diagrams of all species recorded in the study area WABF: Wetland Associated Bamboo Forest, AGL: Agricultural Land, RAL: Riverside Agricultural Land and WAAL: Wetland Associated Agricultural Land. OCT: October, NOV: November, DEC: December.

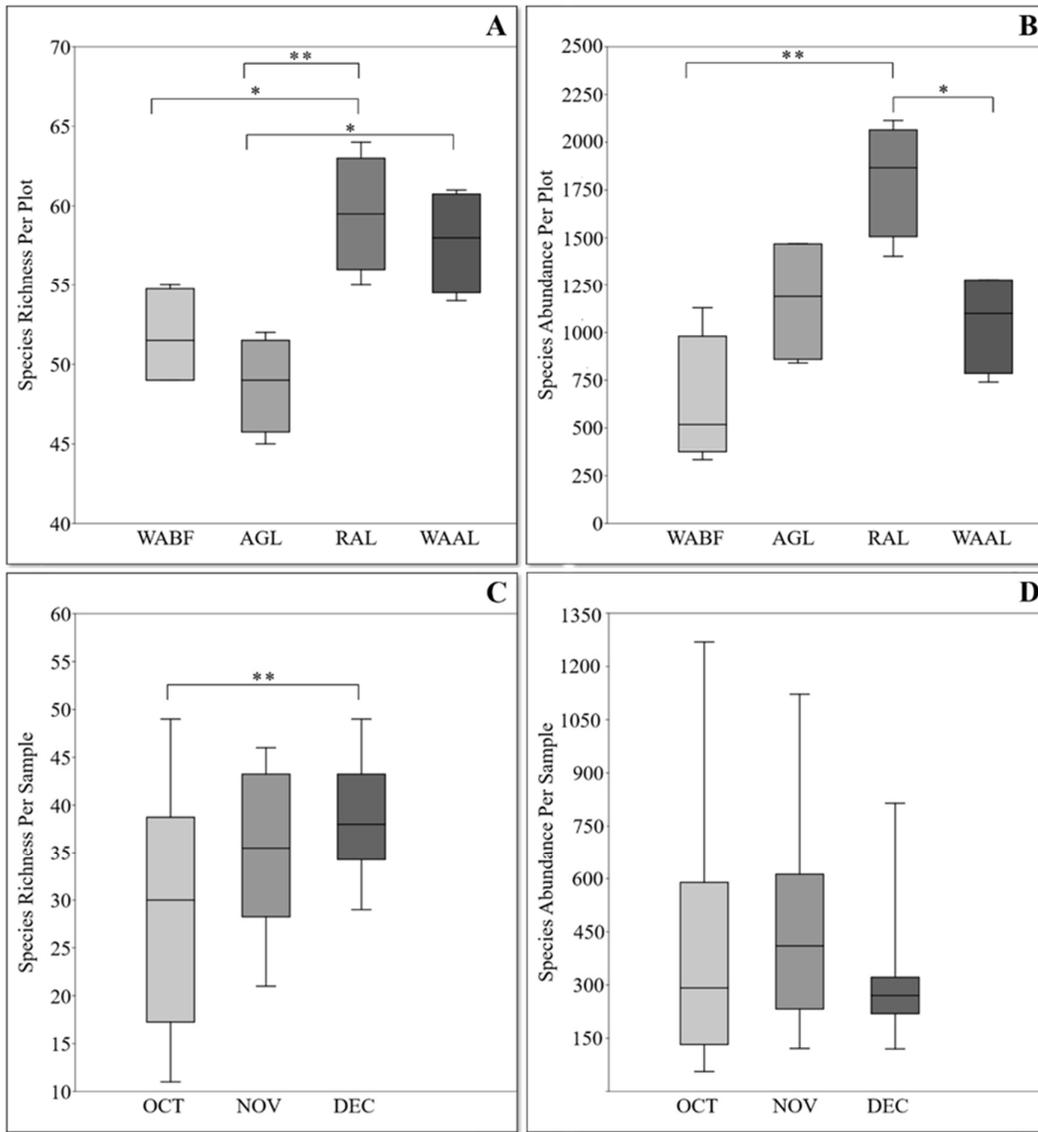


Figure 5. Box plots showing land use type (A,B) and month wise (C,D) species richness and species abundance of avifauna surveyed in the study. A. Land use type wise species richness per plot B. Land use type wise species abundance per plot. C. Month wise species richness per sample D. Month wise species abundance per sample

Each box plot represents minimum, lower quartile, median, upper quartile and maximum values. Mean values were compared using one-way ANOVA with pair-wise comparisons made with Tukey's HSD (honestly significant difference) tests. (Tukey's HSD test, *p < 0.05, ** p < 0.01) bars represent standard error of the mean.

The feeding guild analysis of pooled data from all land types revealed that the study area is dominated by insectivore (38.27%, 31 species) followed by carnivore (25.92%, 21 species), omnivore (18.51%, 15 species) and other species (Figure 6; Table 3). Land type wise data showed that WABF harboured the maximum number of insectivore (38.09%), AGL had the highest proportion of frugivore (8.19%), nectivore (3.27%) and omnivore (21.31%), RAL represented the maximum number of granivore (10.14%), WAAL sheltered the highest proportion carnivore (26.47%) (Figure 6A). Further a month wise analysis showed that the October represented the maximum percentage of frugivore (6.75%), granivore (9.45%) and nectivore (2.70%),

November attracted the maximum percentage of insectivore (40%) and December harboured the maximum number of carnivore (25.64%) and (omnivore (19.23%) (Figure 6B).

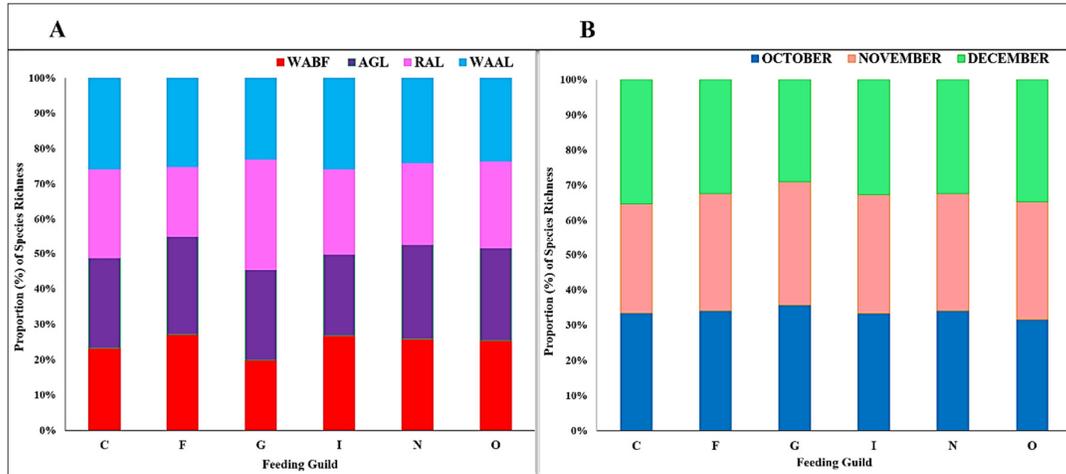


Figure 6. Stacked bar graphs showing land type (A) and month (B) wise proportion (%) of species richness per feeding guild recorded in the study. C: Carnivore, F: Frugivore, G: Granivore, I: Insectivore, N: Nectivore, O: Omnivore

In order to assess habitat and month wise distribution and differences in relative species abundance, species richness and species evenness, rank abundance curves were generated using log transformed proportional abundance (percentage) data of each land type and month (Figure 7). Land types in WABF and WAAL exhibited a very similar pattern (Figure 7A) indicating less differences in bird community structure in these areas. WABF showed maximum evenness in comparison to all other lands. On the other hand, AGL and RAL followed a similar pattern with RAL being the most speciose of all land types (Figure 7A). Month wise rank abundance curves revealed that October and November shared very similar patterns in species richness and evenness. However, December was the most species rich month having the maximum evenness (Figure 7B).

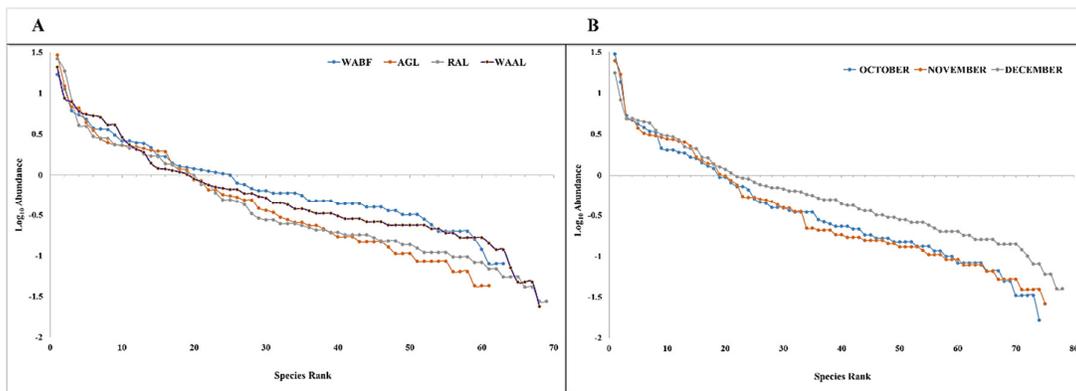


Figure 7. Land type (A) and month (B) wise Rank abundance curves (Whittaker plot) of all species recorded during the post monsoon season from Udaynarayanpur, West Bengal, India

Table 3. List of families, orders and species of birds recorded in different study sites of Udaynarayanpur block of Howrah district, West Bengal, India

Order	Family	Sl. No	Scientific name	Code for CCA	FG	MS	IS
Anseriformes	Anatidae	1	<i>Dendrocygna javanica</i>	Dj	O	LM	LC
Caprimulgiformes	Apodidae	2	<i>Cypsiurus balasensis</i>	Cba	I	RS	LC
Caprimulgiformes	Caprimulgidae	3	<i>Caprimulgus macrurus</i>	Cm	I	RS	LC
Cuculiformes	Cuculidae	4	<i>Centropus sinensis</i>	Cs	C	RS	LC
Cuculiformes	Cuculidae	5	<i>Eudynamis scolopaceus</i>	Es	O	RS	LC
Cuculiformes	Cuculidae	6	<i>Hierococcyx varius</i>	Hv	C	RS	LC
Columbiformes	Columbidae	7	<i>Columba livia</i>	Cl	G	RS	LC
Columbiformes	Columbidae	8	<i>Spilopelia chinensis</i>	Sc	G	RS	LC
Columbiformes	Columbidae	9	<i>Streptopelia decaocto</i>	Sd	G	RS	LC
Columbiformes	Columbidae	10	<i>Treron phoenicopterus</i>	Tph	F	RS	LC
Gruiformes	Rallidae	11	<i>Amaurornis phoenicurus</i>	Ap	O	RS	LC
Charadriiformes	Charadriidae	12	<i>Vanellus indicus</i>	Vi	I	RS	LC
Charadriiformes	Charadriidae	13	<i>Charadrius dubius</i>	Cd	C	LM	LC
Charadriiformes	Jacaniidae	14	<i>Metopidius indicus</i>	Mi	O	RS	LC
Charadriiformes	Scolopacidae	15	<i>Actitis hypoleucos</i>	Ah	I	M	LC
Charadriiformes	Scolopacidae	16	<i>Tringa glareola</i>	Tg	I	M	LC
Charadriiformes	Scolopacidae	17	<i>Gallinago gallinago</i>	Gg	I	M	LC
Ciconiiformes	Ciconiidae	18	<i>Anastomus oscitans</i>	Ao	C	RS	LC
Suliformes	Phalacrocoracidae	19	<i>Microcarbo niger</i>	Mn	C	RS	LC
Suliformes	Phalacrocoracidae	20	<i>Phalacrocorax fuscicollis</i>	Pf	C	LM	LC
Pelecaniformes	Ardeidae	21	<i>Ardeola grayii</i>	Ag	C	RS	LC
Pelecaniformes	Ardeidae	22	<i>Bubulcus ibis</i>	Bi	C	RS	LC
Pelecaniformes	Ardeidae	23	<i>Egretta garzetta</i>	Eg	C	LM	LC
Pelecaniformes	Ardeidae	24	<i>Ixobrychus sinensis</i>	Is	C	RS	LC
Pelecaniformes	Ardeidae	25	<i>Nycticorax nycticorax</i>	Nn	C	RS	LC
Pelecaniformes	Threskiornithidae	26	<i>Plegadis falcinellus</i>	Pfa	C	M	LC
Accipitriformes	Accipitridae	27	<i>Accipiter badius</i>	Ab	C	RS	LC
Accipitriformes	Accipitridae	28	<i>Milvus migrans</i>	Mm	C	RS	LC
Strigiformes	Strigidae	29	<i>Athene brama</i>	Abr	C	RS	LC
Bucerotiformes	Upupidae	30	<i>Upupa epops</i>	Ue	I	RS	LC
Coraciiformes	Alcedinidae	31	<i>Ceryle rudis</i>	Cr	C	RS	LC
Coraciiformes	Alcedinidae	32	<i>Alcedo atthis</i>	Aa	C	RS	LC
Coraciiformes	Alcedinidae	33	<i>Halcyon smyrnensis</i>	Hs	C	RS	LC
Coraciiformes	Alcedinidae	34	<i>Pelargopsis capensis</i>	Pca	C	RS	LC
Coraciiformes	Coraciidae	35	<i>Coracias benghalensis</i>	Cb	C	RS	LC
Coraciiformes	Meropidae	36	<i>Merops orientalis</i>	Mo	I	RS	LC
Piciformes	Megalaimidae	37	<i>Psilopogon haemacephalus</i>	Ph	F	RS	LC
Piciformes	Megalaimidae	38	<i>Psilopogon lineatus</i>	Pl	F	RS	LC
Piciformes	Megalaimidae	39	<i>Psilopogon asiaticus</i>	Pa	F	RS	LC
Piciformes	Picidae	40	<i>Dendrocopos mahrattensis</i>	Dm	I	RS	LC
Piciformes	Picidae	41	<i>Dinopium benghalense</i>	Db	I	RS	LC
Psittaciformes	Psittaculidae	42	<i>Psittacula krameri</i>	Pk	F	RS	LC
Passeriformes	Acrocephalidae	43	<i>Acrocephalus dumetorum</i>	Ad	I	M	LC
Passeriformes	Aegithinidae	44	<i>Aegithina tiphia</i>	Ati	I	RS	LC
Passeriformes	Alaudidae	45	<i>Mirafra assamica</i>	Ma	O	RS	LC
Passeriformes	Artamidae	46	<i>Artamus fuscus</i>	Af	I	RS	LC
Passeriformes	Cisticolidae	47	<i>Orthotomus sutorius</i>	Os	I	RS	LC
Passeriformes	Cisticolidae	48	<i>Prinia inornata</i>	Pi	I	RS	LC
Passeriformes	Corvidae	49	<i>Corvus macrorhynchos</i>	Cma	O	RS	LC
Passeriformes	Corvidae	50	<i>Corvus splendens</i>	Csp	O	RS	LC
Passeriformes	Corvidae	51	<i>Dendrocitta vagabunda</i>	Dv	O	RS	LC
Passeriformes	Dicruridae	52	<i>Dicrurus aeneus</i>	Da	I	LM	LC

Passeriformes	Dicruridae	53	<i>Dicrurus macrocercus</i>	Dma	I	LM	LC
Passeriformes	Estrildidae	54	<i>Euodice malabarica</i>	Em	G	RS	LC
Passeriformes	Estrildidae	55	<i>Lonchura malacca</i>	Lm	G	RS	LC
Passeriformes	Estrildidae	56	<i>Lonchura punctulata</i>	Lp	G	RS	LC
Passeriformes	Estrildidae	57	<i>Lonchura striata</i>	Lst	G	RS	LC
Passeriformes	Hirundinidae	58	<i>Hirundo rustica</i>	Hr	I	M	LC
Passeriformes	Laniidae	59	<i>Lanius cristatus</i>	Lc	I	M	LC
Passeriformes	Laniidae	60	<i>Lanius schach</i>	Ls	C	RS	LC
Passeriformes	Leiothrichidae	61	<i>Turdoides striata</i>	Ts	I	RS	LC
Passeriformes	Monarchidae	62	<i>Terpsiphone paradisi</i>	Tp	I	M	LC
Passeriformes	Motacillidae	63	<i>Motacilla alba</i>	Mal	I	M	LC
Passeriformes	Motacillidae	64	<i>Motacilla cinerea</i>	Mc	I	M	LC
Passeriformes	Motacillidae	65	<i>Motacilla citreola</i>	Mci	I	M	LC
Passeriformes	Motacillidae	66	<i>Motacilla flava</i>	Mf	I	M	LC
Passeriformes	Motacillidae	67	<i>Anthus rufulus</i>	Ar	I	RS	LC
Passeriformes	Muscicapidae	68	<i>Ficedula albicilla</i>	Fa	I	M	LC
Passeriformes	Muscicapidae	69	<i>Copsychus saularis</i>	Csa	I	RS	LC
Passeriformes	Nectariniidae	70	<i>Leptocoma zeylonica</i>	Lz	N	RS	LC
Passeriformes	Nectariniidae	71	<i>Cinnyris asiaticus</i>	Ca	N	RS	LC
Passeriformes	Oriolidae	72	<i>Oriolus xanthornus</i>	Ox	O	RS	LC
Passeriformes	Paridae	73	<i>Parus cinereus</i>	Pc	I	RS	LC
Passeriformes	Ploceidae	74	<i>Ploceus philippinus</i>	Pp	I	RS	LC
Passeriformes	Pycnonotidae	75	<i>Pycnonotus cafer</i>	Pcf	O	RS	LC
Passeriformes	Pycnonotidae	76	<i>Pycnonotus jocosus</i>	Pj	O	RS	LC
Passeriformes	Rhipiduridae	77	<i>Rhipidura albicollis</i>	Ra	I	RS	LC
Passeriformes	Sturnidae	78	<i>Acridotheres tristis</i>	At	O	RS	LC
Passeriformes	Sturnidae	79	<i>Sturnia malabarica</i>	Sm	O	RS	LC
Passeriformes	Sturnidae	80	<i>Gracupica contra</i>	Gco	O	RS	LC
Passeriformes	Turdidae	81	<i>Geokichla citrina</i>	Gc	O	RS	LC

CCA = Canonical correspondence analysis; FG = Feeding Guild; I=Insectivorous; C = Carnivorous; O = Omnivorous; F = Frugivorous; G = Granivorous; N=Nectarivorous; I/N= Insectivore-Nectivore; I/F= Insectivore-Frugivore; MS = Migratory Status; RS- Resident, LM- Local Migratory, M- Migratory, IS = IUCN Status (International Union for Conservation of Nature), LC = Least Concern.

Individual-based rarefaction curves (Figure 8A) of all birds from four land types indicated that bird assemblages of RAL and WAAL were more diverse than that of WABF and AGL. RAL was the most species rich land type while the least diverse land was AGL. Results from month wise rarefaction curves (Figure 8B) revealed that species richness in December consistently exceeds the richness of other two months.

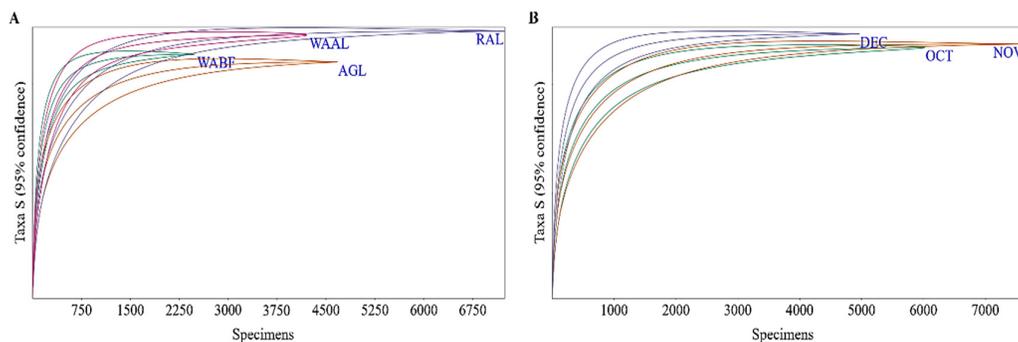


Figure 8. Land type (A) and month (B) wise individual-based rarefaction curves of pooled samples and estimated species richness of birds of Udaynarayanpur documented during the post monsoon season of 2020. Y-axis: species richness, x-axis: number of individuals. (mid line: mean, the upper and lower bounds refer to the confidence interval of 95% of Chao1 estimator)

The results of canonical correlation analysis (Figure 9) revealed that 62.61% of the variance in species abundance was exhibited by only one environmental variable (tree cover) and 37.39% were explained by other four environmental variables. The lowest variance in species abundance was observed in wetland cover. In the present study, four out of five variables were representing vegetation structure that affected the bird assemblage significantly (Figure 9). The CCA Triplot (Figure 9) revealed that birds like *Acridotheres tristis*, *Caprimulgus macrurus*, *Dendrocopos mahrattensis*, *Terpsiphone paradisi* and *Geokichla citrina* tend to co-occur and exhibits positive association with tree and bamboo cover in WABF. However, *Ficedula albicilla*, *Psilopogon haemacephalus*, *Psittacula krameria*, *Pelargopsis capensis* tend to co-occur near WAAL. *Alcedo atthis*, *Bubulcus ibis*, *Motacilla alba*, *Motacilla cinerea* showed positive association with paddy cover near AGL. A cluster of ten species (as mentioned earlier) were exclusively associated with river side land and showed no relationship with the variables. Not surprisingly, *Hierococyx varius* and *Hirundo rustica* were observed mostly in the scrub vegetation near wetland of WABF.

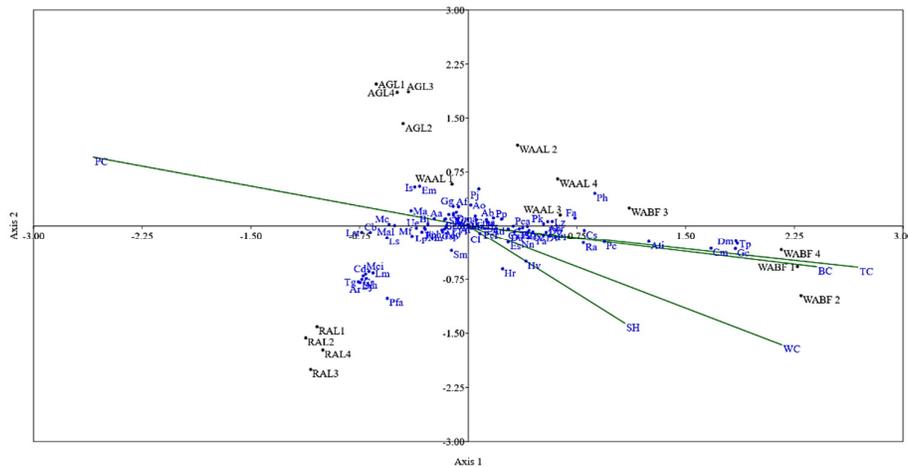


Figure 9. Canonical Correspondence Analysis (CCA) triplot representing bird species distribution with reference to study plots and environmental variables in Udaynarayanpur, West Bengal, India. Vectors indicate direction and strength of relationships between taxa and habitat variables. Environmental variable codes: Tree cover (TC), Bamboo cover (BC), Shrub (SH), Paddy cover (PC) and Wetland cover (WC). Study site/plot codes are given in Table 1 and Species codes are given in Table 3.

Discussion

The present study demonstrates an outline of rural avian assemblages from an extremely flood prone area of South Bengal located in between two rivers. The work provides evidence that areas (e.g. RAL) with highest species richness and maximum total abundance does not always make it to be the most diverse one. On the other hand, less species rich areas (e.g. WABF) in a village might support more bird diversity than others. The findings of the study are important for identification of such small zones and creating awareness for their conservation. This study has also reflected the augmentation of diversity indices in the last month of the post monsoon season and importance of plant composition of an area on the diversity of its avifauna.

In our study the differences in species composition among four land types were more distinct than that of three months of the post monsoon season. This might be explained by the significant habitat heterogeneity (vegetation type and height, wetland abundance, proportion of human habitation etc) between each land types and almost (except last two weeks of December) homogeneous weather patterns (temperature, relative humidity, rainfall, wind etc) during the post monsoon months.

We observed some specialized bird species exclusively on canopy vegetation (e.g. *Aegithina tiphia*, *Athene brama*, *Dinopium benghalense*, *Eudynamis scolopaceus*, *Parus cinereus*, *Psilopogon haemacephalus*, *Psilopogon lineatus*, *Psilopogon asiaticus*, *Terpsiphone paradisi*, *Treron phoenicopterus* etc), some on scrub vegetation (e.g. *Hierococcyx varius*, *Lonchura malacca*, *Lonchura punctulata*, *Lonchura striata*, *Prinia inornata*, *Rhipidura albicollis* etc) and some exclusively on the field (e.g. *Anthus rufulus*, *Mirafra assamica*, *Motacilla alba*, *Motacilla cinerea*, *Motacilla citreola*, *Motacilla flava*, *Vanellus indicus* etc). Therefore, both human and nature driven heterogeneity is needed to create and maintain a more diverse bird community.

Our results indicated that RAL and WAAL attract more species than the other two land types. This can be attributed to the availability of a heterogeneous environment having paddy fields, river bank or submerged land, scrubland, tree cover, water bodies and wetland vegetations. December remained the most species rich month as some of the migratory species arrive late at the start of the Winter and availability of several Winter crops in the fields after the paddy season is over. The effect of human habitation on the total bird abundance has been reflected in the lowest total bird count (2498) of WABF plots in two villages. Other three land types were located far from the human settlements and hence showed significantly higher total bird count. Interestingly total bird counts of December (4978) decreased notably in comparison to the other two months. We presume that a drastic reduction of paddy and water level in the submerged areas in December might have some influences on the lower total bird count.

Our study area is a Doab land, surrounded by two rivers. We documented maximum bird count (~39%) as well as highest species richness near the riverine (RAL) habitats. The principal crop paddy, a variety of vegetables, the riverine canopy and numerous types of invertebrates on riverbed provide higher food availability to attract several birds including some migratory species. The augmented species richness in the riverine landscapes can also be justified by presence of lateral ecotonal linkages as described by previous studies (Ward *et al.*, 1999; Ward and Tockner, 2001; Ward *et al.*, 2002; Buckton and Ormerod, 2002). Furthermore, the physico-chemical complexity and habitat heterogeneity of riverine landscapes might exhibit more species richness than other such habitats with latitudinal trends alone (Arscott *et al.*, 2000; Buckton and Ormerod, 2002). However, being the most species rich and abundant land type for birds, RAL exhibited the lowest diversity indices of all other lands. This has happened due to the lowest species evenness of the area i.e. top ten species occupied more than 70% of total bird abundance. Nearly 1/6th of all species (13) in our study were Winter migrants. Among these four species (*Plegadis falcinellus*, *Actitis hypoleucos*, *Tringa glareola*, *Motacilla citreola*) were confined to the RAL only and one (*Terpsiphone paradisi*) to WABF land type. All these migrants arrived in different months, e.g. *Motacilla citreola* and *Terpsiphone paradisi* in October, *Actitis hypoleucos* and *Tringa glareola* in November and *Plegadis falcinellus* in December.

Bamboo forests can serve as excellent biodiversity zones and provide food and shelter to many species of mammals, birds, soil organisms, insects and plants making an ideal ecosystem (Lou and Henley, 2010). Previous studies have shown that bamboo habitats can harbour unique avian assemblages including some rare and specialist species in different parts of the world (Guilherme and Santos, 2009; Rother *et al.*, 2013; Socolar *et al.*, 2013; Tu *et al.*, 2020). Despite having lowest total count and third species rich area, WABF emerged as the most diverse area with the highest Shannon index, Evenness index and lowest dominance index. Our results are consistent with available results from of a recent study (Tu *et al.*, 2020) in East Asia which showed that bamboo forest significantly decreases bird numbers as well as species richness but significantly increases the bird species evenness. We found the maximum number of dimensions of environmental heterogeneity in WABF including bamboo forest, wetland, shrubs, several ponds, nearby paddy fields, human habitation, private gardens with a variety of medicinal, ornamental species and fruit crops and a huge number of canopy tree species which might have contributed to enrichment in bird diversity of the land type. Furthermore, the plant diversity of the WABF plots (results not shown) was significantly greater in comparison to the other three land types and thus supported highest bird diversity. One of our WABF plots encompasses a public cemetery of nearly one hectare land, a burial ground of dead people belonging to a particular religion. We have recorded a number of rare species of birds in this undisturbed place during the study. Cemeteries are often regarded as biodiversity

islands especially in urban areas. Previous studies have reported a rich avifaunal diversity in these urban burial grounds (Kowarik *et al.*, 2016; Tryjanowski *et al.*, 2017; Csanády and Mošanský 2017; Villaseñor and Escobar, 2019). However, plant communities other than bamboo are facing the threats of massive deforestation. WABF plots in Sultanpur village has recently lost a large number of *Areca catechu*, *Cocos nucifera*, *Neolamarckia cadamba* and *Swietenia mahagoni* trees which are the most dominant trees in the area that support the survival of many canopy dwelling species. Our study revealed that these wet land associated bamboo forests with other plant composition are of greater importance than other land types for maintaining high bird diversity.

Almost every year the study area witnessed devastating floods driven by the simultaneous release of water from several upstream dams on Damodar river causing submergence of the land area for a long time. The consequences of flooding on aquatic birds can be both beneficial and detrimental. After the flood is over, the food sources become abundant in the area which in turn attract several aquatic bird species to breed (Poiani, 2006). Despite flood causes rapid depletion in the soil macroinvertebrate prey for several aquatic birds, it may help the birds in their prey availability by keeping the upper soil moist and soft to probe for the prey (Ausden *et al.*, 2001). Furthermore, floods may increase the landscape connectivity for aquatic birds and thereby facilitating their dispersal and survival without being trapped in isolated water-bodies (Poiani, 2006). We found disappearance of several species like *Anthus rufulus*, *Gracupica contra*, *Sturnia malabarica*, *Nycticorax nycticorax*, *Ardeola grayii*, *Bubulcus ibis*, *Egretta garzetta*, *Ixobrychus sinensis*, *Lonchura malacca*, *Lonchura punctulata*, *Lonchura striata*, *Vanellus indicus*, *Amaurornis phoenicurus*, *Charadrius dubius*, *Metopidius indicus*, *Actitis hypoleucos* and many others during the flood time in August and September. However, these birds again reappear in the early weeks of post monsoon session.

We documented a large number of species in the paddy fields. Except one (WABF) most of the land types in our study were dominated by wet paddy cultivation. West Bengal contributes the highest rice production (~13.9%) in the country and South Bengal yields bulk of the total production. A study by Sundar and Subramanya (2010) has shown that nearly 351 bird species occur in the rice fields of the Indian subcontinent which contributes 27% of all species including 22 endemic species of the region.

One of the remarkable findings of our study was complete absence of house sparrow (*Passer domesticus*), once a very common bird of rural Bengal from all 16 survey grids of the rural study area. Previous studies have reported a steady decline in the house sparrow population in many urban areas in India including West Bengal (Daniels, 2008; Rajashekar and Venkatesha, 2008; Dandapat *et al.*, 2010; Ghosh *et al.*, 2010). However, our findings are in contrast with few previous studies that have reported occurrence of more sparrow population in smaller towns and rural areas in India (Balaji *et al.*, 2013; Roshnath *et al.*, 2018).

Finally, we also recorded some of the very rare species of the study area like *Ammomanes phoenicura*, *Ardea purpurea*, *Clamator jacobinus*, *Dendrocopos macei*, *Dendronanthus indicus*, *Ketupa ketupu*, *Lanius vittatus*, *Ninox scutulata*, *Picus xanthopygaeus*, *Spilornis cheela* and *Zoothera dauma*. However, being very less in number, those species were lastly excluded from the present study.

Conclusions

The present study provides information about the relationship between species diversity and environmental variables in different land types in the flood prone Udaynarayanpur block of South Bengal. We found that river adjoining agricultural lands (RAL) provide much heterogeneity and hence exhibit more species richness, bird abundance but less diversity and evenness than other land types. A much better diversity and evenness have been recorded in AGL and WAAL land types. However, WABF being the lowest bird abundant site revealed the highest bird diversity and evenness. We conclude that protection of natural habitats like bamboo forests, wetland and tree cover in small villages and proper management of agricultural lands is necessary for promoting species diversity and evenness in a rural environment.

Authors' Contributions

Both authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

None of the species was captured or killed or subjected to any experimental treatment during the entire period of the study.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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