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Habitat heterogeneity influences avian feeding guild composition in urban landscapes: evidence from Bhubaneswar, India

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Abstract

Background: Habitat heterogeneity clearly distinguished in terms of availability of food and habitat resources and landscape features (natural or human-modified) play a crucial role in the avian species composition and population structure. To examine this, a study was carried out in Bhubaneswar, India, to understand the ecological niche distinction in birds based on habitat heterogeneity. Regular sampling was conducted in 30 sampling sites covering six different habitat types in a predominantly urban landscape of Bhubaneswar for understanding the ecological niche in birds. The birds were classified into 11 types of foraging guilds.

Results: The insectivorous guild had the highest bird species richness (181 species) and the omnivorous guild had the lowest (11 species). The piscivorous guild and wetland habitat had the strongest linkage, followed by the insectivorous guild and agricultural land. The frugivorous guild was significantly correlated with forest habitats ($r = 0.386$, $p < 0.01$) and park and garden habitats ($r = 0.281$, $p < 0.01$). This urban area hosted a higher number of bird species in certain habitat types, viz., agricultural lands (52%, 115 species) and forest patches (50%, 111 species).

Conclusion: The present study highlights the importance of agricultural lands, forest patches, parks and gardens, and wetlands inside the cityscape for supporting avifauna. It is therefore suggested that such habitats should be conserved inside an urban area to protect native avifauna. Thus, the city development plan must invariably include strategies for conserving the forest patches inside the urban area. Measures must be taken to restrain the degradation of agricultural lands and reduce their utilization for non-agricultural purposes, which will help in further reducing the bird population decline in the urban landscape.

Keywords: Bird species richness, Community structure, Feeding guild, Habitat characteristics, Urban area

Introduction

Birds have long been regarded as excellent model systems for studying all biodiversity clans due to their presence in all climatic zones and habitat types (McCain and Grytnes 2010). Although the species diversity and habitat heterogeneity provide information on birds' fundamental spatial ecology, habitat heterogeneity may impact the ecological

processes of birds (Smith et al. 2013; Leveau et al. 2015). Habitat heterogeneity may also have an impact on habitat resources, ultimately determining species diversity and richness in a given area (Lorenzón et al. 2016). A guild, a fundamental concept in avian ecology, is created when a community of birds uses the same class of environmental resources (Balestrieri et al. 2015). All guilds have different tolerance capacities and resource requirements depending on their environment, which is influenced by various factors, viz., food supply, vegetation cover, predator availability, and other factors (Katuwal et al. 2016). As a result,

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different environmental factors affect the avian species assemblage within a particular guild. For example, the birds' feeding guilds are closely associated with habitat and food availability. Thus, Snep et al. (2015) suggest distinguishing the richness gradients for different guilds for a better understanding of the community structure of birds and their habitat selection mechanisms.

The effect of food availability on an organism's population size is a well-known fact in ecological research (de Bonilla et al. 2012). Hence, avian feeding guild studies help to explain (i) the complex ecosystem structure and enhance the existing knowledge about habitats of that particular ecosystem (Rathod and Padate 2017) and (ii) the organization of functional communities and identifying the resources affecting that community structure (Brandl et al. 1994). To create updated data on any avian community structure, birds' feeding patterns must be known (Tanalgo et al. 2015). The dietary habits of birds are analyzed using several techniques, including fecal analysis, gut content analysis, and regurgitated food analysis. Moreover, behavioral observations combined with videographic evidence can substantiate current understandings of that bird species' diet systematics (Lewis et al. 2004). The dietary habits in birds can be affected by habitat conditions/heterogeneity and anthropogenic impacts on their habitat.

Wildlife researchers have focused their ecological investigations on birds and other animal species in natural environments, specially protected areas, rather than urban areas (Ottoni et al. 2009). Under the tremendous pressures of urbanization, the native habitats of birds have been lost, fragmented, or modified, with the native vegetation altered to a large extent (McKinney 2008; Leveau et al. 2020). Meanwhile, urban areas with fragmented and patchy habitats can still support a high level of biodiversity, especially in their woodlands and wetlands (Panda et al. 2020). Nonetheless, plentiful untapped resources such as food, shelter, nesting sites and breeding areas seem to draw birds to urbanized areas (Čanády and Mošanský 2017). Urban areas, with their concrete structures, recreational parks, and private property gardens, provide breeding and roosting habitats for birds as well as additional food resources (Ottoni et al. 2009). In urban areas, where the presence of several smaller habitats and feeding guilds is greater, a rich diversity of birds can be seen (Leveau and Leveau 2016). On the other hand, diversity can be minimum where the urban structure is highly developed, with very little vegetation (Donnelly and Marzluff 2004; Leveau and Leveau 2020). Given these specifics, the present study was carried out to examine the influence of habitat heterogeneity (represented by small and patchy habitats in a human-modified urban landscape) on bird species diversity, richness, and feeding guild.

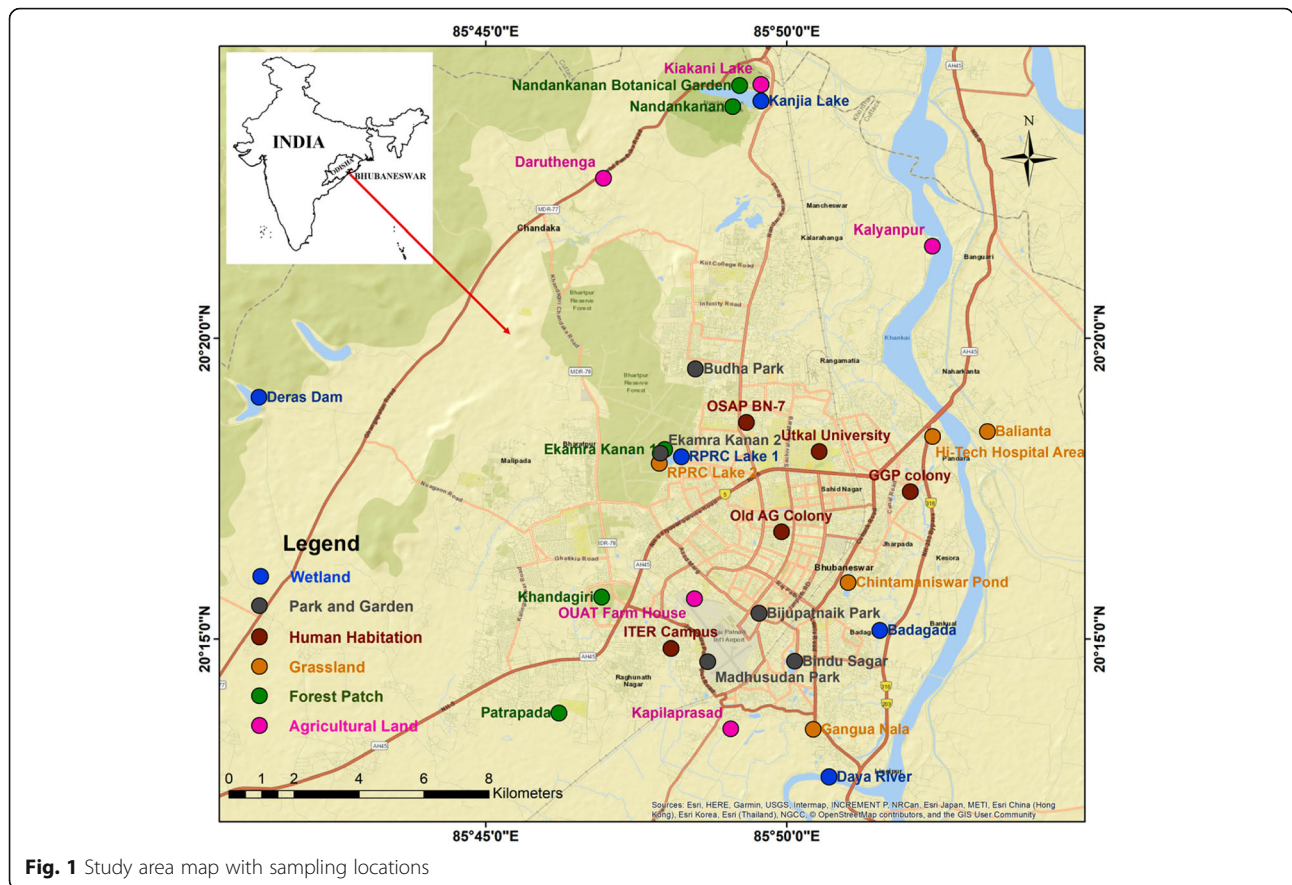
Methods

Study area

The present study was conducted in the urban landscape of Bhubaneswar (Fig. 1), the capital of Odisha state in India. Bhubaneswar has a tropical climate and is located at 45 m asl. The average annual temperature is 27.4 °C and the annual rainfall is 1505 mm. The municipal area is spread over approximately 419 km², and the city's landscape consists of diverse habitats such as urban forests and woodlands as well as highly urbanized residential and commercial complexes. The city has around 10 large wetlands (> 2.25 ha), more than 50 small wetlands (< 2.25 ha), and the River Daya flowing along the eastern part of the city. Besides the urban green spaces and woodlands, the city has over 120 parks and many green spaces that are known to support urban biodiversity (Nair 2014), including human habitation, agricultural lands, grasslands, and parks/gardens. The present study was conducted in six different habitats: (i) grassland (GL): large grass fields are found that have fewer herbs and shrubs, (ii) wetland (WL): large water bodies and swampy area, (iii) forest patch (FP): dense woody vegetation with a high density of trees, (iv) park and garden (PG): scrublands and manmade gardens with human interference, (v) agricultural land (AL): farmlands and crop fields inside the city, and (vi) human habitation (HH): residential colonies and urban structures with high human disturbance. In the present study, for regular bird surveys, five sites were randomly selected in each of these six habitat types, totaling 30 sampling sites (Table 1).

Sampling

Bird surveys and associated samplings were carried out during March 2016 through February 2017, to observe and record birds following the distance point count technique of Bibby et al. (1998). The survey was conducted in each of the 30 sites in every alternative month over the year (Leveau et al. 2015), i.e., six times each in 30 sampling sites for a total of 180 samplings. The geo-coordinates of locations were recorded using a handheld GPS (Garmin etrex10, Heather and Robertson 2000). Monthly 1-day surveys were conducted with 2–3 well-trained observers in each site for 4 h after sunrise and 2 h before sunset (Leveau et al. 2015). In total, 72 h were spent at each site, with a total of 2160 h of effort put in for the entire survey in the present study. Surveys were not conducted during inclement weather (rain or strong winds, Pan et al. 2008). The present survey covered summer (March–June), rainy (July–October) and winter (November–February) seasons. Behavioral observations were recorded manually to generate data on birds' feeding guild throughout the year. The levels of disturbance in and around each of the sampling sites were also



recorded (Rajashekara and Venkatesha 2015, 2017, 2018; Čanády and Mošanský 2017) and noted for further interpretation.

Guild classifications

Based on their diet and foraging habitat, the bird species were grouped into various feeding guilds (DeGraaf et al. 1985; Gray et al. 2007; Prajapati and Prajapati 2013; Ding et al. 2019). In the present study, 11 different guilds were identified (Table 2). In each of the sampling locations, species richness was evaluated for each of the observed feeding guilds.

Data analysis

The birds observed in the area were classified into orders and families with habitat preferences based on their occurrences in various habitats (WL, AL, PG, FP, HH, and GL). For each habitat, the Shannon-Wiener diversity index was determined to understand the avian species’ preference for each of the sites and habitats. The independent percentage contribution for every guild from each habitat was calculated as under:

$$100 \times (\text{number of species of the guild } i \text{ in habitat } j / \text{total number of species in habitat } j) \text{ (de Bonilla et al. 2012).}$$

The significant difference in the habitats and feeding guilds with respect to the species richness was tested using one-way analysis of variance (ANOVA). The Bray-Curtis similarity index was employed to investigate the variations in bird species composition using the adonis function of the vegan package in R (Oksanen et al. 2015). Hierarchical cluster analysis with matrix plot was used to examine the distribution of bird species across habitats and the habitat preferences of different species. Pearson’s correlation test was employed to determine the commonness of avian richness and feeding guild among different urban habitats using corr-plot in the R version 3.4.4 (RStudio 2013). The bird species occurrence according to the feeding guild was considered as the independent variable, while all of the feeding guilds were considered dependent variables. All these different types of analysis were used to give quantitative direction to the work. All the statistical tests were done at $\alpha = 0.05$ level of significance.

Results

In total, 222 bird species belonging to 19 orders and 65 families were recorded in and around Bhubaneswar city, which differed significantly among the habitats ($F = 2.69, p < 0.01$). Among the habitats, agricultural habitat was

Table 1 A snapshot of sampling sites

Sl no.	Place	Habitat	Sampling site details	Level of disturbance
1	Ekamra Kanan 1	FP	One part of the reserve forest and undisturbed area	Low
2	Khandagiri	FP	Undisturbed area but near to road and tourist spot	Moderate
3	Patrapada	FP	Undisturbed area surrounded by shrubland	Low
4	Nandankanan Botanical Garden	FP	One part of wildlife sanctuary area but open for public	Moderate
5	Nandankanan	FP	Zoological park and wildlife sanctuary	High
6	Kapilaprasad	AL	Agricultural land near to a road	Moderate
7	Kalyanpur	AL	Agricultural land near a river	Low
8	Kiakani Lake	AL	Agricultural field near a small industrial area	Moderate
9	Daruthenga	AL	Agricultural fields near the village	Low
10	OUAT Farm House	AL	Agricultural fields near the airport and inside the university campus	Low
11	RPRC Lake 2	GL	Grassland near wetland	Low
12	Gangua Nala	GL	Grassland near a polluted water channel	Moderate
13	Hi-tech Hospital Area	GL	Undisturbed grassland near a riverbank	Low
14	Balianta	GL	Grassland near river and village	Moderate
15	Chintamaniswar Pond	GL	Grassland near pond surrounded by human habitation	Moderate
16	ITER Campus	HH	Human habitation with high urban structure	High
17	OSAP BN-7	HH	Human habitation with moderate canopy cover	High
18	Utkal University	HH	Human habitation but with a large canopy cover	High
19	Old AG Colony	HH	Human habitation with high population density	High
20	GGP Colony	HH	Human habitation with high population density	High
21	Ekamra Kanan 2	PG	Park area connected with a reserve forest	High
22	Madhusudan Park	PG	Park area beside the airport	High
23	Budha Park	PG	Park area near human habitation	High
24	Bindu Sagar	PG	Park area near human habitation and pilgrimage site	High
25	Biju Patnaik Park	PG	Park area near hospital and surrounded by human habitation	High
26	RPRC Lake 1	WL	Wetland near park area and small office complexes	Moderate
27	Badagada	WL	Wetland near highway	Moderate
28	Kanjia Lake	WL	Wetland near a wildlife sanctuary area	Low
29	Deras Dam	WL	Wetland and dam area surrounded by reserve forest and one part open as a tourist spot	Low
30	Daya River	WL	Riverine ecosystem near the peripheral city	Low

GL grassland, WL wetland, FP forest patch, PG park and garden, AL agricultural land, HH human habitation

found to be species-rich (52%, 115 species) and human habitation as species-poor habitat (8%, 17 species). The order of habitats in terms of species richness is AL (52%, 115 species) > FP (50%, 111 species) > PG (39%, 87 species) > WL (32%, 70 species) > GL (11%, 24 species) > HH (8%, 17 species) of the total species richness (Table 3). Further, the number of species in each guild, along with the number of individuals observed in that particular guild, is presented in Fig. 2. It was observed that, in a particular feeding guild, if the number of species was higher, then the number of individuals was also higher. Among the feeding guilds, insectivore was the guild with the highest number of species (181 species)

and omnivore was the guild with the least number of species (11 species), and the observed order was insectivorous > frugivorous > granivorous > piscivorous > molluscivorous > carnivorous > nectarivorous > avivorous > ophiophagus > herbivorous > omnivorous (Fig. 2, Table 3). The feeding guilds differed significantly for the number of bird species ($F = 2.61$, $p < 0.01$). Irrespective of the habitats, the insectivorous guild was represented with a maximum number of species and thereby remained as a dominant one among all the guilds. The comparison of the abundance of species from all habitats within every feeding guild can be shown in Table 3. The Shannon-Wiener diversity index in different habitats was

Table 2 Classification of avian feeding guild based on predominant diet

Feeding guild	Category	Food source
Frugivorous	Frugivore, fruit eater	Fleshy fruits
Carnivorous	Carnivore, raptor, predator	Large arthropods and vertebrate prey
Avivorous	Avivour, egg stealer	Birds
Granivorous	Granivore, seed eater	Grain, seeds, and nuts
Insectivorous	Insectivore, ant follower, woodpecker	Small arthropods
Molluscivorous	Molluscivore	Molluscs
Nectarivorous	Nectarivore, pollen eater	Nectar
Ophiophagous	Ophiophagus, reptile eater	Snake
Piscivorous	Piscivore	Fishes
Omnivorous	Omnivore, miscellaneous (animals and plant parts)	Plant (grain, seed, leaf, stem, root) and animal (insect, mollusc, fish, etc.)
Herbivorous	Herbivore, plant eater	Herbs and macrophytes (stem and roots)

in the order forest patch (4.421) > agricultural land (4.415) > park and garden (4.173) > wetland (3.772) > grassland (2.693) > human habitation (2.615).

These diverse habitats may affect bird feeding guilds, but specific habitats such as agricultural land were found to support the highest species richness of the insectivorous birds. The scatter plot of all the guilds, comparing all birds, is described to show the composition of the abundance of each species in each guild. An asymmetric pattern in the abundance of bird species in each guild was seen in this study area. The insectivorous guild was found to have an abundance-rich pattern in the scatter plot analysis (Fig. 3).

The Pearson correlation coefficient provided insights on the specific preference of bird species under one foraging guild towards a particular habitat (Fig. 4). The

frugivorous guild was significantly correlated with the forest patch habitat ($r = 0.386, p < 0.01$), park and garden habitat ($r = 0.281, p < 0.01$), and human habitation ($r = 0.284, p < 0.01$). The granivorous birds were strongly associated with agricultural habitat ($r = 0.209, p < 0.01$). The birds seen in the insectivorous guild were strongly associated with grassland habitat ($r = 0.168, p < 0.05$). The wetland habitats were strongly associated with birds in the molluscivorous guild ($r = 0.452, p < 0.01$) and the piscivorous guild ($r = 0.515, p < 0.01$). A significant positive correlation was found between the nectarivorous guild and forest habitat ($r = 0.292, p < 0.01$). The birds seen in the omnivorous guild were significantly associated with human habitation ($r = 0.168, p < 0.05$, Fig. 4). On the whole, the feeding guild of birds was a function of the habitat.

Discussion

The patterns of feeding behavior in birds recorded in the present study indicate both the generalist and the specialist nature of birds in the area. Urbanized landscapes with wider habitat differences are known to create an ecosystem for the insectivorous-rich bird community (Gray et al. 2007; de Bonilla et al. 2012; Ding et al. 2019). In agreement with the extant literature (Rajpar and Zakaria 2011), the feeding behavior of bird species’ was in sync with their habitat, which reflected the extent of resource use in that particular habitat. The similarity among all the different habitats and feeding guilds was observed during the present study (Fig. 5), in the form of a dendrogram of similarity index. The most similar cluster is formed between the carnivorous and the avivorous species, indicating that the bird species which feed on birds might also feed on other animals (Sohil and Sharma 2020). In Fig. 5, the omnivorous birds are placed close to human habitation (represented by less

Table 3 Species presence at all habitats of each feeding guild

Feeding guilds	Habitats						No. of species
	WL	FP	PG	AL	HH	GL	
Frugivorous	3	41	32	28	10	4	50
Carnivorous	9	16	13	11	2	3	29
Avivorous	8	12	9	8	1	1	20
Granivorous	4	23	16	31	5	4	43
Insectivorous	58	87	68	95	11	24	181
Molluscivorous	27	5	4	12	0	4	33
Nectarivorous	0	21	12	9	2	4	22
Ophiophagous	4	15	11	11	2	1	20
Piscivorous	32	6	5	15	0	2	38
Omnivorous	3	8	4	6	3	0	11
Herbivorous	6	4	2	6	0	1	13
No. of species	70	111	87	115	17	24	

GL grassland, WL wetland, FP forest patch, PG park and garden, AL agricultural land, HH human habitation

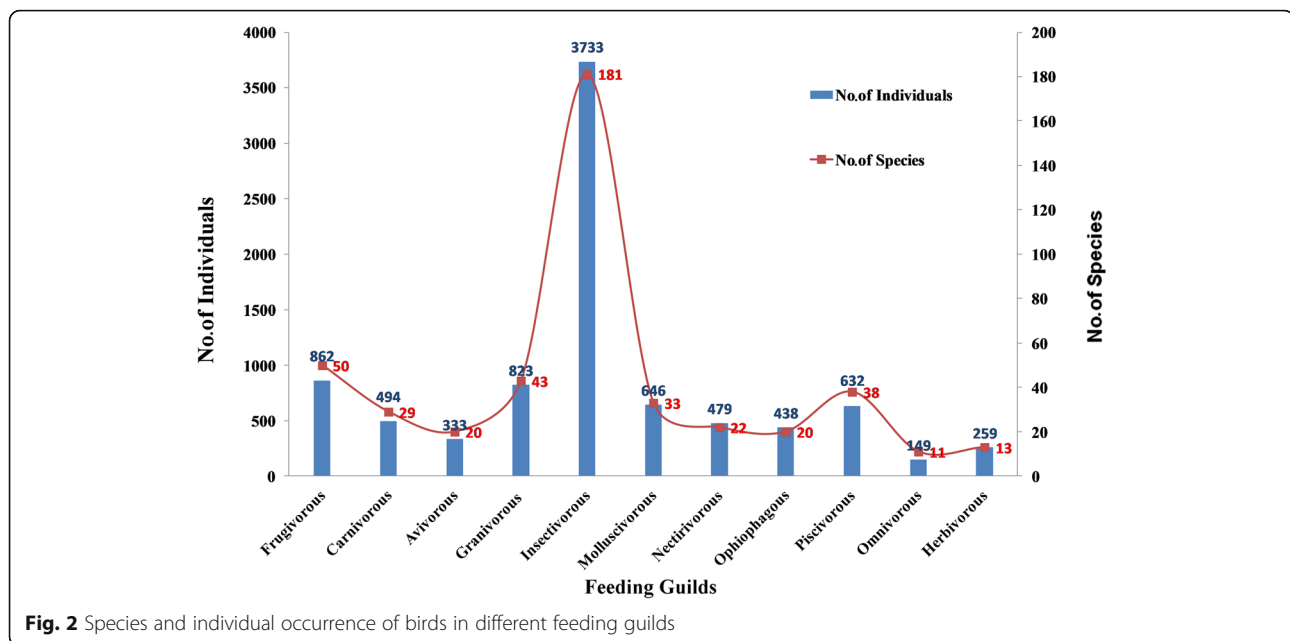
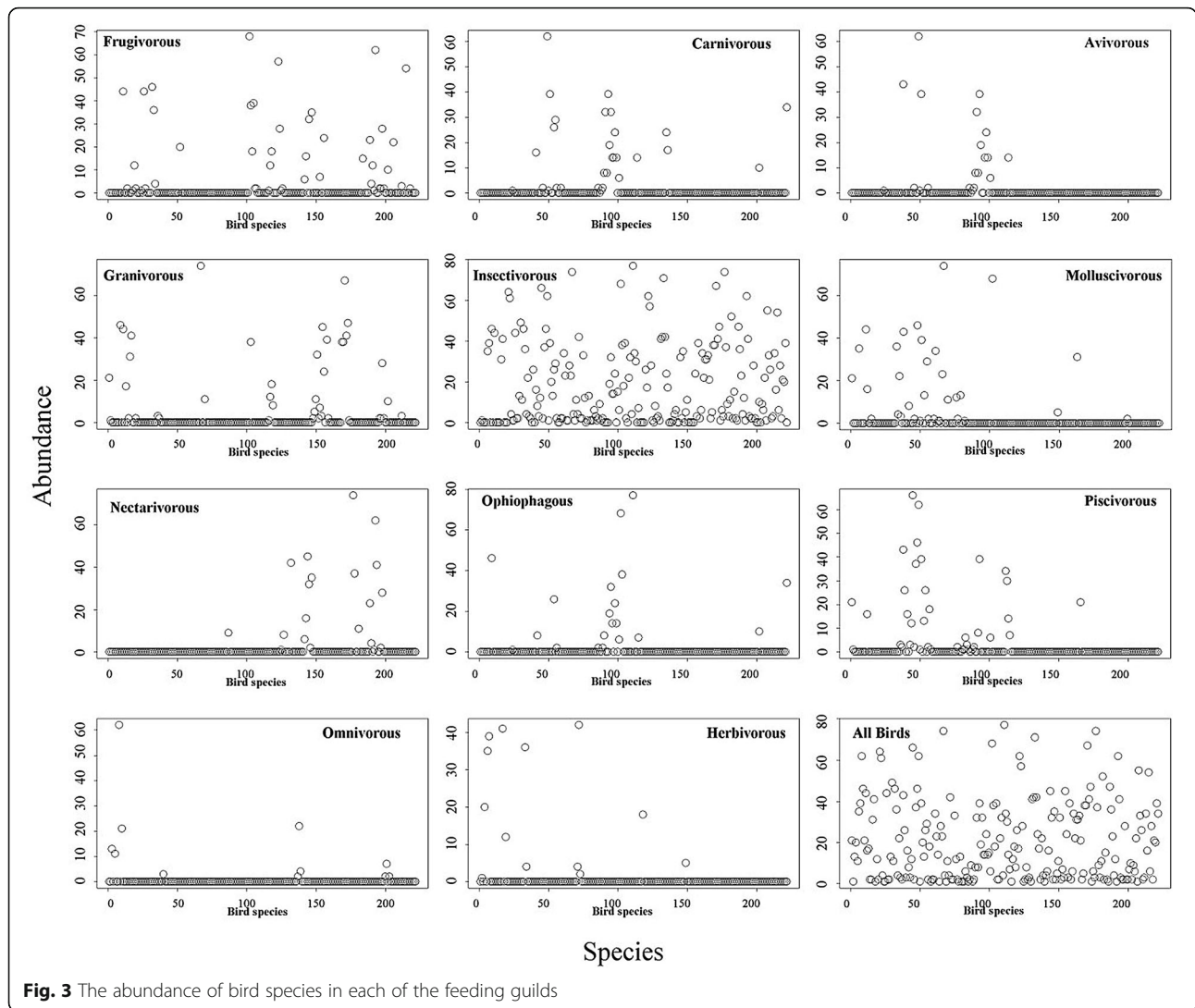


Fig. 2 Species and individual occurrence of birds in different feeding guilds

Euclidean distance from each other), which is suggestive of the fact that the human habitation in urban areas might be a source of various feeding objects for birds. In conforming to earlier studies (Otoni et al. 2009; Mukhopadhyay and Mazumdar 2017, 2019), the omnivorous birds were largely found in human-dominated landscapes and residential areas. In another cluster, the piscivorous and the molluscivorous birds have less Euclidean distance from the wetland habitat. It is known that the abundance of fishes and molluscs is high in wetland habitats, which attracts the wetland birds that are mainly dependent on these organisms for their food (Prajapati and Prajapati 2013; Panda et al. 2021). The frugivorous and the granivorous guilds are in one cluster, which is suggestive of the fact that the fruit-eating birds are mostly grain-eating species that share nearly the same habitat, in the ecosystem like forest and farmlands nearby (Mulwa et al. 2012). The forest patch and park and garden habitats were seen forming one cluster, as these two types of habitats comprise mostly woody vegetation where similar species occurrence is found (Leveau et al. 2019; Wielstra et al. 2011). In line with our expectations, agricultural habitat and the insectivorous feeding guild were found to be clustered together in similarity index. The agricultural lands are rich in insect diversity, thereby attracting the insectivorous birds as an easy foraging ground (Munira et al. 2011).

Bird populations in various fragmented forest landscapes generally respond to these urban-influenced complex environmental combinations in a resilient manner (Leveau 2019, 2021). Birds are not only dependent on the

habitat's resources; the ecosystem's functional viability may also be dependent on the ecological processes provided by these organisms (Gray et al. 2007). Naturally, some bird species are known to be associated with more than one habitat type (Lorenzón et al. 2016), and the presence of the same species in different habitats indicates that resource conditions are met effectively in both natural and human-modified habitats, such as agricultural lands. In the urbanized landscape of Bhubaneswar, the insectivorous feeding guild was found to be the most common, followed by the frugivorous and the granivorous. The mixed habitat of this human-modified landscape might have culminated in an insect-rich habitat, thereby the diversity of the insectivorous guild is higher (Tanalgo et al. 2015). However, due to the lack of suitable soil moisture conditions in highly urbanized habitats, the insectivorous guild seemed to have been severely affected. Because of the availability of a variety of food sources, the omnivorous-rich bird population thrived well in the human-altered landscapes, especially human habitations and residential colonies. Studies carried out elsewhere (Otoni et al. 2009; de Bonilla et al. 2012) are also in agreement with the present findings. In the present study, both the frugivorous and the omnivorous guilds were found to have been positively influenced by both the food resource availability and suitability. The habitat heterogeneity causes significant differences in species richness in specific feeding guilds, *viz.*, the insectivorous and the frugivorous supported by specific habitats like agricultural land and forest habitats, respectively. Major factors such as productivity, disturbance, and habitat heterogeneity may influence local species richness patterns (Lorenzón et al. 2016). Thus, investigations on habitat-specific species



abundances of birds are essential to understand the exact functional relationship. Such functional relationships are manifested in terms of feeding habits of birds, as investigated in the present study, thereby corroborating the hypothesis that feeding guilds in birds can be a function of the habitat. This, in turn, is linked with resource availability in a particular habitat.

Conclusions

The present study is an attempt to create a database on habitat-wise species richness and abundance of birds according to their feeding guild and is the first of its kind study on bird-habitat-feeding guild relationship in an urbanized landscape of Bhubaneswar. The urban landscape of Bhubaneswar supports a good number of bird species, which is a promising factor for furthering the ornithological research in the region. Agricultural lands, forest patches, parks and gardens, and wetlands inside the

cityscape served as the food base for the birds and seemed to have supported a maximum number of bird species. Thus, the creation of small parks and other green patches inside the urban structures can help in promoting bird diversity in the cityscape. The highly modified urban structures supported only a few species of birds, especially the omnivorous ones and those dependent on human habitations. The insectivorous guild being the species-rich feeding guild demonstrated the importance of agricultural landscape in and around the urban area. The urbanized landscapes with diversified habitats support birds under specific feeding guilds as a function of habitat quality and resource (e.g., food) availability. The findings of the study necessitate creating woody habitats and controlling the degradation of agricultural lands for long-term maintenance of such diversity-rich habitats. That is to say the avian affinity structure as a part of urban planning and associated policy frameworks are recommended.

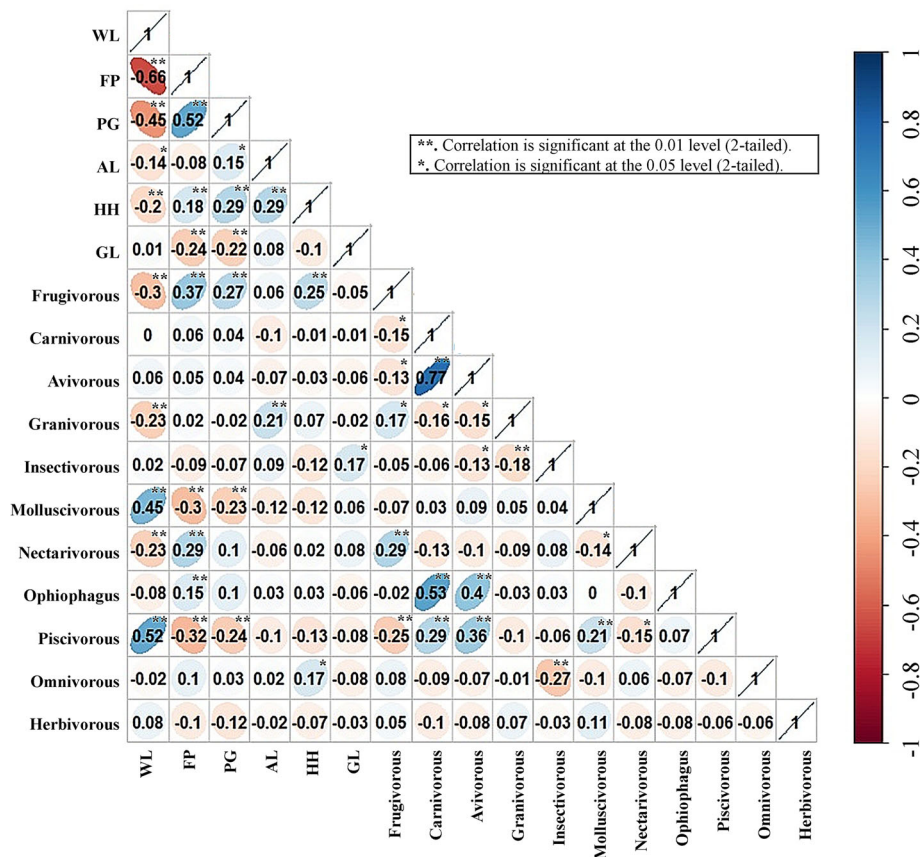


Fig. 4 Corr-plot showing correlations among habitats and feeding guilds concerning bird species abundance. *GL* grassland, *WL* wetland, *FP* forest patch, *PG* park and garden, *AL* agricultural land, *HH* human habitation

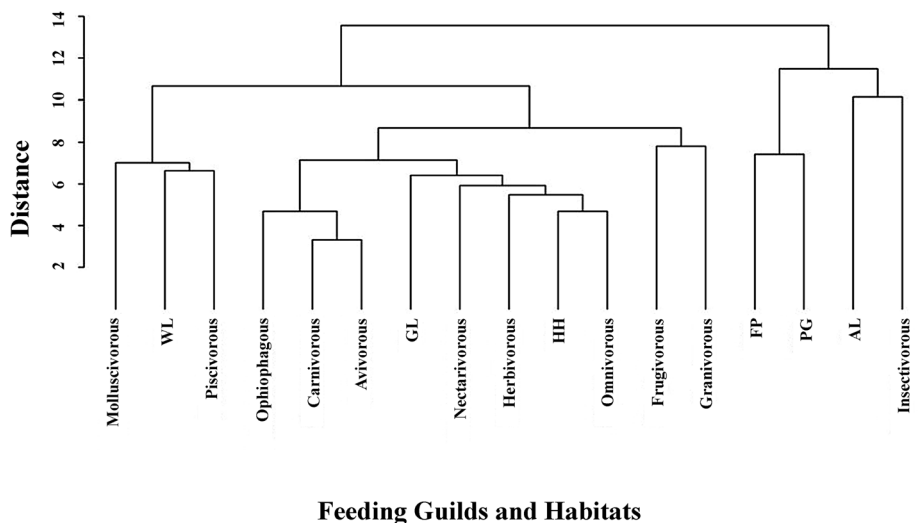


Fig. 5 Hierarchical cluster of feeding guilds and habitats for bird species abundance. *GL* grassland, *WL* wetland, *FP* forest patch, *PG* park and garden, *AL* agricultural land, *HH* human habitation

Abbreviations

AL: Agricultural land; ANOVA: Analysis of variance; FP: Forest patch; GL: Grassland; HH: Human habitation; PG: Park and garden; WL: Wetland

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13717-021-00304-6>.

Additional file 1.**Acknowledgements**

The authors thankfully acknowledge the persons who helped with the completion of the fieldwork. We are thankful to the Department of Forest and Environment, Govt. of Odisha, for according necessary permissions to carry out the survey. We are grateful to the two anonymous reviewers for offering their valuable comments, which helped in improvising the manuscript.

Authors' contributions

BPP conceptualized the study and collected the data along with BP. BPP analyzed the data and wrote the manuscript. BAKP supervised the whole study and finalized the manuscript. AP and SPP edited the manuscript. The authors read and approved the final manuscript.

Funding

The study is self-financed.

Availability of data and materials

Not applicable

Declarations**Ethics approval and consent to participate**

All requisite information and data were collected without disturbing the birds and their habitats. Photographic recordings were made using a telephoto lens.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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Received: 5 March 2021 Accepted: 21 April 2021

Published online: 10 May 2021

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