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Inter-relationship of feeding guilds and different habitats with reference to bird species in Rajkot city, Gujarat, India

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Abstract
The main factor causing habitat change that is hurting avian groups is the quick expansion of residential development in metropolitan areas. Rajkot city is center of Saurashtra region and fourth largest city in Gujarat. In the city, we have surveyed birds at 27 different sampling locations. There are four types of habitats are included in this study. We found 82 species in 20 orders and 44 families overall. With more than 78% of the total diversity, semi-urban habitat like Wetland habitat was the most preferred habitat. Semi-urban habitat like Grassland habitat came in second with 70%, followed by urban habitats like Gardens with 53% and Human habitation with 30%. The bird checklist prepared from this study's observation includes IUCN Red List listed three species as globally Near Threatened. The diversity of the bird communities in the Wetland and Grassland habitats showed a positive correlation ($r = 0.93$, $p < 0.05$). The Garden and Wetland had a negative correlation ($r = -0.096$, $p < 0.05$), according to Corr-Plot showing correlations among habitats and species. This study's findings reveal a high avian species richness. In order to prevent the diversity and richness of these species from declining, a general conservation plan may be recommended.

Keywords: Rajkot city, four types of habitat, urban habitats, semi-urban habitats

Introduction

Due to their existence in all climatic zones and habitat types, birds have long been regarded as effective model systems for researching all biodiversity clans [1] (McCain and Grytnes 2010). Although habitat heterogeneity may have an impact on the ecological processes of birds, species diversity and habitat heterogeneity provide information on the basic spatial ecology of birds [2] (Smith *et al*. 2013). A community of birds using the same class of environmental resources is known as a guild, which is a key idea in avian ecology [3] (Balestrieri *et al*. 2015).

According to their environment, which is influenced by a number of variables, including food availability, vegetation cover, predator availability, and other variables [4] (Katuwal *et al*. 2016), each guild has a varied tolerance capacity and resource demand. As a result, several environmental factors have an impact on the assemblage of bird species within a single guild. For a better understanding of the community structure of birds and their habitat selection mechanisms, some scientists propose differentiating the richness gradients for distinct guilds [5] (Snep *et al*. 2015).

The natural flora has been significantly changed, and the native habitats of birds have been lost, fragmented, or altered due to the intense demands of urbanisation [6] (McKinney 2008). As a result of their forests and wetlands, urban areas with fragmented and patchy habitats can still sustain high levels of biodiversity [7] (Panda *et al*. 2020). Nevertheless, it appears that birds are drawn to urbanised areas by an abundance of untapped resources like food, shelter, nesting locations, and breeding areas [8] (Čanády & Mošanský 2017).

According to the international environmental accords, one of the creative ways to preserve biodiversity is through urban conservation [9] (Khera & Sabata 2009). Since about half of the world's population lives in cities, protecting urban biodiversity is essential if we are to reach all levels of biodiversity [10] (Satterthwaite 2002). The degree of green space within a city and the gradient of urbanisation influence the diversity and richness of native avian species [11] (Chiari *et al*. 2010). Non-native species may be able to adapt to suburban and urban environments if urban habitats are significantly altered [12] (Mckinney 2005). The urban bird community may be negatively impacted by habitat heterogeneity, fragmentation, isolation, and loss [13] (Marzluff & Ewing 2001).

Food and shelter, two main necessities of bird habitat were not available in sufficient manner in Rajkot [14] (Saiyad 2016). Maximum percentage of sparrow population was observed to roosts on Prosopis juliflora (61%) followed Alstromia scholaris (17%) whereas lowest percentage population was on Aegle marmelos, Cascabela thevetia and Azadirachta indica [15] (Chavda *et al*. 2015). The mixed type of habitat supports maximum species richness of diverse vertebrate communities. The less vertebrate diversity observed in human habitat due to human interferences While more number of individuals of few bird communities found due to their human tolerance adaptation [16] (Raval & Soni 2015). Bird species composition is found to be preliminary determined by land use and geographical difference [17] (Jadav 2010).

Materials and methods

Study Area

Rajkot is located in the middle of Gujarat state's Saurashtra region at 22.3039° N, 70.8022° E. Rajkot has a hot, semi-arid climate with a wet monsoon, hot, dry summers and relatively cold winter. The cyclone is among the most significant meteorological events connected to Rajkot. The

temperature in the summertime is between 24 and 42 °C and in the winter between 10 and 22 °C. With the exception of the monsoon months of July through September, the city is situated on the banks of the Aji and Nyari rivers, both of which are dry. The city occupies an area of 170.00 square kilometers. Rajkot is one of Gujarat's main industrial hubs, which makes its position significant. The city is situated in Gujarat's Rajkot district. Rajkot is the fourth-largest city in the Indian state of Gujarat [18] (smartcityrajkot.in 2024).

The city contains approximately 127 parks and other green areas, including inhabited areas, agricultural lands and grasslands are known to promote urban biodiversity. There are 6 wetlands adjacent to Rajkot city area. The current investigation was carried out in four various habitats. Thus, Rajkot City's research area has been separated into four primary habitat types. 1. Man-made parks and gardens with somewhat dense vegetation patches 2. Human habitats with little to no vegetation 3. Low dense vegetation is found in wetlands, and 4. Medium thick vegetation is found in grasslands (Figure 1, Figure 2, Figure 3 & Figure 4).

Methods

Sampling

From January 2018 to December 2018, bird surveys and related samplings were conducted to observe and count birds using point count method. This survey was conducted at each of the 27 sites one time, for a total of 567 samplings, during the course of the one year in a month at each of the 27 sites. A mobile GPS was used to record the geo-coordinates of several sites. Monthly one day surveys were carried out at each site for one hour after sunrise and one hour before sunset by author. Each site was visited for a total of 1,134 hours for the full survey in the current study. No surveys were carried out when it was raining or very windy. The seasons included by the current survey were winter (November-February), summer (March-June) and Monsoon (July-October). Bird observations were collected using the point count method [19] (Volpato *et al*. 2009) and a total of five points within a 20-meter radius were computed at the chosen study site. For the purpose of gathering information on the birds feeding pattern throughout the year, behavioral observations were manually recorded.

An initial survey was carried out with the primary goal of analyzing the research area. Large grass fields with few herbs and shrubs are classified as Grassland habitat, large water bodies and swampy areas are classified as Wetland habitat, scrublands and man-made gardens are classified as Garden habitat and residential colonies and urban structures are classified as Human habitation. Six Wetlands, named as, Randarda lake, Lalpari lake, Aji-1 dam, Aji-2 dam, Nyari-1 dam and Nyari-2 dam are selected as study sites for Wetland habitat. Three Grasslands, named as, Khambhala vidi, Khirasara vidi and Anandpar vidi are selected as study sites in Grassland habitat. Fourteen gardens, named as, Racecouse Main garden, Racecourse Kalpana Chawla Memorial garden, Tatya tope garden, Bhakta Kavi Narsinh Mehta Udhyan, Jubilee garden, Shivaji Park garden, Housing board garden – 2, Kidvainagar Senior Citizen Park, Shaheed Vir Bhagatsinh garden, Shri Chandrashekhar Azad Garden, Jilla garden, Sorathiyawadi chowk garden, Shri Sardar Vallabhbhai Patel swimming pool and garden and Aji dam Main garden are selected as study sites in Garden habitat. Bhilwas area, Sardar Nagar area, Kidvai Nagar area and Aalap Century area are selected as study sites in Human habitation. Six sites, three sites, fourteen sites and four sites were randomly selected respectively from Wetland, Grassland, Garden and Human habitation. Twenty seven sites were randomly selected in current study for routine bird survey (Figure 5, Figure 6, Figure 7 & Figure 8).

Binoculars (Porro Prism Black Olympus Binoculars 10 x 50 DPSI) were used for birding in order to capture physical characteristics for identification. A digital camera (COOLPIX P900) was also used to take pictures in order to aid identify the correct species. Reference books such as Birds of Northern India [20] (Grimmett & Inskipp 2019), Birds of the Indian Subcontinent [21] (Grimmet *et al*. 2015), and The Book of Indian Birds [22] (Ali 2002) were used to identify the birds seen in fields. Other reliable online resources were also consulted [23] (IUCN Red list of Threatened Species 2021).

Classification of recorded and identified avifauna was done according to family, order, zoological name, and common name [24] (Praveen *et al*. 2019). The different bird species were divided into different feeding guilds based on their diet and foraging environment [25, 26] (Grimmett *et al*. 1999, DeGraaf *et al*. 1985).

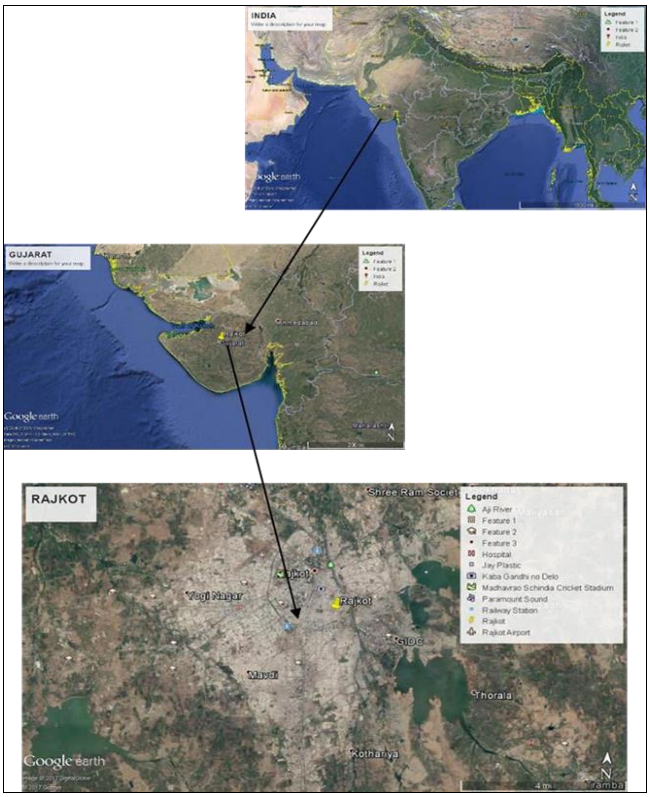

Fig 1: At the top indicates Map of India**, Fig 2:** In the middle indicates Gujarat state**, Fig 3:** At the bottom indicates Rajkot city

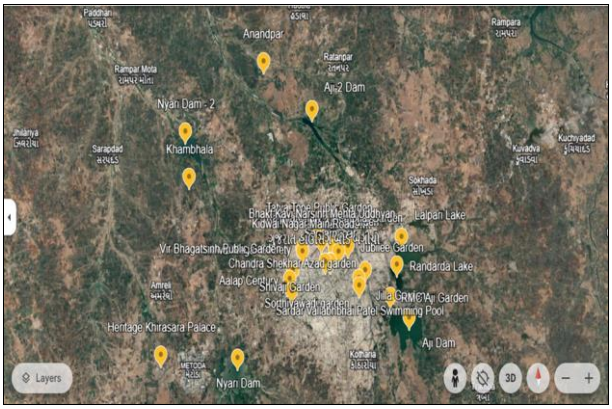

Fig 4: Shows study sites demarcated in and around Rajkot city

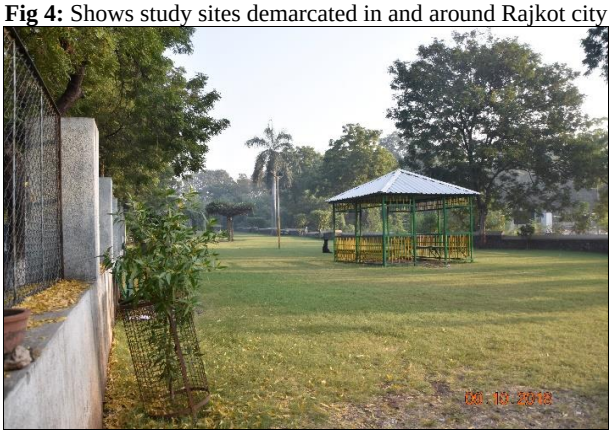

Fig 5: Photograph of one of the Garden habitat (Aji dam Garden)

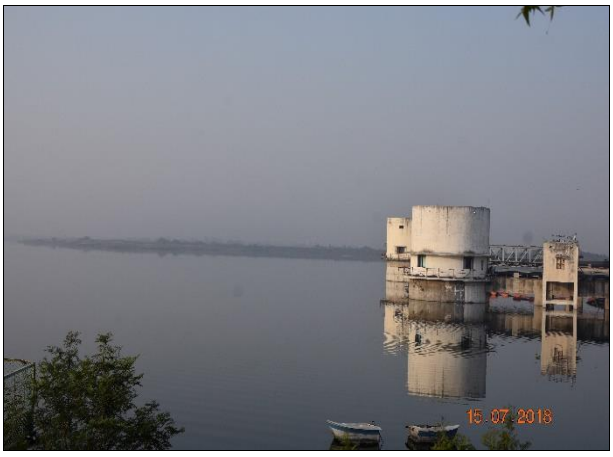

Fig 6: Photograph of one of the Wetland habitat (Nyari-1 dam site)

Fig 7: Photograph for patch of Grassland habitat

Fig 8: Photograph of one of the Human habitation (Aalap century society area)

Data Analysis

Based on their presence in a variety of habitats, the birds that were spotted in the area were divided into orders and families with specific habitat preferences, i.e., Garden, Wetland, Human habitation and Grassland. To discover which avian species preferred which locations and habitats, the Shannon Wiener Diversity index, Simpson Diversity index, Margalef Richness index, Menhinick Richness index, Pielou Evenness index and Berger Parker Dominance index for each habitat was calculated.

For the purpose of gathering information on the bird's feeding pattern throughout the year, behavioural observations were manually recorded. For additional interpretation, the degrees of disturbance at each of the sampling sites were also identified and documented [27, 8] (Rajashekara and Venkatesha 2015, Čanády & Mošanský 2017).

1. **Shannon Wiener Diversity index** is

$\bar{H} = -\sum_{i=1}^{s}\left(\frac{ni}{N} \times \ln\frac{ni}{N}\right)$

where, ni represents the total number of individual species present in respective habitat and N represents the total number of species recorded in that respective habitat.

For Shannon Weiner Diversity index ranges between 1.5 and 3.5. The higher index value, the greater biodiversity in the area.

2. **Simpson Diversity index** (SDI) is

SDI = 1 - sum of n (n-1) / N (N-1)

For Simpson Diversity index ranges 0 to 1. The higher index value, the greater biodiversity in the area.

3. **Menhinick Richness index** is

D_{men} = Total number of species present in habitat/ Total number of individuals present in habitat

For Menhinick Richness index range, higher the index value, the greater the species richness or biodiversity in the area.

4. **Margalef Richness index** is

Margalef Richness index = (S - 1) / ln N

S means total number of species of that habitat and N means total number of individuals of that habitat, ln means natural logarithm.

The Margalef Richness index can range from 0 to positive infinity. The higher the index value, the greater the species richness or biodiversity in the area.

5. Pielou Evenness index is

J = H' / ln (S) where H' = Shannon Weiner index and S = Total number of species in community

Pielou Evenness index is a way to measure how the species are evenly distributed in community.

Higher values indicate higher levels of evenness. At maximum evenness, J = 1. J can be used as measures of species dominance (the opposite of diversity) in a community. It is defined between 0 and 1.

1 represents a community with perfect evenness, and it decreases to 0 as the relative abundance of the species diverge from evenness.

6. Berger Parker Dominance index is

BPI = Nm / n

Nm is number of individuals in the most abundant species and n is number of individuals in the sample. This index expresses proportional importance of the most abundant type.

If Berger Parker Dominance index is higher this means that community is dominated by the most common species. The reciprocal of the index 1/BPI is often used, so that an increase in value of index accompanies an increase in diversity and reduction in dominance. [28, 29, 30] (Shannon & Weiner 1963, Magurran 2004, Van Heezik *et al*. 2008).

We have tallied the bird species in each point and arranged them in accordance with their appropriate taxonomic families for the purpose of performing a Relative Diversity (RDi) analysis. Subsequently. RDi analysis can be calculated as follows [31] (Priya *et al*. 2022):

$$\text{Relative Diversity (RDi)} = \frac{\text{Number of species in respective order /family}}{\text{Total number of bird species}} \times 100$$

The Bray-Curtis similarity index was used to analyse the variations in bird species composition. The chart of Bray-Curtis similarity was created using PAST software [32] (PAST software version 4.16c). Using corr-plot in Microsoft Excel worksheet, the correlation test was used to ascertain the commonality of bird diversity among various urban habitats.

Results and discussion

Our research sought to analyse the richness and abundance of bird species across various urban habitats and to comprehend the function of urban green spaces in the preservation of avian diversity. Eight feeding guilds of birds were discovered in the current investigation. For each of the observed feeding guilds, species richness was assessed at each sampling site.

Bird surveys

A total of 20 orders and 44 families including 82 species were found. With 78.04 % (s = 64 species) of the overall variety, Wetland was the most used habitat, followed by Grassland with 70.73 % (s = 58). Garden covers 53.65 % (s = 44) and Human habitation conversely covers 30.48 % (s = 25).

Taking into account the species' abundance throughout the study period, the maximum quantity of observations deemed very common, and the less observations than very common deemed common. Due to the area's high human population, 15.85 % (s =13) for very common species, and compared to 84.14 % (s =69) for common species. The frequency of common bird species are more than very common bird species in all four habitats (Figure 9 & Figure 11).

Based on their patterns of movement, the species were classified as 84.14 % resident (s =69), 10.97 % winter migratory (s =9), 2.43 % summer migratory (s =2), and 2.43 % local migratory (s =2). The urban vegetation was largely chosen by the resident birds. Most migratory birds favoured the habitats of Wetland and Grassland. Out of all the urban areas, Wetland has the highest level of species richness (Figure 9 & Figure 10).

Three bird species were Near Threatened : the Painted stork (*Mycteria leucocephala*), and the Lesser flamingo (*Phoeniconaias minor*), which are typically limited to Wetland habitat. The Black headed ibis (Threskiornis melanocephalus), which can be found in all four; Garden, Wetland, Human habitation and Grassland habitats.

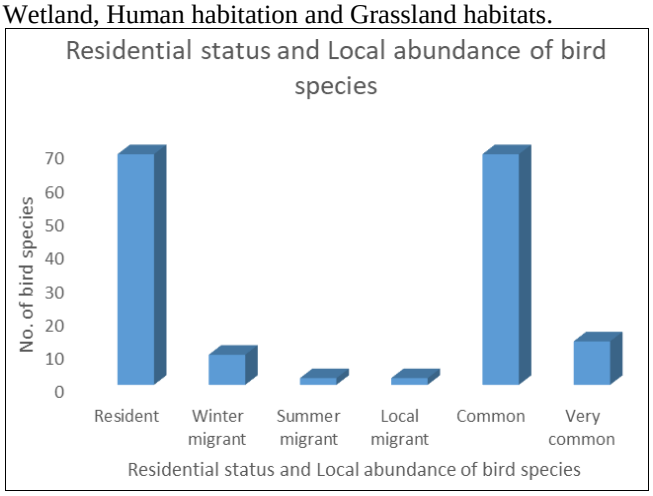

Fig 9: Distribution of bird species according to their Local abundance and Residential status in Rajkot city, Gujarat

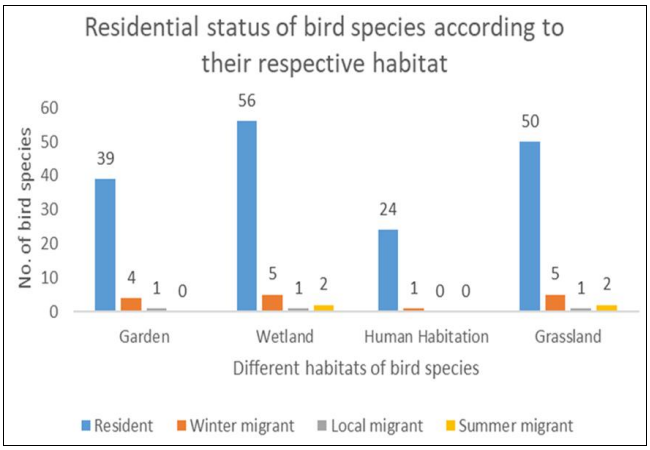

Fig 10: Distribution of Residence, Winter migrant, Summer migrant and Local migrant species along with their respective habitats in Rajkot city, Gujarat (Garden, Wetland, Human Habitation, Grassland)

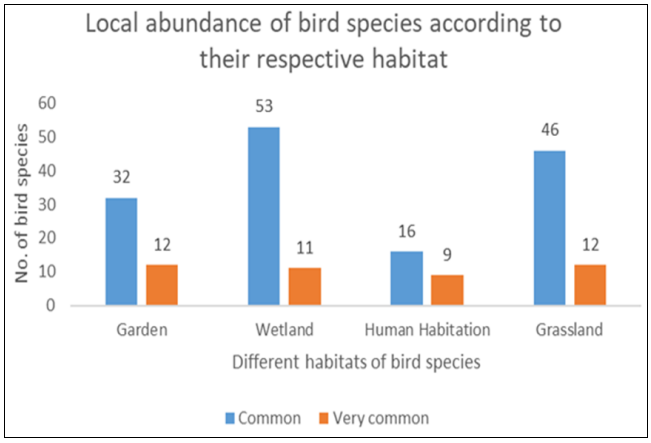

Fig 11: Distribution of Very common and Common along with their respective habitats in Rajkot city, Gujarat (Garden, Wetland, Human habitation and Grassland)

Bird species richness, diversity, and composition

A variety of diversity indicators were calculated. With 3.5555, and 3.4917, respectively, the Shannon-Wiener Diversity index was highest in Grassland, and Wetland. For other habitats like Human habitation and Garden, the Shannon-Wiener Diversity index are 2.7082 and 1.7422, respectively. For Simpson's Diversity index, habitats like Grassland, Wetland, Human habitation and Garden have calculated values like, 0.96, 0.95, 0.90, and 0.59, respectively. In Simpson's Diversity index habitats like Grassland and Wetland have highest values (Table 1).

The environments with the greatest species richness were Grassland and Wetland, whereas Garden and Human habitation had comparatively low species richness. For Margalef Richness index, habitats like Wetland, Grassland, Garden and Human habitation, have computed values, 9.33, 9.31, 6.34 and 4.02, respectively. For Menhinick Richness index, calculated values for habitats like, Grassland, Wetland, Garden and Human habitation, are 2.71, 2.18, 1.47 and 1.26, respectively (Table 1).

For habitats like Grassland, Wetland, Human habitation and Garden, calculated values of Pielou Evenness index are 0.87, 0.84, 0.84 and 0.46, respectively. Garden habitat have highest calculated value 0.62 for Berger Parker Dominance index. Other habitats like Human habitation, Wetland and Grassland have calculated values of Berger Parker Dominance index are 0.26, 0.11, and 0.10, respectively (Table 1).

In all four habitats; Garden, Wetland, Human habitation and Grassland, the order Passeriformes had the highest variety and Relative Diversity value; 40.9 %, 37.5 %, 52 % and 41.37 %, respectively, from all orders. In Human habitation second highest order is order Columbiformes with Relative Diversity value of 16%. In Garden, Grassland and Wetland habitats, second highest order is order Pelecaniformes with relative abundance of 13.63 %, 10.34 % and 9.37%.

The least occurring orders in Garden habitat are order Apodiformes, Bucerotiformes, Charadriiformes, Piciformes and Psittaciformes. The least occurring orders in Wetland habitat are order Anseriformes, Apodiformes, Bucerotiformes, Caprimulgiformes, Piciformes, Psittaciformes and Pterocliformes. The least occurring order in Human habitation is order Psittaciformes. The least occurring orders in Grassland habitat are order Apodiformes, Bucerotiformes, Caprimulgiformes, Piciformes, Psittaciformes, Pterocliformes.

Table 1: Diversity indices of different urban habitats in Rajkot city, Gujarat

Habitat	Shannon Weiner Diversity index	Simpson Diversity index	Margalef Richness index	Menhinick Richness index	Pielou Evenness index	Berger Parker Dominance index	No. of species
Garden	1.742266	0.59	6.34	1.4775	0.46	0.62	44
Wetland	3.491751	0.95	9.33	2.18803	0.84	0.11	64
Human habitation	2.708219	0.9	4.02	1.263264	0.84	0.26	25
Grassland	3.555586	0.96	9.31	2.719175	0.87	0.1	58

The relationship between avian species and urban habitats

The dendrogram model that best explained the similarity in bird composition across the four selected environments was shown in Figure 12. Because Grasslands and Wetland habitats are less disturbed than Garden habitat and Human habitation, Wetland and Grassland habitats showed about comparable diversity ($wi = 0.95$, $p < 0.05$) according to the Bray-Curtis similarity score. Additionally, the similarity index shows that the Wetland and Garden habitats, had lower similarity index $wi = 0.63$, $p < 0.05$. In this case, "wi" stands for the similarity index value.

There are twenty four prevalent species in all four habitats. Some of prevalent bird species are Black kite (*Milvus migrans*), Blue Rock Pigeon (*Columba livia*), Eurasian collared dove (*Streptopelia decaocto*), Green bee eater (*Merops orientalis*), Black drongo (*Dicrurus macrocercus*), Rufous treepie (*Dendrocitta vagabunda*), House crow (*Corvus splendens*), Red vented bulbul (*Pycnonotus cafer*), Common Myna (*Acridotheres tristis*), Brahminy Myna (*Sturnia pagodarum*), Indian robin (*Copsychus fulicatus*), Purple sunbird (*Cinnyris asiaticus*), House sparrow (*Passer domesticus*), Indian silverbill (*Euodice malabarica*) and Cattle Egret (*Bubulcus ibis*).

By treating species diversity as an independent variable and habitats as a dependent variable, the habitat-habitat correlation is achieved. The diversity of the bird communities in the Wetland and Grassland habitats showed a positive correlation ($r = 0.93$, $p < 0.05$) in Figure. The Garden and Wetland had a negative correlation ($r = -0.096$, $p < 0.05$), according to Corr-Plot showing correlations among habitats and species (Figure 13).

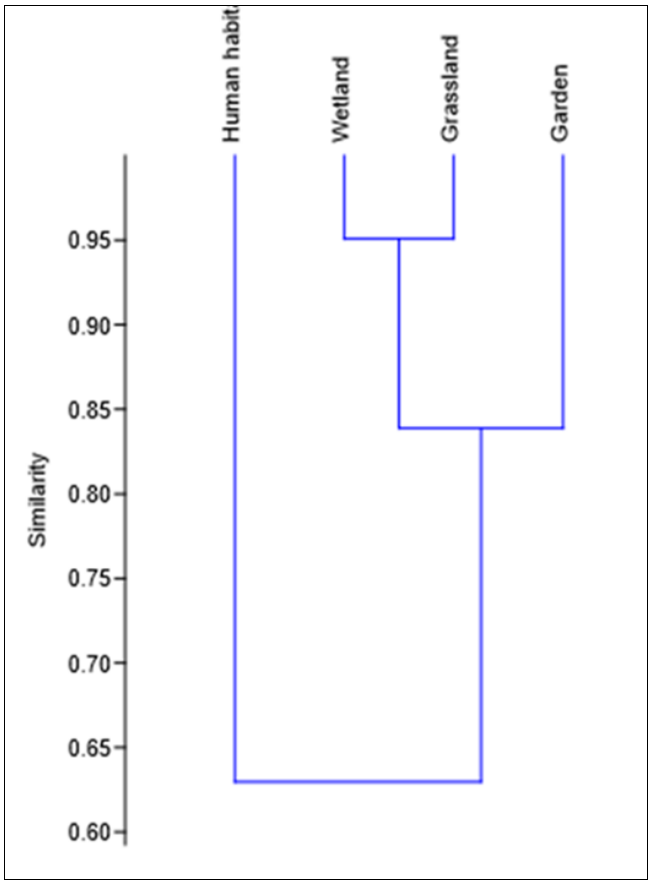

Fig 12: Bray-Curtis index showing the similarity of bird species composition among the different habitats in Rajkot city, Gujarat (Garden, Wetland, Human habitation and Grassland)

	Garden	Wetland	ıan habita	Grassland
Garden	1			
Wetland	-0.09666	1		
Human ha	0.115444	0.758839	1	
Grassland	-0.03742	0.937692	0.879995	1

Fig 13: Corr-Plot showing correlations among habitat and species in the sampling habitats in Rajkot city, Gujarat (Garden, Wetland, Human habitation and Grassland)

Discussion

Given that the study site was an urban area with a large population density, Rajkot city has a range of habitats, from highly constructed landscapes to natural areas. It has been discovered that the majority of birds are favoring green areas. Both Wetland and Grassland habitats have comparable levels of richness. Although fewer migratory and locally migratory species exist. For urban biodiversity to continue, Wetland and Grassland must be preserved.

This study confirmed the prediction that bird diversity is rather low in urban areas across all sampling sites. Urbanisation has destroyed natural habitats, nesting sites, and eating patterns [33, 34] (Murgui 2009, Njoroge *et al*. 2014). Semi-urban areas (Garden habitat) are more diverse than highly urbanised areas (Human habitation). Urban habitats were dominated by urban exploiter species, such as the Rock Pigeon (*Columba livia*), House Sparrow (*Passer domesticus*), House Crow (*Corvus splendens*), and Black Drongo (*Dicrurus macrocercus*). These many species are found in every urban habitat [35] (Khera *et al*. 2009).

Some researchers proposed that different kinds of birds could be drawn to residential areas with well designed natural landscapes [36] (Aurora *et al*. 2009). Some bird species are known to be connected with more than one habitat type [37] (Lorenzón *et al*. 2016). The fragmented Garden habitat within the city contribute the most to the diversity of urban birds, according to this study's species diversity index. It will therefore provide an ideal, unspoiled habitat for bird groups. It has been demonstrated that urbanisation causes bird variety to decline [38, 39] (Caula *et al*. 2014, Ferenc *et al*. 2016). In all four habitats, Passeriformes exhibited the highest relative diversity and species richness. Since most species in this group are granivorous and insectivorous, every habitat might provide a sufficient supply of food for them. According to the results of the current study, the appropriateness and availability of food resources had a favourable impact on the omnivorous guild [40] (Panda *et al*. 2021). In Delhi, India, some researchers discovered that insectivore and omnivore species predominated [35] (Khera *et al*. 2009). This study is confirming the link between diet, habitat preference and species diversity will require more thorough research.

In current study, a dendrogram of similarity index was used to show the resemblance between all of the various habitats and feeding guilds (Figure 12). To understand bird's environmental needs, nesting habits, and functional variety, a thorough investigation is necessary [7] (Panda *et al*. 2020). In order to preserve habitat for urban species, a conservation plan should be created that includes building artificial environments and restoring native vegetation cover to support populations of rare species [41, 42] (Fontana *et al*. 2011, Dale 2018). Additionally, urban growth must be prevented from affecting the remaining habitat of threatened species at order to conserve these uncommon species [43, 44, 45, 46, 47] (Mallik *et al*. 2015, Debata *et al*. 2017, Kar & Debata 2018, Kar *et al*. 2018, Mohapatra *et al*. 2019). By raising public awareness and establishing open plantations on their property, planting trees and bushes, and building urban areas with plantation-appropriate designs, Rajkot citizens may help conserve the diversity of wildlife. Legal implementation of these measures is necessary to safeguard urban avifauna [7] (Panda *et al*. 2020).

Conclusion

It is possible to investigate how urbanisation affects biodiversity through the use of birds [48] (Chace & Walsh 2006). The current project, which is the first of its kind to examine the interaction between birds, habitats, and feeding guilds in the urbanised environment of Rajkot, aims to build a database on the species richness and abundance of birds according to their feeding guild. A lot of different bird species can be found in Rajkot's urban environment, which is encouraging for the development of ornithological studies in the area. In order to encourage bird diversity in urban areas, small Gardens and other green spaces might be created inside of urban structures.

Only a few kinds of birds, particularly omnivorous ones and those depending on human habitations, were supported by the substantially transformed urban settings. The findings

can be used to explain how various micro-habitats within the urban environment influence various bird species distribution patterns. Policymakers and urban planners should learn from this how to preserve urban biodiversity and improve urban design [49] (Farmer *et al*. 2013). The study's conclusions call for the inclusion of avian affinity structures in urban planning and associated policy frameworks in order to prevent the long-term degradation of such diversity-rich habitats and to control the deterioration of natural habitats.

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Conflict of interest
The authors declare that there is no conflict of interest.

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