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Research Article

A comparative study of bird diversity and guild structure of bird communities in urban green patches of Pune metropolitan region, India

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ABSTRACT

Birds are an important component of the food chain as they support associated fauna and their assemblage is dependent on the type of habitat. Changing environments, such as urbanization severely affects bird diversity and their ecology. However, natural green patches and artificial gardens could support significant bird diversity and help them to survive through. Composition of bird species in green patches of a particular urban area may vary depending on the size of the area and type of the vegetation. Bird diversity of five urban green patches in a metropolitan city, Pune, India was studied. Bird diversity was monitored at four urban sites (Panchawati, Saras Baug, Fergusson College, and Nigdi) and one natural hill forest site (Sinhagad valley). Food grid and residential status of the birds was also analyzed which were observed in all study sites. Bird assemblage at Sinhagad valley was distinct than other urban sites. Among the urban sites, Panchawati harbors the highest number of bird species while at Nigdi, we recorded the lowest number of bird species. All the sites were dominated by Passeriformes birds followed by Accipitriformes birds. All the urban sites support native bird species while Sinhagad valley supports native and migratory birds owing to its large area and natural forest coverage. Irrespective of the habitat, all sites predominantly support insectivore and omnivore birds. The results of the present study along with the other reports are useful for monitoring bird diversity, helpful to understand the impact of urbanization on bird assemblage, and prioritizing future conservation action plans.

Key words: Bird assemblage, Bird diversity, Food guild, Urban green patches

INTRODUCTION

Birds are integral part of an ecosystem and play a central role in the food chain (Murakami & Nakano, 2000;González-Bergonzoni *et al*., 2017). Bird diversity and their community structure are dependent on the nature of the vegetation and the type of the wetlands (Steinmetz *et al*., 2003; Klaassen & Nolet, 2007; Green & Elmberg, 2014; Choudaj & Wankhade, 2022). As birds are solely dependent on flora and fauna of the habitats for feeding, roosting, breeding, etc., slight changes in the habitat structure can influence their diversity patterns (Paritsis & Aizen, 2008; Paudel & Šipoš, 2014; Casas *et al*., 2016). For example, changes in natural vegetation by exotic plantation alter bird diversity, assemblage, nesting (Shankar Raman & Sukumar, 2002; Chandrasekaran *et al*., 2014; Mandal & Shankar Raman, 2016). Since birds are sensitive to environmental changes, the data on the pattern of bird diversity and community structure can serve as ecological indicators (O'Connell *et al*., 2000; Alexandrino *et al*., 2016; Kirk *et al*., 2020). Moreover, bird diversity monitoring of changing habitats can also be helpful in evaluating the impact of habitat modifications and environmental changes on biodiversity (Vergara-Tabares *et al*., 2018; Fusco *et al*., 2021).

Growing human settlements as urbanization has devastative impact on biodiversity. As consequence of urbanization, forest acquisition for constructions and industrial effluents severely affect forest and wetland biodiversity respectively (Suarez-Rubio *et al*., 2011; Leveau, 2013; Belskii & Mikryukov, 2018). In addition, urbanization and consequent exotic plantations have negative impact on biodiversity and species community (Kohli *et al*., 2004; Sandström *et al*., 2006; Punalekar *et al*., 2010), especially on local bird community (Strohbach *et al*., 2013). However, green urban areas with native vegetation support local and migratory bird species (Choudaj & Wankhade, 2021b). Natural patches in urban cities play an important role in supporting native bird diversity than those of exotic plantations (Scheiman *et al*., 2003; Zurita *et al*., 2006; Proença *et al*., 2010; Zhou & Chu, 2012). Comprehensive studies of bird diversity of urban cities can help to understand the impact on native diversity and to design conservation action plans (Chiron *et al*., 2024; Guilherme *et al*., 2024). As a part of long term bird monitoring program in the Indian urban cities, Choudaj & Wankhade (2021b, 2022) reported the urban bird diversity with respective to exotic and native forests. In continuation to this, here we report bird diversity of selected urban sites in Pune city.

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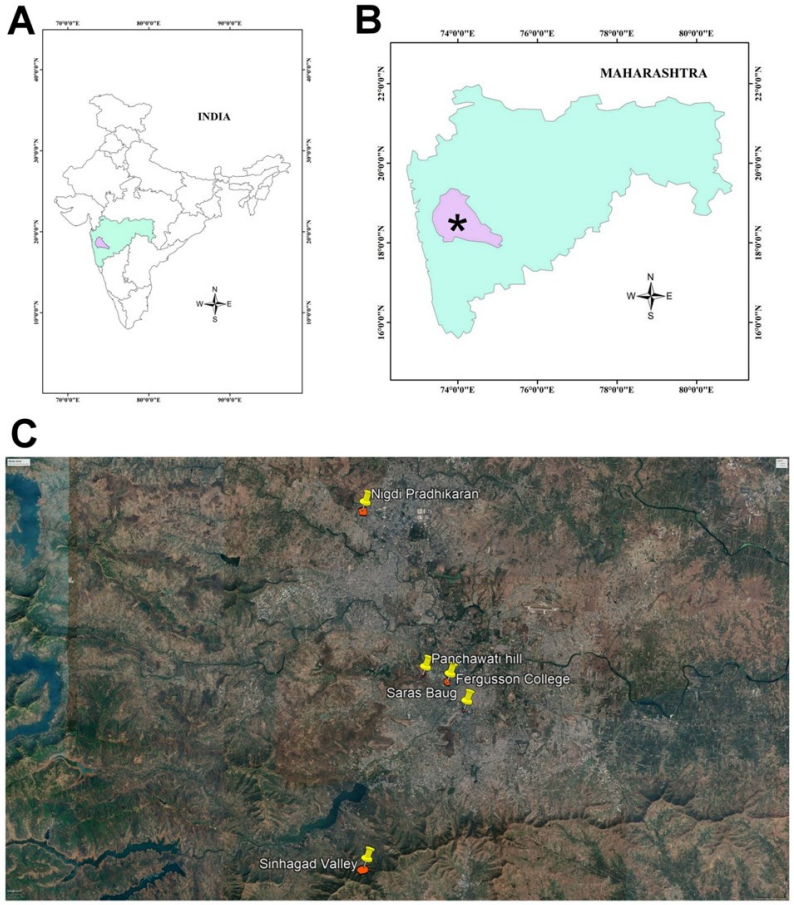

Figure 1. Geographical location of different study sites. (A) and (B) panels show the geospatial location of Pune city (*) in India and Maharashtra, respectively. (C) Satellite image showing locations of different sites selected for the present study.

Pune city (Maharashtra, India; Figure 1) is one of the largest cities in India located in the outskirts of the northern range of the Western Ghats. Pune is the fastest growing metropolitan city spread over 7,256 km² area and encompasses small hills, hill forests, river and wetlands. Previous studies on bird diversity in and around Pune city were mainly focused on urban hill forests and wetlands (Koparde & Raote, 2016; Choudaj & Wankhade, 2021b). There are more than 350 gardens in the city; most of them are artificial gardens composed of exotic plants. Previous reports suggest the residence of more than 250 bird species in Pune city area (eBird, https://ebird.org/). However, bird monitoring studies in the city area are limited (Choudaj & Wankhade, 2022). The present study was undertaken to monitor bird diversity at five locations in and around city with the differences in habitat composition. Bird assemblages were studied at selected sites throughout the year and analyzed for their food guild and residential status. It was observed that urban green patches support bird diversity with similar food preferences.

MATERIAL AND METHODS

Five sites were selected in and around Pune city, Fergusson college campus (FC), Saras Baug (SB), Panchawati (PV), Nigdi (NG), and Sinhagad valley (SV; Figure 1). Table 1 shows location and habitat details of all five sites (Table 1). Figure 2 presents satellite images from Google Earth of the five study sites - Fergusson College campus, Nigdi, Panchawati, Saras Baug, and Sinhagad Valley, outlined in yellow. Sinhagad valley was included which was 40 km far from the city as a natural reference site for bird diversity.

The selected sites were visited from 2019-2021 in different seasons (Table 2). Field visits were made in three different seasons, monsoon (June-September), winter (October-January), and summer (February-May; Table 2). Usually, the visits were made in the morning (6:00 am to 11:00 am) and evening (4:00 pm to 7:00 pm). Birds were recorded following multiple sampling methods (point count and line transact). Birds cited in between two point count or line transect were also recorded. Birds were observed using binocular (Nikon Aculon A211) and photographed using DSLR camera (Cannon EOS 77D). Birds encountered during field visits were identified following (Ali, 1996; Grimmett *et al*., 2016).

Information about food preference and residential status of the birds were extracted from the standard references (Ali, 1996; Grimmett *et al*., 2016). Based on the residential status of the birds at current locations, birds were grouped into two categories, residential and migratory. Birds were grouped into four food guilds based on the food preference viz. omnivore, insectivore, herbivore, and carnivore (Choudaj & Wankhade, 2022).

Diversity indices were calculated (Simpson index, Shannon index, Margalef's richness index, and Pielou;s evenness/equitability index) for all five sites. To compare bird community structure among different sites, cluster analysis of abundance data was performed using Bray-Curtis dissimilarity index. Based on the food

Table 1. Location and habitat details of the sites selected for the present study. We categorized disturbance level of habitats based on the human settlement and location. (Human settlement in urban area - high disturbance, Green patch in urban area without human settlement – Medium disturbance, and Forest green patch without or low human settlement – Low disturbance)

	Latitude	Longitude	Altitude	Approximate area (sq. ms.)	Habitat	Vegeta-tion	Disturb-ance level
Panchawati	18.528369°	73.818295°	680 m	74,964	Hill top	Native + exotic	Medium
Saras Baug	18.501232°	73.852946°	568 m	55,021	Artificial garden	Exotic	High
Sinhagad valley	18.375838°	73.769162°	720 m	613,819	Green hill forest	Native	Low
Fergusson college	18.522807°	73.838905°	569 m	280,025	Small hill slope	Native + exotic	High
Nigdi	18.659465°	73.767653°	604 m	466,308	Residen-tial area	Native	High
Nigdi	18.659465°	73.767653°	604 m	466,308	Residen-tial area	Native	High
Nigdi	18.659465°	73.767653°	604 m	466,308	Residen-tial area	Native	High
Nigdi	18.659465°	73.767653°	604 m	466,308	Residen-tial area	Native	High

Figure 2. Satellite images of different sites outlined with yellow border. (A) Fergusson College campus, (B) Nigdi, (C) Panchawati, (D) Saras Baug, and (E) Sinhagad Valley.

Table 2. Details of the season-wise field visits made at each locality.

	Monsoon	Winter	Summer
Fergusson College	2	6	3
Saras Baug	2	6	3
Panchawati	2	6	3
Nigdi	2	6	3
Sinhagad valley	0	5	5

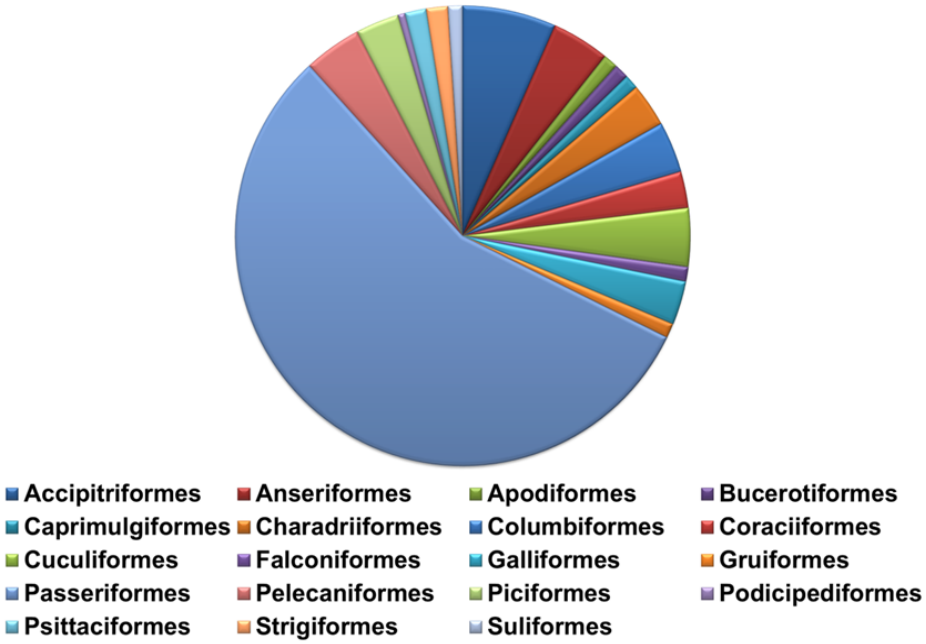

Figure 3. Pie chart depicting order-wise proportion of total birds observed in the present study.

preference, comparison of the bird community structure among different sites was summarized by cluster analysis using Jaccard similarity index. Data on food preference and residential status at different sites were represented as a proportion. Data analysis was performed using PAST (version 4.10) freeware (Hammer & Harper, 2001).

RESULTS

A total of 195 bird species were recorded at five study sites (Table 3). Among study sites, highest number of bird species were observed at Panchawati and the lowest number of bird species at Nigdi site (Table 4). Birds of Passeriformes order were predominantly present at all the study sites (Figure 4). Birds of Passeriformes order were predominantly present at all the study sites (Figure 3). Sinhagad valley was represented by the birds belonging to diverse families and orders (Table 4). The highest bird diversity was recorded at Sinhagad valley (H = 4.82, 1-D = 0.99) (Table 4). The highest Margalef's richness was recorded at Sinhagad valley (24.38) while the lowest Margalef's richness was recorded at Nigdi (5.75; Table 4). Equitability index (Pielou's evenness index) was the highest at Nigdi (J = 0.95) and the lowest at Fergusson college (J = 0.90; Table 4).

Cluster analysis revealed that bird diversity at forest site (Sinhagad valley) is completely different than that of the urban sites (Cophenetic correlation – 0.98). Among urban sites, Fergusson College formed separate clade from rest of the sites (Figure 4). Saras Baug and Nigdi sites harbor the most similar bird diversity (Figure 4).

Food guild analysis revealed that omnivore and insectivore birds dominated all the sites (Figure 5). The highest proportion of omnivore birds was present at Fergusson College while the highest proportion of insectivore birds was reported at Panchawati. Among all the sites, the highest proportions of herbivore and carnivore birds were observed at Saras Baug (Figure 5). Cluster analysis based on the food preference revealed that Sinhagad valley harbors bird fauna with distinct food preference (Figure 6; Cophenetic correlation – 0.96). As compared to other urban sites, Panchawati supports bird community with diverse food preferences. Saras Baug and Nigdi sites harbor bird species with similar food preferences (Figure 6).

Native bird species were predominantly present at all the sites (Figure 7). Among all five sites, the highest proportion of migratory birds were observed at Sinhagad valley (Figure 7).

Table 3. Details of the birds recorded at five study sites with their food habit and residential status.

Scientific name	Common Name	Food habit	Residential status
Accipiter badius	Shikra	Carnivore	Resident
Accipiter nisus	Eurasian sparrowhawk	Carnivore	Migratory
Acridotheres fuscus	Jungle myna	Omnivore	Resident
Acridotheres tristis	Common myna	Omnivore	Resident
Acrocephalus dumetorum	Blyth's reed warbler	Omnivore	Migratory
Acrocephalus stentoreus	Clamorous reed warbler	Insectivore	Resident
Actitis hypoleucos	Common sandpiper	Carnivore	Migratory
Aegithina tiphia	Common iora	Insectivore	Resident
Aethopyga vigorsii	Vigor's sunbird	Omnivore	Resident
Alcedo atthis	Common kingfisher	Carnivore	Resident
Alcippe poioicephala	Brown cheeked fulvetta	Omnivore	Resident
Amandava amandava	Red avadavat	Omnivore	Resident
Amauronis phoenicurus	White-breasted waterhen	Omnivore	Resident
Ammomanes phoenicura	Rufous tailed lark	Omnivore	Resident
Anas acuta	Northern pintail	Omnivore	Migratory
Anas poecilorhyncha	Indian spot-billed duck	Herbivore	Resident
Anthus hodgsoni	Olive-backed pipit	Omnivore	Migratory
Anthus rufulus	Paddyfield pipit	Insectivore	Resident
Anthus trivialis	Tree pipit	Insectivore	Migratory
Apus affinis	Little swift	Insectivore	Resident
Aquila fasciata	Bonelli's eagle	Carnivore	Resident
Ardea cinerea	Grey heron	Carnivore	Resident
Ardea intermedia	Intermediate egret	Carnivore	Resident
Ardeola grayii	Indian pond heron	Carnivore	Resident
Argya malcolmi	Large grey babbler	Omnivore	Resident
Athene brama	Spotted owlet	Carnivore	Resident
Aythya ferina	Common Pochard	Carnivore	Migratory
Aythya fuligula	Tuffted duck	Omnivore	Migratory
Bubulcus ibis	Cattle egret	Carnivore	Resident
Butastur teesa	White eyed buzzard	Carnivore	Resident
Cacomantis passerinus	Grey bellied cuckoo	Insectivore	Resident
Cacomantis sonneratii	Banded bay cuckoo	Insectivore	Resident
Caprimulgus asiaticus	Indian nightjar	Insectivore	Resident
Caprimulgus indicus	Jungle nightjar	Insectivore	Resident
Carpodacus erythrinus	Common rosefinch	Omnivore	Migratory
Centropus sinensis	Greater coucal	Omnivore	Resident
Ceryle rudis	Pied kingfisher	Carnivore	Resident
Chloropsis aurifrons	Golden fronted leafbird	Omnivore	Resident
Chloropsis jerdoni	Jerdon's leafbird	Omnivore	Resident
Chrysomma sinense	Yellow eyed babbler	Omnivore	Resident
Cinnyris asiaticus	Purple sunbird	Omnivore	Resident
Circus aeruginosus	Eurasian Marsh harrier	Carnivore	Migratory
Cisticola juncidis	Zitting cisticola	Insectivore	Resident

Clamator jacobinus	Pied cuckoo/Jacobin cuckoo	Carnivore	Resident
Clanga clanga	Greater spotted eagle	Carnivore	Migratory
Columba livia	Rock pigeon	Granivore	Resident
Copsychus saularis	Oriental magpie-robin	Insectivore	Resident
Coracias benghalensis	Indian roller	Insectivore	Resident
Corvus macrorhynchos	Large billed crow	Omnivore	Resident
Corvus splendens	House crow	Omnivore	Resident
Cuculus canorus	Common Cuckoo	Insectivore	Resident
Culicicapa ceylonensis	Grey headed canary flycatcher	Insectivore	Resident
Cyornis pallidipes	White bellied blue flycatcher	Omnivore	Resident
Cyornis tickelliae	Tickell's blue flycatcher	Insectivore	Resident
Cypsiurus balasiensis	Asian palm swift	Insectivore	Resident
Dendrocitta vagabunda	Rufous treepie	Omnivore	Resident
Dendrocopos nanus	Brown capped pygmy woodpecker	Insectivore	Resident
Dicaeum agile	Thick billed flowerpecker	Herbivore	Resident
Dicaeum erythrorhynchos	Pale-billed flowerpecker	Omnivore	Resident
Dicrurus caerulescens	White bellied drongo	Omnivore	Resident
Dicrurus leucophaeus	Ashy drongo	Insectivore	Resident
Dicrurus macrocercus	Black drongo	Insectivore	Resident
Dinopium benghalense	Black rumped flameback	Omnivorous	Resident
Egretta garzetta	Little egret	Carnivore	Resident
Elanus caeruleus	Black-winged Kite	Carnivore	Resident
Emberiza bruniceps	Red headed bunting	Insectivore	Migratory
Emberiza buchanani	Grey necked bunting	Omnivore	Migratory
Emberiza lathami	Crested bunting	Herbivore	Resident
Emberiza melanocephala	Black-headed bunting	Omnivorous	Migratory
Eudynamys scolopaceus	Asian Koel	Omnivore	Resident
Eumyias thalassinus	Verditer flycatcher	Insectivore	Resident
Euodice malabarica	Indian silverbill	Granivore	Resident
Falco peregrinus	Peregrine falcon	Carnivore	Resident
Falco tinnunculus	Eurasian kestrel	Carnivore	Resident
Ficedula albicilla	Taiga flycatcher	Insectivore	Migratory
Ficedula parva	Red-breasted Flycatcher	Insectivore	Migratory
Ficedula superciliaris	Ultramarine flycatcher	Insectivore	Resident
Francolinus pictus	Painted francolin	Omnivore	Resident
Fulica atra	Eurasian Coot	Omnivore	Resident
Galloperdix spadicea	Red spurfowl	Omnivore	Resident
Gallus sonneratii	Grey junglefowl	Omnivore	Resident
Geokichla citrina	Orange headed thrush	Omnivore	Resident
Gymnoris xanthocollis	Yellow-throated sparrow	Granivore	Resident
Halcyon gularis	White-throated Kingfisher	Carnivore	Resident
Haliastur indus	Brahminy kite	Carnivore	Resident
Hieraaetus pennatus	Booted eagle	Carnivore	Resident
Hierococcyx varius	Common hawk-cuckoo	Insectivore	Resident
Himantopus himantopus	Black-winged stilt	Carnivore	Resident
Hirundo rustica	Barn swallow	Insectivore	Resident
Hirundo rustica	House swallow	Omnivore	Migratory

Hirundo smithii	Wire-tailed swallow	Insectivore	Resident
Hypothymis azurea	Black naped monarch	Insectivore	Resident
Iduna caligata	Booted warbler	Insectivore	Migratory
Iduna rama	Sykes's warbler	Insectivore	Migratory
Jynx torquilla	Eurasian wryneck	Omnivore	Migratory
Lalage melanoptera	Black-headed cuckooshrike	Omnivorous	Resident
Lanius cristatus	Brown Shrike	Carnivore	Migratory
Lanius excubitor	Great grey shrike	Carnivore	Resident
Lanius schach	Long-tailed shrike	Carnivore	Resident
Lanius vittatus	Bay backed shrike	Carnivore	Resident
Leiopicus mahrattensis	Yellow crowned woodpecker	Insectivore	Resident
Leptocoma minima	Crimson-backed sunbird	Omnivore	Resident
Leptocoma zeylonica	Purple-rumped sunbird	Omnivore	Resident
Lonchura malacca	Tri coloured munia	Omnivore	Resident
Lonchura punctulata	Scaly-breasted munia	Omnivore	Resident
Lonchura striata	White-rumped Munia	Granivore	Resident
Luscinia svecica	Bluethroat	Insectivore	Migratory
Machlolophus aplonotus	Indian yellow tit	Omnivore	Resident
Mareca strepera	Gadwall	Omnivore	Migratory
Megalaima viridis	White cheeked barbet	Frugivore	Resident
Merops orientalis	Green bee-eater	Insectivore	Resident
Microcarbo niger	Little cormorant	Carnivore	Resident
Milvus migrans	Black Kite	Carnivore	Resident
Monticola solitarius	Blue rock thrush	Insectivore	Migratory
Motacilla cinerea	Grey wagtail	Insectivore	Migratory
Motacilla citreola	Citrine wagtail	Insectivore	Migratory
Motacilla flava	Western yellow wagtail	Insectivore	Migratory
Muscicapa latirostris	Asian brown flycatcher	Insectivore	Resident
Myophonus horsfieldii	Malabar whistling thrush	Omnivore	Resident
Nettapus coromandelianus	Cotton pygmy goose	Carnivore	Resident
Nisaetus cirrhatus	Changeable hawk eagle	Carnivore	Resident
Nycticorax nycticorax	Black crowned Night Heron	Carnivore	Resident
Ocyceros birostris	Indian grey hornbill	Omnivore	Resident
Oriolus kundoo	Indian golden oriole	Omnivore	Resident
Oriolus xanthornus	Black hooded oriole	Omnivorous	Resident
Orthotomus sutorius	Common Tailorbird	Omnivore	Resident
Ortygornis pondicerianus	Grey francolin	Omnivore	Resident
Parus cinereus	Cinereous tit	Omnivore	Resident
Passer domesticus	House sparrow	Omnivore	Resident
Pastor roseus	Rosy Starling	Omnivore	Migratory
Pavo cristatus	Indian peafowl	Omnivore	Resident
Pellorneum ruficeps	Puff throated babbler	Insectivore	Resident
Perdicula asiatica	Jungle bush quail	Omnivore	Resident
Pericrocotus cinnamomeus	Small minivet	Insectivore	Resident
Pericrocotus erythropygius	White bellied minivet	Insectivore	Resident
Pericrocotus flammeus	Orange minivet	Insectivore	Resident
Pernis ptilorhynchus	Oriental Honey Buzzard	Carnivore	Resident
Phalacrocorax fuscicollis	Indian cormorant	Carnivore	Resident
Phoenicurus ochruros	Black Redstart	Carnivore	Migratory
Phylloscopus affinis	Tickell's leaf warbler	Insectivore	Migratory

Phylloscopus collybita	Common chiffchaff	Insectivore	Migratory
Phylloscopus humei	Hume's warbler	Insectivore	Migratory
Phylloscopus nitidus	Green warbler	Insectivore	Migratory
Phylloscopus occipitalis	Western crowned warbler	Insectivore	Migratory
Phylloscopus trochiloides	Greenish warbler	Insectivore	Migratory
Phylloscopus tytleri	Tytler's leaf warbler	Insectivore	Resident
Plegadis falcinellus	Glossy ibis	Carnivore	Migratory
Ploceus philippinus	Baya weaver	Omnivore	Resident
Pomatorhinus horsfieldii	Indian scimitar babbler	Omnivore	Resident
Prinia buchanani	Rufous fronted prinia	Insectivore	Resident
Prinia hodgsonii	Grey breasted prinia	Insectivore	Resident
Prinia inornata	Plain prinia	Insectivore	Resident
Prinia socialis	Ashy prinia	Insectivore	Resident
Prinia sylvatica	Jungle prinia	Insectivore	Resident
Pseudibis papillosa	Red-naped ibis	Omnivore	Resident
Psilopogon haemacephalus	Coppersmith Barbet	Frugivore	Resident
Psittacula cyanocephala	Plum-headed parakeet	Herbivore	Resident
Psittacula eupatria	Alexandrine parakeet	Herbivore	Resident
Psittacula krameri	Rose-ringed parakeet	Herbivore	Resident
Ptyonoprogne concolor	Dusky craig martin	Insectivore	Resident
Ptyonoprogne rupestris	Eurasian craig martin	Insectivore	Migratory
Pycnonotus cafer	Red-vented bulbul	Omnivore	Resident
Pycnonotus jocosus	Red-whiskered bulbul	Omnivore	Resident
Rhipidura albogularis	Spot-breasted fantail	Insectivore	Resident
Rhipidura aureola	White browed fantail	Insectivore	Resident
Rhipidura aureola	White-browed wagtail	Insectivore	Resident
Saxicola caprata	Pied bushchat	Insectivore	Resident
Saxicola maurus	Siberian stonechat	Insectivore	Migratory
Saxicoloides fulicatus	Indian robin	Carnivore	Resident
Spatula clypeata	Northern shoveler	Omnivore	Migratory
Spilopelia chinensis	Spotted dove	Granivore	Resident
Spilopelia senegalensis	Laughing dove	Granivore	Resident
Spilornis cheela	Crested serpent eagle	Carnivore	Resident
Sterna aurantia	River tern	Carnivore	Resident
Streptopelia decaocto	Eurasian collared dove	Granivore	Resident
Streptopelia orientalis	Oriental turtle dove	Granivore	Resident
Streptopelia tranquebarica	Red collared dove	Herbivore	Resident
Strix ocellata	Mottled wood owl	Carnivore	Resident
Sturnia malabarica	Chestnut-tailed starling	Omnivore	Resident
Sturnia pagodarum	Brahminy starling	Omnivore	Resident
Surniculus dicruroides	Fork tailed-drongo cuckoo	Insectivore	Resident
Sylvia curruca	Lesser whitethroat	Insectivore	Migratory
Tachybaptus ruficollis	Little grebe	Carnivore	Resident
Tadorna ferruginea	Ruddy shelduck	Omnivore	Migratory
Tephrodornis pondicerianus	Common woodshrike	Insectivore	Resident
Terpsiphone paradisi	Indian paradise flycatcher	Insectivore	Resident
Threskiornis melanocephalus	Black headed ibis	Carnivore	Resident
Treron phoenicoptera	Yellow footed green pigeon	Frugivore	Resident
Tringa ochropus	Green sandpiper	Carnivore	Migratory
Turdoides striata	Jungle babbler	Omnivore	Resident
Turdus simillimus	Indian blackbird	Omnivore	Resident
Turnix suscitator	Barred buttonquail	Omnivore	Resident
Tyto alba	Barn owl	Carnivore	Resident
Upupa epops	Eurasian hoopoe	Insectivore	Resident
Vanellus indicus	Red-wattled lapwing	Carnivore	Resident
Zosterops palpebrosus	Oriental white eye	Omnivore	Resident

Table 4. Details of the bird species encountered at five sites and their diversity indices.

	Fergusson College	Saras Baug	Panchawati	Nigdi	Sinhagad valley
Birds	1227	694	1248	876	1817
Species	67	43	84	40	184
Families	39	27	46	27	67
Orders	14	13	15	9	19
Simpson_1-D	0.96	0.96	0.98	0.96	0.99
Shannon_H	3.79	3.43	4.05	3.50	4.82
Equitability_J	0.90	0.91	0.91	0.95	0.92
Margalef's richness	9.28	6.42	11.64	5.756	24.38

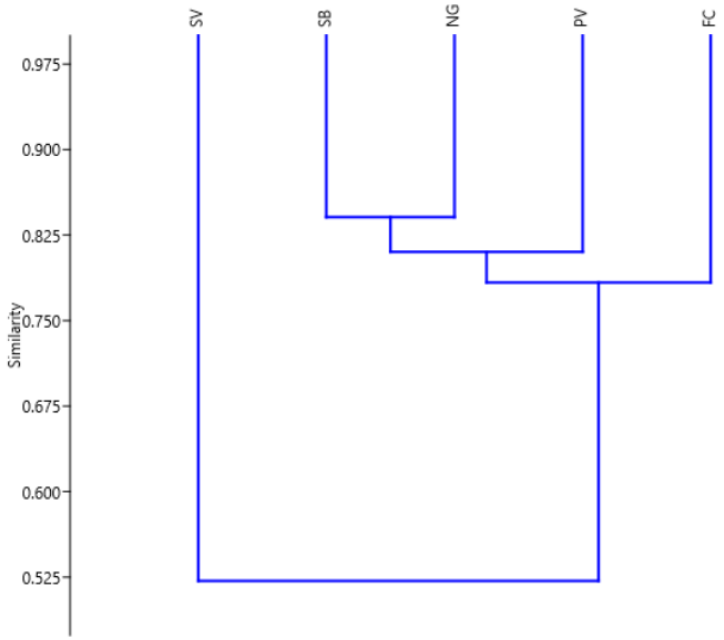

Figure 4 .Cluster analysis of bird community structure at different sites using Bray-Curtis dissimilarity index. (SV: Sinhagad valley, SB: Saras Baug, NG: Nigdi, PH: Panchawati, and FS: Fergusson College)

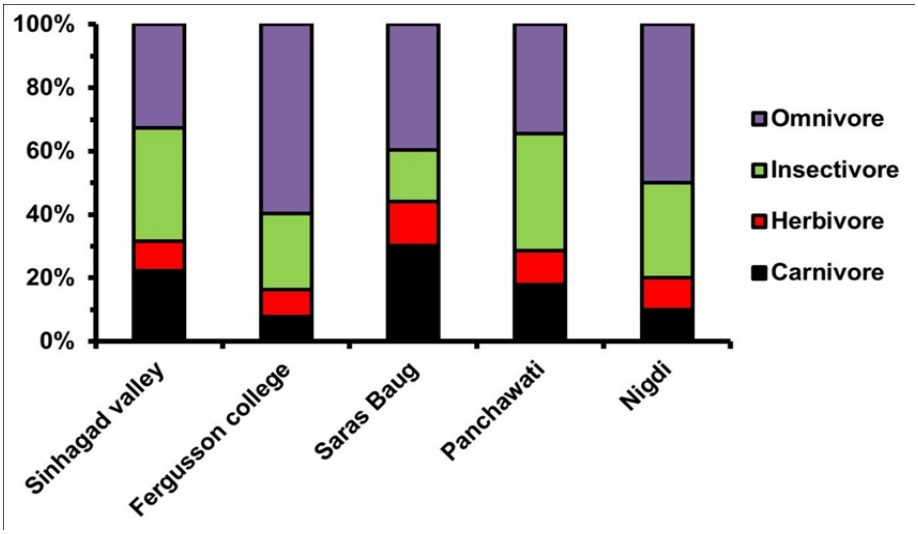

Figure 5. Proportion of bird species at different sites with different food preferences.

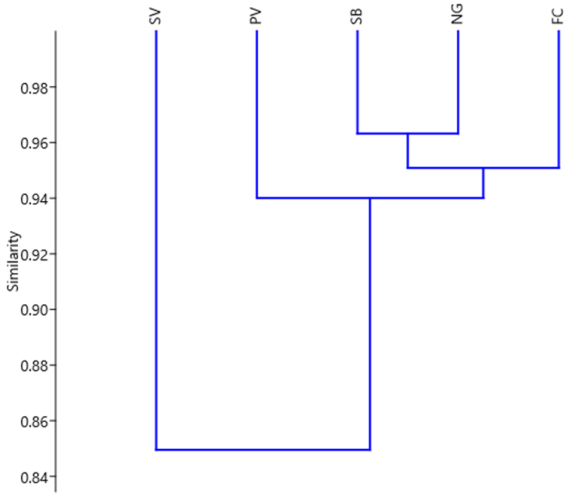

Figure 6. Dendrogram depicting cluster analysis of bird community structure (based on food preference) at different sites using Jaccard similarity index. (SV: Sinhagad valley, SB: Saras Baug, NG: Nigdi, PH: Panchawati, and FS: Fergusson College)

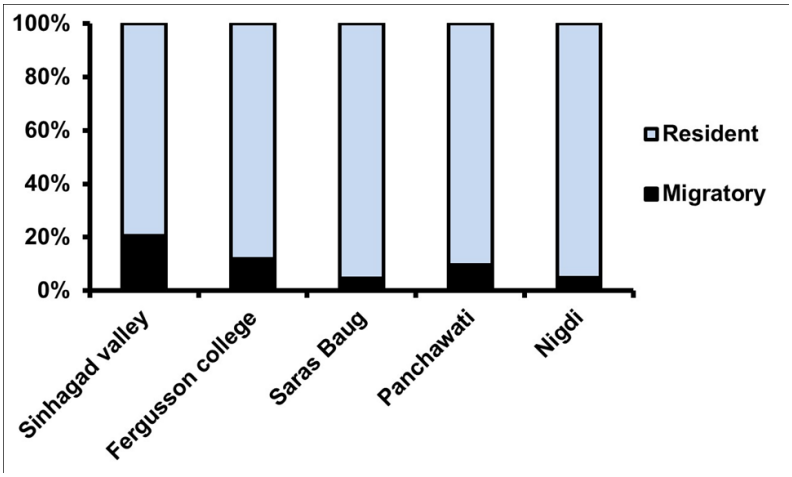

Figure 7 Proportion of residential and migratory birds encountered at different sites.

DISCUSSION

Bird diversity patterns differ in urban forests, surrounding forests, and different sites in the urban area as well (Zhou & Chu, 2012). Bird diversity patterns are also determined by the vegetation at the study site (Rousseau *et al*., 2015; Yang *et al*., 2015; Choudaj & Wankhade, 2021b). In the present study, we observed difference in bird diversity and assemblage at different sites. Particularly, Sinhagad valley has distinct bird assemblage than other selected urban sites. Sinhagad valley is situated far from the urban sites and composed of evergreen hill forest. However, the other sites selected in the present study comprised of modified natural flora or exotic plantations. Difference in the bird diversity pattern between Sinhagad valley and other sites could be due to the altered vegetation as a result of urbanization.

Bird diversity observed at different urban locations in the present study also varied significantly, with highest number of birds recorded at Panchawati. Panchawati is the largest urban hilly area selected in the present study and composed of dense vegetation of native and exotic plantations, nevertheless the site harbors a good number of native and migratory bird species (Choudaj & Wankhade, 2022).

Among the study sites selected in the present study, lowest bird diversity was observed at Nigdi. Nigdi is an urban residential area having low vegetation as compared to the other sites. Nigdi site is surrounded by small hill forest with mostly exotic plantations. Low bird diversity at Nigdi site could be the result of growing industrialization, low vegetation, and surrounding exotic plantation. Previously, variation in bird diversity of urban areas has been reported by several studies (Zhou & Chu, 2012; Strohbach *et al*., 2013; Choudaj & Wankhade, 2022). Bird diversity in different urban green patches is often dependent on the native vegetation and size (Zhou & Chu, 2012; Choudaj & Wankhade, 2021b). Moreover, it is evidenced that bird diversity patterns of urban green patches are dependent of the succession status of the ecosystem (Choudaj & Wankhade, 2021a) and disturbance level of the habitat (Rousseau *et al*., 2015; Casas *et al*., 2016). Systematic

monitoring programs for changing urban ecosystems are important to understand the impact of urbanization in shaping bird community and designing conservation strategies for long term sustainable development (Cooper *et al*., 2023; Fraissinet *et al*. 2023; Tellez-Hernandez *et al*. 2023).

In the present study, Sinhagad valley harbors maximum number of migratory birds as compared to other sites. Several studies reported that urbanization hampers migratory bird diversity and ecology (Cusa *et al*., 2015; Horton *et al*., 2019; Bonnet-Lebrun *et al*., 2020). Sinhagad valley is undisturbed natural site covered with dense native forest plants. This could be the reason for the occurrence of maximum number of migratory birds at Sinhagad valley. All the selected sites in the present study were dominated by Passeriformes birds, possibly due to their generalized food habit *viz*. omnivore. In the present study, food grid analysis revealed that all the sites are dominated by omnivore and insectivore birds suggesting that they support birds with similar food habits. The results of the present study are in accordance with the previous study in Pune city (Choudaj & Wankhade, 2022). These results also imply that irrespective of the vegetation type of the sites, all habitats support birds with similar food preferences (insectivore and omnivore).

CONCLUSION

Bird diversity varies at different urban green patches owing to their vegetation, size, and disturbance level. All the sites selected in the present study support birds with similar type of food habits irrespective of the locality (urban or hill forest). The data generated in the present study will be useful for bird diversity monitoring program. The observation made in the present study will be helpful in understanding the impact of urbanization on native/migratory bird diversity and designing conservation action plans.

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