


Urban habitat diversity and bird species associations in Kochi City, Kerala, India

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Abstract

Identification and characterisation of urban habitats and ascertaining their species associations are essential for the conservation and management of biodiversity in urban landscapes. The study attempts to identify, describe and categorise potential urban habitats in Kochi city, Kerala, India, and to explore the association of bird faunal assemblages within each of the habitats. The study was conducted from June 2018 to May 2020. The Urban Habitat Categories were identified, described and categorised as per the Urban Habitats Biodiversity Assessment (UrHBA) procedure and a sample biotope map was prepared. The habitat association of bird species was determined from each of the identified Urban Habitat Category by evaluating the species composition of each habitat. Species sharing between the identified habitats was also examined. Critical habitats of conservation concern were identified, and their specific features were ascertained. A total of 38 Urban Habitat Categories were characterised from the landscape of Kochi City with 162 species of birds to be found associated within the urban habitats. The wide variety of urban habitats provide excellent dwellings for a large number of birds including several threatened and migratory species. Out of the five major urban habitat categories, most of the species utilise Sparsely vegetated - Life form categories. Among the 38 urban habitats, Forest phanerophytes supports greater numbers of bird species. Vegetation structure is an important factor that determines bird diversity of the urban habitats. Together with the well-vegetated habitats, sparsely vegetated, non-vegetated and artificial built habitats also significantly contribute to biodiversity of urban centres. The diverse urban habitats and the associated bird species identified from Kochi city emphasise that modified urban landscapes are equally potent as natural landscapes in upholding diverse life forms. The study highlights the necessity of maintaining habitat complexity in urban landscapes for sustainable conservation of urban biodiversity. The baseline data on urban habitats and their species association will serve as a planning tool for safeguarding the critical habitats.

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Introduction

Urban habitats offer a wide-variety of resources and provide a wide-range of dwellings for the sustenance of nonhuman urban life. The modifications and alterations performed in the cities to satisfy the requirements of rapidly expanding urban human population impart unrecoverable changes in the

habitats of urban species which in turn threaten their existence. Therefore, preservation of critical habitats and their inhabitants is inevitable with regard to conservation practices in urban landscapes.

Each habitat in an urban landscape is unique from other landscapes. Nilon (2010) suggested identification of the unique urban habitats as an important action to be

undertaken so as to achieve the recommendation of Marzluff and Rodewald (2008) for the protection of available natural habitats in urban landscapes and for the conservation of urban species. Burhans and Thompson (2006) emphasised that planning efforts for conservation of biodiversity and management of habitats in urban settings need to focus on identification of habitats based on the unique role played by each habitat to fulfil the needs of their inhabitants.

A habitat is the sum of resources (food, shelter, etc.) and environmental conditions (biotic and abiotic features) that determine the occupancy of organisms including their survival and reproduction (Hall et al., 1997; Pearson, 2002), i.e., it should be able to meet the requirements of a species for its existence. Therefore, while determining and categorising a habitat in a landscape, it is necessary to look at the factors that influence the survival, reproduction and interactions of a species by providing it sufficient resources and environmental conditions. Prevailing land use (Qiu et al., 2010) and dominant vegetation structure (Bunce et al., 2006; Tzoulas and James, 2010) are some of the important factors which have been considered generally while categorising urban habitats. In addition, variations in the spatial arrangement of habitat structure is also important in this regard (Byrne, 2007; Bunce et al., 2008). Therefore, potential urban habitats can be determined within urban areas by adopting the above criteria.

Farinha-Marques et al. (2017) introduces a standardised, precise and universally applicable procedure known as Urban Habitats Biodiversity Assessment (UrHBA) for identifying and classifying urban habitats. This is an adapted classification of the habitat description by Bunce et al. (2005) and the classification of urban vegetated habitats is on the basis of their recommendation of plant life forms by Raunkiaer (1934). The methodology is specially adapted for urban environments which provide detailed spatial information on the urban habitats and facilitate the opportunity to describe biodiversity in these habitats. Thus, UrHBA procedure is an effective means to describe the characteristic features of urban habitats, to classify them and to analyse their spatial distribution pattern.

Birds are excellent indicators of urbanisation as they instantly respond to the changes in the composition, configuration and function of urban landscapes (Donnelly and Marzluff, 2004). Urban landscape assessments based on species-habitat associations is a useful tool in urban planning. 'Habitat selection' and the consequent 'habitat preference' and 'habitat use' by the individual species are important processes to be considered while ascertaining the association of a species with a habitat (Krausman, 1999; Cassini, 2013). Most of the species-habitat studies in urban landscapes focus on green spaces and protected areas like parks and reserves and the built spaces often remain overlooked. Zúñiga-Vega et al. (2019) identified habitat traits of an urban ecological reserve that are favourable for enhancing the tenancy of migratory birds. Vasquez and

Wood (2022) evaluated the habitat use of birds of urban parks and found the association between urban bird abundance and urban habitat features. Some of the recent studies of species-habitat association of birds in urban environments considered habitats of built spaces including residential settlements. The habitat preference assessments by Havlíček et al. (2021) on declining urban farmland birds and that by Buron et al. (2022) on urban migratory birds investigated critical habitats and important habitat features that are beneficial in conserving the diversity of respective urban bird populations. Therefore, urban habitat studies that focus on urban bird faunal associations of the entire urban landscape would serve as powerful biodiversity conservation tools.

The information on diverse urban habitats and species wealth associated with them are uncertain in many of the Indian cities. By identifying, describing and classifying urban habitats in the landscape of Kochi city, Kerala, India, the present study intends to address different habitat categories in urban areas that are competent enough to sustain urban life by providing required amenities for its dwellers. The investigation also aims to explore the association of urban bird species with each of the identified habitat by ascertaining the species composition of each habitat. As a conservation planning tool to identify species with comparable habitat requirements, the study also intends to evaluate the mode of species sharing between urban habitats. In addition, the research tries to disclose the specific features of urban habitats that are crucial for the sustenance of urban biota and to identify critical habitats of conservation concern.

It is expected that the study would generate a baseline knowledge on the present status of urban habitats and its bird species associations in Kochi city, which would be beneficial for future urban conservation practices.

Material and Methods

Study Area

The study was conducted in Kochi city (Fig. 1), one of the fast-growing urban centres in the state of Kerala situated along the coast of Vembanad estuary in Ernakulam district in the south-west coast of India (9.97°N 76.28°E). The landscape of Kochi is exposed to rapid modifications in its land use patterns and has led to the establishment of new habitat patches of urban and semi-urban nature. At the same time, remnants of pristine natural habitats also occur in the landscape especially associated with protected areas. The study focuses on the mainland of Kochi city (Kochi Municipal Corporation wards 31 to 74) with an area of approximately 50 km² which is the most urbanised part of the city. Though the study area is highly urbanised, together with the bustling zones of heavy traffic and construction activities, there are still quiescent zones with residential areas, agricultural lands, undisturbed vacant lands and intact nature preserves.

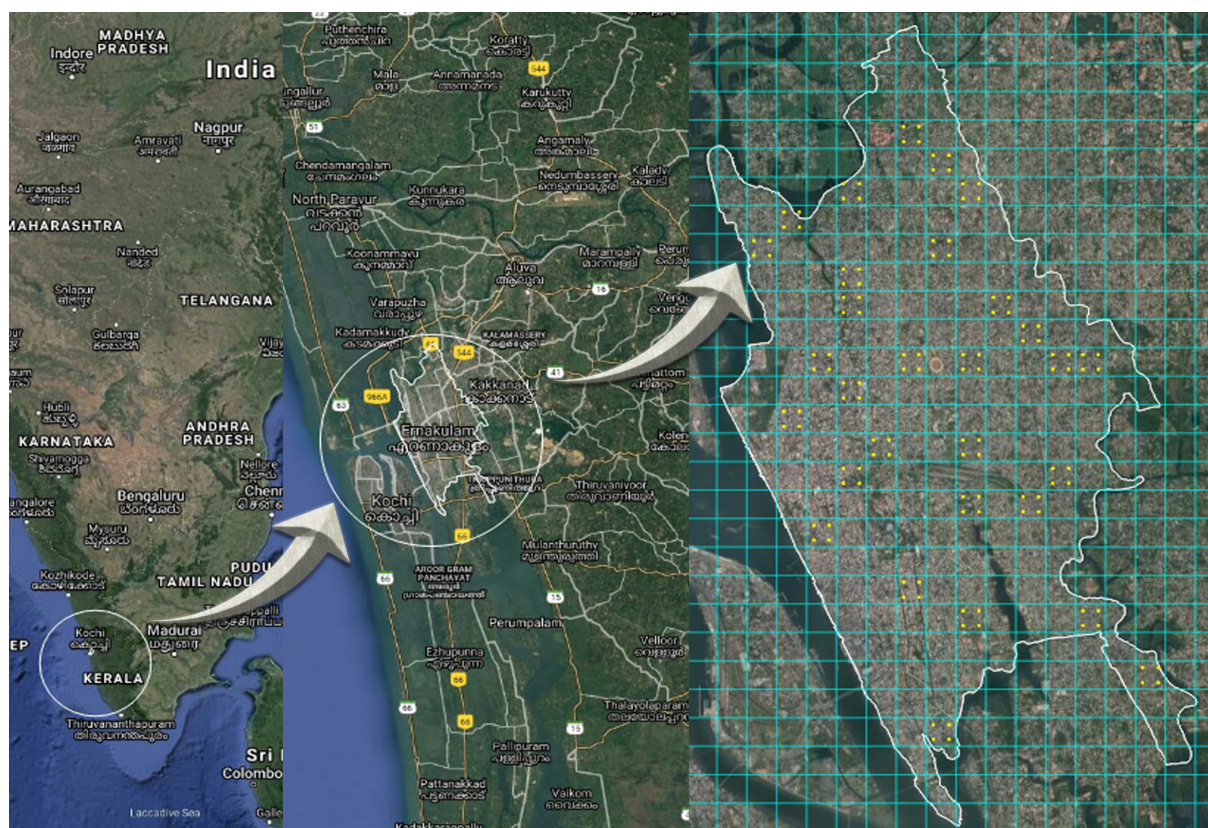


Figure 1: Aerial map of the study area with sampling points (given as yellow spots) – Prepared using QGIS 2.18.6 (QGIS Development Team, 2017).

Habitat identification and categorisation

The entire study area was divided into 0.5 km x 0.5 km grids using QGIS software (QGIS Development Team, 2017). Grids having at least 80% land surface was considered for sampling (182 grids). A total of 30 sampling grids were randomly selected (to cover 15% of the study area) for conducting habitat studies. For identifying habitats from the landscape of Kochi city, aerial images of the 30 selected sampling grids were analysed with the aid of satellite databases, followed by a thorough field visit in each of the grids. The Urban Habitat Categories were identified, described and categorised as per the Urban Habitats Biodiversity Assessment (UrHBA) procedure by Farinha-Marques et al. (2017) on the basis of plant life forms and non-life forms by accommodating the attributes of urban environments. The habitat categories were appropriately modified by adding suitable descriptors to adapt with the characteristic land use pattern and vegetation structure of land elements in Kochi city. Suitable qualifiers were also added to the description of habitats based on specific environmental conditions in land elements favoured by particular species. A sample comprehensive urban biotope map (Qiu et al., 2010) that comprises green spaces as well as built spaces and depicts the variations in the spatial arrangement of habitat structure was also prepared with the aid of QGIS software (QGIS Development Team, 2017) by using an aerial map as well as field observations.

Species-Habitat study

The species-habitat assessment is part of a two-year long urban biodiversity monitoring of bird fauna conducted in the selected sampling grids from June 2018 to May 2020, that followed the identification and classification of the urban habitats. Four sampling points were selected from each sampling grid in a regular pattern to cover the entire grid by keeping a minimum distance of 200 m between nearby points. Inaccessible points were excluded from sampling. Sampling was carried out following fixed-radius (30 m) point-count method at each sampling point for 5 minutes. The sampling points were visited in all months in the exact sequence as in the first month of sampling. The survey was conducted during 07:00 to 10:00 hours in the morning, to coincide with peak singing activity and was restricted to prescribed minimum weather conditions (no heavy rains; cloudless days with minimal breezes). In order to avoid noise disturbances, sampling was done during the earlier hours of the sampling period in the sampling grids belonging to the bustling zones of the study area. All the individual birds spotted from the sampling point were either recorded by sight with the aid of field binoculars (8x40), noted by sound or photo-documented if necessary, and identified to the species level. The habitat-use of each of the observed species in terms of occurrence and behaviour (foraging, resting and nesting activities) at the

preferred urban habitat was recorded to determine the species-habitat associations. The sampling was done monthly to incorporate all the seasonal variations in habitat use of the bird species.

Based on the habitat-use of bird assemblages documented from the 24 months of observation, an annual estimate of species-habitat association was generated with the presence-absence data of each bird species for each of the identified urban habitats. Conservation and residential status of the observed birds were also collected. The scientific name and the conservation status were attributed to the online database, Birds of the World (Billerman et al., 2022) and the residential status was attributed to the field guide, Birds of Kerala – Status and Distribution (Sashikumar et al., 2011). From the species-habitat data, species composition of each of the identified urban habitats was evaluated. To examine species sharing among urban habitats and to group them accordingly, differences in species composition between habitats was analysed from the presence-absence data by using

Ward’s minimum distance algorithm method of hierarchical cluster analysis with the help of BiodiversityR software (Kindt and Coe, 2005). This method employs a matrix based on Euclidian distance which is suitable for analysis of differences in species composition using presence-absence data.

Results

Thirty-eight Urban Habitat Categories (UHCs) were recognised from the landscape of Kochi city. The identified urban habitats were classified under five super-categories - Artificial built elements - Non-life form categories (8), Sparsely vegetated - Life form categories (14), Trees and shrubs (8), Wetland herbaceous (3) and Terrestrial herbaceous (5) as recommended by Farinha-Marques et al. (2015). The Urban Habitat Categories identified from Kochi city are described in Table 1 and illustrated with photographs in Appendix A. A list of dominant plant varieties is also added to the description of habitats with vegetation.

Table 1: Urban habitat categories identified from Kochi city, Kerala, India.

Super-categories	S.No.	Categories	Description
I. Artificial built elements - Non-life form categories artificial constructed elements	1	Built structure without vegetation	Vertical constructed elements without vegetation including buildings, walls, bridges, etc.
	2	Built structure with vegetation	Vertical constructed elements with vegetation including terrace gardens and vertical gardens (Dominant plant varieties: Different species of ornamental plants, <i>Bougainvillea</i> , Curtain Creeper, Creeping Fig, Centipede Tongavine, Ferns, Mosses, Lichens, etc.)
	3	Built aquatic element without vegetation	Aquatic features and waterways enclosed by masonry work including tanks, ponds and canals
	4	Built aquatic element with vegetation	Aquatic features and waterways enclosed by masonry work with vegetation (Dominant plant varieties: Water Cabbage, Eared Watermoss, Mosquito Fern, Ferns, Liverworts, Hornworts, Mosses, Lichens, etc.)
	5	Pavement without vegetation	Horizontal constructed surfaces covered with impervious materials including pathways, walkways and tracks
	6	Pavement with vegetation	Horizontal constructed surfaces covered with impervious materials with vegetation on the verges (Dominant plant varieties: Japanese Lovegrass, Indian Goosegrass, Navua Spikesedge, Spiny Mudgrass, Coatbuttons, Sessile Joyweed, Punarnava, Minnieroot, etc.)
	7	Rubbish without vegetation	Man-made wastes
	8	Rubbish with vegetation	Man-made wastes with vegetation (Dominant plant varieties: Bitter Vine, Railroad Creeper, Tropical Kudzu, Calopo, Grape-leaf Wood Rose, etc.)
II. Sparsely vegetated - Life form categories non-built elements with less than 30% vegetation cover	9	Estuary	Partially enclosed tidal mouth of larger river with brackish water
	10	Lake	Inland still aquatic feature with an area of >100 m ²
	11	Pond	Inland still aquatic feature with an area of <100 m ²
	12	Pool	Shallow stagnant water bodies with an area of <100 m ² that get filled during monsoon and dried during summer
	13	Ditch	Inland watercourse with a width of maximum 1m that may contain water
	14	Brook	Inland watercourse with a width of maximum 3 m that always contains water
	15	River	Watercourse with a width of >3 m that is frequently subjected to tidal action
	16	Open marshland	Marshlands that are always exposed to sunlight
	17	Closed marshland	Canopied marshlands with low sunlight penetration
	18	Open embanked fields	Marshlands used for paddy/fish farming that may or may not contain water
	19	Rocks and stones	Non-vegetated surfaces
	20	Dry bare soil	Non-vegetated dry fallow surfaces with sand or gravel
	21	Wet bare soil	Non-vegetated wet fallow surfaces with silt or clay
	22	Organic litter	Organic matter covering the ground

Table 1: (Continued).

Super-categories	S. No.	Categories	Description	
III. Trees and shrubs woody habitats	23	Chamaephytes	Dwarf shrubs with buds below 0.3 m height (Dominant plant varieties: Licorice Weed, Asian Spiderflower, Fringed Spiderflower, Billygoat Weed, Nodeweed, etc.)	
	24	Phanerophytes	Shrubs with buds between 0.3-2.0 m height (Dominant plant varieties: Common Lantana, Siam Weed, Chinese Hibiscus, Arrowleaf Sida, Bracken, Coffee Senna, Giant Sensitive Plant, False Ironwort, etc.)	
	25	Tall phanerophytes	Tall shrubs with buds between 2.0–5.0 m height (Dominant plant varieties: Castor Bean, Candle Bush, Pink Morning Glory, Prickly Sesban, Pandan, Different species of Mangroves, etc.)	
	26	Forest phanerophytes	Mixed trees between 5.0–40 m that include evergreen (that do not shed their leaves seasonally) and winter deciduous (that lose their leaves in winter) trees (Dominant plant varieties: Rain Tree, Jamaica Cherry, Sacred Fig, Weeping Fig, Indian Ash Tree, Golden Shower, Malabar Plum, Country Almond, Auri, Jumbay, Chandada, Coconut Tree, Mango, Different species of Mangroves, etc.)	
	27	Mega forest phanerophytes	Mixed trees over 40m that include evergreen (that do not shed their leaves seasonally) and winter deciduous (that lose their leaves in winter) trees (Dominant plant varieties: Wild Jack, Blackboard Tree, Tree of Heaven, Cotton Tree, Teak, etc.)	
	28	Lianas	Plants that use trees, shrubs or built structures for support without being attached (Dominant plant varieties: Common Derris, Indian Berry, African Dream Herb, <i>Mucuna</i> , Rangoon Creeper, etc.)	
	29	Creepers and stranglers	Plants that attach themselves to trees, shrubs or built structures rather just using them as support (Dominant plant varieties: Bitter Vine, Railroad Creeper, Tropical Kudzu, Calopo, Grape-leaf Wood Rose, Strangler Fig, etc.)	
	30	Parasites	Plants which depend on trees or shrubs for nutrients (Dominant plant varieties: <i>Loranthus</i> , <i>Cuscuta</i> , <i>Cassytha</i> , etc.)	
	IV. Wetland herbaceous	31	Free-floating hydrophytes	Floating plants on water surface (Dominant plant varieties: Water Hyacinth, Water Cabbage, Eared Watermoss, Alligator Weed, Kangkong, etc.)
		32	Emergent hydrophytes	Plants that grow in aquatic conditions and have emergent shoots out of the water (Dominant plant varieties: Water Lily, Lotus, etc.)
33		Helophytes	Plants with buds in waterlogged conditions (Dominant plant varieties: Tall Reed, Giant Cane, Golden Leather Fern, Javanese Flatsedge, etc.)	
34		Leafy hemicryptophytes	Biannual or perennial broad-leaved herbaceous species (forbs) (Dominant plant varieties: Coatbuttons, Sessile Joyweed, Mountain Knotgrass, etc.)	
35		Caespitose hemicryptophytes	Perennial monocotyledonous grasses, sedges and rushes (Dominant plant varieties: Japanese Lovegrass, Indian Goosegrass, Navua Spikesedge, Spiny Mudgrass, Mission Grass, Desho Grass, Smooth Flatsedge, etc.)	
36		Geophytes	Plants with buds below the soil surface (rhizomes, bulbs, tubers, etc.) (Dominant plant varieties: Nilgiri Turmeric, Taro, Heart of Jesus, etc.)	
37		Cryptogams	Bryophytes and lichens growing on the soil/stone/rock surface (Dominant plant varieties: Different species of Liverworts, Hornworts, Mosses and Lichens)	
38		Herbaceous chamaephytes	Perennial herbaceous plants with buds between 5 and 30 cm height (Dominant plant varieties: Sensitive Plant, Punamava, Minnieroot, Singapore Daisy, Alligator Weed, etc.)	

A sample biotope map prepared for a single sampling grid that depicts the variations in the spatial arrangement of urban habitat patches in Kochi City is given in Figures 2 and 3. This representative comprehensive urban biotope map clearly depicts the spatial heterogeneity and provides detailed spatial information on the urban habitats of Kochi city.

From the sampling, a total of 162 species of birds were observed to be associated with the 38 Urban Habitat Categories identified from the landscape of Kochi City, during the two year monitoring. Out of

the 164 species recorded, two species were excluded from the analysis – the Indian Swiftlet (*Aerodramus unicolor*) and Alpine Swift (*Apus melba*) – because they did not show any association with any of the urban habitats. The scientific name and common name of the bird species observed, conservation status, residential status, with reference to Kerala and habitats utilised by each of the observed species, are listed in Table 2.

Dominant bird groups associated with each of the Urban Habitat Category is described as a checklist in Table 3.

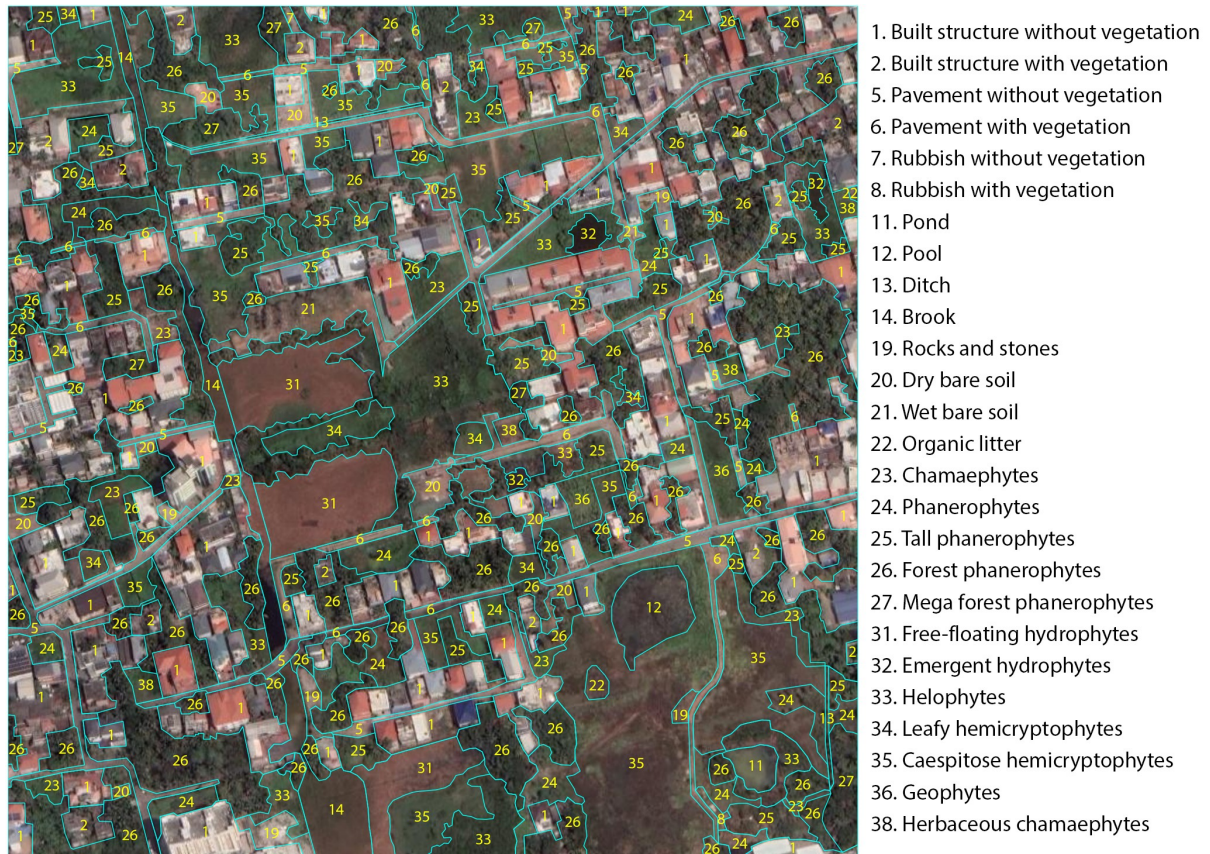


Figure 2: Spatial arrangement of habitat patches in Kochi city, Kerala, India – A sample biotope map (denoted by number).

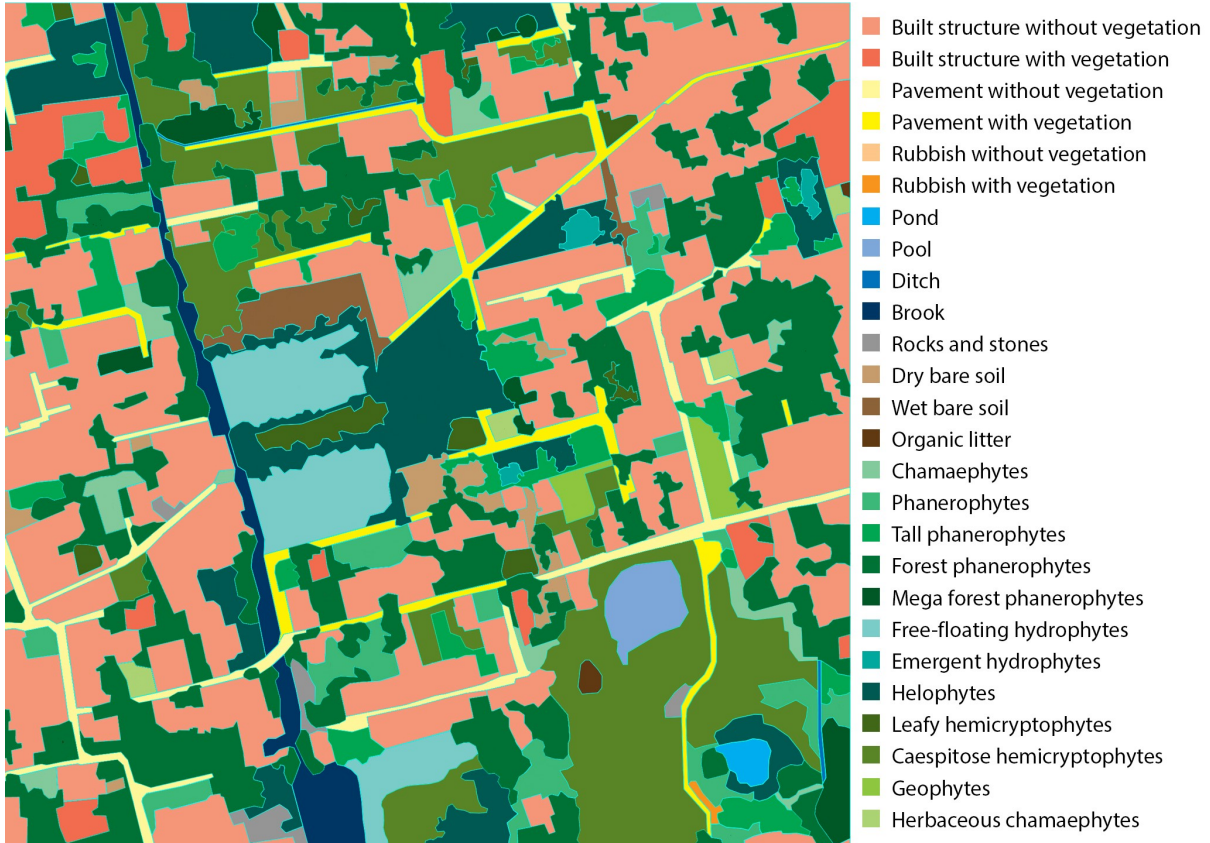


Figure 3: Spatial arrangement of habitat patches in Kochi city, Kerala, India – A sample biotope map (denoted by color gradient).

Table 2: Habitat associations of bird species in Kochi city, Kerala, India.

S. No.	Scientific name	Common name	Conservation status	Residential status	Associated habitats*
Order Anseriformes					
Family Anatidae - Ducks, Geese, and Waterfowl					
1	<i>Dendrocygna javanica</i> (Horsfield, 1821)	Lesser Whistling-Duck	LC	R	10, 11, 12, 15, 16, 18, 31, 32, 33, 35
2	<i>Spatula querquedula</i> (Linnaeus, 1758)	Garganey	LC	WV	10, 16, 31, 32, 33
3	<i>Anas poecilorhyncha</i> Forster, 1781	Indian Spot-billed Duck	LC	R	10, 16, 31, 32, 33
Order Phoenicopteriformes					
Family Phoenicopteridae - Flamingos					
4	<i>Phoenicopus roseus</i> Pallas, 1811	Greater Flamingo	LC	WV	9, 10
Order Podicipediformes					
Family Podicipedidae - Grebes					
5	<i>Tachybaptus ruficollis</i> (Pallas, 1764)	Little Grebe	LC	R	9, 10
Order Columbiformes					
Family Columbidae - Pigeons and Doves					
6	<i>Columba livia</i> Gmelin, 1789	Rock Pigeon	LC	R	1, 2, 5, 6, 7, 8, 18, 19, 20, 21, 35
7	<i>Spilopelia chinensis</i> (Scopoli, 1786)	Spotted Dove	LC	R	25, 26, 28, 29
8	<i>Treron affinis</i> (Jerdon, 1840)	Gray-fronted Green-Pigeon	LC	R	26, 27
Order Cuculiformes					
Family Cuculidae - Cuckoos					
9	<i>Centropus sinensis</i> (Stephens, 1815)	Greater Coucal	LC	R	1, 2, 5, 6, 16, 17, 18, 23, 24, 25, 26, 28, 29, 33, 34, 35, 36, 38
10	<i>Clamator jacobinus</i> (Boddaert, 1783)	Pied Cuckoo	LC	BV	14, 15, 24, 25, 26, 27, 28, 29
11	<i>Eudynamis scolopaceus</i> (Linnaeus, 1758)	Asian Koel	LC	R	2, 16, 17, 24, 25, 26, 27, 28, 29
12	<i>Cacomantis passerinus</i> (Vahl, 1797)	Gray-bellied Cuckoo	LC	WBV	25, 26, 27, 28, 29
13	<i>Hierococcyx varius</i> (Vahl, 1797)	Common Hawk-Cuckoo	LC	R	26, 27, 28, 29
14	<i>Cuculus canorus</i> Linnaeus, 1758	Common Cuckoo	LC	V	9, 14, 15, 24, 25, 28, 29, 31
Order Caprimulgiformes					
Family Caprimulgidae - Nightjars and Allies					
15	<i>Caprimulgus asiaticus</i> Latham, 1790	Indian Nightjar	LC	R	19, 22, 26
Family Apodidae - Swifts					
16	<i>Apus affinis</i> (Gray, 1830)	Little Swift	LC	R	1
17	<i>Cypsiurus balasiensis</i> (Gray, 1829)	Asian Palm-Swift	LC	R	26
Order Gruiformes					
Family Rallidae - Rails, Gallinules, and Coots					
18	<i>Gallinula chloropus</i> (Linnaeus, 1758)	Eurasian Moorhen	LC	R	10, 31, 32, 33
19	<i>Porphyrio poliocephalus</i> (Latham, 1801)	Gray-headed Swamphen	LC	R	4, 10, 11, 12, 13, 14, 15, 16, 18, 31, 32, 33, 35
20	<i>Gallinula cinerea</i> (Gmelin, 1789)	Watercock	LC	R	4, 10, 11, 12, 13, 14, 15, 16, 18, 31, 32, 33, 35
21	<i>Amaurornis phoenicurus</i> (Pennant, 1769)	White-breasted Waterhen	LC	R	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 31, 32, 33
22	<i>Rallina eurizonoides</i> (de Lafresnaye, 1845)	Slaty-legged Crane	LC	R	9, 31, 33

Table 2: (Continued).

S. No.	Scientific name	Common name	Conservation status	Residential status	Associated habitats*
Order Charadriiformes					
Family Recurvirostridae - Stilts and Avocets					
23	<i>Himantopus himantopus</i> (Linnaeus, 1758)	Black-winged Stilt	LC	WV	9, 10, 11, 12, 15, 16, 18
Family Charadriidae - Plovers and Lapwings					
24	<i>Pluvialis fulva</i> (Gmelin, 1789)	Pacific Golden-Plover	LC	WV	9, 10, 15, 16, 18, 35
25	<i>Charadrius dubius</i> Scopoli, 1786	Little Ringed Plover	LC	BV	12, 18
26	<i>Vanellus indicus</i> (Boddaert, 1783)	Red-wattled Lapwing	LC	R	4, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 35
27	<i>Anarhynchus atrifrons</i> (Wagler, 1829)	Tibetan Sand-Plover	LC	WV	15, 16
Family Jacanidae - Jacanas					
28	<i>Metopidius indicus</i> (Latham, 1790)	Bronze-winged Jacana	LC	R	4, 11, 12, 13, 14, 15, 16, 18, 31, 32
Family Scolopacidae - Sandpipers and Allies					
29	<i>Limosa lapponica</i> (Linnaeus, 1758)	Bar-tailed Godwit	NT	WV	9, 10
30	<i>Limosa limosa</i> (Linnaeus, 1758)	Black-tailed Godwit	NT	WV	9, 10
31	<i>Gallinago gallinago</i> (Linnaeus, 1758)	Common Snipe	LC	WV	12, 16, 33, 35
32	<i>Actitis hypoleucos</i> (Linnaeus, 1758)	Common Sandpiper	LC	WV	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 31, 32, 33
33	<i>Tringa ochropus</i> Linnaeus, 1758	Green Sandpiper	LC	WV	2, 9, 10, 11, 12, 13, 14, 15, 16, 18, 31, 32
34	<i>Tringa stagnatilis</i> (Bechstein, 1803)	Marsh Sandpiper	LC	WV	2, 9, 10, 11, 12, 13, 14, 15, 16, 18, 31, 32
35	<i>Tringa glareola</i> Linnaeus, 1758	Wood Sandpiper	LC	WV	2, 9, 10, 11, 12, 13, 14, 15, 16, 18, 31, 32
36	<i>Tringa totanus</i> (Linnaeus, 1758)	Common Redshank	LC	WV	9, 10, 15, 16
37	<i>Tringa erythropus</i> (Pallas, 1764)	Spotted Redshank	LC	WV	9, 10, 15, 16
38	<i>Tringa nebularia</i> (Gunnerus, 1767)	Common Greenshank	LC	WV	9, 10, 12, 15, 16, 18
Family Laridae - Gulls, Terns, and Skimmers					
39	<i>Chroicocephalus ridibundus</i> (Linnaeus, 1766)	Black-headed Gull	LC	WV	9, 10
40	<i>Chroicocephalus brunnicephalus</i> (Jerdon, 1840)	Brown-headed Gull	LC	WV	9, 10
41	<i>Gelochelidon nilotica</i> (Gmelin, 1789)	Gull-billed Tern	LC	WV	9, 10, 15, 16
42	<i>Chlidonias hybrida</i> (Pallas, 1811)	Whiskered Tern	LC	WV	9, 10, 14, 15, 16
43	<i>Sterna aurantia</i> Gray, 1831	River Tern	VU	R	9, 10, 15, 16
44	<i>Thalasseus bengalensis</i> (Lesson, 1831)	Lesser Crested Tern	LC	R	9, 16
45	<i>Thalasseus bergii</i> (Lichtenstein, 1823)	Great Crested Tern	LC	R	9, 16
Order Ciconiiformes					
Family Ciconiidae - Storks					
46	<i>Anastomus oscitans</i> (Boddaert, 1783)	Asian Openbill	LC	WV	4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 25, 26, 27, 35
47	<i>Ciconia episcopus</i> (Boddaert, 1783)	Asian Woolly-necked Stork	NT	WV	11, 12, 18, 35
48	<i>Mycteria leucocephala</i> (Pennant, 1769)	Painted Stork	LC	WV	10, 11, 12, 26, 27

Table 2: (Continued).

S. No.	Scientific name	Common name	Conservation status	Residential status	Associated habitats*
Order Suliformes					
Family Anhingidae - Aningas					
49	<i>Anhinga melanogaster</i> Pennant, 1769	Oriental Darter	NT	R	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 25, 26
Family Phalacrocoracidae - Cormorants and Shags					
50	<i>Microcarbo niger</i> (Vieillot, 1817)	Little Cormorant	LC	R	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 25, 26
51	<i>Phalacrocorax carbo</i> (Linnaeus, 1758)	Great Cormorant	LC	WV	9, 10
52	<i>Phalacrocorax fuscicollis</i> Stephens, 1826	Indian Cormorant	LC	R	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 25, 26
Order Pelecaniformes					
Family Pelecanidae - Pelicans					
53	<i>Pelecanus philippensis</i> Gmelin, 1789	Spot-billed Pelican	NT	V	10, 26, 27
Family Ardeidae - Herons, Egrets, and Bitterns					
54	<i>Ixobrychus flavicollis</i> (Latham, 1790)	Black Bittern	LC	R	10, 11, 13, 14, 16, 31, 32, 33
55	<i>Ixobrychus cinnamomeus</i> (Gmelin, 1789)	Cinnamon Bittern	LC	R	10, 11, 13, 14, 16, 31, 32, 33
56	<i>Ixobrychus sinensis</i> (Gmelin, 1789)	Yellow Bittern	LC	R	10, 11, 13, 14, 16, 31, 32, 33
57	<i>Nycticorax nycticorax</i> (Linnaeus, 1758)	Black-crowned Night-Heron	LC	R	9, 10, 11, 14, 15, 16, 17, 25, 26, 27
58	<i>Egretta garzetta</i> (Linnaeus, 1766)	Little Egret	LC	R	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 25, 26, 31, 32, 33
59	<i>Egretta gularis</i> (Bosc, 1792)	Western Reef-Heron	LC	M	4, 9, 16, 31
60	<i>Butorides striata</i> (Linnaeus, 1758)	Striated Heron	LC	R	13, 14, 17
61	<i>Ardeola grayii</i> (Sykes, 1832)	Indian Pond-Heron	LC	R	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 25, 26, 31, 32, 33
62	<i>Bubulcus ibis</i> (Linnaeus, 1758)	Western Cattle Egret	LC	WV	6, 7, 8, 31, 34, 35, 36, 38
63	<i>Ardea alba</i> Linnaeus, 1758	Great Egret	LC	R	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 25, 26, 31, 32, 33
64	<i>Ardea intermedia</i> Wagler, 1829	Medium Egret	LC	WV	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 25, 26, 31, 32, 33
65	<i>Ardea cinerea</i> Linnaeus, 1758	Gray Heron	LC	WV	4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 25, 26, 31, 33
66	<i>Ardea purpurea</i> Linnaeus, 1766	Purple Heron	LC	R	4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 25, 26, 31, 33
Family Threskiornithidae - Ibises and Spoonbills					
67	<i>Plegadis falcinellus</i> (Linnaeus, 1766)	Glossy Ibis	LC	WV	9, 10, 18
68	<i>Threskiornis melanocephalus</i> (Latham, 1790)	Black-headed Ibis	NT	R	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 25, 26
69	<i>Platalea leucorodia</i> Linnaeus, 1758	Eurasian Spoonbill	LC	WV	9, 10
Order Accipitriformes					
Family Pandionidae - Osprey					
70	<i>Pandion haliaetus</i> (Linnaeus, 1758)	Osprey	LC	WV	9, 10, 15, 16
Family Accipitridae - Hawks, Eagles, and Kites					
71	<i>Pernis ptilorhynchus</i> (Temminck, 1821)	Oriental Honey-buzzard	LC	R	1, 2, 26, 27
72	<i>Spilornis cheela</i> (Latham, 1790)	Crested Serpent-Eagle	LC	R	25, 26, 27
73	<i>Nisaetus cirrhatous</i> (Gmelin, 1788)	Changeable Hawk-Eagle	LC	R	25, 26, 27, 35
74	<i>Clanga clanga</i> (Pallas, 1811)	Greater Spotted Eagle	VU	WV	9, 10, 35
75	<i>Hieraetus pennatus</i> (Gmelin, 1788)	Booted Eagle	LC	WV	26, 27, 35
76	<i>Circus aeruginosus</i> (Linnaeus, 1758)	Western Marsh Harrier	LC	WV	15, 16, 33, 35
77	<i>Accipiter badius</i> (Gmelin, 1788)	Shikra	LC	R	25, 26, 27, 28, 29
78	<i>Milvus migrans</i> (Boddaert, 1783)	Black Kite	LC	R	1, 2, 7, 8, 9, 10, 15, 16, 20, 21, 25, 26, 27, 28, 29, 35
79	<i>Haliastur indus</i> (Boddaert, 1783)	Brahminy Kite	LC	R	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 18, 20, 21, 25, 26, 27, 28, 29, 35

Table 2: (Continued).

S. No.	Scientific name	Common name	Conservation status	Residential status	Associated habitats*
Order Strigiformes					
Family Tytonidae - Barn-Owls					
80	<i>Tyto alba</i> (Scopoli, 1769)	Barn Owl	LC	R	1
Family Strigidae - Owls					
81	<i>Otus bakkamoena</i> Pennant, 1769	Indian Scops-Owl	LC	R	26, 27
82	<i>Ketupa zeylonensis</i> (Gmelin, 1788)	Brown Fish-Owl	LC	R	9, 15, 26, 27
83	<i>Glaucidium radiatum</i> (Tickell, 1833)	Jungle Owlet	LC	R	17, 25, 26, 27, 28, 29
84	<i>Athene brama</i> (Temminck, 1821)	Spotted Owlet	LC	R	1, 26
85	<i>Strix ocellata</i> (Lesson, 1839)	Mottled Wood-Owl	LC	R	26, 27
86	<i>Ninox scutulata</i> (Raffles, 1822)	Brown Boobook	LC	R	17, 25, 26, 27, 28, 29
Order Bucerotiformes					
Family Upupidae - Hoopoes					
87	<i>Upupa epops</i> Linnaeus, 1758	Eurasian Hoopoe	LC	R	19, 20, 22, 24, 25, 26, 35
Order Coraciiformes					
Family Alcedinidae - Kingfishers					
88	<i>Alcedo atthis</i> (Linnaeus, 1758)	Common Kingfisher	LC	R	4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 24, 25, 28, 29, 31, 32, 33
89	<i>Pelargopsis capensis</i> (Linnaeus, 1766)	Stork-billed Kingfisher	LC	R	9, 10, 15, 16, 17, 18, 25, 26, 28, 29
90	<i>Halcyon smyrnensis</i> (Linnaeus, 1758)	White-throated Kingfisher	LC	R	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 24, 25, 26, 28, 29, 31, 32, 33
91	<i>Ceryle rudis</i> (Linnaeus, 1758)	Pied Kingfisher	LC	R	12, 15, 18, 24, 25
Family Meropidae - Bee-eaters					
92	<i>Merops orientalis</i> Latham, 1801	Asian Green Bee-eater	LC	R	1, 2, 12, 18, 24, 25, 26, 28, 29, 31, 33
93	<i>Merops philippinus</i> Linnaeus, 1766	Blue-tailed Bee-eater	LC	WV	1, 2, 3, 4, 5, 6, 7, 8, 12, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 33, 35
Family Coraciidae - Rollers					
94	<i>Coracias benghalensis</i> (Linnaeus, 1758)	Indian Roller	LC	R	1, 2, 12, 18, 25, 26
Order Piciformes					
Family Megalaimidae - Asian Barbets					
95	<i>Psilopogon haemacephalus</i> (Müller, 1776)	Coppersmith Barbet	LC	R	17, 26, 27
96	<i>Psilopogon viridis</i> (Boddaert, 1783)	White-cheeked Barbet	LC	R	2, 17, 25, 26, 27, 28, 29
Family Picidae - Woodpeckers					
97	<i>Micropternus brachyurus</i> (Vieillot, 1818)	Rufous Woodpecker	LC	R	17, 25, 26, 27, 28, 29
98	<i>Dinopium benghalense</i> (Linnaeus, 1758)	Black-rumped Flameback	LC	R	17, 25, 26, 27, 28, 29
Order Psittaciformes					
Family Psittaculidae - Old World Parrots					
99	<i>Psittacula krameri</i> (Scopoli, 1769)	Rose-ringed Parakeet	LC	R	18, 26, 27, 28, 29
Order Passeriformes					
Family Pittidae - Pittas					
100	<i>Pitta brachyura</i> (Linnaeus, 1766)	Indian Pitta	LC	WV	22, 23, 24, 28, 29
Family Campephagidae - Cuckooshrikes					
101	<i>Coracina macei</i> (Lesson, 1831)	Large Cuckooshrike	LC	R	25, 26, 27, 28, 29

Table 2: (Continued).

S. No.	Scientific name	Common name	Conservation status	Residential status	Associated habitats*
Family Oriolidae - Old World Orioles					
102	<i>Oriolus kundoo</i> Sykes, 1832	Indian Golden Oriole	LC	WV	2, 17, 26, 27, 28, 29
103	<i>Oriolus chinensis</i> Linnaeus, 1766	Black-naped Oriole	LC	WV	26, 27, 28, 29
104	<i>Oriolus xanthornus</i> (Linnaeus, 1758)	Black-hooded Oriole	LC	R	2, 17, 26, 27, 28, 29
Family Artamidae - Woodswallows, Bellmagpies, and Allies					
105	<i>Artamus fuscus</i> Vieillot, 1817	Ashy Woodswallow	LC	R	1, 12, 26
Family Aegithinidae - Ioras					
106	<i>Aegithina tiphia</i> (Linnaeus, 1758)	Common Iora	LC	R	25, 26, 27, 28, 29
Family Dicruridae - Drongos					
107	<i>Dicrurus macrocercus</i> Vieillot, 1817	Black Drongo	LC	R	1, 2, 3, 4, 5, 6, 7, 8, 12, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 33, 35
108	<i>Dicrurus leucophaeus</i> Vieillot, 1817	Ashy Drongo	LC	WV	26, 27, 28, 29
109	<i>Dicrurus aeneus</i> Vieillot, 1817	Bronzed Drongo	LC	R	26, 27, 28, 29
110	<i>Dicrurus paradiseus</i> (Linnaeus, 1766)	Greater Racket-tailed Drongo	LC	R	2, 17, 25, 26, 27, 28, 29
Family Monarchidae - Monarch Flycatchers					
111	<i>Terpsiphone paradisi</i> (Linnaeus, 1758)	Indian Paradise-Flycatcher	LC	WV	2, 17, 24, 25, 26, 27, 28, 29
Family Laniidae - Shrikes					
112	<i>Lanius cristatus</i> Linnaeus, 1758	Brown Shrike	LC	WV	2, 23, 24, 25, 28, 29, 33, 38
113	<i>Lanius vittatus</i> Valenciennes, 1826	Bay-backed Shrike	LC	R	24, 25, 26, 28, 29
Family Corvidae - Crows, Jays, and Magpies					
114	<i>Dendrocitta vagabunda</i> (Latham, 1790)	Rufous Treepie	LC	R	2, 17, 25, 26, 27, 28, 29
115	<i>Corvus splendens</i> Vieillot, 1817	House Crow	LC	R	1, 2, 3, 4, 5, 6, 7, 8, 12, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 33, 35
116	<i>Corvus macrorhynchos</i> Wagler, 1827	Large-billed Crow	LC	R	2, 4, 6, 17, 25, 26, 27, 28, 29
Family Paridae - Tits, Chickadees, and Titmice					
117	<i>Parus cinereus</i> Vieillot, 1818	Cinereous Tit	LC	R	17, 26, 27, 28, 29
Family Alaudidae - Larks					
118	<i>Mirafra affinis</i> Blyth, 1845	Jerdon's Bushlark	LC	R	4, 6, 12, 19, 20, 24, 25, 35
Family Cisticolidae - Cisticolas and Allies					
119	<i>Orthotomus sutorius</i> (Pennant, 1769)	Common Tailorbird	LC	R	1, 2, 16, 17, 24, 25, 26, 27, 28, 29
120	<i>Prinia hodgsonii</i> Blyth, 1844	Gray-breasted Prinia	LC	R	26, 27, 28, 29
121	<i>Prinia socialis</i> Sykes, 1832	Ashy Prinia	LC	R	16, 17, 23, 24, 25, 28, 29, 31, 33, 35, 36, 38
122	<i>Prinia inornata</i> Sykes, 1832	Plain Prinia	LC	R	16, 17, 23, 24, 25, 28, 29, 31, 33, 35, 36, 38
123	<i>Cisticola juncidis</i> (Rafinesque, 1810)	Zitting Cisticola	LC	R	23, 24, 35, 38
Family Acrocephalidae - Reed Warblers and Allies					
124	<i>Iduna caligata</i> (Lichtenstein, 1823)	Booted Warbler	LC	WV	23, 24
125	<i>Acrocephalus dumetorum</i> Blyth, 1849	Blyth's Reed Warbler	LC	WV	16, 17, 23, 24, 25, 28, 29, 31, 33, 35, 36
126	<i>Acrocephalus stentoreus</i> (Hemprich and Ehrenberg, 1833)	Clamorous Reed Warbler	LC	WV	16, 17, 24, 25, 28, 29, 33, 35, 36
Family Hirundinidae - Swallows					
127	<i>Hirundo rustica</i> Linnaeus, 1758	Barn Swallow	LC	WV	1, 2, 12, 16, 18, 26, 35
128	<i>Hirundo smithii</i> Leach, 1818	Wire-tailed Swallow	LC	R	9
129	<i>Cecropis daurica</i> (Laxmann, 1769)	Red-rumped Swallow	LC	R	1, 21
Family Pycnonotidae - Bulbuls					
130	<i>Pycnonotus luteolus</i> (Lesson, 1841)	White-browed Bulbul	LC	R	2, 24, 25, 26, 28, 29
131	<i>Pycnonotus jocosus</i> (Linnaeus, 1758)	Red-whiskered Bulbul	LC	R	1, 2, 16, 17, 24, 25, 26, 28, 29
132	<i>Pycnonotus cafer</i> (Linnaeus, 1766)	Red-vented Bulbul	LC	R	1, 2, 16, 17, 24, 25, 26, 28, 29

Table 2: (Continued).

S. No.	Scientific name	Common name	Conservation status	Residential status	Associated habitats*
Family Phylloscopidae - Leaf Warblers					
133	<i>Phylloscopus trochiloides</i> (Sundevall, 1837)	Greenish Warbler	LC	WV	2, 16, 17, 25, 26, 27, 28, 29
Family Leiothrichidae - Laughingthrushes and Allies					
134	<i>Argya striata</i> (Dumont, 1823)	Jungle Babbler	LC	R	2, 6, 17, 22, 25, 26, 28, 29
135	<i>Argya affinis</i> (Jerdon, 1845)	Yellow-billed Babbler	LC	R	17, 24, 25, 26, 28, 29, 33
Family Sturnidae - Starlings					
136	<i>Pastor roseus</i> (Linnaeus, 1758)	Rosy Starling	LC	WV	25, 26, 27, 35
137	<i>Sturnia pagodarum</i> (Gmelin, 1789)	Brahminy Starling	LC	R	8, 25, 26
138	<i>Sturnia malabarica</i> (Gmelin, 1789)	Chestnut-tailed Starling	LC	WV	25, 26, 27
139	<i>Sturnia blythii</i> (Jerdon, 1845)	Malabar Starling	LC	R	8, 21, 25, 26, 27
140	<i>Acridotheres tristis</i> (Linnaeus, 1766)	Common Myna	LC	R	1, 2, 3, 4, 5, 6, 7, 8, 12, 16, 17, 18, 19, 20, 21, 22, 25, 26, 27, 28, 29, 31, 33, 34, 35, 36
141	<i>Acridotheres fuscus</i> (Wagler, 1827)	Jungle Myna	LC	R	2, 4, 6, 7, 8, 12, 17, 18, 20, 21, 22, 25, 26, 27, 28, 29, 31, 33, 34, 35, 36
Family Turdidae - Thrushes and Allies					
142	<i>Geokichla citrina</i> (Latham, 1790)	Orange-headed Thrush	LC	R	17, 22, 24, 25, 28, 29
Family Muscicapidae - Old World Flycatchers					
143	<i>Copsychus fulicatus</i> (Linnaeus, 1766)	Indian Robin	LC	R	1, 2, 5, 6, 19, 20, 23, 24, 25, 26, 28, 29
144	<i>Copsychus saularis</i> (Linnaeus, 1758)	Oriental Magpie-Robin	LC	R	1, 2, 3, 4, 5, 6, 7, 8, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 28, 29
Family Dicaeidae - Flowerpeckers					
145	<i>Dicaeum erythrorhynchos</i> (Latham, 1790)	Pale-billed Flowerpecker	LC	R	2, 16, 17, 25, 26, 27, 28, 29, 30
Family Nectariniidae - Sunbirds and Spiderhunters					
146	<i>Leptocoma zeylonica</i> (Linnaeus, 1766)	Purple-rumped Sunbird	LC	R	1, 2, 16, 17, 24, 25, 26, 27, 28, 29, 30
147	<i>Cinnyris asiaticus</i> (Latham, 1790)	Purple Sunbird	LC	R	1, 2, 16, 17, 24, 25, 26, 27, 28, 29, 30
148	<i>Cinnyris lotenius</i> (Linnaeus, 1766)	Loten's Sunbird	LC	R	1, 2, 16, 17, 24, 25, 26, 27, 28, 29, 30
Family Chloropseidae - Leafbirds					
149	<i>Chloropsis aurifrons</i> (Temminck, 1829)	Golden-fronted Leafbird	LC	R	26, 27
Family Ploceidae - Weavers and Allies					
150	<i>Ploceus manyar</i> (Horsfield, 1821)	Streaked Weaver	LC	R	18, 24, 33, 35
151	<i>Ploceus philippinus</i> (Linnaeus, 1766)	Baya Weaver	LC	R	18, 24, 33, 35
Family Estrildidae - Waxbills and Allies					
152	<i>Lonchura punctulata</i> (Linnaeus, 1758)	Scaly-breasted Munia	LC	R	2, 6, 18, 21, 23, 24, 25, 33, 34, 35, 38
153	<i>Lonchura striata</i> (Linnaeus, 1766)	White-rumped Munia	LC	R	1, 2, 5, 6, 18, 21, 23, 24, 25, 33, 34, 35, 38
154	<i>Lonchura malacca</i> (Linnaeus, 1766)	Tricolored Munia	LC	R	2, 6, 18, 21, 23, 24, 25, 33, 34, 35, 38
Family Passeridae - Old World Sparrows					
155	<i>Passer domesticus</i> (Linnaeus, 1758)	House Sparrow	LC	R	1, 2, 5, 6, 19, 20
Family Motacillidae - Wagtails and Pipits					
156	<i>Dendronanthus indicus</i> (Gmelin, 1789)	Forest Wagtail	LC	WV	17, 22, 23, 24, 25, 28, 29
157	<i>Motacilla cinerea</i> Tunstall, 1771	Gray Wagtail	LC	WV	12, 17, 18, 21
158	<i>Motacilla flava</i> Linnaeus, 1758	Western Yellow Wagtail	LC	WV	10, 11, 12, 13, 14, 15, 16, 18, 21, 31, 35
159	<i>Motacilla citreola</i> Pallas, 1776	Citrine Wagtail	LC	WV	13, 14, 18, 31
160	<i>Motacilla maderaspatensis</i> Gmelin, 1789	White-browed Wagtail	LC	R	3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 31
161	<i>Motacilla alba</i> Linnaeus, 1758	White Wagtail	LC	WV	12, 21, 37
162	<i>Anthus rufulus</i> Vieillot, 1818	Paddyfield Pipit	LC	R	6, 19, 20, 35

*Denoted by serial number of habitats in Table 1

VU = Vulnerable; NT = Near Threatened; LC = Least Concern; WV = Winter Visitor; BV = Breeding Visitor; M = Migrant; V = Vagrant; R = Resident

Table 3: Checklist of dominant bird groups associated with Urban Habitat Categories of Kochi city, Kerala, India.

S. No.	Urban habitats	Dominant groups
1	Built structure without vegetation	Pigeons, Cuckoos and Allies, Swifts, Hawks, Kites, Barn-owls, Owls, Bee-eaters, Rollers, Woodswallows, Drongos, Crows and Allies, Cisticolas and Allies, Swallows, Bulbuls, Starlings, Robins, Sunbirds, Munias, Sparrows
2	Built structure with vegetation	Pigeons, Cuckoos and Allies, Sandpipers and Allies, Hawks, Kites, Bee-eaters, Rollers, Barbets, Orioles, Drongos, Flycatchers, Shrikes, Crows and Allies, Cisticolas and Allies, Swallows, Bulbuls, Leaf-warblers, Babblers, Starlings, Robins, Flowerpeckers, Sunbirds, Munias, Sparrows
3	Built aquatic element without vegetation	Gallinules, Sandpipers and Allies, Anhingas, Cormorants, Egrets, Herons, Ibises, Kites, Kingfishers, Bee-eaters, Drongos, Crows and Allies, Starlings, Robins, Wagtails
4	Built aquatic element with vegetation	Gallinules, Lapwings, Jacanas, Sandpipers and Allies, Storks, Anhingas, Cormorants, Herons, Egrets, Ibises, Kites, Kingfishers, Bee-eaters, Drongos, Crows and Allies, Larks, Starlings, Robins, Wagtails
5	Pavement without vegetation	Pigeons, Cuckoos and Allies, Bee-eaters, Drongos, Crows and Allies, Starlings, Robins, Munias, Sparrows
6	Pavement with vegetation	Pigeons, Cuckoos and Allies, Egrets, Bee-eaters, Drongos, Crows and Allies, Larks, Babblers, Starlings, Robins, Munias, Sparrows, Pipits
7	Rubbish without vegetation	Pigeons, Egrets, Kites, Bee-eaters, Drongos, Crows and Allies, Starlings, Robins
8	Rubbish with vegetation	Pigeons, Egrets, Kites, Bee-eaters, Drongos, Crows and Allies, Starlings, Robins
9	Estuary	Flamingos, Grebes, Cuckoos and Allies, Gallinules, Rails, Stilts, Plovers, Sandpipers and Allies, Gulls, Terns, Storks, Anhingas, Cormorants, Herons, Egrets, Ibises, Spoonbills, Osprey, Eagles, Kites, Owls, Kingfishers, Swallows, Wagtails
10	Lake	Ducks, Flamingos, Grebes, Gallinules, Stilts, Plovers, Sandpipers and Allies, Gulls, Terns, Storks, Anhingas, Cormorants, Pelicans, Bitterns, Herons, Egrets, Ibises, Spoonbills, Osprey, Eagles, Kites, Kingfishers, Wagtails
11	Pond	Ducks, Gallinules, Stilts, Lapwings, Jacanas, Sandpipers and Allies, Storks, Anhingas, Cormorants, Bitterns, Herons, Egrets, Ibises, Kites, Kingfishers, Wagtails
12	Pool	Ducks, Gallinules, Stilts, Lapwings, Plovers, Jacanas, Sandpipers and Allies, Storks, Anhingas, Cormorants, Herons, Egrets, Ibises, Kites, Kingfishers, Bee-eaters, Rollers, Woodswallows, Drongos, Crows and Allies, Larks, Swallows, Starlings, Wagtails
13	Ditch	Gallinules, Lapwings, Jacanas, Sandpipers and Allies, Storks, Anhingas, Cormorants, Bitterns, Herons, Egrets, Ibises, Kites, Kingfishers, Wagtails
14	Brook	Cuckoos and Allies, Gallinules, Lapwings, Jacanas, Sandpipers and Allies, Terns, Storks, Anhingas, Cormorants, Bitterns, Herons, Egrets, Ibises, Kites, Kingfishers, Wagtails
15	River	Ducks, Cuckoos and Allies, Gallinules, Stilts, Plovers, Lapwings, Jacanas, Sandpipers and Allies, Terns, Storks, Anhingas, Cormorants, Herons, Egrets, Ibises, Osprey, Hawks, Kites, Owls, Kingfishers, Wagtails
16	Open marshland	Ducks, Cuckoos and Allies, Gallinules, Stilts, Plovers, Lapwings, Jacanas, Sandpipers and Allies, Terns, Storks, Anhingas, Cormorants, Bitterns, Herons, Egrets, Ibises, Osprey, Hawks, Kites, Kingfishers, Bee-eaters, Drongos, Crows and Allies, Cisticolas and Allies, Reed-warblers and Allies, Swallows, Bulbuls, Leaf-warblers, Starlings, Robins, Flowerpeckers, Sunbirds, Wagtails
17	Closed marshland	Cuckoos and Allies, Gallinules, Sandpipers and Allies, Storks, Anhingas, Cormorants, Herons, Egrets, Ibises, Owls, Kingfishers, Bee-eaters, Barbets, Woodpeckers, Orioles, Drongos, Flycatchers, Crows and Allies, Stilts, Cisticolas and Allies, Reed-warblers and Allies, Bulbuls, Leaf-warblers, Babblers, Starlings, Thrushes, Robins, Flowerpeckers, Sunbirds, Wagtails
18	Open embanked fields	Ducks, Pigeons, Cuckoos and Allies, Gallinules, Stilts, Plovers, Lapwings, Jacanas, Sandpipers and Allies, Storks, Anhingas, Cormorants, Herons, Egrets, Ibises, Kites, Kingfishers, Bee-eaters, Rollers, Parrots, Drongos, Crows and Allies, Swallows, Starlings, Robins, Weavers, Munias, Wagtails
19	Rocks and stones	Pigeons, Nightjars, Lapwings, Hoopoes, Bee-eaters, Drongos, Crows and Allies, Larks, Starlings, Robins, Sparrows, Pipits
20	Dry bare soil	Pigeons, Lapwings, Kites, Hoopoes, Bee-eaters, Drongos, Crows and Allies, Larks, Starlings, Robins, Sparrows, Pipits
21	Wet bare soil	Pigeons, Gallinules, Lapwings, Sandpipers and Allies, Herons, Kites, Bee-eaters, Drongos, Crows and Allies, Swallows, Starlings, Robins, Munias, Wagtails
22	Organic litter	Nightjars, Hoopoes, Bee-eaters, Pittas, Drongos, Crows and Allies, Babblers, Starlings, Thrushes, Robins, Wagtails

Table 3: (Continued).

S. No.	Urban habitats	Dominant groups
23	Chamaephytes	Cuckoos and Allies, Bee-eaters, Pittas, Drongos, Shrikes, Crows and Allies, Cisticolas and Allies, Reed-warblers and Allies, Robins, Munias, Wagtails
24	Phanerophytes	Cuckoos and Allies, Hoopoes, Kingfishers, Bee-eaters, Pittas, Drongos, Flycatchers, Shrikes, Crows and Allies, Larks, Cisticolas and Allies, Reed-warblers and Allies, Bulbuls, Babblers, Thrushes, Robins, Sunbirds, Weavers, Munias, Wagtails
25	Tall phanerophytes	Doves, Cuckoos and Allies, Storks, Anhingas, Cormorants, Herons, Egrets, Ibises, Eagles, Hawks, Kites, Owls, Hoopoes, Kingfishers, Bee-eaters, Rollers, Barbets, Woodpeckers, Cuckooshrikes, Ioras, Drongos, Flycatchers, Shrikes, Crows and Allies, Larks, Cisticolas and Allies, Reed-warblers and Allies, Bulbuls, Leaf-warblers, Babblers, Starlings, Thrushes, Robins, Flowerpeckers, Sunbirds, Munias, Wagtails
26	Forest phanerophytes	Doves, Pigeons, Cuckoos and Allies, Nightjars, Swifts, Storks, Anhingas, Cormorants, Pelicans, Herons, Egrets, Ibises, Hawks, Eagles, Kites, Owls, Hoopoes, Kingfishers, Bee-eaters, Rollers, Barbets, Woodpeckers, Parrots, Cuckooshrikes, Orioles, Woodswallows, Ioras, Drongos, Flycatchers, Shrikes, Crows and Allies, Tits, Cisticolas and Allies, Swallows, Bulbuls, Leaf-warblers, Babblers, Starlings, Robins, Flowerpeckers, Sunbirds, Leafbirds
	Trees and shrubs	
27	Mega forest phanerophytes	Pigeons, Cuckoos and Allies, Storks, Pelicans, Herons, Hawks, Eagles, Kites, Owls, Bee-eaters, Barbets, Woodpeckers, Parrots, Cuckooshrikes, Orioles, Ioras, Drongos, Flycatchers, Crows and Allies, Tits, Cisticolas and Allies, Leaf-warblers, Starlings, Flowerpeckers, Sunbirds, Leafbirds
28	Lianas	Doves, Cuckoos and Allies, Hawks, Kites, Owls, Kingfishers, Bee-eaters, Barbets, Woodpeckers, Parrots, Pittas, Cuckooshrikes, Orioles, Ioras, Drongos, Flycatchers, Shrikes, Crows and Allies, Tits, Cisticolas and Allies, Reed-warblers and Allies, Bulbuls, Leaf-warblers, Babblers, Starlings, Thrushes, Robins, Flowerpeckers, Sunbirds, Wagtails
29	Creepers and stranglers	Doves, Cuckoos and Allies, Hawks, Kites, Owls, Kingfishers, Bee-eaters, Barbets, Woodpeckers, Parrots, Pittas, Cuckooshrikes, Orioles, Ioras, Drongos, Flycatchers, Shrikes, Crows and Allies, Tits, Cisticolas and Allies, Reed-warblers and Allies, Bulbuls, Leaf-warblers, Babblers, Starlings, Thrushes, Robins, Flowerpeckers, Sunbirds, Wagtails
30	Parasites	Flowerpeckers, Sunbirds
31	Free-floating hydrophytes	Ducks, Cuckoos and Allies, Gallinules, Rails, Jacanas, Sandpipers and Allies, Bitterns, Herons, Egrets, Kingfishers, Bee-eaters, Drongos, Crows and Allies, Cisticolas and Allies, Reed-warblers and Allies, Starlings, Wagtails
32	Emergent hydrophytes	Ducks, Gallinules, Jacanas, Sandpipers and Allies, Bitterns, Herons, Egrets, Kingfishers
33	Helophytes	Ducks, Cuckoos and Allies, Gallinules, Rails, Sandpipers and Allies, Bitterns, Herons, Egrets, Hawks, Kingfishers, Bee-eaters, Drongos, Shrikes, Crows and Allies, Cisticolas and Allies, Reed-warblers and Allies, Babblers, Starlings, Weavers, Munias
34	Leafy hemicryptophytes	Cuckoos and Allies, Egrets, Starlings, Munias
35	Caespitose hemicryptophytes	Ducks, Pigeons, Cuckoos and Allies, Gallinules, Plovers, Lapwings, Sandpipers and Allies, Storks, Egrets, Eagles, Hawks, Kites, Hoopoes, Bee-eaters, Drongos, Crows and Allies, Larks, Cisticolas and Allies, Reed-warblers and Allies, Swallows, Starlings, Weavers, Munias, Wagtails, Pipits
36	Geophytes	Cuckoos and Allies, Egrets, Cisticolas and Allies, Reed-warblers and Allies, Starlings
37	Cryptogams	Wagtails
38	Herbaceous chamaephytes	Cuckoos and Allies, Egrets, Shrikes, Cisticolas and Allies, Munias

Species richness of major Urban Habitat Categories based on species-habitat association data is depicted in Figure 4.

Out of the 162 urban bird species found associated with the five major Urban Habitat Categories in Kochi city, most of the species utilise Sparsely vegetated - Life form categories (131 species), followed by Trees and shrubs (104 species), Artificial built elements - Non-life form categories (72 species), Wetland herbaceous (50 species) and Terrestrial herbaceous (40 species).

Species richness of the individual Urban Habitat Categories on the basis of species-habitat association is illustrated in terms of number of species in Figure 5.

Among the 38 Urban Habitat Categories, Forest phanerophytes supports the greatest number of bird species (85 species). Tall phanerophytes (75 species), Lianas (60 species), Creepers and stranglers (60 species) and Mega forest phanerophytes (54 species) are the other species-rich urban habitats that contribute to the species wealth within the Trees and shrubs habitat category, in rank order. Open marshlands (69 species) is the most species-rich habitat under Sparsely vegetated - Life form categories. Closed marshland (57 species), Lake (54 species), Open embanked fields (53 species), Estuary (49 species), Pool (45 species) and River (44 species) are the other crucial Sparsely vegetated urban habitat categories that provide resources and environmental conditions for the existence of urban bird species, in rank order. Among the Artificial built elements - Non-life form categories, most of the species find Built structure with vegetation (40 species) as their suitable habitat. Built aquatic element with vegetation (30 species) is another favorable built habitat for urban birds. Helophytes (40 species) and Free-floating hydrophytes (39 species) provide habitat for most of the species within the Wetland herbaceous habitat category. Caespitose hemicryptophytes (38 species) serves as a major habitat for urban birds amid Terrestrial herbaceous habitats.

Conservation status and residential status of birds observed from the Urban Habitat Categories are depicted in the species richness illustrations in Figures 6 and 7.

Among the 162 species of birds observed from the Urban Habitat Categories, two are threatened with global extinction (Vulnerable), six are close to the threatened threshold (Near Threatened) and 154 have a lower risk of extinction (Least Concern). The species at high risk of extinction are associated mostly with the Sparsely vegetated and Terrestrial herbaceous urban habitat categories. The species that are close to being at high risk of extinction are frequently found in the Sparsely vegetated, Trees and shrubs, Artificial built elements and Terrestrial herbaceous habitat categories.

Among the birds recorded, 55 species are Migratory; and most of them visit the urban habitats during winter (Winter Visitors). Two species are Vagrants (irregular visitors) and 105 species are Residents of the city. The migratory species exploit all the five major Urban Habitat Categories, of which Sparsely vegetated habitats are the most favourable habitat for them followed by Trees and shrubs. Vagrant birds are associated mostly with the Sparsely vegetated and Trees and shrubs habitats. The resident birds make use of all the urban habitats of the city, of which Sparsely vegetated and Trees and shrubs habitats are the most preferred habitats. Artificial built elements also support a reasonable number of resident birds. Nesting of several resident species is observed even in the highly disturbed habitats of the city centre.

The difference in species composition between the varied Urban Habitat Categories is summarised in the form of a cluster dendrogram, based on Euclidean ecological distance, and is illustrated in Figure 8. The habitats that are grouped into the same cluster have a low ecological distance as they share most of their avian species.

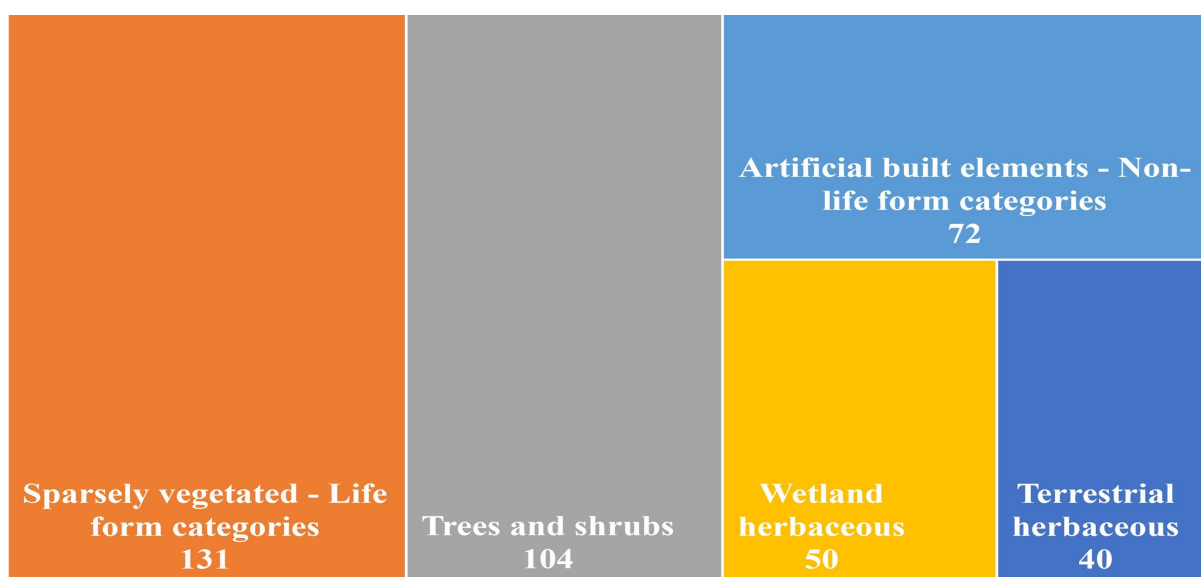


Figure 4: Species richness of major Urban Habitat Categories in Kochi city, Kerala, India.

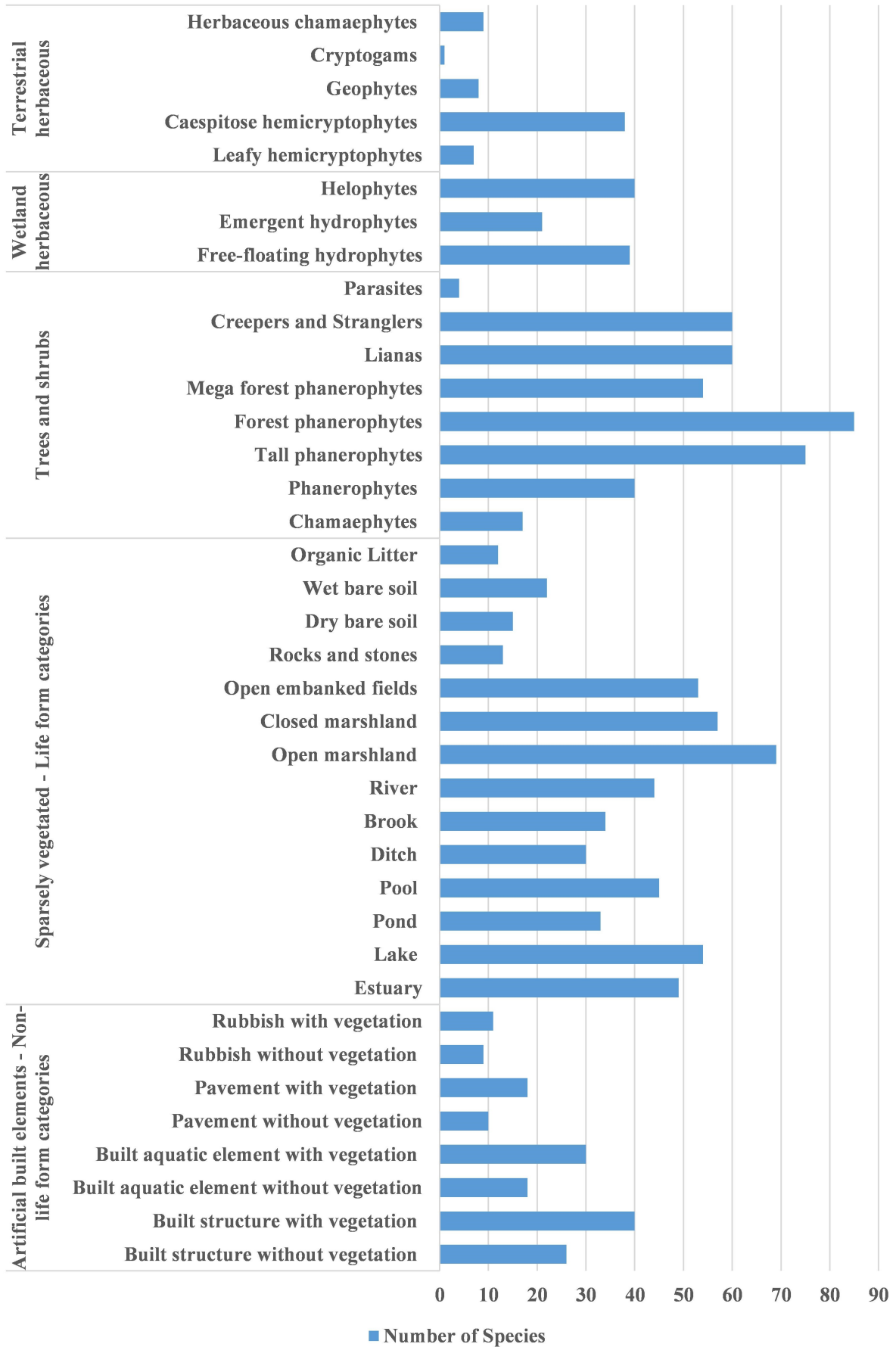


Figure 5: Species richness of Urban Habitat Categories in Kochi city, Kerala, India.

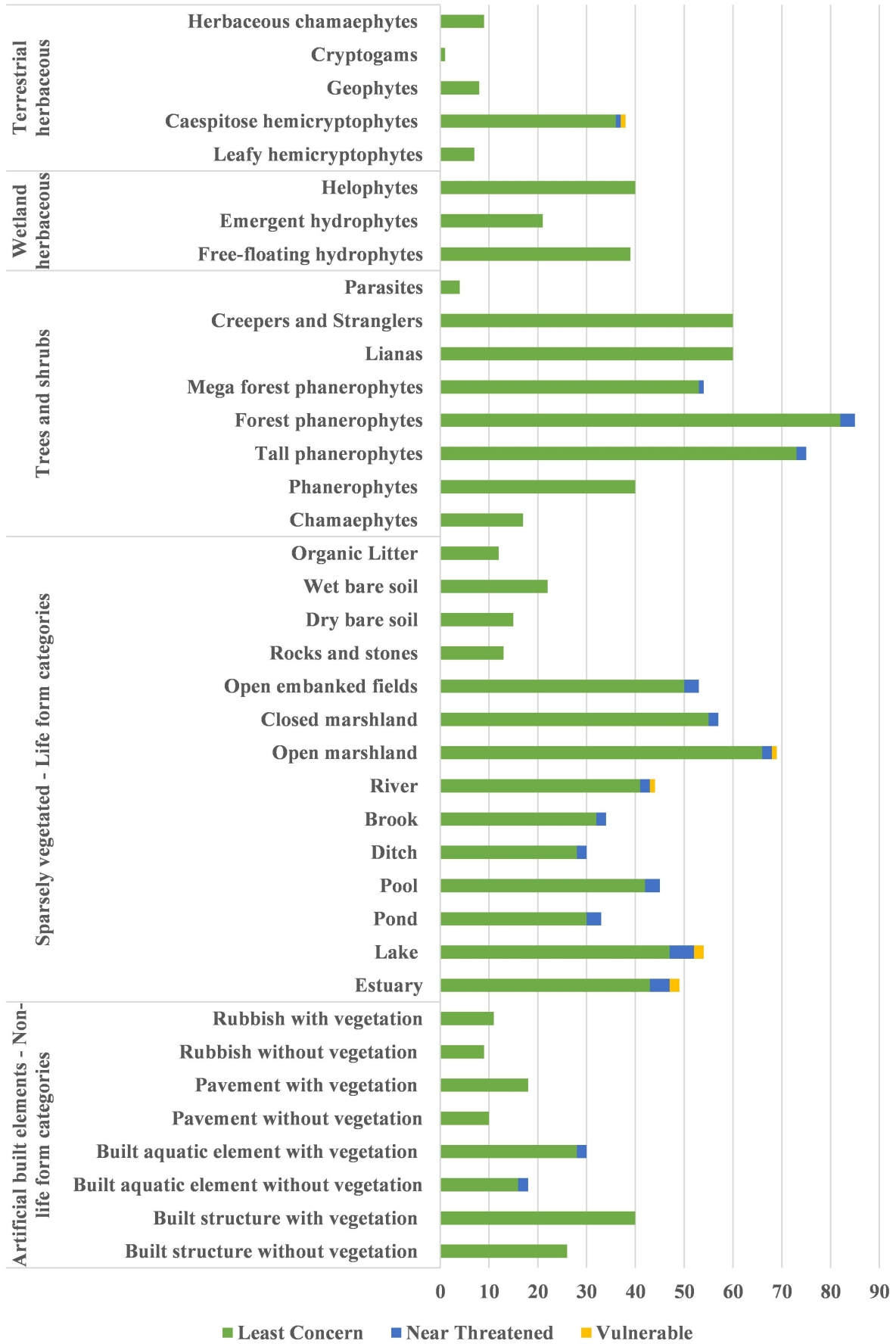


Figure 6: Conservation status of birds observed from Urban Habitat Categories of Kochi city, Kerala, India.

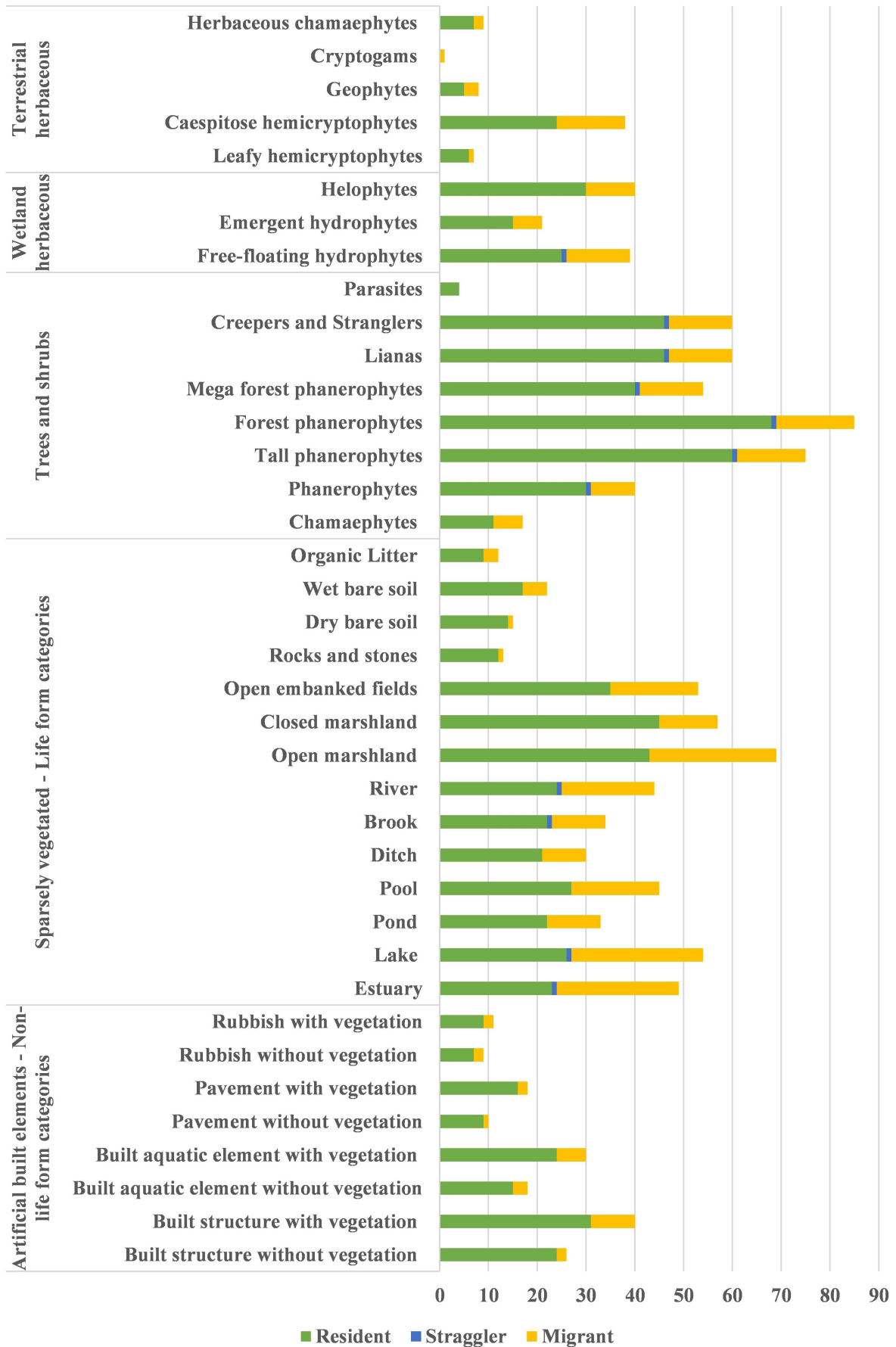


Figure 7: Residential status of birds observed form Urban Habitat Categories of Kochi city, Kerala, India.

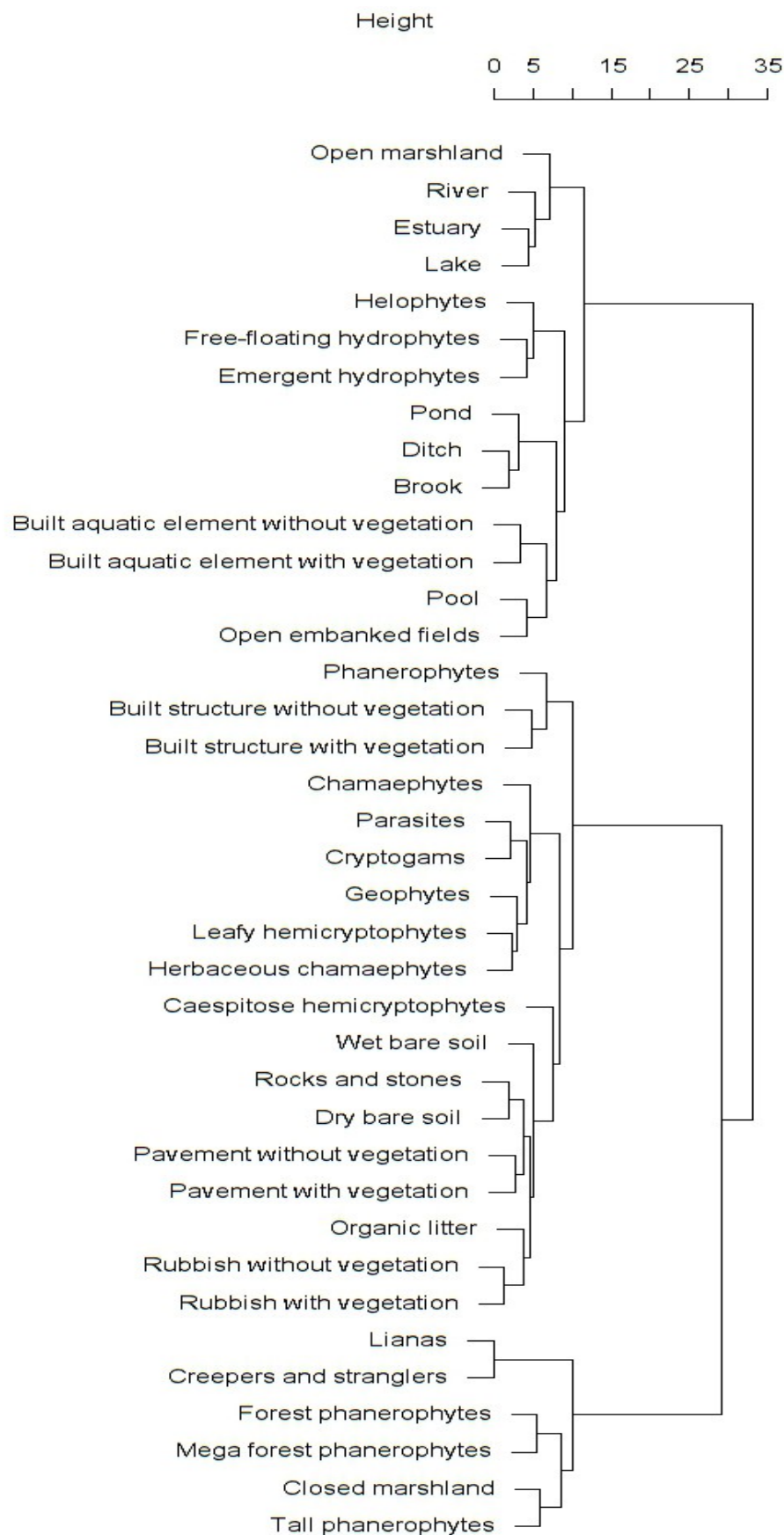


Figure 8: Species sharing among the Urban Habitat Categories of Kochi city, Kerala, India – Cluster Dendrogram (method = ward; distance = euclidian) prepared using BiodiversityR 4.2.2 (Kindt and Coe, 2005).

Presence or absence of vegetation shows no difference in species composition in artificial constructed elements such as Built structure, Built aquatic element, Pavement and Rubbish. The species composition of Built structures is similar to that of medium shrubs, the Phanerophytes. The species make-up of Pavements is quite comparable to the cluster that includes non-vegetated terrestrial habitats, namely Rocks and stones and Dry bare soil. The man-made wastes, which constitute the habitat Rubbish, have more shared species with Organic litter than elsewhere. The species structure of Built aquatic elements is analogous to the species make-up of the sparsely vegetated aquatic cluster - Pool and Open embanked fields.

Among the non-built aquatic elements with sparse vegetation, large, comparatively still aquatic features like Estuary and Lake are similar in their shared species compared to the other larger water features such as River and Open marshland. Shallow, stagnant open water bodies such as Pool and Open embanked fields have more species in common. Narrow inland watercourses like Ditch and Brook exhibit similar species composition; and the species make-up of Pond is also fairly similar to this cluster. The species structure of Closed marshland with low sunlight penetration is quite different from the other sparsely vegetated aquatic habitats that are exposed to sunlight; and displays similarity with tall shrubs, the Tall phanerophytes. The species structure of non-vegetated terrestrial habitats namely Rocks and stones and Dry bare soil are more alike than Organic litter whereas the species composition of Wet bare soil is different from all the others.

The habitats of mixed trees, that includes evergreen and winter deciduous trees, such as Forest phanerophytes and Mega forest phanerophytes, show a similar species composition. This cluster is more related to the cluster with tall Tall phanerophytes and Closed marshland. Lianas and Creepers and stranglers which are seen in association with the trees, shrubs and built structures share most of their species; and their species composition is comparable to the trees and tall shrubs. Unlike the tall trees though, shrubs and associated flora, habitats with comparatively dwarf vegetation show an altered species composition. The species structure of dwarf shrubby habitats such as Chamaephytes and Parasites are more comparable to that of Terrestrial Herbaceous habitats than the other woody habitats. Phanerophytes, the medium shrubs share most of their species with Built structures.

Wetland herbaceous habitats share species composition with the other aquatic habitats. Among them, Free-floating hydrophytes and Emergent hydrophytes share most of their species while Helophytes have a distinct species make-up. The Terrestrial herbaceous habitats such as Leafy hemicryptophytes and Herbaceous chamaephytes

have more species in common than Geophytes and Cryptogams. Caespitose hemicryptophytes show an exclusively different species composition, when compared to the other herbaceous habitats.

Discussion

The variety and variability of habitats identified from Kochi city demonstrate the structural complexity and diversity of urban habitats and unveils information on the extent of procurable and accessible residences for urban biota in the urban landscape. It also discloses the competence of this landscape to deliver suitable conditions for the survival and existence of diverse urban flora and fauna. The 'habitat availability' and 'habitat quality' (Krausman, 1999) of the city emphasise that modified urban landscapes are equally relevant as natural landscapes.

This variety and variability is evident from the biotope map that shows a patchy distribution of habitats throughout the urban setting. Habitat mapping and categorisation are essential for urban conservation planning (Müller, 1997). By aiding incorporation of urban biodiversity into development practices (Müller, 2008), urban biotope maps will contribute to biodiversity conservation. Also, it will help in spatial prioritisation for evaluating biodiversity quality (Jalkanen et al., 2020) of urban areas.

The habitat utilisation by bird species in terms of occurrence and behaviour shows how biodiversity wealth is nurtured by each of the urban habitats. The data on bird species association with various urban habitats indicates the current status of bird diversity in the urban landscape of Kochi city.

The observations on species-habitat association indicate that vegetation structure is an important factor that determines bird diversity in urban habitats. The vegetation make-up of these urban habitats includes not only native plant species, but also a number of invasive alien species. The vegetation not only includes plants of pristine natural environments, but also includes spontaneous/opportunistic vegetation and deliberately planted vegetation. The presence of trees, shrubs and herbs provide appropriate environment and resources for foraging and nesting birds. The associated vegetation makes the built habitats more ideal for urban birds. Hence, maintaining a diverse, heterogenic vegetation structure in urban landscapes will enhance urban biodiversity (Beninde et al., 2015), and specifically, it will contribute to higher bird diversity (Khera et al., 2009).

The diverse tree and shrub vegetation in the city and the climbers and creepers attached to trees, shrubs and buildings serve as desirable abodes for large numbers of terrestrial bird species. The wide variety of aquatic water bodies and marshlands in the city with sparse vegetation and nearby estuary provide similar amenities for aquatic bird species. A significant number of bird species are also associated

with buildings, pavements, rubbish and other, anthropogenic, non-vegetated surfaces of the city. A wide variety of species utilise the herbaceous wetland and terrestrial habitats of the urban centre. Even though the presence of vegetation is an important factor that determines the habitat association of a bird species, together with the well-vegetated habitats, sparsely vegetated and non-vegetated habitats are also of substantial importance in urban settings. Artificial built environments (Opoku, 2019), pavements (Bonthoux et al., 2019) and even wastelands can (Dover, 2015) significantly promote biodiversity in urban areas.

Assessment of the conservation status of birds associated with urban habitats shows that threatened species chiefly depend on the habitats with high species richness, but that vegetated and built habitats also support threatened birds. These observations agree with results of the investigation by Jokimaki et al. (2018) who found threatened species among the species-rich habitats in highly urbanised city centres. The value of urban areas in providing shelter for species of high conservation status was also ascertained by Alvey (2006). These findings point to the need for urgent conservation measures to be adopted in critical urban habitats, especially the species-rich ones, to ensure the protection of threatened urban bird species.

Evaluation of the residential status of birds reveals that migratory bird species mostly prefer vegetated urban habitats. The vertical vegetation structures such as trees and shrubs are more suitable for migrants than the horizontal herbs; as previously intimated by Buron et al. (2022). Resident birds make use of both the built, as well as the vegetated, habitats, as observed by Li et al. (2019) who stated that native species are distributed in urbanised as well as vegetated habitats. These findings call attention to the necessity of preserving diverse urban habitats for ensuring the conservation of native, as well as immigrant, urban bird faunas.

The information on the similarity of urban habitats and which species are shared between them, manifested in the cluster dendrogram (Fig. 8), is crucial for conservation and management of biodiversity on a broader scale. The dendrogram offers opportunities to choose species with comparable habitat requirements (Simberloff, 1999) of biodiversity concern (Ozaki et al., 2006), from which efficient umbrella species (Noss, 1990) can be proposed. Common conservation strategies can be planned for the species that are grouped into same cluster so that the conservation strategies adopted for the cluster would be advantageous for a large number of species.

These outcomes are of utmost importance for the conservation and management of urban biodiversity, as this baseline knowledge facilitates planning, designing and decision making in urban landscapes

(Farinha-Marques et al., 2015) and enables cities to achieve sustainable development goals, especially SDG11 (sustainable cities and communities) and SDG15 (life on land - biodiversity) (UNDP, 2016). These results are also beneficial for conservation prioritisation (Jalkanen et al., 2020) in order to ensure the protection of each species in its most suitable habitat. This study highlights the necessity of retaining structural complexity of urban habitats (Cornelis and Hermy, 2004; Kovalenko et al., 2012; Pacheco and Vasconcelos, 2012) in a sustainable manner for preserving the diversity of urban biota.

To preserve threatened habitat patches, especially patches of remnant vegetation, and to plan strategies for restoring habitats in accordance with the land alterations (Faeth et al., 2011), this study suggests a long-term biotope mapping and biodiversity assessments in urban areas approach. This will aid in monitoring the changes in habitat availability of the landscape and in evaluating the effect of these changes on the inhabitant species. This study also recommends adopting sustainable building design (Opoku, 2019) that incorporates sufficient green space in the built environment (Lepczyk et al., 2017), such as vegetated buildings - green walls, green roofs, etc. (Mayrand and Clergeau, 2018). These interventions should mainly focus on retaining the structural complexity of urban habitats by conserving the existing diverse pristine natural vegetation and by incorporating a wide-range of native species into the landscape design. Wise management and restoration practices of this kind should be adopted in all types of urban land elements, from urban streets to urban building premises, urban parks and vacant lands. This will improve habitat heterogeneity by enhancing the availability of potential urban habitats (Firth et al., 2014) and in turn enrich biodiversity of urban environments.

Conclusions

The heterogeneous landscape of Kochi city possesses a wide variety of urban habitats that provide excellent dwellings for a large number of bird species. The diverse terrestrial and aquatic habitats in the city serve as an exceptional residence for the terrestrial and aquatic urban bird fauna, including several threatened and migratory species. Therefore, urgent conservation measures need to be adopted for these critical urban habitat categories to ensure the protection of diverse urban bird fauna. The composition and complexity of habitats determined by the assessment are indicators of habitat availability and habitat quality in the urban landscape. This accentuates the ability of this urban area to support diverse flora and fauna and indicates its overall urban biodiversity; and also points to the urgent need to retain structural complexity among urban habitats. This baseline data can be incorporated into urban planning for identifying priority areas for conservation. Appropriate management measures can

be adopted for the conservation of critical habitats that are crucial for the existence and survival of several species. Alterations in the habitat availability for any target species can also be monitored in the future based on the outcomes of the present assessment. This will not only ensure the protection of target species, but also safeguard overall biodiversity within the urban landscapes in order to achieve sustainable development goals.

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Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Joseliph Abin and Padayatty Davis Samson. The first draft of the manuscript was written by Joseliph Abin and Padayatty Davis Samson and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Conflicts of interest

The authors declare that there are no conflicting issues related to this research article.

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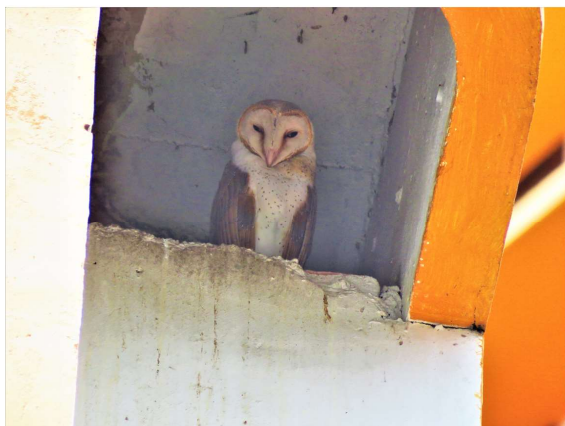
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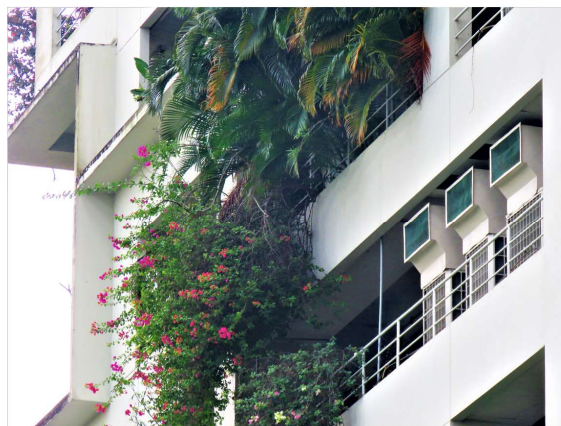
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Appendix A. Photographs of Urban Habitat Categories from Kochi City, Kerala, India – Captured by Joseliph Abin using Canon PowerShot SX60 HS Digital Camera.

Plate 1



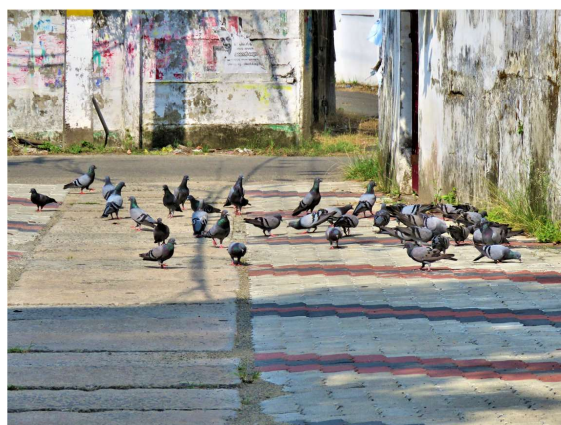
Built structure without vegetation



Built structure with vegetation



Built aquatic element with vegetation



Pavement without vegetation



Rubbish with vegetation

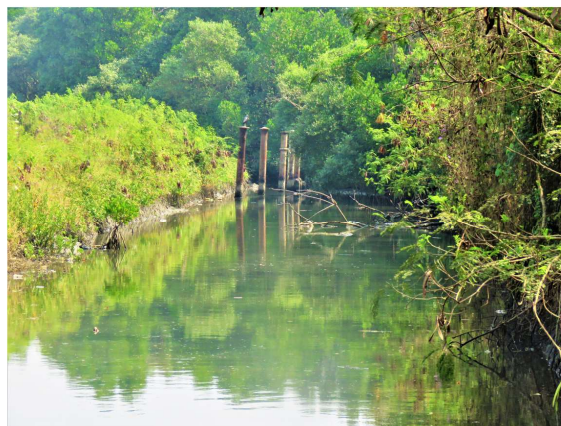


Lake

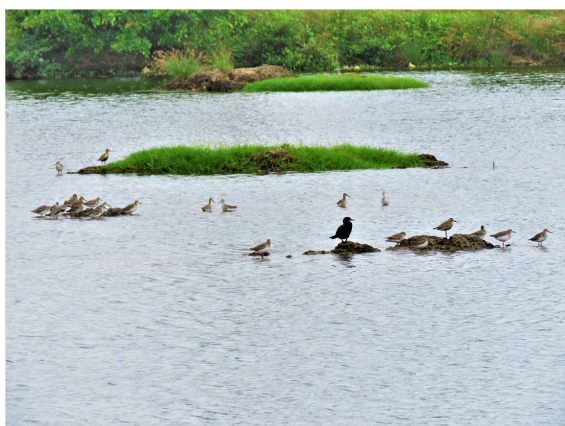
Plate 2



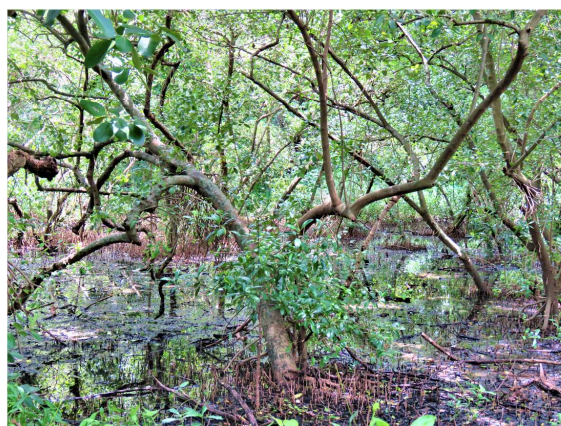
Pool



Brook



River



Closed marshland



Open embanked fields



Rocks and stones

Plate 3



Wet bare soil



Organic litter



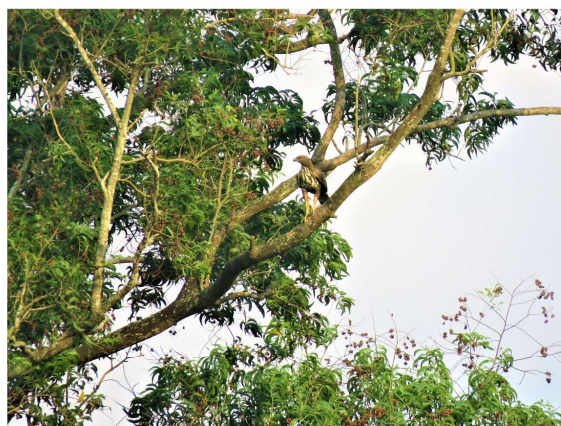
Phanerophytes



Tall phanerophytes

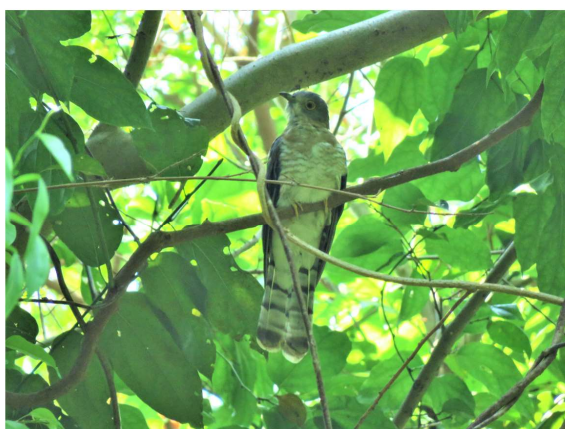


Forest phanerophytes

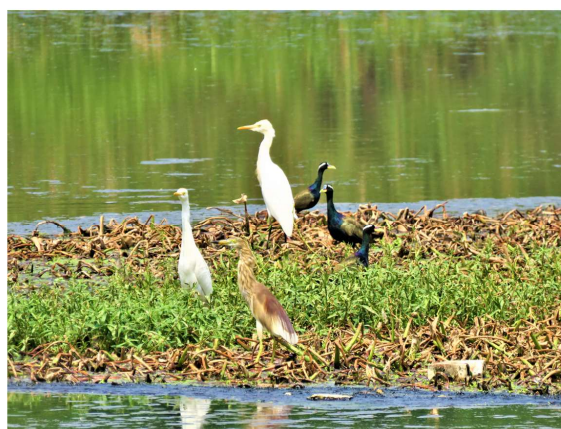


Mega forest phanerophytes

Plate 4



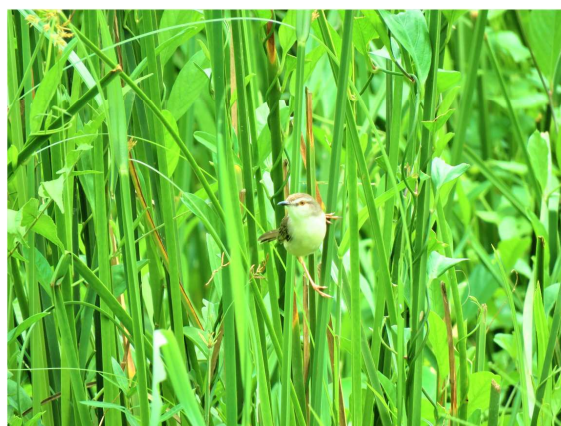
Lianas



Free-floating hydrophytes



Helophytes



Caespitose hemicryptophytes



Cryptogams



Herbaceous chamaephytes