DETERMINING THE TEMPORAL CHANGES IN AVIAN POPULATION INHABITING URBAN SEASONALLY WATERLOGGED AREAS IN HYDERABAD SINDH, PAKISTAN

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Abstract. Determining the temporal change in avian population is crucially important in order to understand whether their population is increasing or decreasing. The information about population parameters will help in conservation and protection efforts of avian species in future. Hence, the present study was carried out to determine the temporal changes in avian species in the 2014/15 and 2018/19 periods in urban waterlogged area of Hyderabad district Sindh, Pakistan. The highest relative abundance (28229 bird individuals representing 50 species and 14 families) was detected in 2018/19 rather than in 2014/15 (17454 individuals representing 38 bird species and 12 families). Out of the 50 bird species detected in 2018/2019, 30 were migrants (18965 individuals); 15 residents (5370 individuals), and 5 resident–migrants (3897 individuals) and while in the case of 2014/15 period, 22 species were migrants (11547 individuals), 15 residents (5247 individuals) and one resident–migrant (660 individuals). IUCN and BirdLife Status indicated that one migrant species was critically endangered; two species Rare/Accidental/Vulnerable and the rest of the 23 species were of the least concern. All resident bird species were totally protected (LC) while one resident–migrant species was data deficient. Foraging guild structure indicated that omnivore (32.489%) and Piscivore (12.808%) were the most dominant guilds of 2018/19 rather than 2014/15 while Carnivore was absent in detections of 2014/15. Alpha diversity analysis indicated that urban seasonal waterlogged was more diverse, rich and evenly distributed in 2018/19 than 2014/15. The findings of this study indicated that urban seasonal waterlogged area is suitable habitat (foraging sites and stopover) for a wide array of waterbird species especially migrant birds to refuel, rest, and forage.
Keywords: *waterbirds, population parameters, native, threatened, BirdLife*

Introduction

Waterbirds are directly or indirectly depend on the aquatic environment and foraged either near water body's edges or banks or on the surface. They are bioindicators of aquatic ecosystems due to cause–effect association with different microclimate and

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vegetation composition. Waterbirds may exploit broad scale of habitat, responded quickly to any environmental change either microclimate or vegetation structure and composition. Waterbird can be easily detected and identified (i.e., they showed their presence through vocalization). They can be surveyed more efficiently over the large spatial scale, e.g., presence, abundance, and influenced by surrounded habitats as compared to other animals.

The urban seasonal waterlogged areas are the undeveloped residential low-lying landscape within the city that received the water from domestic sewage and rainfall drain. They are characterized with shallow water overlying the interspersed soil and dominated either by submerged and emergent aquatic vegetation (Zhang et al., 2010). Waterlogged areas have been considered highly productive habitats for diverse fauna species, such as birds, amphibians, reptiles and mammals (Ehrenfed, 2000; Gibbs et al., 2005; Van der Walk, 2006). Due to loss and degradation of natural wetland areas, urban sewage has become a hotspot habitat for a wide array of waterbird species, i.e., waterfowls, waders, grebes, gulls, cormorants, terns to refuel, rest, and forage. These areas provide an important stopover foraging habitat for migrant as well as resident waterbird species due to high productivity (Hoffmann and Dodson, 2005). The other reason could be that, these areas are rich in fishes, amphibians, aquatic invertebrates (i.e. snails, worms, larvae of dragonflies, and water beetles that mostly occurs in soft damp soils, ditches, ponds), and organic matter.

It has been stated that more than 50% of the world's population inhabit in cities (Mackintosh and Davis, 2013) that may cause huge domestic sewage. A rapid increased in urbanization i.e., draining and infilling of wetland for development may also have caused the disappearing of wetlands from landscape (Sutula and Stein, 2003). The loss and degradation of wetland areas have increased runoff from urban sewage and industrial plants, which has adversely affected the hydrology of waterways and the remaining rest of wetlands (Catford et al., 2007; Vermoden et al., 2009; Davis et al., 2010). It has also been reported that more 50% of natural wetlands had been lost and degraded (Fraser and Keddy, 2005) that caused almost 40% of migrant bird species (i.e., 200 bird species) to be declined worldwide (BirdLife, 2015).

Previously, no study has been conducted to examine the temporal changes in avian population parameters inhabiting urban seasonal waterlogged areas. Hence, this study was conducted to examine the temporal changes in the avian population (i.e., relative abundance, diversity, status, and foraging guild structure) that utilizing the urban seasonal waterlogged areas.

Materials and methods

Study Area

These urban seasonal waterlogged areas lie in within the heart of the city 25^0 22' 45" N and 68^0 22' 06" E along the east bank of the Indus River, Hyderabad Sindh, Pakistan (*Figure 1*). Hyderabad city is densely populated, i.e., 2.323 million urban inhabitants and covers a total area of 3,198 km^2. It received monsoon rainfall from mid–April to late June and mostly remains warm (i.e., 50^0F to 119^0F) year–round, but sometimes temperature may fall at 34^0F during winter. The urban seasonal waterlogged areas are undeveloped residential wastelands that are under control of the cantonment board. These areas encompass the ditches and low laying grounds that receive water from domestic sewage and rainfall.

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Birds Survey

It has been known that avian populations fluctuate from time to time and habitat to habitats (Schieck, 1997; Blake and Loiselle, 2001). Determining the temporal changes is highly essential to understand the trends in avian population in the wetland areas (Thompson et al., 2002; DeSante et al., 2005). For this reason, the Distance Sampling Point Count Method is one of the most common quantitative survey technique that has been widely used to examine the temporal changes in avian populations (i.e. relative abundance, foraging guilds, and diversity) inhabiting different habitats (Verner and Purcell, 1999; Codesido and Bilenca, 2000). This method involves the visual and auditory detection of birds with fixed or variable radius plots, and it provides detailed information on avian population parameters (Verner and Ritter, 1985; Mills et al., 2000). The design of this study was encompassing of the following factors: (i) suitability for habitats, such as open water bodies and vegetated areas, i.e. submerged vegetation; (ii) suitability for surveying cryptic, shy, and skulking species; (iii) suitability for species–rich populations; (iv) suitability in situations where human access was restricted; and (v) areas best situated for bird–habitat studies.

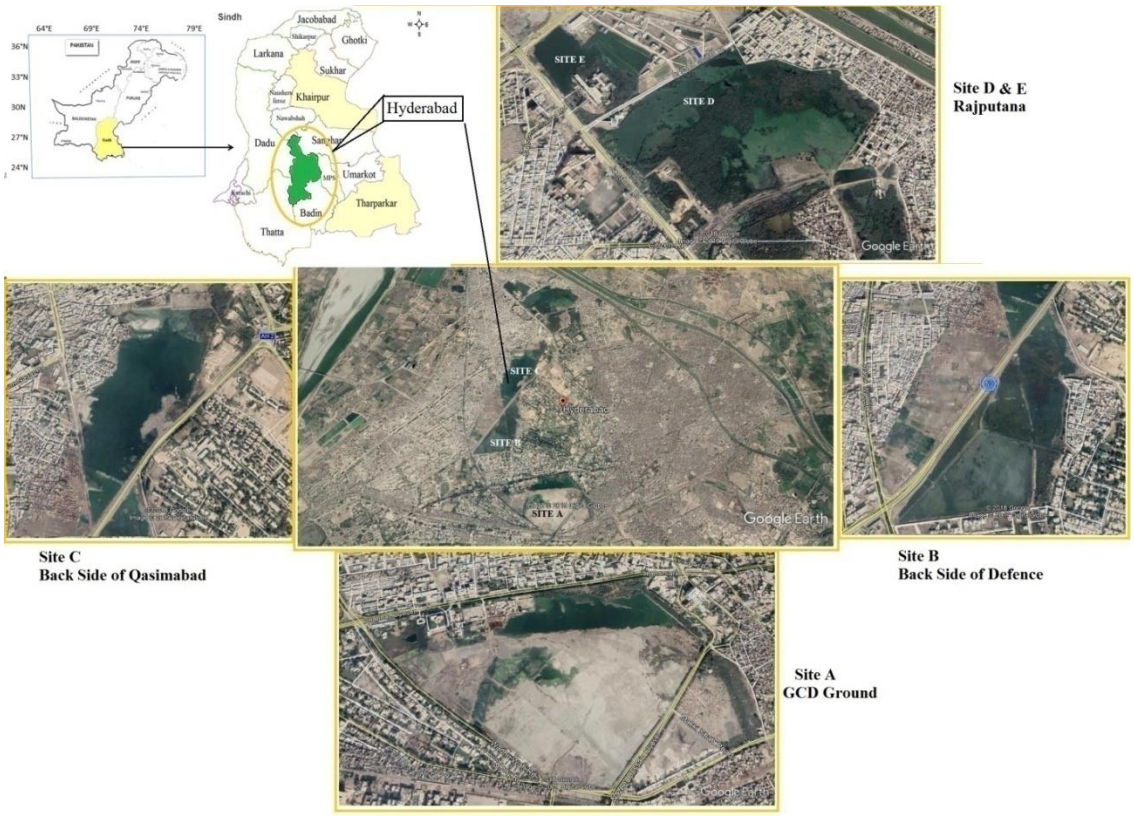

Figure 1. *Location map of the study area*

Avian species inventories at five selected sites were carried out from September 2014 to February 2015 and September 2018 to February 2019 employing Distance Sampling Point Count method. A total of 150 point count stations (i.e., in site 30 point count stations) were fixed at 300 m intervals along the edges of water bodies to avoid double counting the same bird individuals at more than one station (Meadows et al.,

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2012; Wijesundara and Wijesundara, 2014; Adams et al., 2015). The birds were surveyed at each point count station for 15 minutes during each visit. The surveys were carried out during 0750–1100 hrs. This period of time is appropriate as most of the avian species remain active in search of food. The sampling methodology was followed as described by Richardson et al. (2001), Buckland et al. (2004), Aborn (2007), Nadeau et al. (2008), and Yu-Seong et al. (2008).

Data Analysis

Relative abundance revealed the common or rare species inhabiting in a particular area. It is the percentage composition of particular bird species among all detected bird species utilizing the waterlogged area (Simon and Okoth, 2016; Walag and Canencia, 2016; James and Bright, 2017). Relative abundance (%) of avian species was determined to employ the following formula;

$$\text{Relative Abundance} = \frac{ni}{N} \text{ X } 100 \qquad \text{(Eq.1)}$$

where, n*i* = is the number of individuals in the *i*th bird species, N = is total detected numbers of individuals of species detected in urban seasonal waterlogged areas (Bibby et al., 2000; Hubbell, 2001; McGill et al., 2007).

Avian diversity was analyzed using the Community Analysis Package (PCA) Version 4.0 by Henderson and Seaby (2007). The reliability of data of tested through Shapiro–Wilk normality test (Analytical Software version 8.1) by Razali (2011).

The status of avian species was identified and confirmed with the help of IUCN RedList and BirdLife International checklist.

Results

Relative Abundance

The results of 2018/19 stated that urban waterlogged areas had attracted highest relative abundance (i.e., 28229 bird individuals equal to 61.793%) representing 50 species and 14 families as compared to 2014/15 (i.e., 17454 bird individuals equal to 38.207%) represent 38 species and 12 families. This indicated that 23.586% higher numbers of bird individuals were detected in 2018/19. Furthermore, twelve new avian species namely; Common Teal – *Anas cerca*, Green–winged Teal – *Spatula discors*, Mallard – *Anas platyrhinchos*, Gadwall – *Meraca strepera*, Great Cormorant – *Phalacrocorax carbo*, Brown–headed Gull – *Larus brunnicephalus*, Black Kite – *Milvus migrans*, Bar–tailed Godwit – *Limosa lapponica*, Spoon–billed Ibis – *Platalea leucorodia*, Pied Avocet – *Recurvirostra avosetta*, Solitary Sandpiper – *Tringa solitaria*, Spotted Sandpiper – *Actitis macularius*, and White–tailed Lapwing – *Chettus ialeucura* were detected in 2018/19 as compared to 2014/15 (*Table 1*).

In addition, the results obtained using the One–Way ANOVA and Tukey's HSD test showed that the avian relative abundance of the urban seasonal waterlogged area was significantly different in the 2018/19 and 2014/15 periods (i.e., F_1, 86 = 4.46, $P < 0.05$; CV = 2/81).

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Table 1. *Ranking of waterbird species recorded in urban seasonal waterlogged areas*

Family	Common Name	*Scientific name*	Detected Observation in 2014/15	%	Detected Observation in 2018/19	%
Anatidae	Northern Pintail	*Anas acuta*	1490	3.262	1958	4.286
Anatidae	Common Teal	*Anas cerca*	1870	4.093	1922	4.207
Anatidae	Green–winged Teal	*Spatula discors*	–	–	1870	4.093
Anatidae	Mallard	*Anas platyrhinchos*	–	–	1824	3.993
Anatidae	Gadwall	*Meraca strepera*	–	–	1760	3.853
Anatidae	Baikal Teal	*Sibirionetta formosa*	1260	2.758	1656	3.625
Anatidae	Northern Shoveler	*Spatula clypeata*	1630	3.568	1558	3.410
Anatidae	Falcated Duck	*Mareca falcate*	975	2.134	1234	2.701
Laridae	River Tern	*Sterna aurantia*	486	1.064	860	1.883
Anatidae	Garganey	*Spatula querquedula*	680	1.489	859	1.880
Scolopacidae	Black–winged Stilt	*Himantopus himantopus*	660	1.445	752	1.646
Phalacrocoracidae	Indian Cormorant	*Phalacrocorax fuscicollis*	610	1.335	752	1.646
Laridae	Common Tern	*Sterna hirundo*	640	1.401	742	1.624
Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo*	–	–	656	1.436
Laridae	Black-headed Gull	*Chroicocephalus ridibundus*	240	0.525	639	1.399
Phalacrocoracidae	Little Cormorant	*Micro carboniger*	780	1.707	576	1.261
Laridae	Brown–headed Gull	*Larus brunnicephalus*	–	–	545	1.193
Charadriidae	Red–wattled Lapwing	*Vanellus indicus*	130	0.284	537	1.175
Ardeidae	Little Egret	*Egretta garzetta*	870	1.904	460	1.007
Laridae	Short–billed Gull	*Larus brachyrhynchus*	235	0.514	458	1.003
Scolopiacidae	Little Stint	*Calidris minuta*	830	1.817	447	0.978
Ardeidae	Cattle Egret	*Bubulcus ibis*	567	1.241	439	0.961
Laridae	Short–tailed Gull	*Larus canus*	340	0.744	434	0.950
Accipitridae	Black Kite	*Milvus migrans*	–	–	430	0.941
Charadriidae	Yellow–wattled Lapwing	*Vanellus malarbaricus*	40	0.088	388	0.849
Scolopacidae	Bar–tailed Godwit	*Limosa lapponica*	–	–	376	0.823
Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	589	1.289	348	0.762
Ardeidae	Intermediate Egret	*Egretta intermedia*	546	1.195	324	0.709
Ardeidae	Indian Pond Heron	*Ardeol grayii*	100	0.219	290	0.635
Scolopacidae	Marsh Sandpiper	*Tringa stagnatilis*	290	0.635	267	0.584
Motacillidae	Yellow Wagtail	*Motacilla flava*	181	0.396	220	0.482
Scolopacidae	Common Sandpiper	*Actis hypoleucos*	214	0.468	217	0.475
Motacillidae	White Wagtail	*Motacilla alba*	150	0.328	198	0.433
Ardeidae	Great Egret	*Casmerodius albus*	367	0.803	195	0.427
Scolopacidae	Terek Sandpiper	*Xenus cinereus*	209	0.458	194	0.425
Threskiornithidae	Spoon–billed Ibis	*Platalea leucorodia*	–	–	189	0.414
Phoenicopteridae	Greater Flamingo	*Phoenicopterus roseus*	34	0.074	180	0.394
Recurvirostridae	Pied Avocet	*Recurvirostra avosetta*	–	–	170	0.372
Scolopacidae	Wood Sandpiper	*Tringa glareola*	50	0.109	168	0.368
Alcedinidae	Pied Kingfisher	*Ceryle rudis*	20	0.044	160	0.350
Rallidae	Common Moorhen	*Gallinula chlorpus*	40	0.088	155	0.339
Scolopacidae	Green Sandpiper	*Tringa ochropus*	164	0.359	148	0.323
Scolopacidae	Solitary Sandpiper	*Tringa solitaria*	–	–	134	0.293
Scolopacidae	Spotted Sandpiper	*Actitis macularius*	–	–	130	0.285
Scolopacidae	Lesser Sand Plover	*Charadrius mongolus*	27	0.059	124	0.271
Charadriidae	White–tailed Lapwing	*Chettus ialeucura*	–	–	106	0.232
Scolopacidae	Grey Plover	*Pluvialis squatarola*	18	0.039	64	0.140
Rallidae	White–breasted Waterhen	*Amaurornis phoenicurus*	78	0.171	46	0.101
Alcedinidae	White–throated Kingfisher	*Halcysmyrnensis*	30	0.066	45	0.099
Scolopacidae	Sociable Lapwing	*Vanellus gregarius*	14	0.031	25	0.055
	Total 39 Species	**Total**	**17454**		**28229**	
				45683		

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Relative Abundance of Migrant, Resident, Resident-Migrant Bird Species

Notably, 18965 bird individuals of 30 migrant species representing 6 families were detected in 2018/19 as compared to 11547 bird individuals of 22 species and 5 families detected in 2014/15. Likewise, 5370 individuals of 15 resident species were detected in 2018/19 and 5247 individuals of 15 resident species in 2014/15. However, 5 resident–migrant bird species (i.e. 3897 individuals) were detected in 2018/19 while 660 bird individuals of *Himantopus himantopus* resident–migrant species (i.e.) were detected in 2014/15. Out of 30 migrant bird species, one species was critically endangered; two species Ra/A/Vu (Rare/Accidental/Vulnerable) and the rest 23 species were least concern based on IUCN Status. All resident bird species were totally protected and one resident–migrant bird species as data deficient (*Table 2*).

Foraging Guilds Structure in the 2018/19 and 2014/15 Periods

Notably, the findings of foraging guild structure 2018/19 stated that currently, urban seasonal waterlogged areas had attracted a higher number of bird individuals than previous years (i.e., guild omnivore; 32.489% in 2018/19 and 17.562% in 2014/15). Likewise, the higher relative abundance of guild Piscivore was detected in 2019 (12.808%) rather than 2014/15 (7.292%). On the contrarily, lower number of bird individuals of guild Carnivore/Piscivore/Insectivore were detected in 2019 (4.188%) rather than 2014/15 (5.472%). Moreover, the member of guild Carnivore was detected in 2018/19 but no individuals of Carnivore was documented in 2014/15 period (*Table 3*).

Comparison of Diversity Indices

The results of the alpha diversity analysis indicated that urban seasonal waterlogged areas had attracted higher diversity of avian species in 2018/19 rather than 2014/15 (*Table 4*).

Discussions

The urban seasonal waterlogged areas investigated in this study encompasses of 30.0% rush and sedge aquatic plants while rest is shallow water open areas devoid of aquatic vegetation. Rush and sedge plants serve as hiding cover for avian species while open water areas as foraging grounds. The shallow water is rich in food resources, such as fishes, amphibians, insects, crustaceans and aquatic plants which is the major diet of avian species especially waterfowl, seagulls, cormorant, grebes, plovers, sandpipers, stilt, and egrets.

Urban seasonal waterlogged areas are a highly important habitat for a wide array of waterbirds and terrestrial birds. Their importance depends on many factors, namely; size, connectivity to surrounding areas, diversity of vegetation, water quality, occurrence of food resources and disturbance. Besides, determining the temporal changes in avian population parameters is highly important to obtain the population trend of different avian species utilizing these areas. Evidently, the results of the diversity analysis in the study indicated that the bird diversity during consequent time period might vary depending on the habitat suitability, richness of food resources, and feeding guilds in the wetland reserve.

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Table 2. *List of migrant, resident, and resident–migrant bird species detected in urban seasonal waterlogged areas of Hyderabad, Sindh Pakistan in the 2014/15 and 2018/19 periods*

Family	Common Name	Scientific Name	Current Status	Detected Observation in 2014/15	%	Detected Observation in 2018/19	%
Migrant Bird Species							
Anatidae	Northern Pintail	*Anas acuta*	LC	1490	4.883	1958	6.417
Anatidae	Common Teal	*Anas cerca*	LC	1870	6.192	1922	6.299
Anatidae	Mallard	*Anas platyrhinchos*	LC	–	–	1824	5.978
Anatidae	Gadwall	*Meraca strepera*	LC	–	–	1760	5.768
Anatidae	Baikal Teal	*Sibirionetta formosa*	Ra/A/Vu	1260	4.130	1656	5.427
Anatidae	Northern Shoveler	*Spatula clypeata*	LC	1630	5.342	1558	5.106
Anatidae	Falcated Duck	*Mareca falcate*	Ra/A/Vu	975	3.195	1234	4.044
Anatidae	Garganey	*Spatula querquedula*	LC	680	2.229	859	2.815
Laridae	Common Tern	*Sterna hirundo*	LC	640	2.098	742	2.432
Laridae	Black-headed Gull	*Chroicocephalus ridibundus*	LC	240	0.787	639	2.094
Laridae	Brown–headed Gull	*Larus brunnicephalus*	LC	–	–	545	1.786
Laridae	Short–billed Gull	*Larus brachyrhynchus*	LC	235	0.770	458	1.501
Scolopiacidae	Little Stint	*Calidris minuta*	LC	830	2.720	447	1.465
Laridae	Short–tailed Gull	*Larus canus*	LC	340	1.114	434	1.422
Charadriidae	Yellow–wattled Lapwing	*Vanellus malarbaricus*	LC	40	0.132	388	1.272
Scolopacidae	Bar–tailed Godwit	*Limosa lapponica*	LC	–	–	376	1.232
Scolopacidae	Marsh Sandpiper	*Tringa stagnatilis*	LC	290	0.950	267	0.875
Motacillidae	Yellow Wagtail	*Motacilla flava*	LC	181	0.593	220	0.721
Scolopacidae	Common Sandpiper	*Actis hypoleucos*	LC	214	0.701	217	0.711
Motacillidae	White Wagtail	*Motacilla alba*	LC	150	0.492	198	0.649
Scolopacidae	Terek Sandpiper	*Xenus cinereus*	LC	209	0.685	194	0.636
Recurvirostridae	Pied Avocet	*Recurvirostra avosetta*	LC	–	–	170	0.557
Scolopacidae	Wood Sandpiper	*Tringa glareola*	LC	50	0.164	168	0.551
Scolopacidae	Green Sandpiper	*Tringa ochropus*	LC	164	0.537	148	0.485
Scolopacidae	Solitary Sandpiper	*Tringa solitaria*	LC	–	–	134	0.439
Scolopacidae	Spotted Sandpiper	*Actitis macularius*	LC	–	–	130	0.426
Scolopacidae	Lesser Sand Plover	*Charadrius mongolus*	LC	27	0.088	124	0.406
Charadriidae	White–tailed Lapwing	*Vanellus leucurus*	LC	–	–	106	0.347
Scolopacidae	Greater Sand Plover	*Charadrius leschenaultii*	LC	18	0.059	64	0.210
Scolopacidae	Sociable Lapwing	*Vanellus gregarious*	CE	14	0.046	25	0.082
		Sub-Total		**11547**		**18965**	
					30512		

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Family	Common Name	Scientific Name	Current Status	Detected Observation in 2014/15	%	Detected Observation in 2018/19	%
Resident Bird Species							
Laridae	River Tern	*Sterna aurantia*	LC	486	4.579	860	8.103
Phalacrocoracidae	Indian Cormorant	*Phalacrocorax fuscicollis*	LC	610	5.747	752	7.085
Phalacrocoracidae	Little Cormorant	*Micro carboniger*	LC	780	7.349	576	5.427
Charadriidae	Red–wattled Lapwing	*Vanellus indicus*	LC	130	1.225	537	5.059
Ardeidae	Little Egret	*Egretta garzetta*	LC	870	8.197	460	4.334
Ardeidae	Cattle Egret	*Bubulcus ibis*	LC	567	5.342	439	4.136
Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	LC	589	5.549	348	3.279
Ardeidae	Intermediate Egret	*Egretta intermedia*	LC	546	5.144	324	3.053
Ardeidae	Indian Pond Heron	*Ardeol grayii*	LC	100	0.942	290	2.732
Ardeidae	Great Egret	*Casmerodius albus*	LC	367	3.458	195	1.837
Phoenicopteridae	Greater Flamingo	*Phoenicopterus roseus*	LC	34	0.320	180	1.696
Alcedinidae	Pied Kingfisher	*Ceryle rudis*	LC	20	0.188	160	1.507
Rallidae	Common Moorhen	*Gallinula chlorpus*	LC	40	0.377	155	1.460
Rallidae	White–breasted Waterhen	*Amaurornis phoenicurus*	LC	78	0.735	46	0.433
Alcedinidae	White–throated Kingfisher	*Halcysmyrnensis*	LC	30	0.283	45	0.424
		Sub-Total		**5247**		**5367**	
					10614		
Resident–Migrant Bird Species							
Anatidae	Green–winged Teal	*Spatula discors*	LC	–	–	1870	41.036
Recurvirostridae	Black–winged Stilt	*Himantopus himantopus*	LC	660	14.483	752	16.502
Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo*	DD	–	–	656	14.395
Accipitridae	Black Kite	*Milvus migrans*	LC	–	–	430	9.436
Threskiornithidae	Eurasian Spoonbill Ibis	*Platalea leucorodia*	LC	–	–	189	4.147
		Sub-Total		**660**		**3897**	
					4557		
		Grand Total		**17454**	**-**	**28229**	
		Overall Total			**45683**		

(LC = Least Concern, Ra = Rare, A = Accidental, Vu = Vulnerable, CE = Critically Endangered, DD = Data Deficient, M = Migrant, Re = Resident, and R–M = Resident–Migrant)

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Table 3. *List of foraging guild based on the number of species and the total number of detections*

Guild Name	Year 2014/15		Year 2018/19	
	Observations	Percentage	Observations	Percentage
Omnivore	8023	17.562	14842	32.489
Piscivore	3331	7.292	5851	12.808
Piscivore/Insectivore	3235	7.081	4595	10.058
Carnivore/Piscivore/Insectivore	2500	5.472	1913	4.188
Insectivore	331	0.725	418	0.915
Detritivore	34	0.074	180	0.394
Carnivore	–	–	430	0.941
Sub–Total	**17454**		**28229**	
Grand Total	**45683**			

Table 4. *Comparison of diversity indices of avian species inhabiting urban seasonally waterlogged areas in the 2018/19 and 2014/15 periods*

Indices	2018/19				2014/15			
	Overall	Migrant	Resident	Resident–Migrant	Overall	Migrant	Resident	Resident–Migrant
Shannon's Index								
H	17.48	11.38	7.399	2.232	8.04	4.866	3.036	0.502
Exp. H	82.6	48.47	27.43	4.762	55.54	31.21	20.96	4.527
Lower H @ 95%	12.2	7.737	4.757	0.558	8,04	4.866	3.038	0.562
Upper H @ 99%	14.84	10.01	6.342	2.232	8.04	4.866	3.036	0.502
Margalef's Index								
R_1	4.414	3.881	3.312	1.561	4.017	3.441	3.043	1.51
Lower H @ 95%	3.943	3.393	2.741	0.637	4.008	3.43	3.029	1.495
Upper H @ 99%	4.181	3.677	3.128	1.561	4.026	3.453	3.054	1.527
McIntosh's Index								
E	0.971	0.960	0.947	0.893	0.851	0.802	0.773	0.525
Lower H @ 95%	0.929	0.902	0.853	0.430	0.850	0.801	0.771	0.520
Upper H @ 99%	0.950	0.937	0.918	0.893	0.852	0.804	0.774	0.532

Evidently, the results of population parameters are noteworthy, in comparisons; the higher relative abundance, bird species, foraging guilds, and diversity indices were detected in the 2018/19 rather than 2014/15 period. This indicate that urban seasonal waterlogged areas has becomes more attractive habitat with the passage of time for avian species as compared to previous years. The recording of higher relative abundance, species composition, foraging guilds, and diversity indices could be that these areas are less disturbed even though they are located within the heart of the city. Because nobody hunting in these areas due to under administration of cantonment board. The other reason might be that these areas are rich in fish fingerlings, amphibians, insect larvae, and organic matter. These food resources are the major diet of waterbird as well as terrestrial bird species. The third reason could be that natural wetland areas of the Hyderabad have lost due to conversion into agriculture fields, water pollution, and aquaculture ponds, and urban settlements. Due to these reasons, urban seasonal waterlogged areas of the Hyderabad serve as an alternate habitat for a wide array of waterbird as well as terrestrial bird species, especially in winter.

Furthermore, it was observed that the relative abundance of waterbird was influenced by vegetation structure, food resources, and water level that affected the habitat selection. This could be that these factors indicated where and how the waterbirds used the urban waterlogged areas. For example; waterfowl, grebes and cormorant often

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utilized open water areas devoid of aquatic vegetation for foraging (waterfowls, sandpipers, lapwings, stilts, cormorants, terns, and egrets) and dead fallen trees for perching (cormorants and egrets). Likewise, egrets, herons, sandpipers, plovers, and lapwings selected shallow waters for foraging and substrate for perching and avoided the deep waters. This could be that deep water may restrict their prey accessibility and reduced the prey–capturing success (Gawlik, 2002; Brönmark and Hansson, 2005).

Additionally, it was also observed that the richness and diversity of food resources may regulate the distribution and diversity of waterbird species in aquatic habitat (Johnson and Sherry, 2001; Sutula and Stein, 2003). Furthermore, this study highlighted that waterbird species are habitat specialist, they often selected habitat that offers ideal foraging and perching sites, shelter from predator and harsh weather. Relatively, water depth, vegetation structure and composition, richness and diversity of food resources, and dead fallen trees in urban waterlogged areas play a significant role in foraging guild structure (Kiviat and MacDonald, 2004; Benassi et al., 2007; Guadagnin et al., 2009; Tsai et al., 2012).

Conversely, seven foraging guilds were recorded in 2018/19 and six foraging guilds in 2014/15 period. Apparently, the recording of seven feeding guilds of the avian species in urban waterlogged areas in the 2018/19 showed that this seasonal fragile habitat provided suitable food and foraging sites for a wide array of avian species (i.e., waterbirds and terrestrial birds). Furthermore, the results of foraging guild structure revealed that urban seasonal waterlogged areas are rich in food diversity, vegetation structure, and water level that may play a crucial role to attract a higher diversity of avian species especially waterbirds. It was observed that piscivore, i.e., cormorant, egrets, heron, and kingfishers preyed on fishes especially in shallow waters, omnivore i.e., waterfowls foraged on animal (fishes, amphibians, invertebrates, etc.) and plant matter (aquatic plants) that floating at the surface of the water or occurs in shallow waters, insectivore, i.e., stilt, sandpipers, and lapwing, etc mostly preferred shallow water and soft mud to prey on aquatic invertebrates (Guadagnin et al., 2009).

Furthermore, the results foraging behavior also indicated that the waterbirds and terrestrial birds inhabiting in urban waterlogged areas were highly variable in their morphological structures, foraging behavior, and food capturing tactics, and habitat selections. The members of each foraging guild varied in their food selection due to morphological differences, bill and tarsus size, water depth and habitat preferences.

Conclusions

The findings of this study indicated that urban seasonal waterlogged area is suitable habitat (foraging sites and stopover) for a wide array of waterbird species especially migrant birds to refuel, rest, and forage. Unfortunately, these fragile areas have been shrinking at an alarm rate due to urban development. For conservationist, dealing with the human and maintaining the functional waterlogged ecosystem is the greatest challenge to conserve and protect these fragile aquatic habitats. The existence, sustainability, and future of avian species directly depend on protection and conservation of the urban waterlogged areas of Hyderabad and across the country. Hence, it is strongly recommended that the urban seasonal waterlogged areas should be declared as wetland reserve (wetland of global importance) due to harboring a variety of migrants as well as native waterbird species that belong to different taxonomic groups.

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