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Monitoring of water bird population with an account of heronry at Surajpur lake, an urban wetland in National Capital Region, India

NASIM AHMAD ANSARI[1]

Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand 248 001, India

ABSTRACT

Surajpur wetland is a prominent wetland site in National Capital Region, India, known for its rich biodiversity of flora and fauna. The present study was conducted to record the water bird diversity with an account of heronry from March 2010 to February 2013 by applying standard methods. During the study period, a total of 95 water bird species belonging to 22 families were recorded. Family Anatidae dominated the list by 18 species, followed by Scolopacidae (13 species) and Ardeidae (11 species). A total of 45 species recorded as resident, 43 species as winter migrant and 7 species as summer migrant. The relative abundance analysis showed that, 41% bird species were common, 40% occasional and 19% were uncommon in the study area. Month-wise, January recorded maximum number of species and individual while February recorded maximum density and Common Teal witnessed maximum count during the study period. Winter season and third year of study (2012-13) recorded maximum number of species, abundance and density. Among five ecological categories, maximum richness of small waders (34%) was recorded. TWINSPAN and Cluster analysis identified four dominant bird communities in the study area. The heronry revealed 18 bird species nesting in *Phoenix sylvestris* and *Prosopis juliflora* trees, with maximum number of nests observed of Asian Openbill, Black-crowned Night Heron and Black-headed Ibis recorded from April to September. IUCN listed 2 species as Vulnerable, 6 species under Near Threatened and rest species under Least Concern category. The conservation and management implications are discussed in light of results.

Key words: Heronry, India, National Capital Region, Surajpur wetland, Water birds

Surajpur wetlands is a significant urban wetland which provides habitat for water birds and used for nesting, breeding, roosting and rearing their young ones. Monitoring of water birds in wetlands provides significant information on the ecological health and status of wetlands, and can be a vital tool for developing awareness regarding the conservation value of the wetlands (Kumar and Gupta 2013). Through the ages, urban wetlands are considered as the lifeline of most of the cities in India and they provide numerous ecological benefits. The rapid urbanisation and industrialisation in the post-independence era in India has brought several water bodies either within or nearby urban settlements and so they are suffering from pollution caused by anthropogenic activities.

Heronries are the nesting and breeding areas of Herons, Egrets and other associated colonial aquatic bird species, and play an important role in providing suitable habitat and conservation of water birds. Very few studies have been conducted on urban wetlands, breeding biology, heronries and the growing need for their conservation in India and in the National Capital Region. Reports are available on heronries in the Protected Areas of Uttar Pradesh, but there is no systematic data available on breeding ecology of the colonial birds (Islam and Rahmani 2008, Kumar 2011, Rahmani *et al.* 2011). Also, Surajpur wetland has never been explored in terms of heronry and breeding ecology of water birds. Hence, present study was undertaken to provide the analytical information on the diversity, breeding and ecological aspects of heronry birds from Surajpur wetland, National Capital Region, India. The study would help in monitoring the course of changes in future and better understanding of the conservation perspectives of the heronry in Surajpur wetland.

Present address: [1]Project Associate (dr.ansari.nasim@gmail.com).

MATERIALS AND METHODS

The study was carried out in Surajpur lake (28°31'425'N; 77°29'714'E), an urban wetland located in district Gautam Budh Nagar, Uttar Pradesh falls under National Capital Region, India at an elevation of 184.7 meter above mean sea level (Supplementary Fig. 1). Surajpur Lake has been protected under reserve forest and spreads over an area of 308 hectare including a 60 hectare of natural perennial water body (Ansari *et al.* 2016). Data were collected on monthly basis from March 2010 to February 2013 to assess the population of water birds in Surajpur wetland and a total of 36 surveys were made during the study period. Total count method to count water birds and direct search technique for counting nesting colonies in heronry of water birds was applied (Urfi *et al.* 2005). Observations on water birds were made from 10 selected vantage points, one in each wetland block to facilitate easy count and also to avoid double

counting or missing of birds. These vantage points were selected based on the best visibility of the site without overlap of areas counted and without missing any part of the site. Each site was assigned a fixed view point. From each fixed point, area was scanned for bird flocks. Nikon binocular of 10×50 X specification was used for sighting birds during the most active period of the day, i.e., from 0600 h to 1000 h and from 1600 h to 1800 h. However, observations were also made other than the survey timings to locate the illusive taxa. Birds seen were recorded along with habitat type, season and frequency of occurrence and species sighted were confirmed by consulting standard field guides (Grimmett *et al.* 2001) and the nomenclature of common and scientific names was followed (Rasmussen and Anderton 2012). The status of birds was categorized as resident (R), winter migrant (WM), summer migrant (SM), and passage migrant (PM) (Rasmussen and Anderton 2012, Urfi 2003). The different water birds were ecologically grouped into five categories on the basis of their activities as diving birds, swimming birds, small waders, large waders and aerial foragers based on Ramamurthy and Rajakumar (2014) and Manikannan (2011). The abundance status of the recorded bird species was established on the basis of frequency of sightings following Javed and Rahmani (1998) as, common (seen frequently, more than 10 sightings), occasional (less than 10 sightings) and uncommon (less than 5 sightings). The conservation status of birds was determined as per IUCN Red List Criteria (IUCN 2016).

Data analysis was performed by using PAST software (Versions 3.08) (Hammer *et al.* 2001). Species diversity was assessed by using alpha diversity indices, viz. Shannon and Margalef's indices in temporal spectrum. The bird densities were calculated as numbers per hectare for different months, climatic season, years and habitats. Bird community classification was done by using the polythetic divisive clustering technique in TWINSPAN (Siddiqui *et al.* 2010).

RESULTS AND DISCUSSION

Overview of bird species composition: The study reveals the occurrence of 95 water bird species belonging to 22 families during the study period (Table 1). Among 22 families, Anatidae dominated the list with 18 species followed by Scolopacidae with 13 species; Ardeidae with 11 species; Accipitridae with 9 species; Hirundinidae and Rallidae with 5 species each; Charadridae, Ciconidae and Motacillidae with 4 species each; Alcedinidae, Phalacrocoracidae, Threskiornithidae with 3 species each; Jacanidae, Muscicapidae and Recurvirostridae with 2 species each whereas Anhingidae, Corvidae, Cuculidae and Gruidae with 1 species each, respectively.

The residence status of bird species recorded 45 species (43.37%) as resident, 43 species (45.26%) as winter migrant and 7 species (7.27%) as summer migrant. The occurrence status of bird species based on the frequency of sightings revealed, 41% (n=39) common, 40% (n=38) occasional and 19% (n=18) uncommon water bird species. The study area supports threatened water bird species. According to IUCN Red List (2013), 2 bird species (i.e. Sarus Crane and Greater Spotted Eagle) listed in vulnerable category (VU), 6 bird species (i.e. Oriental Darter, Black-necked Stork, Painted Stork, Black-headed Ibis, Ferruginous Duck and Black-tailed Godwit) listed in near threatened (NT) category and rest all the species were listed as under least concern (LC) category of IUCN Red List 2013.

Similar avifaunal exploration studies were also made. Ansari and Nawab (2015) reported a checklist of 186 bird species in Surajpur wetland; Ansari and Ram (2016) reported 193 bird species in satellite wetlands of Gautam Budh Nagar district including Surajpur wetland; Shukla and Lone (2010) reported 63 bird species from Soor Sarovar Bird Sanctuary, Agra; Kumar and Gupta (2009) reported 54 bird species from Kurukshetra wetland, Haryana; Kaushik and Gupta (2013) reported 60 water birds from Asan Conservation Reserve, Uttarakhand.

In the present study, more than half of the water bird populations were migratory in nature as reported by Kaushik and Gupta (2013) in Asan Barrage and Urfi (2003) in Okhla Bird Sanctuary. Family Anatidae dominated the list by 18 species due to the presence of diverse group of waterfowl as reported by many similar studies (Shukla and Lone 2010, Kumar and Gupta 2009, Kaushik and Gupta 2013). Deshkar *et al.* (2010) also reported density and richness highest during winter season due to the arrival of migratory bird population and least during monsoon due to leave back of migratory bird populations, when the resident species have been engaged in the nesting activities.

Monthly bird species composition: The entire bird species recorded during the span of 3 years (36 months) were pooled together and divided into 12 months from March to February. Bird species richness was highest in January (69 species) followed by December (68 species) and lowest in the month of August (35 species); whereas abundance was recorded maximum in February (3369 individuals) followed by December (2836 individuals) and minimum in August (428 individuals) (Supplementary Fig. 2). The mean monthly fluctuation in species abundance of each bird species was also calculated and abundance of 35 most common species is reported here. Common Teal was the most abundant during January (670.7 individuals), February (610.7 individuals), November (355.3 individuals) and December (666.7 individuals); Northern Shoveler in March (240 individuals), Black-winged Stilt in April (173.3 individuals); Indian Spot-billed Duck in rest of months during May (88.3 individuals), June (122.7 individuals), July (115.3 individuals), August (99 individuals), September (118.3 individuals) and October (140.3 individuals) respectively (Table 2). Shannon Weiner species diversity index (H') was observed highest during October (H2 = 3.30) and least in August (H2 = 2.74); whereas Margalef's species richness index (D') was observed highest during the month of January (D2 = 8.87) and least in June (D2 = 5.58) (Supplementary Fig. 3). Month wise an overall mean water bird species density recorded 23.44±5.52 individuals/ha,

Table 1. List of water birds recorded from Surajpur wetland

S. No.	Family	Common name	Scientific name	Residence status	Occurrence status	IUCN status
1	Podicipediae	Little Grebe	*Tachybaptus ruficollis*	R	O	LC
2	Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo*	WM	O	LC
3	Phalacrocoracidae	Indian Shag	*Phalacrocorax fuscicollis*	R	O	LC
4	Phalacrocoracidae	Little Cormorant	*Microcarbo niger*	R	C	LC
5	Anhingidae	Oriental Darter	*Anhinga melanogaster*	WM	O	NT
6	Ardeidae	Black Bittern	*Dupetor flavicollis*	SM	U	LC
7	Ardeidae	Black-crowned Night-heron	*Nycticorax nycticorax*	R	C	LC
8	Ardeidae	Chestnut Bittern	*Ixobrychus cinnamomeus*	SM	O	LC
9	Ardeidae	Great Egret	*Egretta alba*	R	O	LC
10	Ardeidae	Grey Heron	*Ardea cinerea*	R	O	LC
11	Ardeidae	Indian Pond-heron	*Ardeola grayii*	R	C	LC
12	Ardeidae	Intermediate Egret	*Egretta intermedia*	R	C	LC
13	Ardeidae	Little Egret	*Egretta garzetta*	R	C	LC
14	Ardeidae	Purple Heron	*Ardea purpurea*	R	C	LC
15	Ardeidae	Western Cattle Egret	*Bubulcus ibis*	R	C	LC
16	Ardeidae	Yellow Bittern	*Ixobrychus sinensis*	SM	U	LC
17	Ciconidae	Asian Openbill	*Anastomus oscitans*	R	C	LC
18	Ciconidae	Black-necked Stork	*Ephippiorhynchus asiaticus*	R	O	NT
19	Ciconidae	Painted Stork	*Mycteria leucocephala*	R	O	NT
20	Ciconidae	Woolly-necked Stork	*Ciconia episcopus*	R	C	LC
21	Threskiornithidae	Black-headed Ibis	*Threskiornis melanocephalus*	R	O	NT
22	Threskiornithidae	Eurasian Spoonbill	*Platalea leucorodia*	WM	O	LC
23	Threskiornithidae	Indian Black Ibis	*Pseudibis papillosa*	R	C	LC
24	Anatidae	Bar-headed Goose	*Anser indicus*	WM	C	LC
25	Anatidae	Common Pochard	*Aythya ferina*	WM	O	LC
26	Anatidae	Common Teal	*Anas crecca*	WM	C	LC
27	Anatidae	Cotton Teal	*Nettapus coromandelianus*	SM	O	LC
28	Anatidae	Eurasian Wigeon	*Mereca penelope*	WM	C	LC
29	Anatidae	Ferruginous Duck	*Aythya nyroca*	WM	O	NT
30	Anatidae	Gadwall	*Mereca strepera*	WM	C	LC
31	Anatidae	Gargany	*Querquedula querquedula*	WM	O	LC
32	Anatidae	Greylag Goose	*Anser anser*	WM	C	LC
33	Anatidae	Indian Spot-billed Duck	*Anas poecilorhyncha*	R	C	LC
34	Anatidae	Knob-billed Duck	*Sarkidiornis melanotos*	R	C	LC
35	Anatidae	Lesser Whistling-duck	*Dendrocygna javanica*	SM	C	LC
36	Anatidae	Mallard	*Anas platyrhynchos*	WM	U	LC
37	Anatidae	Northern Pintail	*Anas acuta*	WM	C	LC
38	Anatidae	Northern Shoveler	*Spatula clypeata*	WM	C	LC
39	Anatidae	Red-crested Pochard	*Netta rufina*	WM	O	LC
40	Anatidae	Ruddy Shelduck	*Tadorna ferruginea*	WM	C	LC
41	Anatidae	Tufted Duck	*Aythya fuligula*	WM	O	LC
42	Accipitridae	Black Kite	*Milvus migrans*	R	C	LC
43	Accipitridae	Black-shouldered Kite	*Elanus caeruleus*	R	O	LC
44	Accipitridae	Crested Serpent-eagle	*Spilornis cheela*	R	O	LC
45	Accipitridae	Greater Spotted Eagle	*Clanga clanga*	WM	O	VU
46	Accipitridae	Oriental Honey-buzzard	*Pernis ptilorhynchus*	R	O	LC
47	Accipitridae	Steppe Eagle	*Aquila nipalensis*	WM	U	LC
48	Accipitridae	Tawny Eagle	*Aquila rapax*	R	U	LC
49	Accipitridae	Western Marsh Harrier	*Circus aeruginosus*	WM	O	LC
50	Accipitridae	White-eyed Buzzard	*Butastur teesa*	R	U	LC
51	Gruidae	Sarus Crane	*Grus antigone*	R	O	VU
52	Rallidae	Common Moorhen	*Gallinula chloropus*	R	C	LC
53	Rallidae	Eurasian Coot	*Fulica atra*	WM	C	LC
54	Rallidae	Purple Swamphen	*Porphyrio porphyrio*	R	C	LC
55	Rallidae	Watercock	*Gallicrex cinerea*	SM	U	LC
56	Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*	R	O	LC
57	Rostratulidae	Greater Painted-snipe	*Rostratula benghalensis*	R	U	LC

(contd...)

(Concluded table 1)

S. No.	Family	Common name	Scientific name	Residence status	Occurrence status	IUCN status
58	Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*	R	C	LC
59	Recurvirostridae	Pied Avocet	*Recurvirostra avosetta*	WM	U	LC
60	Jacanidae	Bronze-winged Jacana	*Metopidius indicus*	R	C	LC
61	Jacanidae	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	SM	O	LC
62	Charadridae	Little Ringed Plover	*Charadrius dubius*	R	U	LC
63	Charadridae	Northern Lapwing	*Vanellus vanellus*	WM	U	LC
64	Charadridae	Red-wattled Lapwing	*Vanellus indicus*	R	C	LC
65	Charadridae	White-tailed Lapwing	*Vanellus leucurus*	WM	O	LC
66	Scolopacidae	Common Greenshank	*Tringa nebularia*	WM	C	LC
67	Scolopacidae	Common Redshank	*Tringa totanus*	WM	C	LC
68	Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	WM	C	LC
69	Scolopacidae	Common Snipe	*Gallinago gallinago*	WM	U	LC
70	Scolopacidae	Green Sandpiper	*Tringa ochropus*	WM	C	LC
71	Scolopacidae	Little Stint	*Ereunetes minutus*	WM	O	LC
72	Scolopacidae	Marsh Sandpiper	*Tringa stagnatilis*	WM	C	LC
73	Scolopacidae	Pintail Snipe	*Gallinago stenura*	WM	U	LC
74	Scolopacidae	Ruff and Reeve	*Philomachus pugnax*	WM	C	LC
75	Scolopacidae	Spotted Redshank	*Tringa erythropus*	WM	U	LC
76	Scolopacidae	Temminck's Stint	*Ereunetes temminckii*	WM	U	LC
77	Scolopacidae	Western Black-tailed Godwit	*Limosa limosa*	WM	C	NT
78	Scolopacidae	Wood Sandpiper	*Tringa glareola*	WM	C	LC
79	Cuculidae	Greater Coucal	*Centropus sinensis*	R	O	LC
80	Alcedinidae	Common Kingfisher	*Alcedo atthis*	R	O	LC
81	Alcedinidae	Lesser Pied Kingfisher	*Ceryle rudis*	R	O	LC
82	Alcedinidae	White-throated Kingfisher	*Halcyon smyrnensis*	R	C	LC
83	Hirundinide	Barn Swallow	*Hirundo rustica*	WM	O	LC
84	Hirundinide	Grey-throated Sand-martin	*Riparia chinensis*	WM	O	LC
85	Hirundinide	Red-rumped Swallow	*Cecropis daurica*	WM	U	LC
86	Hirundinide	Streak-throated Swallow	*Petrochelidon fluvicola*	WM	U	LC
87	Hirundinide	Wire-tailed Swallow	*Hirundo smithii*	R	O	LC
88	Motacillidae	Citrine Wagtail	*Motacilla citreola*	R	C	LC
89	Motacillidae	Grey Wagtail	*Motacilla cinerea*	WM	O	LC
90	Motacillidae	White-browed Wagtail	*Motacilla madaraspatensis*	R	U	LC
91	Motacillidae	Yellow Wagtail	*Motacilla flava*	WM	O	LC
92	Musicapide	Bluethroat	*Luscinia svecica*	WM	O	LC
93	Musicapide	Striated Babbler	*Turdoides earlei*	R	O	LC
94	Sturnidae	Common Starling	*Sturnus vulgaris*	WM	O	LC
95	Corvidae	House Crow	*Corvus splendens*	R	C	LC

Residence status: R, Resident; SM, Summer migrant; WM, Winter migrant. Occurrence status: C, Common; O, Occasional; U, Uncommon. IUCN Conservation Status: VU, Vulnerable; NT, Near threatened; LC, Least concern; NE, Not evaluated

whereas February recorded highest mean density (56.15±12.87 individuals/ha) and August recorded lowest mean density (7.13±2.39 individuals/ha) (Supplementary Fig. 3). Common Teal recorded highest mean density during January (11.18 individuals/ha), February (10.18 individuals/ha), November (5.92 individuals/ha) and December (11.11 individuals/ha) followed by Northern Shoveler in March (4.0 individuals/ha).

Yearly and seasonal bird species composition: All the bird species recorded during the span of 3 years (36 months) were pooled together and divided into 3 study years, viz. 2010-11, 2011-12 and 2012-13 and each year divided into three distinct seasons i.e. summer (March to June), monsoon (July to October) and winter (November to February). Bird species richness, density, Margalef's richness and Shannon diversity were calculated on seasonal and yearly basis. Overall 88 water bird species were recorded during sampling in 3 years, with density 23.44 individuals/ha, Margalef's richness (12.05) and Shannon diversity (3.40) (Table 3). Yearly bird species richness (n=82), density (30.16 individuals/ha) and Margalef's richness (D2 =10.83) were recorded highest in third year 2012-13 whereas Shannon diversity (H2 =3.48) was recorded highest during the first year 2010-11. On seasonal basis, overall species richness (n=79) and density (42.84 individuals/ha) were recorded maximum in winter, Margalef's richness recorded maximum in monsoon (D2 =7.81) and Shannon diversity recorded maximum in summer (H2 =3.38) (Table 3).

Bird species density, diversity and richness recorded highest in the winter showed an increase from monsoon to

Table 2. Mean monthly abundance of selected bird species in wetland habitat (n = 36)*

Bird species	Months 2010 - 2013											
	M	A	M	J	J	A	S	O	N	D	J	F
Asian Openbill	3.0	3.7	18.7	45.3	80.0	66.0	65.7	72.7	15.7	2.0	3.0	3.0
Black-crowned Night-heron	6.3	-	1.3	9.7	23.7	20.3	36.0	51.3	13.3	-	-	0.7
Black-headed Ibis	29.3	19.7	17.0	4.0	22.0	26.0	25.3	64.7	20.7	13.3	17.7	20.0
Black-winged Stilt	182.0	173.3	36.3	9.7	8.3	4.0	7.0	10.7	99.0	57.3	48.3	131.3
Common Greenshank	0.7	1.3	-	-	-	-	-	0.7	0.7	15.3	85.0	4.7
Common Moorhen	88.3	45.7	6.0	3.0	2.3	4.0	3.0	45.0	37.7	56.0	48.3	98.7
Common Redshank	20.3	21.7	-	-	18.3	-	9.0	12.0	31.0	39.3	17.0	27.0
Common Teal	63.7	-	0.3	-	2.3	-	-	15.7	355.3	666.7	670.7	610.7
Eurasian Coot	40.7	1.7	-	0.3	-	-	-	25.0	136.7	136.3	123.0	141.0
Eurasian Spoonbill	13.3	26.0	0.7	1.0	-	-	-	11.7	2.7	4.7	7.0	30.3
Eurasian Wigeon	34.0	-	-	-	-	-	-	0.7	25.0	29.7	33.3	56.3
Gadwall	129.0	-	-	-	-	-	-	23.0	208.3	329.7	195.0	442.3
Greylag Goose	3.3	0.3	-	-	-	-	-	-	22.3	20.3	64.0	89.7
Indian Black Ibis	60.7	102.0	35.7	5.3	3.7	0.7	1.7	7.7	6.3	2.0	5.0	7.3
Indian Pond-heron	57.7	18.0	4.0	3.3	1.7	2.7	9.3	19.3	11.7	15.3	11.3	29.3
Indian Shag	9.0	15.7	-	0.7	0.3	-	2.3	2.0	5.3	3.0	3.3	10.3
Indian Spot-billed Duck	178.3	152.3	88.3	122.7	115.3	99.0	118.3	140.3	244.3	266.3	122.7	184.3
Intermediate Egret	41.0	36.3	37.7	37.7	8.7	13.0	12.0	15.0	18.7	11.3	8.7	26.3
Knob-billed Duck	2.0	3.7	12.0	3.7	1.7	0.7	2.0	-	0.3	1.0	2.0	15.0
Lesser Whistling-duck	-	2.3	41.7	31.7	30.7	20.7	24.7	8.3	3.3	-	-	-
Little Cormorant	21.0	20.3	11.3	8.3	7.0	6.7	9.0	37.7	35.7	12.7	7.7	10.0
Little Egret	20.3	7.7	26.7	19.7	4.0	5.7	2.3	7.0	5.3	6.3	4.7	15.7
Marsh Sandpiper	12.3	16.3	-	-	1.7	-	2.3	4.3	4.7	3.7	2.7	11.0
Northern Pintail	15.7	0.7	-	-	-	-	-	4.0	90.7	322.7	147.7	272.7
Northern Shoveler	240.0	27.3	-	-	-	-	-	18.3	160.0	256.7	133.0	530.7
Painted Stork	13.7	33.0	8.3	3.7	2.3	1.0	3.3	4.3	-	6.3	3.3	8.0
Pheasant-tailed Jacana	-	7.3	43.0	20.0	7.0	5.0	5.7	2.3	0.7	-	-	-
Purple Heron	11.7	10.7	14.0	14.0	26.7	22.7	19.7	20.3	12.3	11.7	6.0	10.0
Purple Swamphen	41.3	62.7	59.0	68.0	40.3	32.7	29.0	46.7	88.7	86.3	44.7	137.7
Red-wattled Lapwing	78.7	123.7	67.3	33.0	11.3	6.0	11.3	14.0	24.3	28.7	17.7	29.7
Ruff and Reeve	124.7	24.3	-	0.7	-	-	2.7	5.0	8.0	88.7	114.0	57.3
Western Black-tailed Godwit	46.3	56.3	9.7	18.3	2.7	-	-	16.0	112.7	96.7	65.7	136.0
Western Cattle Egret	43.7	94.7	80.7	29.7	32.3	37.3	21.0	28.3	14.0	15.0	11.0	26.3
Wood Sandpiper	19.3	35.7	2.0	-	17.3	-	8.3	11.7	1.7	15.7	12.3	12.7
Woolly-necked Stork	18.3	19.0	14.3	11.0	2.7	4.0	5.3	7.3	10.7	20.0	11.7	19.3

*(n = Number of months)

winter. This is because the area is located in the Central Asian Flyway of migratory birds and thousands of birds use it as a wintering ground as well as a stopover site. These migratory birds form a major part of waterfowl population of the wetland and as the summer approaches, these start flying back to their breeding grounds (Manral and Khudsar 2013). The presence of locally moving birds and winter visitors are the major factors responsible for the higher diversity in the winter season and food availability was also higher during this season. It could be concluded that the abundance of insects, availability of fruits and rainfall attracted more birds from the month of September onwards. The seasonal variation in the occurrence of birds could be due to the fluctuation in the abundance of food (Vijayan *et al.* 2000). The abundance and density of water birds are maximum in the winter period, indicating the interrelationship between water birds and the abiotic and biotic factors. The peak counts in the winter season are mainly due to the availability of food which includes the planktons and smaller animals as reported by Kumaran *et al.* (2012).

A considerable increasing trend of various avifaunal parameters i.e. bird species richness, abundance, diversity and density was reported during the three year study period from 2010-13. This is because of the continuous improvement in habitat quality due to the ongoing ecological study of Surajpur wetland. The restoration of the area, various management activities continued enhanced the quality of the wetland for the native flora and fauna. Least bird species population recorded during the first year of study (2010-11) could be due to the tremendous anthropogenic pressure from local villages. Initially the area had enormous anthropogenic pressure in terms of cattle grazing, fishing, fuel wood collection, *tadi* extraction from Datepalm trees and hunting, poaching etc. During the third year of study (2012-13), there was no substantial

anthropogenic pressure except cattle grazing (Ansari 2015).

Ecological group of water birds: Different ecological groups of water birds were recorded in the Surajpur wetland site. The water birds observed in the study area were divided into 5 ecological groups based on similarities in their methods of procuring food (Manikannan 2011). The ecological categories included 34% small waders (32 species), 20% large waders (19 species), 21% aerial foragers (20 species), 11% diving birds (11 species) and 14% dabbling birds (13 species). Since, Surajpur wetland is marshy land type of wetland area (Ansari and Ram 2016), it supports shallow small breeding waders and hence reported maximum species (34%) included Sandpipers and Shanks as reported by Manikannan (2011). Whereas diving birds prefer deep water wetland areas, this could be due the less availability of food material in deep water, as more food material has been available in marshy land areas having less water. The shallow water supports a diverse array of aquatic vegetation and insects (Arner and Hepp 1989), important resources for waterfowl and nongame birds (Edwards and Otis 1999). Marshes support more life than any other type of habitat. The bird diversity is being affected by this as the deeper areas preferred by diving ducks like pochards are only in few numbers in the area.

Bird community analysis: TWINSPAN and Cluster analysis was done for bird community classification. One year data (i.e. 2012-13) of water bird sampling was used for community classification and cluster analysis. A total of 58 species of water birds were recorded in all the 10 blocks, were pooled together for TWINSPAN and cluster analysis. The total number of species and pseudo species were 168. Length of data array after defining pseudo species was 574. The application of TWINSPAN technique made it possible to divide the set of 10 sampling blocks for water birds into 4 groups at level 4 of the hierarchical classification. By applying TWINSPAN analysis technique, four water bird communities were identified (Table 4). Since the waterfowl recorded maximum richness and abundance, three bird communities included waterfowl species with other associated species like Stilts, Coots and Swaphens. The fourth community included only Swamphens and Egrets. Cluster analysis was performed to evaluate the grouping of water birds based on their similarity in habitat use. The analysis revealed that the water bird species bearing block numbers 1 and 3, 6 and 8, 5 and 7 formed distinct bird assemblages and two homogenous groups were identified (Supplementary Fig. 4).

Structure of Heronry: Surajpur wetland heronry reported a mix of 18 water bird species belonging to 5 families (Fig. 5). Family Ardeidae included the maximum heronry birds with 8 water bird species followed by Ciconidae with 4 water bird species, Phalacrocoracidae with 3 water bird

Table 3. Yearly and seasonal changes in water bird species density, Margalef's richness and Shannon diversity

Year	Seasons	Species richness	Density (individuals/ha)	Margalef's richness	Shannon diversity
2010-2011	Summer	43	16.63	6.1	2.78
	Monsoon	30	3.47	5.51	3.1
	Winter	60	26.54	8.02	3.07
	Yearly	67	15.54	9.7	3.48
2011-2012	Summer	63	20.87	8.71	3.48
	Monsoon	51	10.42	7.8	3.01
	Winter	67	42.58	8.42	2.87
	Yearly	78	24.63	10.59	3.39
2012-2013	Summer	63	16.44	9.16	3.07
	Monsoon	56	14.65	7.99	3.05
	Winter	63	59.40	7.83	2.59
	Yearly	82	30.16	10.83	3.07
Overall 3 years	88	23.44	12.05	3.40	
Overall Summer	73	17.98	7.60	3.38	
Overall Monsoon	73	9.51	7.81	3.15	
Overall Winter	79	42.84	7.64	2.91	

Table 4. Waterbird communities identified by TWINSPAN analysis in wetland habitat

Dominant bird communities identified	Block numbers in which species reported
Eurasian Coot, Eurasian Wigeon, Northern Pintail, Northern Shoveler, Gadwall, Common Teal and Indian Spot-billed Duck community	06 and 08
Northern Shoveler, Common Teal and Purple Swamphen community	02 and 03
Northern Shoveler and Black-winged Stilt community	04, 09 and 10
Purple Swamphen and Western Cattle Egret community	01, 05 and 07

species and Threskiornithidae with 2 water bird species, Anhingidae with one water bird species each. A total of 7155 water birds recorded in the heronry of 18 bird species. Among 18 heronry species, Asian Openbill had the highest population size (15.18%) followed by Cattle Egret (11.57%), Black-headed Ibis (10.23%), Black-Crowned Night Heron (8.83%), Little Cormorant (7.85%), Purple Heron (7.53%) and Oriental Darter recorded the least population size with 8 individuals (0.11%) only (Table 5).

Surajpur wetland heronry structured in the dense mix of beautiful *Phoenix sylvestris* trees with *Ipomea* sp. in the understory vegetation in the centre of wetland habitat and *Prosopis juliflora* trees heronry at the periphery of wetland habitat. It was observed that water bird breeds in the heronry from summer to monsoon seasons and after reaching the heronry, they chose different stratum for new nest building or old nest occupying in the crown of trees. Usually Asian Openbill, Wooly-necked Stork, Black-necked Stork, Oriental Darter and Black-headed Ibis occupy the top canopy space in the crown. Middle storey birds included Grey Heron, Black-crowned Night Heron, Intermediate Egret, Purple Heron, Little Cormorant and Indian Cormorant. Lower storey birds included Indian Pond Heron, Little Egret, Cattle Egret and Little Cormorant. There were some birds restricted to certain stratum like Indian Pond Heron, Cattle Egret (lower stratum), Intermediate Egret, Black-crowned Night Heron and Great Egret (middle stratum), and Asian Openbill, Black-headed Ibis, Wooly-necked Stork and Black-necked Stork (upper stratum).

Thousands of potential breeding birds of different species arrived in the heronry of Surajpur wetland every year and involved in nesting and breeding activities during summer and monsoon seasons. Depending on the arrival of rains in late or early monsoons, the arrival of birds in the heronry also varies. Early arriver birds seen in April-May include Little Egret, Cattle Egret, Grey Heron, Great Egret, Intermediate Egret and Indian Pond Heron. Late arriver birds seen in June-July included Asian Open-bill, Black-crowned Night Heron, Black-headed Ibis, Purple Heron, Little Cormorant, Indian Cormorant and Spoonbill, whereas very late arrival seen in August-September included Wooly-necked Stork, Painted Stork, Black-necked Stork. The nest contributor bird species in the heronry vary from place to place and different in different months. In Surajpur wetland, the maximum number of nest contributor was Asian Openbill (200–300 nests) followed by Black crowned Night Heron (150–200 nests), Black-headed Ibis (130–180 nests), Cattle Egret (100–150 nests), Little Cormorant (80–120 nests), Little Egret (<100 nests), Indian Cormorant (<50 nests) and least nest contributor was Oriental Darter (<10 nests) from April to September.

Surajpur wetland heronry supported a mixture of breeding Storks, Ibises, Herons, Egrets, Cormorants and Darters which shared the nesting environment in space and time and this study forms the first of its kind. Mixed colonial breeding of aquatic birds was also reported earlier from other Indian heronries (Jha 2012, Gopi and Pandav 2011, Narayanan and Vijayan 2007, Santoro *et al.* 2010). The

Table 5. List of water bird species observed in heronry of Surajpur wetland

Family and Species name	Abundance			Total no. of individuals	%
	2010–11	2011–12	2012–13		
		Phalacrocoracidae			
Indian Cormorant	54	16	10	80	1.11
Great Cormorant	25	92	3	120	1.67
Little Cormorant	245	182	135	562	7.85
		Anhingidae			
Darter	6	2	0	8	0.11
		Ardeidae			
Cattle Egret	83	408	337	828	11.57
Grey Heron 51	51	39	141	1.97	
Large Egret 71	77	33	181	2.52	
Little Egret 42	116	108	266	3.71	
Median Egret	82	264	125	471	6.58
Black-Crowned Night Heron	130	293	209	632	8.83
Pond Heron 150	149	108	407	5.68	
Purple Heron	102	301	136	539	7.53
		Ciconidae			
Open-bill stork	216	532	338	1086	15.17
Painted Stork	60	9	67	136	1.90
White-necked stork	110	135	188	433	6.05
Black-necked Stork	1	133	0	134	1.87
		Threskiornithidae			
Black-headed Ibis	250	129	353	732	10.23
Eurasian Spoonbill	65	236	98	399	5.57
Total			7155		

Fig. 5 (Figs 1-4 available online). Heronry of Surajpur wetland. a. Black-headed Ibis in Date Palm tree. b. Cormorants and Darter in *Proposis juliflora* tree. c. Asian Openbill and Black headed Ibis in Date Palm tree. d. Asian Openbill in Date Palm tree. e. Black-crowned Night Heron and Little Cormorant in Date Palm tree. f. Black-necked Stork in Date Palm tree

heronry of Surajpur wetland reported maximum number of individuals of Asian Openbill, Black-crowned Night Heron, Black-headed Ibis and Cormorants, also reported by Jha (2012) and Narayanan and Vijayan (2007). Successful conservation of water bird species will depend on an improved understanding of their ecological requirements and patterns of movement (Fellowes *et al.* 2001). Further detailed study on requirements of individuals species, breeding and nesting success of birds need to be done in detail for conservation and management of heronry birds of Surajpur wetland.

The present study concluded that the Surajpur wetland is an important urban wetland with total 186 bird species including 95 water bird species and 18 heronry species in National Capital Region (NCR) provides an opportunity to conserve and preserve the native flora, fauna and biodiversity amidst a densely populated urban area without hindering the development of the same. The area has been established as a prominent site for wintering birds, provides a larger place to congregate water birds, feeding ground for the migratory and the resident species. The area supports the globally threatened water bird species, such as Sarus Crane, Greater Spotted Eagle, Egyptian Vulture, Black-headed Ibis, Bristled Grassbird, Oriental Darter, Black-necked Stork and Painted Stork in a very good number; it needs very much protection. Surajpur wetland site falls under the purview of National Capital Region (NCRPB 2013); this study can be used by National Capital Region Planning Board to develop this area as a green zone or wildlife zone. The area is already identified under Potential Ecotourism Site in Uttar Pradesh by the Government. Since the area has immense potential, it should be declared Bird Sanctuary and as an important bird area (IBA) in the outskirts of Delhi, the National Capital Region, India.

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