Population Status of Waterbirds in Human-Impacted Urban Wetland of Gangetic Plain: A Study from Okhla Bird Sanctuary, National Capital Region of Delhi

Abstract

Okhla Bird Sanctuary (OBS) is an urban, human-modified floodplain wetland located in the Central Asian Flyway of migratory birds, thus acting as an ideal transit as well as wintering ground for migratory waterfowl. It faces various anthropogenic disturbances such as habitat degradation, and water level and flow regime alterations, which threaten the biological integrity of the system. OBS is an 'Important Bird Area', included in the protected area network of Uttar Pradesh, with one-third of the area lying in the state of Delhi. This study was part of a project to prepare management plan for the sanctuary. We carried out total counts for wetland-dependent birds every fortnight from November 2009 to March 2010. Opportunistic sightings of waterbirds were also recorded. We recorded a total of 67 species of waterbird belonging to 19 families from the sanctuary. Of these species, five *(Anhinga melanogaster, Mycteria leucocephala, Threskiornis melanocephalus, Limosa limosa* and *Aythya nyroca)* are listed as Near Threatened and one *(Sterna acuticauda)* as Endangered in the IUCN Red List. The waterfowl habitat in the sanctuary is threatened due to weed infestation, siltation of the reservoir, frequent water level fluctuations and pollution. Thus, the number of waterfowl has decreased drastically, with many species that were sighted frequently earlier being absent.

Keywords: Okhla Bird Sanctuary, Important Bird Area, Urban Wetland, Waterfowl Habitat and Yamuna River.

Introduction

There are several man-made wetlands in India that have been formed due to irrigation and hydroelectric projects, through the creation of irrigation canals, tanks and dams. In the course of time, many of these waterbodies have attracted wildlife and therefore attained high conservation value. Okhla Bird Sanctuary (OBS), in Noida, is one such example, with 302 bird species and 14,000-20,000 waterbirds recorded from the sanctuary and its surrounding areas (Urfi 2003).

Wetlands are important bird habitats, and birds use them for nesting, breeding, roosting and rearing young ones, feeding, as shelter and for social interaction (Stewart 2001). With intensification of human activities causing environmental changes, wetlands are subject to heavy pressure (Turner *et al.* 2000) and are among most threatened habitats on earth (Mitsch & Gossenlink 2000). Encroachment of wetland habitats, unsustainable harvesting of resources, industrial pollution, poisoning, agricultural runoff, siltation and introduction of exotic and invasive species threaten wetland biodiversity (Baral & Inskipp 2005, Kafle *et al.* 2008). This has severe consequences on waterbird populations, leading to changes in the community structure of birds and population declines (Kloskowski *et al.* 2009). Changes in bird populations and distribution in natural habitats have been studied well in India; however, very few studies have investigated the impacts of urbanization on birds, particularly waterbirds (Urfi *et al.* 2005, Urfi 2006). Many Indian cities offer foraging and nesting habitats for birds, especially colonial waterbirds such as herons, egrets, storks, cormorants and ibises, and wintering grounds for waterfowl. Additionally, many of these are located along river channels and are associated with Important Bird Areas (IBAs), which support sizeable populations of both resident and wintering waterfowl. A large number of these areas, despite being protected, are usually the first victims of urban expansion and may act as habitat islands in a concrete matrix. High species diversities and intensive human impacts occur together in urban protected areas (Cincotta *et al.* 2000, Liu *et al.* 2003), making them semi-natural habitats within an urban landscape.

OBS is an important wetland sanctuary, providing a good example of a wetland located in a densely populated urban conglomeration, in the National Capital Region of India. Despite its protected status, OBS faces threats due to urbanization, pollution and reduced flow in the River Yamuna, as a result of which the sanctuary's flora and fauna are

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under intense pressure. The sanctuary area has seen a reduction in wintering waterfowl numbers, from over 25,000 in 1990-1995 to less than 10,000 in 2005-2006, with a significant change in the community structure of the birds (Urfi 2006). During this study, the sanctuary was under the authority of the National Chambal Project Division, Agra, UP. A management plan developed for Chambal Wildlife Sanctuary was being used for OBS too. In order to prepare a management plan specifically for OBS, we needed to overcome various information gaps. Therefore, we studied many biological and physical parameters of the sanctuary and paid special attention to the avian community.

Study Area

OBS is a man-modified floodplain wetland situated within the National Capital Region and Bio-geographic Province 7A, Upper Gangetic Plains (Rodgers & Panwar 1988) of India (Figure 1). In 1990, the Government of Uttar Pradesh declared an area of 400 ha upstream of Okhla Barrage a bird sanctuary, including the main channel of the River Yamuna, a lake created due to the construction of the barrage and various sand-bed islands within the river channel. The extent of open water in the sanctuary is 273 ha, and the reed beds and sand beds have an area of 97 ha. The roads and bunds constitute the rest of the area, 30 ha. In general, the area of the sanctuary is a vast alluvial plain with a gentle south-eastern slope. Well-metaled roads surround this sanctuary, and its boundaries are physically well defined by mesh-wiring structures and bunds. The sanctuary experiences three seasons: summer (April-June, temperature range from 29°C to 40°C), winter (November-March, temperature range from 5°C to 21°C) and the monsoon (July-September). The major sources of the surface water entering the study area (inputs) include the River Yamuna (water released from the Wazirabad Barrage and municipal and industrial wastewater discharged into the river through a number of drains after Wazirabad) and Hindon Cut (water discharged from the Hindon Barrage), and the major outflows include water released into the Agra Canal for irrigational purposes and excess water released downstream (WII 2002). The water level in the sanctuary is maintained by the Okhla Barrage, which is controlled by the Irrigation Department of Uttar Pradesh. The pollution load in the 22 km stretch between the Wazirabad and Okhla barrages is the highest recorded in the entire 1370 km length of the Yamuna, through the Indo-Gangetic plains (Gopal & Sah 1993).

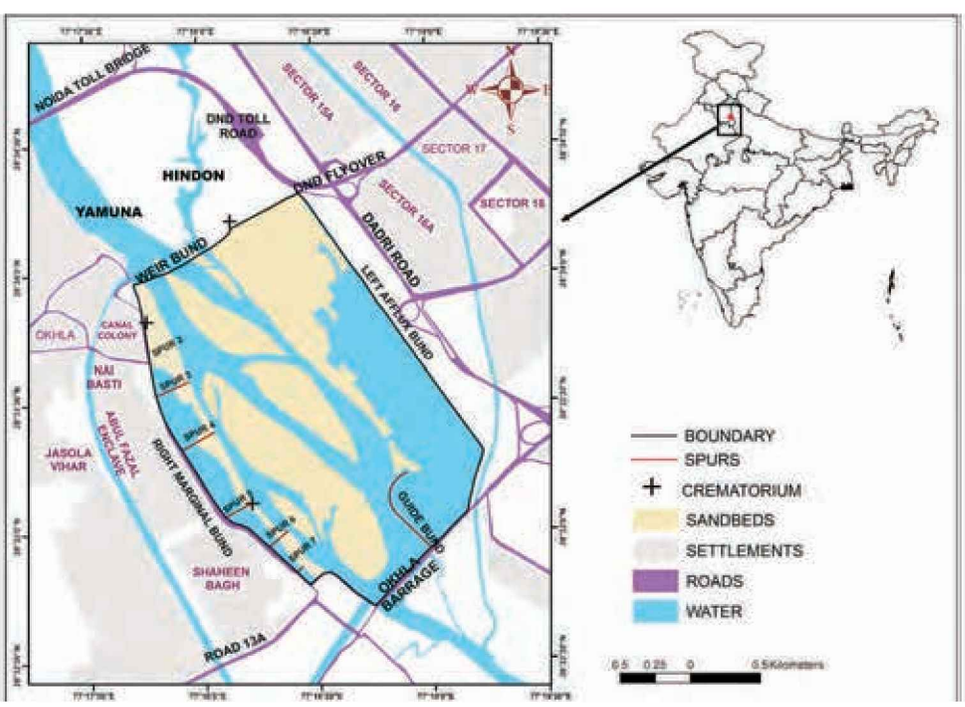


Figure1 : *Map showing location of Okhla Bird Sanctuary in National Capital Region, India*

Geographically, the sanctuary is located at 28°32' N, 77°18' E, where the River Yamuna leaves the territory of Delhi. The floodplains of Yamuna in Delhi are restricted between two lateral bunds, with the greatest width of active floodplains being in and around OBS. This results in a mosaic of habitats supporting a diversity of life. So far, a total of 186 species of plant, 87 fish species, 6 species of anuran, 28 species of reptile and 30 species of mammal have been reported from OBS (Manral *et al.* 2013, WII 2002). A total of 302 species of bird have been reported since 1989 from the sanctuary (Urfi 2003). The sanctuary is recognized as an Important Bird Area and a centre for conservation education and recreation, and it serves as a prominent wintering ground for waterbirds, with 13 globally threatened bird species found here.

Methodology

The population of aquatic birds was estimated from total counts carried out every fortnight for 4 months following methods (Bibby *et al.* 2000). Total counts of birds were made from the shore, and each census lasted 4-6 hours (Vijayan 1991). Opportunistic sightings of waterbirds were also recorded. We extracted information on the status of birds (resident or migratory) from Ali and Ripley (1972) and Urfi (2003). We compared the waterbird abundance with that noted during a previous study (WII 2002). As this study was conducted as a part of the preparation of a management plan for the sanctuary (WII 2011), the methodology used and details of the waterfowl habitat parameters (water depth, pollution, vegetation, etc.) have been presented in other publications (WII 2011, Manral *et al.* 2012, 2013).

Results

Overall, 67 species of wetland-dependent birds belonging to 19 families (Table 1) were recorded during the study. The family Anatidae was the richest family, represented by 14 species, followed by the families Laridae (eight species), Ardeidae (seven species), Charadriidae and Rallidae (five species each). A total of 31 species were residents, and 35 were winter migrants. Two of the migrant species were passage migrants, and three species were local migrants. The seasonal status of *Platalea leucorodia* (Eurasian Spoonbill) was unknown. Five Near Threatened species *(Anhinga melanogaster, Mycteria leucocephala, Threskiornis melanocephalus, Limosa limosa* and *Aythya nyroca)* and one Endangered species *(Sterna acuticauda)* were recorded from the area (IUCN Red List 2014). During the total bird counts, 37 species belonging to 11 families were recorded, among which the members of the families Anatidae (82%), Laridae (8%) and Rallidae (7%) dominated in terms of the total number of birds (Table 2). Species found commonly throughout the counting period included the Northern Shoveler *Anas clypeata*, Eurasian Wigeon *Anas penelope*, Common Teal *Anas crecca*, Northern Pintail *Anas acuta,* Common Coot *Fulica atra* and Brown-headed and Black-headed gulls *Chroicocephalus* spp. The maximum count of the 2009-2010 migratory season was recorded on 17 December 2009 (a total of 10,435 waterbirds).

A comparison was made between the waterbird data of 2002 and 2010 to detect changes in the bird population between the two study periods. Three maximum counts of birds belonging to nine families for the above-mentioned years were taken, and the paired samples t-test was performed (Table 3). The results of the test showed that the populations of the families Anatidae (ducks and geese), Ciconiidae (storks), Ardeidae (egrets and herons) and Phalacrocoracidae (cormorants) in the sanctuary have changed significantly ($p = <0.05$, $df = 2$) between 2002 and 2010. The populations of the Anatidae (migratory) and Ardeidae (local migrants) had increased, while those of the Ciconidae and Phalacrocoracidae (local migrants) had decreased, in 2010 compared with 2002. The populations of the families Laridae (gulls) and Rallidae (coots and moorhens) had decreased, but the change in their populations were not significant.

Table 1 : Checklist of waterbird species recorded during the present study at Okhla Bird Sanctuary

Order	Family	Common Name	Scientific Name	Status
Anseriformes	Anatidae	Lesser Whistling Duck	*Dendrocygna javanica*	R
		Greylag Goose	*Anser anser*	W
		Bar-headed Goose	*Anser indicus*	W
		Ruddy Shelduck	*Tadorna ferruginea*	W
		Gadwall	*Anas strepera*	W
		Eurasian Wigeon	*Anas penelope*	W
		Indian Spot-billed Duck	*Anas poecilorhyncha*	R
		Northern Shoveler	*Anas clypeata*	W
		Northern Pintail	*Anas acuta*	W
		Garganey	*Anas querquedula*	PM
		Eurasian Teal	*Anas crecca*	W
		Common Pochard	*Aythya ferina*	W
		Ferruginous Duck	*Aythya nyroca*	W, NT
		Tufted Duck	*Aythya fuligula*	W
Podicipediformes	Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	R
		Great Crested Grebe	*Podiceps cristatus*	W
Phoenicopteriformes	Phoenicopteridae	Greater Flamingo	*Phoenicopterus roseus*	LM

Ciconiiformes	Ciconidae	Painted Stork	*Mycteria leucocephala*	R, NT
		Asian Openbill	*Anastomus oscitans*	R (?)
		Woolly-necked Stork	*Ciconia episcopus*	R (?)
Pelecaniformes	Threskiornithidae	Black-headed Ibis	*Threskiornis melanocephalus*	R, NT
		Red-naped Ibis	*Pseudibis papillosa*	R (?)
		Eurasian Spoonbill	*Platalea leucorodia*	?
	Ardeidae	Black Bittern	*Dupetor flavicollis*	R
		Black-crowned Night Heron	*Nycticorax nycticorax*	R
		Indian Pond Heron	*Ardeola grayii*	R
		Grey Heron	*Ardea cinerea*	R
		Purple Heron	*Ardea purpurea*	R
		Yellow-billed Egret	*Egretta intermedia*	R
		Little Egret	*Egretta garzetta*	R
	Phalacrocoracidae	Little Cormorant	*Microcarbo niger*	R
		Indian Cormorant	*Phalacrocorax fuscicollis*	R
		Great Cormorant	*Phalacrocorax carbo*	R
		Oriental Darter	*Anhinga melanogaster*	R, NT
Accipitriformes	Pandionidae	Western Osprey	*Pandion haliaetus*	W
	Accipitridae	Eurasian Marsh Harrier	*Circus aeruginosus*	W
Gruiformes	Rallidae	Brown Crake	*Amaurornis akool*	R
		White-breasted Waterhen	*Amaurornis phoenicurus*	R
		Purple Swamphen	*Porphyrio porphyrio*	R
		Common Moorhen	*Gallinula chloropus*	R
		Eurasian Coot	*Fulica atra*	W
Charadriiformes	Charadriidae	Black-winged Stilt	*Himantopus himantopus*	LM
		River Lapwing	*Vanellus duvaucelii*	R
		White-tailed Lapwing	*Vanellus leucurus*	W
		Green Sandpiper	*Tringa ochropus*	W
		Common Sandpiper	*Actitis hypoleucos*	W
	Rostratulidae	Greater Painted Snipe	*Rostratula benghalensis*	R
	Jacanidae	Bronze-winged Jacana	*Metopidius indicus*	R
	Scolopacidae	Black-tailed Godwit	*Limosa limosa*	W, NT
		Common Redshank	*Tringa totanus*	W, PM
		Common Greenshank	*Tringa nebularia*	W
		Temminck's Stint	*Calidris temminckii*	W
	Laridae	Brown-headed Gull	*Chroicocephalus brunnicephalus*	W
		Black-headed Gull	*Chroicocephalus ridibundus*	W
		Pallas's Gull	*Ichthyaetus ichthyaetus*	W
		Yellow-legged Gull	*Larus cachinnans*	W
		Little Tern	*Sternula albifrons*	?
		River Tern	*Sterna aurantia*	LM
		Black-bellied Tern	*Sterna acuticauda*	R(?), EN
		Whiskered Tern	*Chlidonias hybrida*	R
Passeriformes	Hirundinidae	Barn Swallow	*Hirundo rustica*	W
		Wire-tailed Swallow	*Hirundo smithii*	R
	Motacillidae	Citrine Wagtail	*Motacilla citreola*	W

		Grey Wagtail	*Motacilla cinerea*	W
		White Wagtail	*Motacilla alba*	W
		White-browed Wagtail	*Motacilla madaraspatensis*	R
Coraciiformes	Alcedinidae	White-throated Kingfisher	*Halcyon smyrnensis*	R

W = Wintering; **R** = Resident; **M** = Migrant (summer or monsoon migrant); **PM** = Passage Migrant; **LM** = Local Migrant; **?** = unknown seasonal status; **EN** = Endangered, **NT** = Near Threatened

Table 2 : Results of waterbird counts conducted during the present study (November 2009 to March 2010) (for each month, the average of two counts is given here)

Species	November	December	January	February	March	Average	Maximum Count
Greylag Goose	64	297	539	485	171	338	757
Bar-headed Goose	0	170	204	188	108	149	235
Ruddy Shelduck	0	22	19	46	54	31	84
Gadwall	102	1070	369	478	441	535	1262
Eurasian Wigeon	3	325	450	905	471	478	1230
Indian Spot-billed Duck	36	62	72	90	45	64	102
Northern Shoveler	117	2704	1636	2045	1374	1737	3359
Northern Pintail	25	628	351	787	475	501	976
Garganey	0	0	0	81	83	36	103
Common Teal	43	682	326	1298	589	648	1520
Common Pochard	145	636	486	494	441	473	740
Ferruginous Pochard	0	0	6	0	0	1	6
Tufted Duck	92	569	263	588	456	427	750
Little Grebe	20	45	64	64	31	47	73
Great Crested Grebe	5	0	0	0	0	1	5
Greater Flamingo	0	9	24	84	50	37	92
Painted Stork	7	23	16	18	5	14	35
Black-headed Ibis	4	18	5	14	5	10	20
Black Ibis	0	20	29	40	25	25	46
Eurasian Spoonbill	0	9	5	6	3	5	12
Black-crowned Night Heron	0	6	0	0	0	1	12
Indian Pond Heron	24	23	30	52	27	32	61
Grey Heron	4	9	8	8	11	8	13
Purple Heron	2	7	7	5	3	5	9
Little Egret	6	12	13	32	23	18	35
Intermediate Egret	1	3	3	5	6	4	7
Little Cormorant	6	9	12	6	5	8	18
Indian Cormorant	3	6	6	8	3	5	12
Great Cormorant	9	10	9	7	3	7	12
Oriental Darter	1	2	2	2	1	1	2
Purple Swamphen	41	66	60	124	103	83	145
Common Moorhen	39	73	56	99	56	67	113
Eurasian Coot	56	123	273	413	462	289	438
White-breasted Waterhen	12	14	14	9	5	11	18
Bronze-winged Jacana	7	16	23	35	11	20	36
Black-headed Gull	61	299	502	947	429	490	1200
White-throated Kingfisher	2	2	2	3	2	2	3
Total	**937**	**7964**	**5875**	**9459**	**5971**		

Table 3 : Family-wise status of bird populations in the sanctuary between 2002 and 2010

Family	Mean±SE (2002-2003)	Mean±SE (2009-2010)	t Stat	df	Sig. (2-Tailed)
Anatidae	5368±737.04	8085.67±638.83	-15.41	2	0.004
Podicipedidae	97±18.23	66.67±3.28	1.84	2	0.21
Phoenicopteridae	65.33±3.76	75.33±9.82	-1.64	2	0.24
Ciconiidae	61.33±11.35	23.67±5.70	6.65	2	0.02
Threskiornithidae	52.33±5.78	61.33±2.60	-1.58	2	0.254
Ardeidae	65.33±12.84	95±10.15	-9.33	2	0.01
Phalacrocoracidae	43±6.56	28±3.51	4.91	2	0.039
Rallidae	1339.67±198.13	729.33±91.39	2.48	2	0.131
Laridae	3837.33±1163.53	855±172.63	2.98	2	0.097

Discussion

OBS is an important habitat for waterfowl despite severe anthropogenic pressure such as flow regime alteration, pollution and eutrophication and urban developmental activities in the surroundings. OBS's location on the Central Asian Flyway of migratory waterfowl and the presence of a mosaic of habitats in and around the sanctuary make it an ideal transit as well as wintering ground for migratory water birds.

Diverse habitat patches in close proximity within a landscape may result in an increased capacity of a wetland complex to support bird populations (Dunning *et al.* 1992). The sanctuary has extensive submerged and emergent reed beds, shallow vegetated areas, offshore sand bars and open, deep waters. Tall vegetation, e.g. *Phragmites carca* and *Typha angustifolia*, along the shore and sedges along the wetland and in the drawdown areas provide shelter and security from predators to waterfowl species such as *Anser indicus, Tadorna ferruginea, Ardea purpurea, Pseudibis papillosa* and *Mycteria leucocephala*. The presence of an extensive reed cover and floating vegetation provides an ideal habitat for bird species such as *Gallinula chloropus, Porphyrio porphyrio, Ardea cinerea* and *Ardeola grayii*. Tall grasses and other vegetation act as a buffer against disturbances from roads and provide an ideal escape for waterfowl. The *Nelumbo-Eichornia* community provides a good roosting habitat for waterfowl. Because of a large quantum of organic pollutants and shallower habitats, there are large numbers of dabbling ducks such as Shovelers and Pintails. However, the large monotypic stands of *Eichornia crassipes* and continuous monotypic stands of *Typha angustifolia* have reduced the value of the wetland as a good waterfowl habitat (Manral *et al.* 2013).

Waterfowl habitat modification and degradation

Anthropogenic pressures such as pollution and unplanned management practices in and around OBS threaten the habitats and biodiversity of the sanctuary. The weed infestation, particularly aquatic weeds, is very intense in the sanctuary. OBS faces serious threats from the rapid proliferation of *Typha* spp. and *Eicchornia crassipes*. It was observed that 70% of the plots surveyed for vegetation in the islands of OBS contained *Typha* spp. Most of these areas were earlier good shallow-water areas for dabbling ducks and waders. The rapid spread of *Typha* spp., particularly *Typha angustifolia* (Cattail), has resulted in a lower habitat diversity and, in turn, a lower species diversity. We found that the spread of *Typha* has been aided by the creation of new high ground due to siltation in OBS. The spread of *Eicchornia,* particularly in summer, is another important problem that causes habitat modification. The spread of *Eicchornia* has resulted in the depletion of the open water habitat, which is essential for the growth of submerged floral communities. Thus, the fauna associated with the submerged vegetation is also affected. The diversity of birds preferring open water for foraging has also declined. Eutrophication, a direct consequence of water pollution and nutrient enrichment, was also observed in parts of the sanctuary. Eutrophication results in an initial increase in food plants for waterfowl, followed by a gradual replacement by less desirable plants and finally a total loss of floating-leaved and submerged plants. As a result of eutrophication, *Typha* extends in such wetlands (Crowder & Bristow 1988). This might be happening in OBS as well.

The high rate of siltation is also destroying deep-water habitats preferred by diving ducks. It was observed that most of the wetland had shallow water, with the depth ranging from 1 to 2 m (Manral *et al.* 2012). Increased turbidity due to siltation decreases the amount of light reaching submerged macrophytes beyond their compensation point, resulting in death of the plants. However, the decreased depth is correlated with an increases in the population of Greater Flamingos in the sanctuary (Urfi 2006). Frequent water level and flow-regime alterations affect the abundance of dabbling ducks, waders, flamingoes etc. and the composition of the floral and other faunal groups in the sanctuary. Complete draining of

the reservoir is not a regular practice but is carried out occasionally, primarily for repairing the sluice gates of the barrage. When this coincides with the peak season of the migratory birds (as observed in January 2002 and February 2003 from satellite images and secondary data), the waterbird population in the sanctuary is impacted drastically. Similarly, sudden increase in the water level due to release of water from upstream barrages also impact birds in the sanctuary. This submerges sand beds and shallow areas along the shores, essential for waders, thus resulting in shrinkage of suitable habitats for waders. During this study, in January (2010), the waterfowl abundance, particularly that of dabbling ducks, was reduced drastically, by almost 50%, with the release of more water upstream. The waterfowl in the sanctuary were largely seen congregating or preferring shallow parts of the wetland rather than deep water. Thus, birds might have avoided the wetland due to the sudden increase in the water level.

Conclusions

OBS is located amidst an urban settlement and is a unique habitat providing opportunities for conservation in a metropolis like Delhi, serving as a stopover for migratory waterbirds and a home for several other plant and animal taxa. However, there has been a drastic decline in the waterbird population. A change in the population of migratory birds is often related to the status of the source population, rainfall and local habitat status. Therefore, long-term monitoring of the bird population, regional and local environmental parameters and habitat management practices in the sanctuary is needed to obtain a better understanding of the status of the bird population in the sanctuary.

References

Ali, S. & Ripley, S. D. (1972). *Handbook of the Birds of India and Pakistan.* Volumes. 1-9. Oxford University Press, Bombay, India. 2667 pp.

Baral, H. S. & Inskipp, C. (2005). *Important Bird Areas in Nepal: Key Sites for Conservation.* Bird Conservation Nepal and Birdlife International, Kathmandu and Cambridge. 242 pp.

Bibby, C. J., Burgess, N. D., Hill, D. A. & Mustoe, S. H. (2000). *Bird Census Techniques.* Second edition. Academic Press, London. 302 pp.

Cincotta, R. P., Wisnewski, J. & Engelman, R. (2000). Human population in the biodiversity hotspots. *Nature* 404: 990-992.

Crowder, A. A. & Bristow, J. M. (1988). The future of waterfowl habitats in the Canadian lower Great Lakes wetlands. *Journal of Great Lakes Research* 14(1): 115-127.

Dunning, J. B., Danielson, J. B. & Pulliam, H. R. (1992). Ecological processes that affect populations in complex landscapes. *Oikos* 65: 169-175.

Gopal, B. & Sah, M. (1993). Conservation and management of rivers in India: Case study of the River Yamuna. *Environmental Conservation* 20: 243-254.

Iucn Red List For Birds. (2014). BirdLife International, Accessed from http://www.birdlife.org

Kafle, G., Cotton, M., Chaudhary, J. R., Pariyar, H., Adhikari, H., Bohora, S. B., Chaudhary, U. K., Ram, A. & Regmi, B. (2008). Status of and threats to waterbirds of Rupa Lake, Pokhara, Nepal. *Journal of Ecology* 1(1/2): 9-12.

Kloskowski, J., Green, A. J., Polak, M., Bustamante, J. & Krogulec, J. (2009). Complementary use of natural and artificial wetlands by waterbirds wintering in Donana, Southwest Spain. *Aquatic Conservation: Marine and Freshwater Ecosystems* 19: 815-826.

Liu, J., Daily, G. C., Ehrlich, P. R. & Luck, G. W. (2003). Effects of household dynamics on resource consumption and biodiversity. *Nature* 421: 530-533.

Manral, U., Raha, A., Solanki, R., Hussain, S. A., Mohan, D., Talukdar, G. & Gopi, G. V. (2012). Hydrological characteristics and flood plain vegetation of human impacted wetlands: A case study from Okhla Bird Sanctuary, National Capital Region, India. *Asian Journal of Conservation Biology* 1: 110-119.

Manral, U., Raha, A., Solanki, R., Hussain, S. A., Babu, M. M., Mohan, D., Gopi, G. V., Sivakumar, K. & Talukdar, G. (2013). Plant species of Okhla Bird Sanctuary: A wetland of upper Gangetic plains, India. *Check list Journal of Species Lists and Distribution* 9: 263-274.

Mitsch, W. J. & Gossenlink, J. G. (2000). *Wetlands.* Third edition. John Wiley and Sons, New York. 920 pp.

Rodgers, W. A. & Panwar, H. S. (1988). Planning a Wildlife Protected Area Network in India. Volumes I & II. A report prepared for the Department of Environment, Forests & Wildlife, Government of India. Wildlife Institute of India, Dehradun. 267 pp.

Stewart, R. E., Jr. (2001). Technical Aspects of Wetlands: Wetlands as Bird Habitats. National Water Summary on Wetland Resources. United States Geological Survey Water Supply Paper 2425. Accessed from http://water.usgs.gov/nwsum/WSP2425/birdhabitat.html on 2 May 2009.

Turner, R. K., Van Den Bergh, J. C. J. M., Soderqvist, T., Barendregt, A., Van Der Straaten, J., Maltby, E. & Van Ierland, E. C. (2000). Ecological-economic analysis of wetlands: scientific integration for management and policy. *Ecological Economics* 35(1): 7-23.

Urfi, A. J. (2003). The birds of Okhla Barrage Bird Sanctuary, Delhi, India. *Forktail* 19: 39-50.

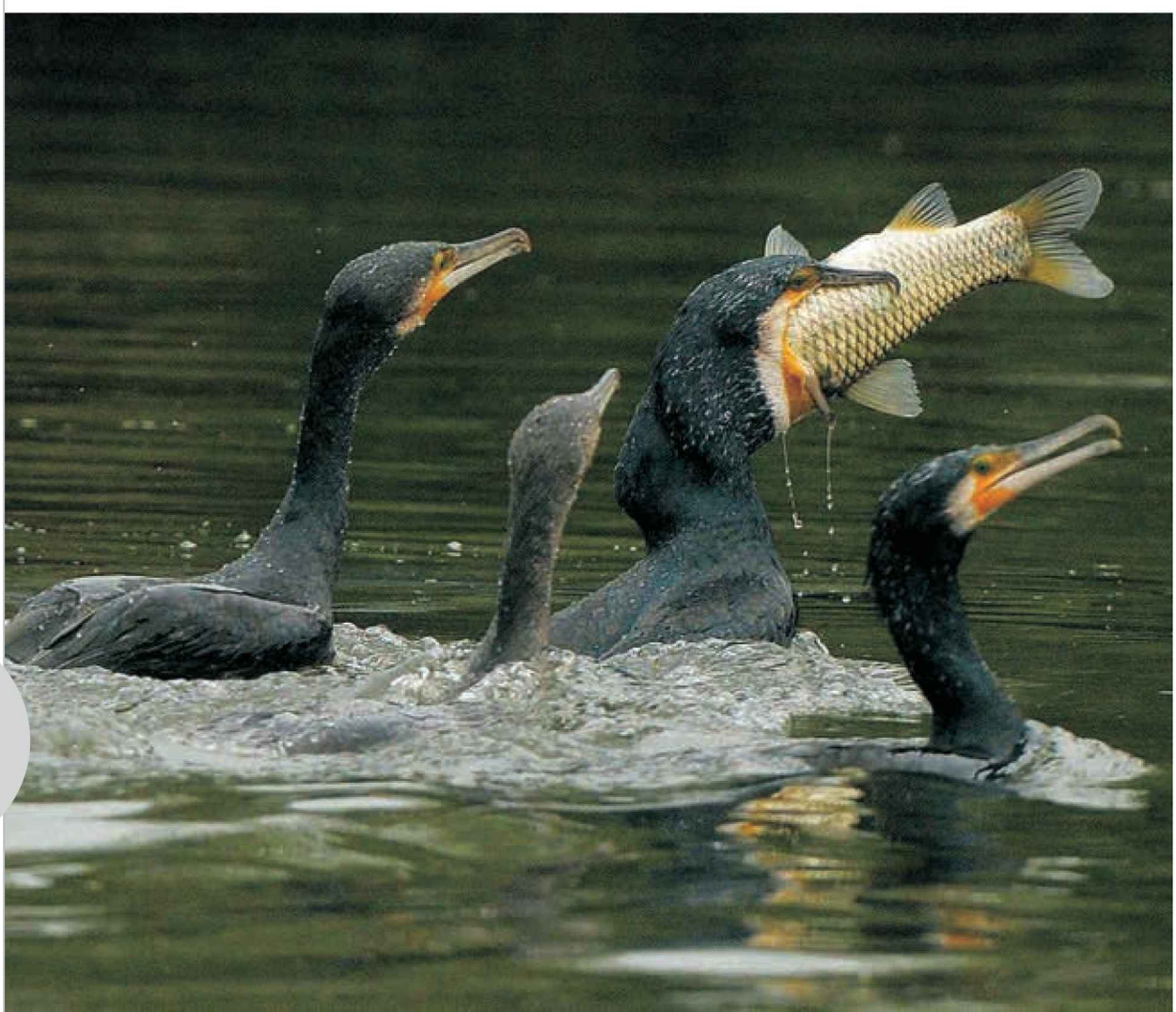
Urfi, A. J. (2006). Biodiversity conservation in an urban landscape: A case study of some important bird areas on the river Yamuna in Delhi (India). In McNeely, J. A., McCarthy, T. M., Smith, A., Olsvig-Whittaker, L., and Wikramanayake, E. D. (eds.) *Conservation Biology in Asia.* Society for Conservation Biology-Asia Section and Resources Himalaya, Kathmandu, Nepal. 455 pp.

Urfi, A. J., Sen, M., Kalam, A. & Meganathan, T. (2005). Counting birds in India: A review of methodologies and trends. *Current Science* 89: 1997-2003.

Vijayan, V. S. (1991). Keoladeo National Park Ecology Study: 1980-1990. Bombay Natural History Society, Mumbai.

Wildlife Institute of India. (2002). Ecological, Social and Hydrological Factors Affecting the Management of Wetland Systems in Uttar Pradesh with Special Reference to Vijay Sagar and Associated Water Bodies in Mahoba District, Okhla and Associated Water Bodies in Ghaziabad District, Bakhira Bird Sanctuary, and Nawabganj Bird Sanctuary. Wildlife Institute of India, Dehra Dun. 198 pp.

Wildlife Institute Of India. (2011). Management Plan for Okhla Bird Sanctuary (2011 to 2021). Wildlife Institute of India, Dehra Dun. 217 pp.



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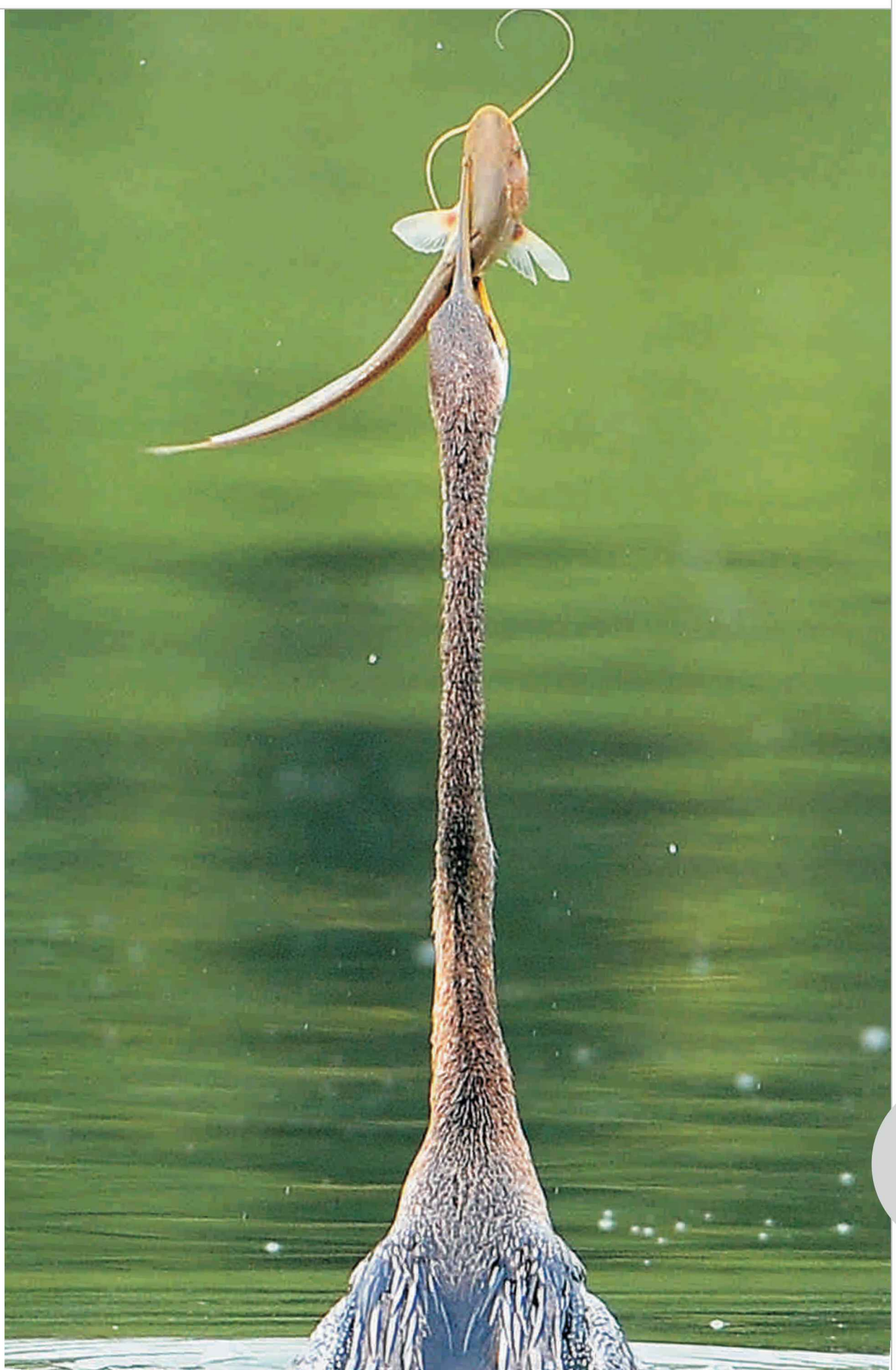

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