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Composition and Dynamics of Migratory and Resident Avian Population in Wintering Wetlands from Northern India

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Abstract

Twelve wetlands occurring in four different ecozones in Uttar Pradesh (UP), India, were selected for studying the winter composition and dynamics of avian populations. Wetland information was collected from office records of the UP Forest department. Bird populations were estimated by transect method and block-in-flock-in-sector method for woodland and aquatic birds, respectively. Across the twelve selected wetlands a total of 486,182 individuals belonging to 161 species of birds on 15,592 ha were recorded during the winter of 2010-11. The data were analyzed to assess the relationship between wetland characteristics and avian populations. Aquatic vegetation, surrounding vegetation, water availability and climate were found as important factors related to avian populations. January was found to be the peak of bird assemblage, while winter times before and after January were the waxing and waning period, respectively. Species richness and species diversity of aquatic birds varied between 18-58 and 1.90-3.20, respectively, and of all bird species between 23-109, and 1.73-3.81, respectively. The density of aquatic birds ranged between 17-384 ha^{-1}. The most common migratory birds in wetlands were Northern Pintail, Common Teal and Greylag Goose. Common resident birds included Asian Openbill, Darter, Little Egret, Common Coot, Little Cormorant, Grey Heron, Purple Heron, Indian Pond Heron, Common Moorhen, Purple Swamphen, Cattle Egret, Indian Sarus Crane and White-throated Kingfisher. For improved conservation of aquatic avian fauna, management prescriptions are suggested for wetlands under current management which could also be extended to other wetlands, whereas conservation of avian fauna to be the emphasis.

Keywords: aquatic habitat, avian fauna, abundance, diversity, richness, threats, vegetation

Introduction

Uttar Pradesh (UP), one of the north Indian states, contains 8% of the total wetland area of India, and has a network of man-made and natural wetlands covering 121,242 ha (SAC, 2011). There are a large number of important wetlands supporting avian populations, but in spite of having the potential of being declared as Ramsar sites or Important Bird Areas (such wetlands hold significant number of threatened species or more than 20,000 water birds or supports vulnerable, endangered or critically endangered birds or threatened ecological community on regular basis) these areas remain relatively unmanaged and community owned (Islam and Rahmani, 2004, 2008). However, some of the larger and ecologically significant wetlands known as wildlife or bird sanctuaries are wintering sites for the migratory birds and managed by the UP Forest Department (UPFD) for the conservation of wildlife, especially avian diversity (Jha, 2014). These wetlands fall in three major ecozones of UP: the Terai region, the Gangetic Plains and the Bundelkhand region, including Vindhyan ranges (Rahmani *et al*., 2011). The extreme western part of the Gangetic Plain is somewhat different from rest of the region as it is comprised of several semi-arid districts (Jha, 2010) forming the Semi-arid Plain region. Therefore, UP wetlands are considered to belong to four major landscapes or ecozones (File record of UPFD).

Uttar Pradesh is in the tropical zone of the south Asian flyway resulting in several migratory bird species coming from northern temperate countries and taking refuge during winter months. As such, a number of important migratory bird species live here from November to April (Rahmani *et al*., 2010), with wetlands supporting the highest number of water birds during the winter (Rajashekara and Venkatesha, 2011). In addition to the migratory birds, UP wetlands support a number of resident bird species. Therefore, these wetlands are important conservation sites due to the extensive food chain and rich biodiversity they support (Getzner, 2002).

To provide effective management of the wetland sites, some important information is required; 1) understanding of habitats and species occurrence, 2) interaction between the two to form an ecosystem, 3) the natural process that sustain them, and 4) threats to these processes (Chatterjee *et al*., 2008).

Managed wetlands support a greater abundance and diversity of waterfowl and other water birds than non-managed wetlands in all seasons (Kaminski *et al*., 2006). It has

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been long recognized that many factors influence aquatic bird populations, including geographic location, habitat condition, and climatic factors (Weller and Spatcher, 1965). Two recent publications indicated that habitat variables like wetland size, vegetation, topography etc. affect the use of wetland by the avian population (Ma *et al.*, 2010). It has also been suggested that wetland area, vegetation cover, structural heterogeneity etc. of the habitat are important features affecting wetland bird richness and abundance (Gajardo *et al.*, 2009). In this study we examined how UP wetlands fare individually as well as collectively in relation to the bird population, richness and diversity vis-à-vis size, depth, vegetation cover, protection, status etc.

Materials and methods

Study sites

Wetlands studied are legally classified as Protected Areas under the provisions of the Wildlife (Protection) Act 1972. Since these wetlands have protection we designated them as managed wetlands sensu stricto for academic purposes. The wetlands are distributed in all four ecological zones of UP (Fig. 1; geographical location in Table 1). While the Okhla (OKL) wetland fall in the Gangetic plain, climate wise this area of the Gangetic Plain is very similar to the Semi-arid region. Therefore, for the purpose of this study this wetland is considered in the Semi-arid region.

Although the wetlands under consideration, except Sarsainawar, are in the protected (managed) category, the level of protection of wetlands varies considerably due to ecological and socio-political reasons. The various levels of protection, as provided in Table 1, the areas are categorized as follows:

a. Order V (Very low protection): shortage of staff for ensuring regulatory provisions, large amount of private land falling in the sanctuary area, economy and other activities dependent on the wetland;
b. Order IV (Low protection): shortage of staff for ensuring regulatory provisions, large amount of private land falling in the sanctuary area, people's economy and other activities not dependent on wetland;
c. Order III (Protection): no shortage of staff, large amount of private land falling in the sanctuary area, economy not dependent on wetland;
d. Order II (High protection): no shortage of staff, practically no private land, economy not dependent, but other activities dependent on the wetland;
e. Order I (Very high protection): no shortage of staff, no private land and no economy nor other activities dependent on the wetland.

On the basis of tree availability in and around the wetlands, these wetlands (Table 1) could be categorized into:

a. Wetland with forest block (WFB; with plantation or natural tree block);
b. Wetland with trees on bunds or dykes (WAP; with avenue plantation);
c. Simple wetland (SPW; with very few scattered trees in wetland, may have orchards or forests nearby).

Across the state, these wetlands (Table 1) could be categorized into natural (e.g.: oxbow lakes and ponds) and created (e.g. the reservoirs for regulated water supply) on the basis of their origin.

Another categorization was made on the basis of aquatic emergent and floating vegetation cover classes (Table 1), modified from Ritter and Savidge (1999). We did not consider submerged vegetation for this purpose:

a. High vegetation wetland (HVW; vegetation cover > 50%);
b. Medium vegetation wetland (MVW; vegetation cover 25-50%);
c. Low vegetation wetland (LVW; vegetation cover < 25%).

Fig. 1. Map of Uttar Pradesh showing different protected wetlands in four different ecozones, namely, Tarai plain, Gangetic plain, Semi-arid western plain and Vindhyan Bundelkhand region. Inset map courtesy: Himalayan footsteps

Bird identification

Two field guides, The Book of Indian Birds (Ali, 1964) and Birds of Northern India (Grimmett and Inskipp, 2003) were used for identification and latest nomenclature of birds observed in and around the wetlands under study. Birds were classified on the basis of their habits and residency in the habitat. For these classifications following terms of references were used:

Habits

i. Aquatic: Bird(s) completing the whole life cycle in the water or wetland habitat. This category of birds could be migratory as well as residents.
ii. Semi-aquatic: Bird(s) which complete(s) at least part of the life cycle in water and the remainder in forest or countryside habitat. This category of birds could include migratory as well as residents.
iii. Non-aquatic: Bird(s) seen around the wetland, either arboreal or countryside dweller(s), may or may not use the aquatic resource as food.

This classification convention is similar to the one used by Brown and Smith (1998) as wetland dependent (aquatic),

wetland associated (semi-aquatic) and non-wetland (non-aquatic) birds.

Residency

i. Migrant: A bird that undertakes special movements between widely separated breeding and non-breeding areas (UNEP, 2009). This category of birds comes to UP wetlands and spends winter time here.

ii. Resident: A non-migratory bird, generally indigenous, which completes its life cycle in a limited area. This category of birds spends its time in local wetlands in all seasons.

iii. Vagrant: A bird of accidental appearance often strayed outside breeding or wintering range.

After the preparation of the check list of different bird species on different wetlands and a common checklist of all the wetlands, observed birds were categorized on the basis of

Table 1. Characteristic features of ecozones and wetlands under study

Ecological zone, Rainfall (mm) Temperature (°C), Landscape, Wetland area (ha)	Wetland with geographical location (00° 00' 00") Total area; Watered area (ha)	Protection level, wetland category, wetland status, and management start year	Threats to Avian fauna conservation*	Earlier reported bird residency**
Tarai Region (TAR), 1400, 4.3 to 38, Agriculture with fragments of Tropical moist deciduous forests, 328258	Bakhira 26 34 60 N 83 00 00 E 2894; 2000	Order II, SPW, natural, 1990	Boating for fish and *Phragmites* removal is a severe problem	40,000-80,000
	Parvatiarga 27 25 00 N 82 19 00 E 1084; 1000	Order I, SPW, natural, 1990		>20,000 waterfowls
	Lakhbahoshi 27 30 00 N 79 30 00 E 8024; 225	Order III, WFB, Natural, 1988		>240 species, >50,000
	Nawabganj 26 34 60 N 80 40 00 E 225; 100	Order I, WFB, natural, 1984		>200 species
	Patna 27 34 60 N 78 45 00 E 109; 70	Order III, WFB, Natural, 1990	Agriculture crop cultivation and post rainy season water scarcity	180 species, 60,000-70,000 waterfowls
Gangetic Plains (GPL), 800-1200, 1.5 to 45.4, Dominant agriculture with planted trees and orchards and abundant water bodies, 523287	Sandi 27 15 00 N 79 55 00 E 308; 258	Order III, WAP, Natural, 1990		
	Samaspur 26 00 00 N 81 25 00 E 799; 305	OrderIII, WFB, Natural, 1987	Over flooding of the lake	80,000
	Saman 27 04 60 N 79 00 00 E 526; 230	Order III, WFB, Natural, 1990	Private agriculture cultivation within the wetland area	>40,000
	Sarsainawar 26 58 10 N 79 15 17 E 161; 40	Order V, SPW, Natural, Unmanaged	Community owned wetland with no restriction at all	>18,000
Bundelkhand-Vindhyan Region (BVR), 1000-1100, 3 to 47, Agriculture with fragments of Tropical dry deciduous forests, 250542	Vijaisagar 25 15 78 N 79 68 20 E 262; 75	Order IV, WFB, Created, 1990,	Water availability highly dependent on rainfall, water shortage during migratory bird assemblage period	
Semi-arid Plain (SAP), <800, 4 to 47, Agriculture with fragments of ravenous vegetation, 044488	Okhla 28 33 00 N 77 17 60 E 400; 273	Order I, WAP, Created, 1990	Water pollution level is very high, irregular water level maintenance, light vehicular traffic on the periphery	>20,000, 300 species 14,000-20,000***
	Sursarovar 27 00 00 N 77 45 00 E 799; 250	Order I, WFB, Created, 1991,	Insufficient aquatic vegetation, irregular water level maintenance due to drawdown for industrial supply, light vehicular traffic	>30,000 water birds

Sources: File record UPFD; (Singh *et al.*, 2003); (RSAC, 2009); *See (Jha and Chaudhary, 2011) for general threats** (Islam and Rahmani, 2004; Rahmani *et al.*, 2011); *** (Urfi, 2003)

spatial occurrence as (i) Abundant: appearing on 10-12 wetlands, (ii) Common: appearing on 7-9 wetlands, (iii) Frequent: appearing on 4-6 wetlands, and (iv) Occasional: appearing on 1-3 wetlands.

Population estimation

Weekly census counts were carried out for the winter months (November through March) for the aquatic, semi-aquatic and non-aquatic birds in selected wetlands. Depending upon the availability of the staff in different wetlands, one or more counting teams were formed. Each team comprised of one bird observer and one data recorder. Each wetland had different team(s) for counting. Methodology used for population estimation was as follows:

Aquatic and semi-aquatic birds:

The "block-in-flock-in-sector" method was adopted. The watered area of the wetland was divided into "sectors" using permanent landmarks of physical features in the wetland. In these sectors, a flock of birds was marked and the flock was divided into imaginary blocks, generally 3 to 5 depending on the size of the flock. Within the block, the individual number of different bird species were identified and counted. Species' numbers were multiplied by "block" numbers to get flock numbers. Flock numbers were summed to get "sector" numbers and "sector" numbers were added to determine wetland number.

Counting was done by a team of two members, who walked slowly along a pre-determined path to cover all the "sectors" of the wetland. Counting started at 08:30 am and continued until counts were finished, generally in the forenoon.

Non-aquatic birds

The "Line transect" method was adopted to assess the population of non-aquatic or woodland birds with the ratio of the area censused to total area used to estimate total populations, as it is considered one of the best methods to estimate the passerines (Gates *et al.*, 1968; Cassagrande and Beissinger, 1997).

The team of data collectors and bird counters were different at every wetland; therefore, observational difference is possible. Based upon observers' comments, it is believed that estimation of the birds in large flocks may have 10-15% error.

Data analysis

The population ecology of wetland birds has been studied using diversity index, species richness, species evenness, bird density, habitat similarity index etc. (Akbar *et al.*, 2009; Aynalem and Bekele, 2008; Gadhvi, 2007; Garry *et al.*, 1991; Harisha and Hosetti, 2009; Kumar *et al.*, 2011; Mukherjee *et al.*, 2002; Rajashekara and Venkatesha, 2011; Sullivan and Vierling, 2009; Verma, 2011) of population structure and composition. The statistical formulas used in this study are as follows:

i) Shannon index of diversity

$$H = \sum_{i=1}^{S} -(p_i * \ln p_i)$$

where: H= the Shannon diversity index; p_i= fraction of the entire population made up of species i; s= number of species encountered

ii) Evenness index

$$E = \frac{H}{\ln S}$$

where: E= Evenness index; H= Shannon diversity index; S= Species richness

iii) Species richness:

Total number of species in the habitat considered (S)

iv) Sorensen index of similarity

$$Si = \frac{2 * C}{A + B}$$

where: Si= similarity index; C= common species of two habitats; A and B are the number of species at two different habitats intended to be compared for similarity

v) Bird density: Calculated by dividing the number of birds by the area of wetland supporting the bird population at particular time.

The areas chosen in this calculation for different types of bird-groups aquatic, semi-aquatic and non-aquatic were the winter water spread area, whole sanctuary area (vegetation area and water spread) and only the vegetation area, respectively, as the various bird-groups used only these specific parts of the wetland. For resident, migrant and vagrant birds' density, the whole wetland area was used. The number of birds taken for density calculation was the highest count of winter months, which was normally at the end of January.

While presenting the results in the form of charts natural log values have been used in some figures instead of actual number. This is to facilitate capturing the large variation among actual numbers (for e.g. 1 individual in Phoenicopteridae to 224,692 in Anatidae) and their display on the same figure.

Habitat quality assessment

Apart from collecting information from published materials and file records of the UPFD, semi-structured interviews were conducted with In-charges responsible for management of their Protected Area and with frontline staff involved in protection of the wetland resources. These interviews were conducted to collect additional information about the wetlands, for example, bio-geographic features of the wetlands, management threats, conservation issues etc. A questionnaire in local language was also circulated among randomly selected individuals from the villages near the wetlands about perceptions regarding the wetland issues and management.

Estimation of vegetation cover

Watchtowers were used as vantage points to have aerial viewing of the wetlands. The wetlands were divided into smaller sectors with the help of landmarks. In these sectors,

vegetation cover on the wetland was visually estimated as a percentage of the total wetland area. Vegetation cover of all the blocks was averaged to estimate the wetland's vegetation cover. On the ground, emergent vegetation was identified with the help of identification manuals (Fassett, 2000; Saini *et al*., 2010).

Results

Wetlands

Data regarding wetland characteristics are presented in Table 1. Important features of the various wetlands are discussed in following text at relevant places.

Tree cover

Wetlands like Nawabganj, Patna, Samaspur, Sursarovar, Saman and Vijaisagar have are natural forest blocks, where Bakhira, Okhla, Parvatiarga and Sandi have planted trees are found. Sarsainawar and Lakhbahosi are simple wetlands. Trees on these wetlands attracted non-aquatic birds for food and provided perching and roosting place as well. *Syzigium cumini, Ficus benghalensis, Ficus religiosa, Ficus* spp. (gular, pakar), *Pithecolobium dulci, Azadirachta indica, Zyziphus mauritiana, Morus alba, lisorha, Caparis,* provided fruits to the woodland or countryside frugivorus birds. *Accacia arabica, Dalbergia sissoo, Terminalia arjuna, Bombax ceiba, Albizia procera, Eucalyptus, Phoenix sylvestris, Holoptelia integrifolia* etc. provided perching and nesting place to these birds. It was observed at the Sursarovar wetland that *Prosopis juliflora* trees were the excellent heronry for Cattle Egrets, Black-crowned Night Heron and associated species (Jha, 2012).

Wetland area and water depth

Winter watered areas of wetlands varied from 40 ha to 2,000 ha and average depth ranged from 1 m to 5 m (exceptions Parvatiarga, 7 m and Vijaisagar, 10 m). Insignificant differences in density of either aquatic birds or all bird species in relation to wetland area, as well as wetland depth, were observed. However, there was a trend for shallow wetlands to have a higher number of birds. Area and species richness relationships were insignificant in both counters for all bird species and aquatic bird species. The relation between wetland size and species richness suggested larger wetlands had more species, but the increase in number of species is not proportional to added area. This result is similar to that of Brown and Smith (1998). In this analysis, perceived outliers were removed (wetlands larger than 500 ha) from the regression for all species, but results did not change. In the case of aquatic birds, regression analysis showed a significant relationship {R^2= 0.703, n= 8, P=> 0.005; y= $0.9655x^{2.2682}$ where the independent variable (x) was wetland area and dependent variable (y) was species richness}.

Threats

Common resource use

From the semi-structured interviews and responses to the questionnaire survey, it was evident that villagers around the wetlands are major stakeholders in common resource use. They often extracted *Typha angustifolia* and *Phragmites maxima* for their domestic practice, which was otherwise used as shelter and nesting by the aquatic birds. Some of the aquatic plants (*Jussiaea repens*, *Cerratophyllum demarsum*, *Ipomea aquatica*, *Nymphoides indicum* etc.) were also extracted for human use in traditional medicine system, otherwise used by the birds as food material. Food-providing plants (*Ipomea aquatica, Trapa natans, Nelumbo nucifera*) of birds were also removed from the wetlands to be used as food supplement by the villagers. This removal coincided with the residency period of the migratory birds and caused immense disturbance to them. Illegal fishing and bird trapping in the wetlands were also reported by the respondents, resulting into changes in bird population.

Some of the managed wetlands (Bakhira, Patna, Saman and Vijaisagar) suffered from major agriculture activities, which generates avian disturbances. Parts of the wetlands often belong to the private ownership as a result of lack of land settlement procedures. This private ownership pattern also leads to illegal fishing and bird trapping by the farmers, due to ineffectiveness of the regulatory provisions.

Hydrological changes

Pond water is often used by the cattle for drinking and used by humans for bathing, clothes washing and cattle cleaning. This use of pond water causes disturbance to birds and results in water pollution. The Okhla wetland is used for immersion of cremation wastes, along with other religious activities, adding further to the pollution. Sarsainawar wetland is also used for religious rituals that generate pollution.

A large number of questionnaire respondents believed that the depth of the wetlands had decreased (49%) and the water surface area had increased (46%) during last 10-15 years.

Weed growth

Sixty percent of the respondents agreed with the information provided by the wetland managers that the amount of aquatic weeds had increased in the last decade. Although some weeds were removed on regular basis, the lack of complete eradication resulted in weeds appearing every year, resulting in reduced space for water birds. Very common weeds in the wetlands under study were *Eichhornia crassipes, Ipomea carnea* and *Pistia stratiotes*. Almost all the wetlands were found infested with *Eichhornia crassipes* in varying quantities. The Sursarovar wetland was a notable exception to this trend.

Wetland similarity

A wetland similarity index was determined on the basis of occurrence of bird species on two wetlands, with results presented in Table 2. Values closer to 1 indicate higher similarity, while values closer to 0 indicate lower similarity among the habitats compared (Brown *et al*., 2002). Some highly similar habitat pairs are Samaspur-Sandi; SMP-SND (0.93) and Samaspur-Lakhbahosi; SMP-LKB (0.79). Some lower similar habitat pairs are Sarsainawar-Vijaisagar; SRN-VJS (0.28), Okhla-Vijaisagar; OKL-VJS (0.30), Sarsainawar-Sandi; SRN-SND (0.33) and Sarsainawar-Samaspur; SRN-SMP (0.33). Interestingly but not unexpected, most of the highly similar pairs are from same ecozones, while less similar wetlands are from different ecozones.

Vegetation cover (Emergent)

Typha angustifolia, Phragmites maxima, Saccharum spontaneum and *Ipomea carnea* were found to be the prominent emergent plants. These plants are generally located on the shore of the wetlands. Resident aquatic birds were seen

Table 2. Similarity index of Sorensen for wetlands (color bar indicates wetlands from similar ecozones)

	PAR	LKB	NBG	PAT	SMN	SMP	SND	SRN*	OKL	SSR	VJS
BKR	0.48	0.51	0.59	0.64	0.44	0.52	0.52	0.45	0.53	0.52	0.40
PAR		0.41	0.44	0.51	0.44	0.42	0.46	0.28	0.44	0.41	0.42
LKB			0.59	0.55	0.57	0.79	0.76	0.38	0.50	0.55	0.46
NBG				0.57	0.46	0.69	0.72	0.43	0.43	0.47	0.47
PAT					0.62	0.50	0.51	0.54	0.70	0.69	0.49
SMN						0.46	0.47	0.51	0.49	0.49	0.40
SMP							0.93	0.33	0.50	0.50	0.45
SND								0.33	0.49	0.50	0.46
SRN*									0.43	0.42	0.28
OKL										0.72	0.30
SSR											0.40

Table 3. Vegetation: open water ratio and avian population attributes of different wetlands

Wetland	*Vegetation: open water ratio (%)	Aquatic bird density (ha^{-1})**	Species richness		Species diversity (±sd)		Species evenness		Highest winter population	
			All species	Aquatic birds	All species	Aquatic birds	All species	Aquatic birds	All species	Aquatic birds
Bakhira	75:25; HVW	17 (12)	44	29	2.49(0.22)	2.34(0.31)	0.66	0.70	35052	33863
Parvatiarga	40:60; MVW	61 (60)	35	20	2.45(0.21)	1.90(0.29)	0.69	0.63	65245	60858
Lakhbahosi	45:55; MVW	384 (274)	97	47	3.05(0.27)	2.50(0.13)	0.67	0.65	95915	86318
Nawabganj	60:40; HVW	249 (146)	61	32	3.14(0.20)	2.73(0.21)	0.76	0.79	32916	24946
Patna	40:60; MVW	358 (230)	40	38	1.95(0.29)	1.93(0.29)	0.53	0.53	25107	25079
Sandi	50:50; MVW	377 (411)	105	52	3.81(0.08)	3.20(0.08)	0.82	0.81	133026	97356
Samaspur	45:55; MVW	103 (60)	109	52	3.55(0.32)	2.86(0.15)	0.76	0.72	47800	31528
Saman	70:30; HVW	6 (3)	47	28	2.82(0.37)	2.32(0.46)	0.73	0.69	1650	1270
Sarsainawar	40:60; MVW	26 (11)	23	17	2.55(0.06)	2.18(0.09)	0.81	0.77	1758	1026
Vijaisagar	05:95; LVW	145 (34)	42	18	1.73(0.25)	1.44(0.26)	0.46	0.50	8935	8678
Okhla	35:65; MVW	119 (82)	51	46	2.96(0.21)	2.90(0.20)	0.75	0.76	32935	32356
Sursarovar	05:95; LVW	119 (40)	68	58	2.93(0.21)	2.75(0.22)	0.67	0.68	31708	29728

*HVW=high vegetation wetland, MVW=medium vegetation wetland, LVW=low vegetation wetland; **Figures in parentheses are for all species

to be using the thickets for breeding, nesting and as hiding place. Other emergent plants were *Polygonum limbatum, Eleocharis dulcis, Van Dhania, Cyperus alopecuroides* and *Oryza rufipogon*. Prominent floating plants included *Jussiaea repens, Ipomea aquatica, Trapa natans, Potamogeton nodosus, Nymphaea pubescens, Nelumbo nucifera, Nymphoides indica*. These floating plants are well known for providing food for aquatic birds. However, *Nelumbo nucifera* provided food only to the very early arrivals as it was the first vegetation to disappear during winter.

On the basis of emergent vegetation cover Bakhira (75%), Saman (70%) and Nawabganj (60%) were in the high vegetation cover category. Vijaisagar (05%) and Sursarovar (05%) were in the low vegetation category. The medium vegetation category wetlands had high populations (more than 25,000 aquatic birds) except for Sarsainawar. High vegetation wetlands had lower populations, except of Bakhira, in which density was very low. Low vegetation wetlands also had lower populations, except Sursarovar (Table 3).

Foraging and vegetation

Aquatic birds were seen eating various types of food, ranging from various plant products like seeds, fruits, tubers, young shoots, etc. to different animals such as fish, insects, mollusks etc. available in the wetlands. What could be gathered from the observation of the field staff and the villagers during interview and questionnaire survey is that

Common Coot, Eurasian Wigeon, Gadwall, Lesser Whistling-duck, Mallard, Northern Pintail, Northern Shoveler, Purple Swamphen, Red-crested Pochard etc. were seen to feed on *Azolla pinnata, Ceratophyllum demersum, Cyperus alopecuroides, Eleocharis dulcis, Hydrilla verticillata, Ipomoea aquatica, Jussiaea repens, Najas minor, Nelumbo nucifera, Neptunia oleracea, Nymphea pubescens, Nymphoides indicum, Oryza rufipogon, Polygonum limbatum, Potamogeton nodosus, Spirodella polyrhiza, Trapa natans, Wolffia arrhiza* etc. Some birds also were seen utilizing agricultural fields to forage on the residue of early winter crops, shoots and grains of mid and late winter crops. It was noted that commonly-growing agriculture crops visited by the wetland birds were paddy, wheat, mustard, pigeon pea, gram, green pea. Region-specific crops included sugarcane, tobacco, sunflower, barley, sorghum and lentil. The aquatic birds foraging in these fields were Bar-headed Goose, Comb Duck, Common Coot, Common Moorhen, Common Pochard, Graylag Goose, Northern Shoveler, Purple Swamphen, Red-crested Pochard, Spot-billed Duck, Egrets, Herons etc. Reaction of the farmers about the pest nature of the birds varied, as some farmers considered them harmful, while others considered them useful. Those individuals considering the birds useful believed they increased the number of tillers by picking young shoots and providing fertilizers through defecating, resulting into coexistence. Birds were also observed to forage on insects and mollusks found in the agriculture fields.

Avian fauna

We recorded 486,182 avian individuals of 161 species over a 15,592 ha area. These birds were distributed in twelve wetlands, in four different ecozones. Counts were obtained through a weekly census during winter months of 2010-11. The observed wetlands attracted water birds as a result of the large water-bodies (70-2,894 ha, rainy season), as well as attracted woodland birds and countryside birds due to the presence of forest/plantation blocks, avenue trees, and/or agriculture fields in surrounding or nearby areas. The species observed included the following categories: aquatic (73), semi-aquatic (24), non-aquatic (64); or migrant (48), resident (105) and vagrant (8). These birds represented 41 families. Three families (duck, rail and egret families) comprised more than half of the total birds recorded in January (Fig. 2). Detailed results are discussed in following subsections with emphasis on total birds or all bird species and aquatic species. Species richness, species diversity and highest population during January (winter) are presented for individual wetlands in Table 3.

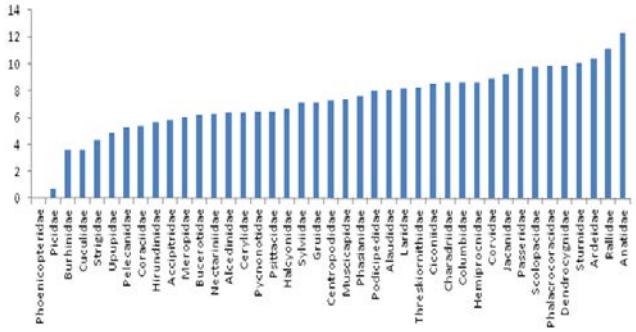

Fig. 2. Wetlands birds (by family) across managed wetlands of UP represented by numbers (in natural log scale) in different families. Around 60% birds are from top three families of aquatic birds, eg. Anatidae, Rallidae, and Ardeidae

Species richness

Across the twelve wetlands in the four ecozones, 161 bird species encountered in the winter weeks of 2010-11 (Tables 4 and 5). The proportion of these birds by habitat was 45% aquatic, 15% semi-aquatic, and 40% non-aquatic. Thirty percent were migrant, 65% resident and 5% vagrant.

Species richness by wetland for all categories of birds was: Samaspur (109), Sandi (105), Lakhbahosi (97), Sursarovar (68), Nawabganj (61), Okhla (51), Saman (47), Bakhira (44), Vijaysagar (42), Patna (40), Parvatiarga (35) and Sarsainawar (23). When only aquatic birds (73) were taken into account this order changed as follows: Sursarovar (58), Samaspur (52), Sandi (52), Lakhbahosi (47), Okhla (46), Patna (38), Nawabganj (32), Bakhira (29), Saman (28), Parvatiarga (20), Vijaisagar (18) and Sarsainawar (17). Ecozone wise species richness of all the birds was the highest in Gangetic plain (126) followed by Semi-arid (76), Tarai (60) and Bundelkhand (42). This order changed slightly as Semi-arid (63) followed by Gangetic plain (58), Tarai (35) and Bundelkhand (18) when bird richness was considered for aquatic species.

Species assemblage

Spatial occurrence of all 161 avian species across the state is given in Tables 4 and 5. Out of this species richness 51% were in occasional, 22% were in frequent, 17% were in common and 10% were in abundant categories respectively. Distribution of aquatic, semi-aquatic and non-aquatic birds was 81%, 19% and 0%, respectively, within abundant; 82%, 7% and 11%, respectively, within common; 31%, 11% and 58%, respectively, within frequent; and 32%, 20% and 48%, respectively, within occasional category. The top five "Abundant" species recorded on 10-12 wetlands were Northern Pintail (*Anas acuta* AQ; M), Asian Openbill (*Anastomus oscitans* AQ; R), Darter (*Anhinga melanogaster* AQ; R), Little Egret (*Egretta garzetta* AQ; R) and Common Teal (*Anas crecca* AQ; M).

Other top five species recorded on more than 50% wetlands (7-9) and categorized as "Common" were Northern Shoveler (*Anas clypeata* AQ; M), Spot-billed Duck (*Anas poecilorhyncha* AQ; R), Great Egret (*Casmerodius albus* AQ; R), Lesser Whistling-duck (*Dendrocygna javanica* AQ; R) and Intermediate Egret (*Mesophoyx intermedia* AQ; R). Among the remaining species categorized as "Frequent" and "Occasional" occurring on 4-6 and 1-3 wetlands, respectively, were mainly the non-aquatic birds (80%). Most commonly occurring birds from these categories were Shikra (*Accipiter badius*), Indian Roller (*Coracias benghalensis*), Indian Grey Hornbill (*Ocyceros birostris*), Spotted Dove (*Streptopelia chinensis*), Jungle Myna (*Acridotheres fuscus*), Large-billed Crow (*Corvus macrorhynchos*), House Crow (*Corvus splendens*) etc. Least occurring birds, both spatially and temporally, categorized also as "Vagrant" in this text were Greater Scaup (*Aythya marila*), Common Ringed Plover (*Charadrius hiaticula*), Forest Wagtail (*Dendronanthus indicus*), Pintail Snipe (*Gallinago stenura*), Black Eagle (*Ictinaetus malayensis*), Marbled Duck (*Marmaronetta angustirostris*), Purple-rumped Sunbird (*Nectarinia zeylonica*) and Common Tern (*Sterna hirundo*).

Temporal occurrence of the population of 161 species across the state through all the four weeks of the winter months (November through March) in Uttar Pradesh is depicted in Fig. 3 showing values of total (all species), aquatic, semi-aquatic and non-aquatic birds. Fig. 4 depicts the value for

Table 4. List of bird species of Abundant (10-12), Common (7-9) and Frequent (4-6) occurrence across the protected wetlands of Uttar Pradesh; (AQ= Aquatic, SA= Semi-aquatic, NA= Non-aquatic)

SN	Abundant	Common	Frequent
1	*Anas acuta (AQ)*	*Acridotheres tristis (NA)*	*Accipiter badius (NA)*
2	*Anas crecca (AQ)*	*Anas clypeata (AQ)*	*Acridotheres fuscus (NA)*
3	*Anastomus oscitans (AQ)*	*Anas penelope (AQ)*	*Acridotheres ginginianus (NA)*
4	*Anhinga melanogaster (AQ)*	*Anas platyrhynchos (AQ)*	*Alcedo atthis (SA)*
5	*Anser anser (AQ)*	*Anas poecilorhyncha (AQ)*	*Amauronis phoenicurus (AQ)*
6	*Ardea cinerea (AQ)*	*Anas querquedula (AQ)*	*Anser indicus (AQ)*
7	*Ardea purpurea (AQ)*	*Anas strepera (AQ)*	*Aythya fuligula (AQ)*
8	*Ardeola grayii (AQ)*	*Aythya ferina (AQ)*	*Aythya nyroca (AQ)*
9	*Bubulcus ibis (SA)*	*Casmerodius albus (AQ)*	*Centropus sinensis (NA)*
10	*Egretta garzetta (AQ)*	*Ceryle rudis (SA)*	*Ciconia episcopus (AQ)*
11	*Fulica atra (AQ)*	*Dendrocygna javanica (AQ)*	*Columba livia (NA)*
12	*Gallinula chloropus (AQ)*	*Ephippiorhynchus asiaticus (AQ)*	*Copsychus saularis (NA)*
13	*Grus a antigone (SA)*	*Francolinus pondicerianus (NA)*	*Coracias benghalensis (NA)*
14	*Halcyon smyrnensis (SA)*	*Mesophoyx intermedia (AQ)*	*Corvus macrorhynchos (NA)*
15	*Phalacrocorax niger (AQ)*	*Metopidius indicus (AQ)*	*Corvus splendens (NA)*
16	*Porphyrio porphyrio (AQ)*	*Mycteria leucocephala (AQ)*	*Dicrurus macrocercus (NA)*
17		*Nettapus coromandelianus (AQ)*	*Eudynamys scolopacea (NA)*
18		*Nycticorax nycticorax (AQ)*	*Haliastur indus (AQ)*
19		*Pavo cristatus (NA)*	*Himantopus himantopus (AQ)*
20		*Phalacrocorax carbo (AQ)*	*Hydrophasianus chirurgus (AQ)*
21		*Phalacrocorax fuscicollis (AQ)*	*Motacilla alba (SA)*
22		*Platelea leucerodia (AQ)*	*Motacilla flava (SA)*
23		*Rhodonessa rufina (AQ)*	*Motacilla maderaspatensis (NA)*
24		*Sarkidiornis melanotos (AQ)*	*Ocyceros birostris (NA)*
25		*Tachybaptus ruficollis (AQ)*	*Passer domesticus (NA)*
26		*Tadorna ferruginea (AQ)*	*Podiceps cristatus (AQ)*
27		*Threskiornis melanocephalus (AQ)*	*Pseudibis papillosa (SA)*
28		*Vanellus indicus (SA)*	*Psittacula krameri (NA)*
29			*Pycnonotus jocosus (NA)*
30			*Saxicoloides fulicata (NA)*
31			*Sterna aurantia (AQ)*
32			*Streptopelia chinensis (NA)*
33			*Streptopelia decaocto (NA)*
34			*Sturnus contra (NA)*
35			*Tringa stagnatilis (AQ)*
36			*Upupa epops (NA)*

total, migrant, resident and vagrant birds. It is evident from these two figures that the wetland birds appeared before November with populations increasing until the end of January. Populations started declining from early February, with some left at the end of March. Out of 161 species 84% were present in the first week of November and 82% were present until the end of March. This result suggests that very few species appear after November and leave until March (e.g. converging and dispersing period). However, the number of birds swelled from 135,157 (November, first week) to 486,182 (January, fourth week) and declined sharply to 119,518 (March, fourth week). Figs. 3 and 4 also indicate that the major contribution to these populations was from aquatic and resident birds, with semi-aquatic and vagrants being less.

Twenty four birds species totaled more than 5,000 individuals on all wetlands (15,592 ha). The top five non-breeding and aquatic bird species in decreasing order were Northern Pintail (*Anas acuta*), Common Coot (*Fulica atra*), Northern Shoveler (*Anas clypeata*), Common Teal (*Anas crecca*) and Lesser Whistling-duck (*Dendrocygna javanica*).

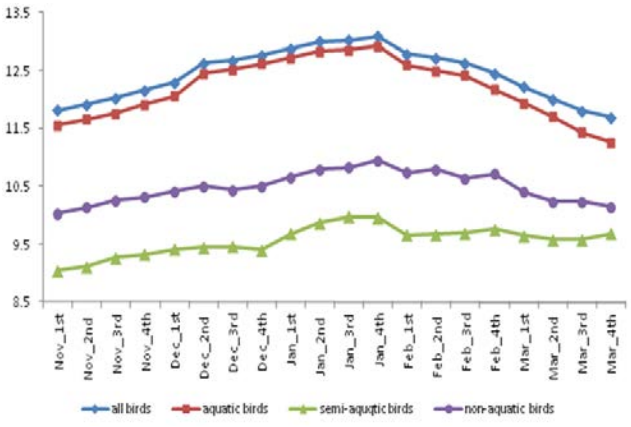

Fig. 3. Distribution of total avian population studied on all twelve wetlands. Y axis has log natural data of all individuals of all species coming under the categories. The data pertains to different winter weeks of 2010-11. Months are abbreviated to first three letters and week in ordinal number

Table 5. List of the birds of occasional occurrence (1-3) across the protected wetlands of Uttar Pradesh

SN	Aquatic	Semi-aquatic	Non-aquatic
1	*Amaurornis phoenicurus*	*Actitis hypoleucos*	*Apus afinis*
2	*Aythya marila*	*Amandava amandava*	*Aquila clanga*
3	*Gallinago gallinago*	*Botaurus stellaris*	*Athene brama*
4	*Gallinago stenura*	*Butorides striatus*	*Clamator jacobinus*
5	*Ixobrychus sinensis*	*Charadrius dubius*	*Coturnix coturnix*
6	*Larus brunicephalus*	*Charadrius hiaticula*	*Cursorius coromandelicus*
7	*Larus ridibundus*	*Ciconia ciconia*	*Cypsiurus balasiensis*
8	*Limosa limosa*	*Circus aeruginosus*	*Dendracitta vagabunda*
9	*Lymnocriptes minimus*	*Dupetor flavicollis*	*Dendronanthus indicus*
10	*Marmaronetta angustirostris*	*Esacus recurvirostris*	*Dinopium benghalense*
11	*Motacilla citreola*	*Hirundo rustica*	*Ducula aenea*
12	*Pandion haliaetus*	*Ixobrychus cinnamomeus*	*Elanus caeruleus*
13	*Pelecanus onocrotalus*	*Ixobrychus cinnamoneus*	*Francolinus francolinus*
14	*Pelecanus philippensis*	*Ploeceus benghalensis*	*Galerida cristata*
15	*Philomachus pugnax*	*Vanellus duvaucelli*	*Gracula religiosa*
16	*Phoenicopterus ruber*	*Vanellus malabaricus*	*Ictinaetus malayensis*
17	*Plegadis falcinellus*		*Ketupa zeylonensis*
18	*Recurvirostra avocetta*		*Loriculus vernalis*
19	*Rostratula benghalensis*		*Merops orientalis*
20	*Rynchops albicollis*		*Milvus migrans*
21	*Sterna hirundo*		*Milvus migrans govinda*
22	*Tadorna tadorna*		*Motacilla cinerea*
23	*Tringa glareola*		*Nectarinia zeylonica*
24	*Tringa nebularia*		*Neophron percnopterus*
25	*Tringa ochropus*		*Oriolus oriolus*
26	*Tringa tetanus*		*Oriolus xanthornus*
27			*Otus bakkamoena*
28			*Perdicula asiatica*
29			*Ploeceus philippinus*
30			*Psittacula cyanocephala*
31			*Psittacula eupatria*
32			*Pycnonotus cafer*
33			*Streptopelia orientalis*
34			*Streptopelia senegalensis*
35			*Sturnus pagodarum*
36			*Timalia pileata*
37			*Treron phoenicoptera*
38			*Turdoides caudatus*
39			*Turdoides striatus*
40			*Vanellus gregarius*

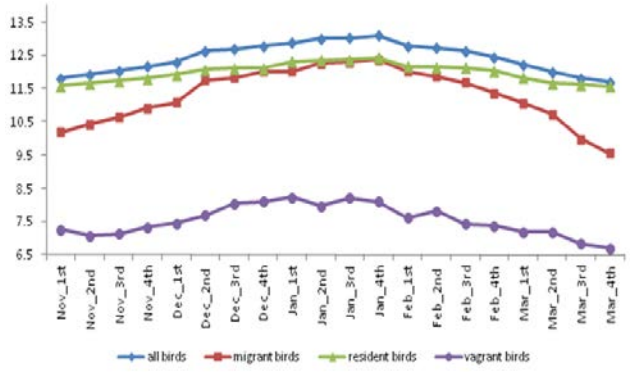

Fig. 4. Distribution of total avian population studied on all twelve wetlands. Y axis has log natural data of all individuals of all species coming under the categories. The data pertains to different winter weeks of 2010-11. Months are abbreviated to first three letters and week in ordinal number

These species predominantly inhabited Lakhbahosi, Patna, Sandi and Parvatiarga wetlands. Other dominant, but breeding birds like Indian Moorhen (*Galinula chloropus*), Purple Swamphen (*Pophyrio porphyrio*) and White-breasted Waterhen (*Amauromis phoenicurus*) were observed to be reed and bush birds found in large numbers in Bakhira, Parvati Arga and Sandi wetlands.

Bird density

Across all the wetlands, birds density per hectare ranged between 6-384, 1-27, 1-534 and 3-431 for aquatic, semi-aquatic, non-aquatic and all species, respectively. For migrant, resident and vagrant birds this range was 1-216, 3-235 and 1-7, respectively. Average density for the former set of category of habitats and all species was 164, 4, 54 and 93, respectively and for latter set of residency category it was 51, 44 and 1, respectively. Ecozone wise, average density is given in Table 6. These density figures are comparable within habitats and

zone wise, not within the categories (aquatic, semi-aquatic, non-aquatic, migrant, resident, vagrant and all species birds) since the area used for these are different as mentioned in the methods section. Density data indicated that the Gangetic zone is best suited to the birds of different categories followed by the Semi-arid zone. The Bundelkhand-Vindhyan is the least suited zone.

Table 6. Density of individuals (ha^{-1}) by habitat and residency of bird species in different ecozones

Habitat/Residency	Tarai	Gangetic	Semi-arid	Bundelkhand-Vindhyan
Aquatic	39	215	119	145
Semi-aquatic	1	7	2	0
Non-aquatic	13	98	1	1
Migrant	16	93	42	6
Resident	22	72	25	30
Vagrant	0	2	1	0
All species	36	165	61	34

On the basis of density of all species the wetlands fell in the following order of decrease: Sandi > Lakh-bahosi > Patna > Nawabganj > Okhla > Parvati-arga = Samaspur > Sursarovar > Vijaisagar > Bakhira > Saman (Table 3). This order of wetlands for aquatic bird density varied from the previous order and stood as follows: Lakh-bahosi > Sandi > Patna > Nawabganj > Vijaisagar > Sursarovar = Okhla > Samaspur > Parvati-arga > Sarsainawar > Bakhira > Saman. The order of resident bird density was in the following order: Sandi > Lakh-bahosi > Nawabganj > Samaspur > Parvati-arga > Vijaisagar > Okhla > Sursarovar > Patna > Sarsainawar> Saman. In these categories, the highest two wetlands are from Gangetic zone, indicating its suitability for bird residency of different categories.

In these categories, the area of the wetland was not apparently related to the density of birds, which is a result contrary to the earlier report that density of waterfowl correlate negatively to the size of the wetland (Garry *et al.*, 1991).

Relative abundance

Figs. 5 and 6 show the relative abundance of aquatic and non-aquatic birds in the fourth week of January when the wetland bird population was the highest. It is apparent that when the number of species increased, the population of each species decreased. A similar result was observed with aquatic migrant and aquatic resident bird populations (Figs. 7 and 8). These figures suggest a normal distribution of community structure where few species were dominant in population, while other species were low in number and showing a decreasing trend in population with an increase in number of species. Polynomial regression equations on the data arranged in higher to lower population of the species were highly significant.

Species evenness

Determinations indicated that species evenness indices across all the wetlands, for all the species, was 0.756 and for the aquatic species it was 0.760. Ranked on this index (Table 3) the wetlands placed in decreasing order was Sandi > Sarsainawar > Nawabganj = Samaspur > Okhla > Saman > Parvati-arga = Sursarovar > Lakh-bahosi > Bakhira > Patna > Vijaisagar for all species and Sandi > Nawabganj >

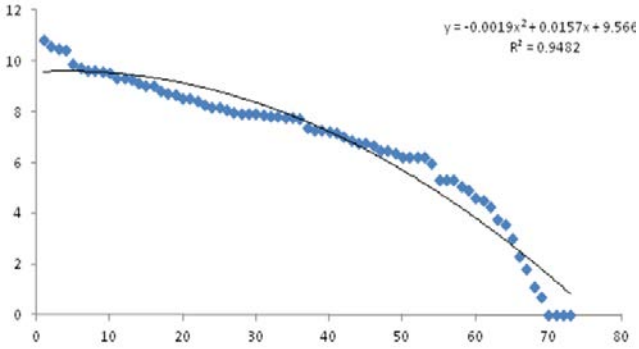

Fig. 5. Relative abundance of aquatic birds in wetlands of UP. Data on X axis is number of species encountered and Y axis number of individuals of corresponding species observed, converted to natural log

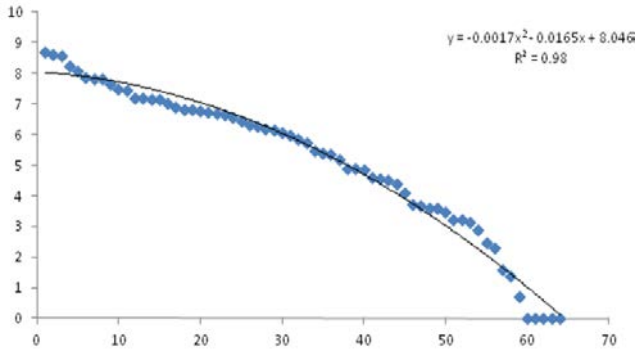

Fig. 6. Relative abundance of non-aquatic birds in wetlands of UP. Data on X axis is number of species encountered and Y axis number of individuals of corresponding species observed, converted to natural log

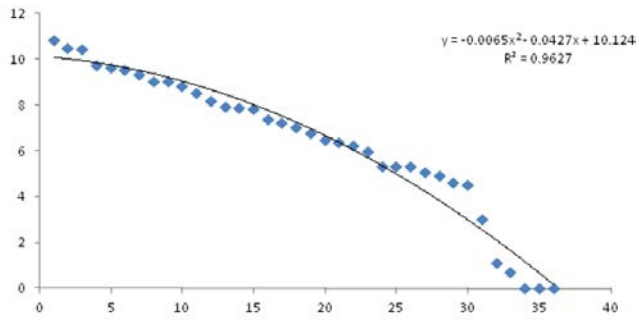

Fig. 7. Relative abundance of aquatic migrant birds. Data on X axis indicates species and on y axis individuals of corresponding species converted to natural log

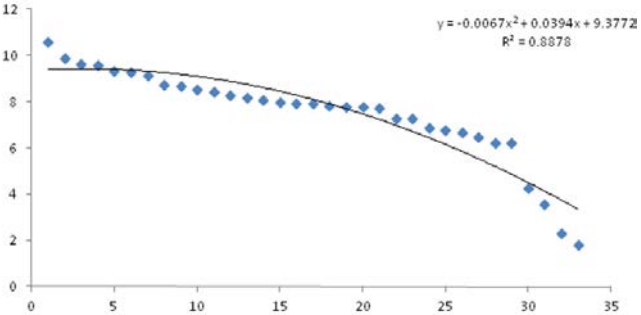

Fig. 8. Relative abundance of aquatic resident birds. Data on X axis indicates species and on y axis individuals of corresponding species converted to log natural

Sarsainawar > Okhla > Samaspur > Bakhira > Saman > Sursarovar > Lakh-bahosi > Parvati-arga > Patna > Vijaisagar for aquatic birds. Evenness was the highest for Gangetic plain (0.726) followed by Semi-arid (0.724), Tarai (0.674) and Bundelkhand-Vindhyan (0.464) in the case of all the species and Semi-arid (0.718) was the highest followed by Gangetic plain (0.710), Tarai (0.665) and Bundelkhand-Vindhyan (0.498) for aquatic species.

Species diversity

Average weekly value of Shannon index in the winter across all the wetlands was 3.85 for all bird species and 3.26 for aquatic birds. The ordering of wetlands for all species diversity was Sandi (3.81) > Samaspur (3.55) > Nawabganj (3.14) > Lakh-bahosi (3.05) > Okhla (2.96) > Sursarovar (2.93) > Saman (2.82) > Sarsainawar (2.55) > Bakhira (2.49) > Parvati-arga (2.45) > Patna (1.95) > Vijaisagar (1.73) and for aquatic birds diversity ordering was Sandi (3.20) > Okhla (2.90) > Samaspur (2.86) > Sursarovar (2.75) > Nawabganj (2.73) > Lakh-bahosi (2.50) > Bakhira (2.34) > Saman (2.32) > Sarsainawar (2.18) > Patna (1.93) > Parvati-arga (1.90) > Vijaisagar (1.44). All species average diversity was the highest in Gangetic plain (2.98) followed by Semi-arid (2.95), Tarai (2.47) and Bundelkhand-Vindhyan zone (1.73), but the average aquatic bird diversity was highest in Semi-arid (2.83), followed by Gangetic (2.53), Tarai (2.12) and Bundelkhand-Vindhyan zone (1.44).

Discussions

Different ecozones of UP have different edaphic-climatic factors supporting different vegetation composition. On the basis of species composition, wetland similarity within and dissimilarity among ecozones confirmed the importance of locality factors on bird assemblage. Cueto and de Casenave (1999) have also suggested that among the numerous ecological factors that determine the spatial variation of bird species, richness, climate and habitat seem to be important. Another review (Yardi *et al.*, 2007) suggests that the density and diversity of water birds are influenced by rainfall, temperature, humidity and cloudiness. While rainfall has greater influence on the bird population, water depth is reported to influence the population of migratory water birds (Briggs and Homes, 1988; Sayre and Rindle, 1984). This idea is further discussed in the following paragraphs.

Managed and unmanaged wetlands

Sarsainawar is an unmanaged wetland, where management intervention has not been done for bird conservation. In fact, some of the activities in this wetland, for example, cultivation of water chestnut (= reduction in open water area and disturbance to birds due to activities from sowing to harvesting), irrigation drawdown (= early shortage of water in winter) and agriculture expansion (= disturbance to the birds due to various agricultural activities) in the wetland could be treated as conservation threats (Rahmani *et al.*, 2010; Rahmani, *et al.*, 2011). Therefore, the status of bird species at this wetland could be used as comparison with the status of managed wetlands where disturbances are minimized. Habitat similarity of this wetland with respect to other wetlands relative to avian fauna is average or below average (0.54-0.28, Table 2). All the other wetlands had higher number of species in both the cases of bird species and aquatic birds than Sarsainawar wetland (Table 3). However, some of the wetlands had greater species diversity (Sandi > Samaspur > Nawabganj > Lakh-bahosi > Okhla > Sursarovar > Saman for all the species and Sandi > Okhla > Samaspur > Sursarovar > Nawabganj > Lakh-bahosi > Bakhira > Saman for aquatic birds, while other wetlands had less species diversity > Parvati-arga > Patna > Vijaisagar for all species and Patna > Parvati-arga > Vijaisagar for aquatic birds. Greater diversity on the former group of wetlands is attributed to better overall management interventions, whereas less diversity in the latter group could be due to a negative impact of management intervention and a management-environment interaction (Ma *et al.*, 2010; Tori *et al.*, 2002). Enhanced available habitat and quality may enable managed wetlands to support greater numbers and diversity of water birds than non-managed wetlands (Kaminski *et al.*, 2006).

Natural and created wetlands

Okhla, Sursarovar and Vijaisagar are created wetlands. Okhla and Sursarovar are of semi-impoundment nature, since water of the natural channel has been dammed, maintained at minimum level and water drawn out for various purposes. In Vijaisagar, water is permanently impounded and its level is naturally maintained, meaning the water level may go down due to evaporation and specified uses. The remaining wetlands in this study are of natural origin. The nine natural wetlands had higher species diversity in both all species and the aquatic bird classes than Vijaisagar.

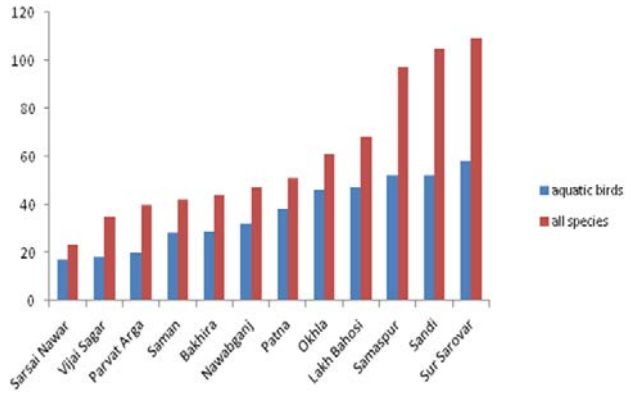

Fig. 9. Vertical bars showing species richness in different wetlands

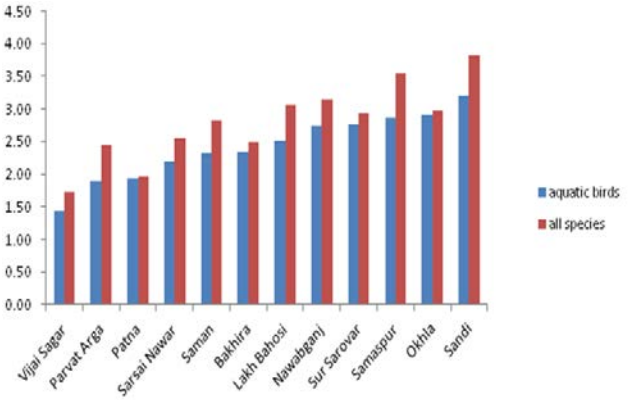

Fig. 10. Vertical bars showing species diversity in different wetlands

Compared to Sursarovar and Okhla only Sandi, Samaspur, Nawabganj and Lakhbahosi had higher diversity for all species and Sandi and Samaspur for aquatic species. For species richness in aquatic or all species category, almost all natural wetlands had higher values, except Sarsainawar. Okhla had less richness than three natural wetlands (Lakhbahosi, Samaspur and Sandi), but Sursarovar had the highest richness among all wetlands (Figs. 9 and 10). This result suggests that created wetlands have inferior species diversity and richness than the natural ones do. This result is consistent with an earlier report of created wetlands having lower diversity and species richness (Snell-Rodd and Cristol, 2003). The gaps shown among the created wetlands (one much better than the other) could be due to a differing rate of successional development of vegetation and differences in hydrology. With regard to Sursarovar, the results are consistent with the finding that restored and created wetlands often support bird abundances similar to natural wetlands (Brown and Smith, 1998; La Grange and Dinsmore, 1989) and sometimes have even greater species richness (Brawley *et al*., 1998; Warren and Askins, 1998).

Disturbance and population

Wetlands are known for common resource use resulting into threat as avian conservation (Islam and Rahmani, 2004; Sarma and Saikia, 2010). Removal of vegetation and other human activities such as fishing, domestic use etc. during the migratory bird assemblage period resulted in disturbances to birds in almost all wetlands. Managers of the wetlands provide varying degrees of control on these acts. However, over several years these disturbances likely resulted in the reduction of the population of aquatic bird as perceived by the respondents. Bakhira is one of the striking examples where the water bird population has decreased from 40,000-80,000 (Islam and Rahmani, 2004) to < 35,000 (in this study). In Patna the number of waterfowls has decreased from 60,000-70,000 (Islam and Rahmani, 2004) to 25,000 (present study). It was earlier reported that prolonged and extensive disturbances may cause a large number of waterfowl to leave disturbed wetlands and migrate elsewhere (Korschgen and Dahlgren, 1988). Recently it was also recorded in an Indian wetland that there was more richness and diversity in the undisturbed habitats than in disturbed habitats (Harisha and Hosetti, 2009).

Bird assemblage and temporal dynamics

All the bird species started appearing conspicuously in UP wetlands in October. The total number of individuals increased until the end of January due to major influx of migratory species. This observation is consistent with earlier reports, whereas the highest number of birds was recorded in the month of January along with the highest diversity of species (Gadhvi, 2007; Mohan and Gaur, 2008). Our observation that migratory birds were coming in larger numbers to add to the avian population was in agreement with previous records that migratory waterfowl began arriving in October and the diversity increased through the winter months and become maximum during January (Mohan and Gaur, 2008; Mukherjee *et al*., 2002). After the peak population in the fourth week of January, species diversity started declining through March with the important observation of migratory fowls taking off in larger flocks. This reduction in populations was primarily due to rise in temperature and reduction in availability of food (personal observation). There are many annual aquatic avian food plants that complete their life cycle during winter (Mishra and Narain, 2010) and are no longer available in spring, resulting in food shortage. In the beginning of the winter season, November, when migratory waterfowl begin arriving from their breeding grounds there is abundant food availability, but the available food supply declines after January. Thus, birds start moving to other suitable wetlands (Rahmani *et al*., 2010; Yardi *et al*., 2007).

Vegetation cover and bird richness and diversity

Upland habitats immediately adjacent to wetlands attract a number of bird species that may be only facultative wetland inhabitants (Knight *et al*., 2001). Vegetation outside the water body influences woodland birds or non-aquatic population, while vegetation inside the wetland promotes aquatic bird population. In either case, vegetation provides food, shelter and nesting place. Ideally, higher vegetation levels should result in higher populations on wetlands. However, vegetation cover and open water ratio play an important role in marsh utilization (Duffield, 1986) as the population of waterfowl is often comprised of ducks utilizing open water. Fifty-fifty ratio of covered area to open area is considered to be the ideal proportion and increase or a decrease from this level reduces the population (Smith *et al*., 2004). Out of twelve wetlands under study, only one, Sandi, had ideal vegetation:water ratio and the highest aquatic bird population. All other wetlands, having higher or lower ratio than the ideal one, had much lower number of birds indicating the hypothesis positive. However, among the rest of the wetlands vegetation:water ratio was not directly proportional to the number of aquatic birds. For example, few sets of wetlands: Sursarovar-Vijaisagar, Parvatiarga-Patna-Sarsainawar, and Lakhbahosi-Samaspur had similar vegetation:water ratio, but very different water bird numbers. Possible reasons for this variation could be other factors, such as wetland area, water depth and other environmental conditions. Optimum use of wetlands by waterfowl depends on habitat structure, water depth/regime, food quality/type, habitat degradation, disturbance etc. (Fredrickson and Reid, 1988). Therefore, it is suggested that vegetation cover should not be taken as single characteristic for prediction of species richness and diversity in our wetlands.

High vegetation cover tended to show a reduced number of overall aquatic birds, but the number of breeding birds like Purple Swamphen, Common Moorhen and White-breasted Waterhen was found in greater abundance in such wetlands. This result is considered to be due to the shelter provided by *Phragmites*, *Typha* and *Ipomea* bushes. Our observation is supported by earlier works which recorded that the abundance of reed and bush birds correlated positively with the area of rushes (Kosinski, 1999).

Foraging by aquatic birds outside the wetlands in agriculture areas was reported earlier (Mukherjee *et al*., 2002; Urfi, 2003), with soybean (Twedt *et al*., 1998), sorghum (Rahmani and Shobrak, 1992) and rice (Lane and Fujioka, 1996) utilized in particular. Many waterfowl species are opportunistic feeders and some species have learned to capitalize on the abundant food produced in agriculture (Ringleman, 1988). Glossy Ibis, Black-tailed Godwit,

Common Coot, Northern Pintail, Eurasian Wigeon and Common Teal were reported feeding on Sorghum (Rahmani and Shobrak, 1992). In this study, a shortage of aquatic vegetation in certain wetlands yet having a high number of water birds (e.g. Sursarovar) could be linked to the fact that large flocks of birds (Asian Openbill, Bar-headed Goose, Comb Duck, Indian Sarus Crane, Painted Stork, Northern Pintail, Spot-billed Duck) utilized adjacent agriculture areas (harvested paddy fields and wheat) for foraging, which compensates for the quality and quantity of food, water and cover in the wetlands themselves.

Increases in vegetation in one wetland and increases in the bird populations as suggested by the respondents, corroborated by an increase of birds on certain wetlands like Lakhbahosi, Parvatiarga, Sandi (Tables 1 and 3); this could be the result of positive changes in the aquatic system as suggested by Western and Grimsdell (1979), who stated that changes in vegetation community structure could affect the quantity and quality of food, water and cover.

Although individual characteristics of the wetlands influenced the avian fauna on it, the preceding discussion suggests that there is a combined effect of different characteristics regarding the avian faunal composition. This summation is in agreement with earlier reporting of Germaine *et al.*, (1998) and review of Guadagnin *et al.* (2005) that bird assemblage respond to a complex combination of factors in natural or urbanized habitats.

Wetland size and bird population

In this study wetland size increase did not correspond with an increase in aquatic species richness or bird population increase. Gawlik (2002) reported that it is not the size of wetland that matters but that accessibility to the habitat is crucial in determining the suitability of habitat for a particular water bird group. Being restricted by their morphology or ecological habits, water birds may avoid or be unable to access specific areas, such as deep water, dense vegetation etc. (Ma *et al.*, 2010). It has also been suggested that several factors other than area are associated with abundance and richness of water birds, such as physical-chemical conditions, food resources, vegetation cover and interspersion, as well as habitat and landscape configuration (Amezaga *et al.*, 2002; Caziani *et al.*, 2001).

Most of the studies that conclude that abundance and richness of birds is controlled by wetland size have observed relatively smaller wetlands (not more than 100 ha), while wetlands in this study are somewhat larger. It has also been suggested that although larger sites have more species, increases are not proportional to the added area (Brown and Smith, 1998). Therefore, we speculate that the possible correlation of richness and wetland size may not be true for wetlands of large dimensions.

Management implications

Each wetland has a different set of variables that influence the avian population, therefore generalizations are difficult if not impossible. For example, certain wetlands are having positively population influencing characters (large area, optimum vegetation: water ratio, disturbance free environment, low polluted water body), while others had negative population influencing character (high or low vegetation:water ratio, high disturbance, highly polluted water body). Wetlands with smaller area also tend to have a negative influence on population.

While threats to the wetland avian fauna continue to exist, management interventions like controlled fishing, reduced poaching, beneficial agriculture practices, weed removal, etc. appear to have helped conserve species in several instances. It has been suggested that additional unmanaged wetlands, at least the Important Bird Areas (Rahmani *et al.*, 2011) and Potential Ramsar Sites (Islam and Rahmani, 2008) could be worth diverting if the aim is to conserve the avian flora and webbed diversity in large numbers. Conservation of existing wetlands is becoming more critical in the sense that more than 50% of world's wetlands have been lost and additional pressure on subtropical and tropical wetlands have increased since the latter half of 20th century (Finlayson and Davidson, 1999).

For optimum results wetland management could be modified by manipulating wetland features themselves. Such management might include effective surveillance, weed and food plants management, pollution reduction (both aquatic and noise) and emergent plant regulation individually or in combination in certain wetlands, that might include:

I. For maximum species richness and abundance, vegetation:water ratio in large wetlands should be maintained close to 50:50. The wetland should have shallow water body with emergent vegetation as well as a deep area with open water.

II. For maintenance of open water species, the lake should have low vegetation:water ratio and for marshy bird species this ratio should be maintained at a higher level by increasing shallow areas and encouraging vegetation in those areas.

III. For conservation of breeding resident birds, reed and bush plants should be encouraged to occupy greater areas.

However, there is an urgent need of additional study in the wetlands to determine to what extent the above suggested manipulations should be implemented in various wetlands of Uttar Pradesh.

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