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Abundance and species diversity of waterbirds at Nangal Wetland, Punjab, India

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Abstract

Observations were made on the occurrence, abundance, species richness and diversity of waterbirds of Nangal wetland during February, 2013 to January, 2015. 45 waterbird species were reported and they belonged to 10 families under 5 orders. Data was collected every month for 5 days per month and twice a day. The number of waterbird species was highest in winter season due to the arrival of migratory birds as compared to the other seasons. Among various waterbird species, Common Coot, Gadwall, Common Pochard, Red-crested Pochard, Northern Pintail, Bar-headed Goose, Ruddy-shelduck, Northern Shoveller were frequently encountered in the study area. Two waterbird species i.e. Common Shelduck and Lesser-white Fronted Goose (migratory species) were spotted first time from Nangal wetland. Highest number of birds was recorded in the month of January, 2014 (10508.51) during the study period of 2013-14 and in the months of February, 2014 (9996.84) and January, 2015 (7466.02) during the study period of 2014-15. The Shannon-Wiener's diversity of waterbirds was higher during year 2013-14 (i.e. 2.683) than 2014-15 (i.e. 2.606). Abundance of waterfowls declined in the second year of study as compared to previous year. The occurrence and determination of bird species will help in the evaluation of status of this wetland from availability of food, habitat and suitable environment of an area.

Keywords: Aquatic avifauna, Migration, Occurrence, Community structure, Biological Indicators

Introduction

Wetlands are known as "biological supermarkets" because of the extensive food chains and rich biodiversity they support, providing unique habitats for a wide range of flora and fauna viz., birds, fishes and a variety of other aquatic life forms, including microorganisms (Mitsch & Gosselink, 2000) [45]. Wetlands also offer a range of ecosystem services, from preserving ecological balance to supporting human livelihoods (Sisodia & Moundiotiya, 2006) [54]. Wetlands are among the most important habitats for birds, providing them with places for feeding, resting, nesting, breeding, raising their young, seeking shelter, and socializing (Stewart, 2007) [57]. Wetlands provide food for birds which include plants, invertebrates, and other animals (Jaikrishna, 2008; Lameed, 2011) [28, 37].

At present, bird biodiversity is better understood than that of most other major groups of organisms. This is because birds attract greater human interest, are often visually striking, relatively easy to observe, and generally easy to identify (Bruford, 2002) [8]. Birds are very sensitive indicators of any kind of pollution in both terrestrial and aquatic ecosystems (Gaston, 1975; Hardy *et al.*, 1987; Gregory *et al.*, 2008) [22, 27, 24]. Water birds serve as important indicators of water quality and help assess the biodiversity of aquatic ecosystems (Weller, 1999; Jayson & Mathew, 2002) [64, 29].

Water birds can be classified into two categories: wetland specialists and generalists. Wetland specialists build their nests, feed, and roost primarily in aquatic habitats. They are highly dependent on wetlands and generally cannot survive in other types of habitats (Airinawe, 1999) [5]. Generalists are birds that commonly visit wetlands but can also be found in a variety of other habitats. Cranes, for instance, are generally considered terrestrial birds, yet they breed exclusively in wetlands, with a particular preference for seasonal grass swamps (Mengistu, 2003) [43]. Birds that use wetlands for nesting, feeding, or roosting are generally referred to as 'Water birds'. This category comprises bird groups commonly recognized as waterfowl and waders.

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Besides these, various other groups, including kingfishers, raptors, and certain passerines, rely ecologically on wetlands and are therefore described as wetland-dependent and associated birds. Collectively, these water birds, wetland-dependent birds, and associated birds are referred to as 'wetland birds'. Thus, the term 'wetland birds' encompasses diverse species that utilize wetland habitats for essential activities such as breeding, feeding, resting, and survival throughout their life cycles (Kumar *et al.*, 2005) [34].

Waterbirds play a vital role in wetland ecosystems, occupying various trophic levels and contributing significantly to wetland food webs and nutrient cycling (Kushlan, 1992) [35]. The migratory behaviour, distribution, and population dynamics of these birds offer valuable insights into the health and status of the wetland (Kushlan, 1993) [36]. Bird migration is among the most remarkable phenomena observed in ornithology. These birds undertake yearly journeys through various flyways, frequently covering vast distances between their breeding and wintering grounds. During these extensive migrations, waterbirds routinely cross both national and international borders (Wetlands International, 2002) [65]. Ducks and geese (Anatidae) are the most abundant and notable winter migrants to the Indian subcontinent, accounting for nearly 85% of the approximately 3 million migratory birds (Scott, 1989; Alfred *et al.*, 2001) [52, 1]. The essential needs of migratory waterbirds at their wintering grounds include sufficient food availability and protection from threats (Bharatha Lakshmi, 2006) [7].

The study of wetlands is essential because migratory birds currently face numerous threats, including habitat loss, destruction of breeding and nesting sites, unsustainable tourism, poaching, air and water pollution, and inadequate transboundary conservation efforts. The decline of valuable

bird species due to anthropogenic activities is occurring at an alarming rate and requires immediate attention through systematic research on wetland ecosystems. Therefore, the present study is an effort in this direction, aimed at contributing to a better understanding of wetland ecosystems and supporting the conservation of migratory bird species.

Materials and Methods

Study Area: Nangal Wetland (Fig. 1), situated in District Rupnagar (Ropar), Punjab, northern India, is located along the Sutlej River, a major tributary of the Indus River system. The wetland lies at approximately 31°24'13.52"N latitude and 76°22'03.05"E longitude, at an elevation of about 1,172 feet above mean sea level. It covers an area of approximately 700 acres, extending across land belonging to six adjoining villages. The wetland supports a rich diversity of flora and fauna and possesses significant hydrological importance. Its water resources are also utilized for drinking and irrigation by the surrounding population. Nangal Wetland holds considerable socio-economic, ecological, hydrological, and recreational significance. The unique wetland ecosystem provides suitable feeding, nesting, and breeding habitats for a variety of aquatic organisms and avifauna. Consequently, thousands of migratory birds visit the wetland annually during the winter season, making it an important habitat for both resident and migratory bird species. Geographically, the wetland is situated in the Shivalik foothills, where the Sutlej River emerges from the hills and enters the plains of Punjab. The wetland was developed downstream of the Bhakra Reservoir and serves an important strategic function as a balancing reservoir, further enhancing its hydrological significance (PSCST, 1994) [48].

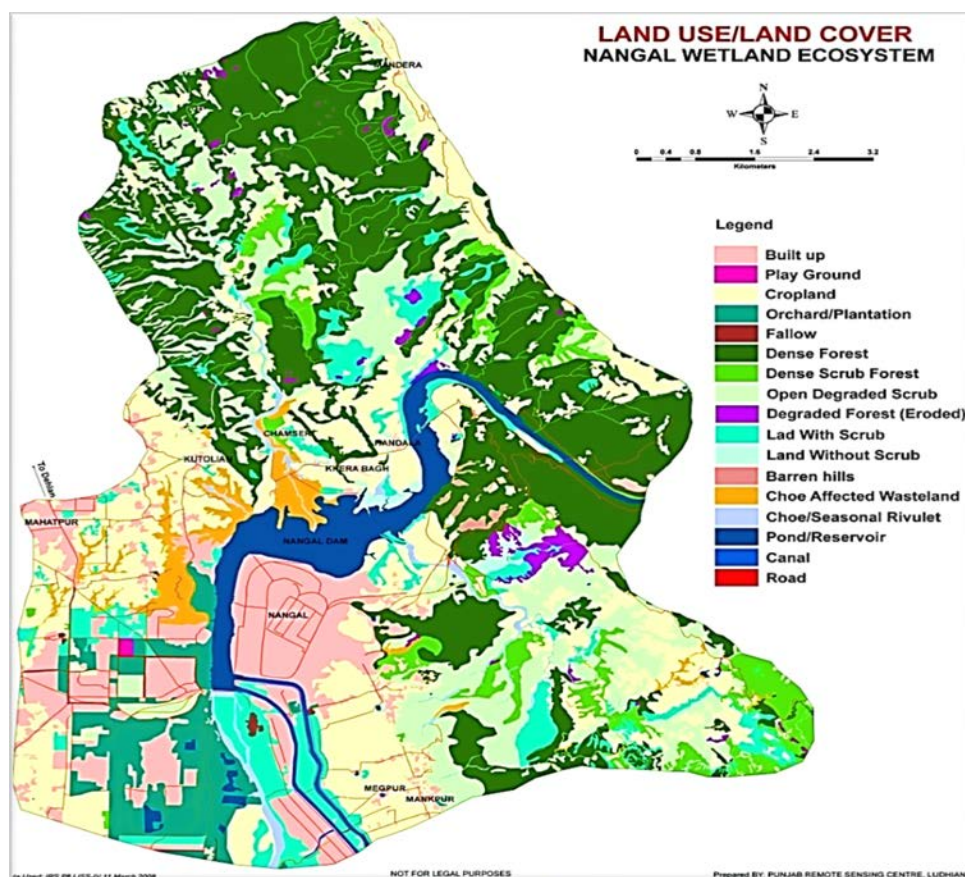


Fig 1: Map showing the Nangal Wetland.

The Line Transect method was employed to survey waterbirds during the present study, as it is considered an efficient technique for assessing waterbird populations. The method involves an observer travelling along a predetermined route by boat and recording all birds detected on either side of the transect. The length of each transect may vary depending on the nature and objectives of the survey and is often influenced by site accessibility; therefore, transects may not always be of a fixed length. During the survey, birds were recorded based on visual and auditory detections, including individuals observed in flight (Buckland *et al.*, 1993, 2001, 2004) [9, 10, 11]. Data was collected on monthly basis for five days per month and twice in a day. During winter season data was collected from 7.00am - 10.00am in the morning and 4.00pm - 6:30pm in the evening and during the summer season from 6.00am - 9.00am in the morning and 5:00pm - 7:30pm in the evening. Identification has been done with the help of various field guides (Ali & Ripley, 1987; Grewal *et al.*, 1995; Ali, 1996; Grimmett *et al.*, 2001; Kazmierczak, 2002) [3, 25, 2, 26, 32]. Number of individuals of the bird species counted for five days and an average was calculated.

Diversity Indices

Three indices were used to obtain estimation of species diversity, species richness and species evenness.

1. Diversity index values were obtained by using Shannon-Wiener's (1949) [56] and Simpson (1949) [53] diversity indices:

$$H' = -\sum(P_i \ln P_i) \text{ (Shannon-Wiener's index)}$$

$$\lambda = -\sum n_i(n_i - 1)/n(n - 1) \text{ (Simpson index)}$$

Where,

P_i = Proportion of the first species.

The proportions are given $P_i = n_i/n$

2. Species richness (R1 and R2) obtained using Margalef (1958) [40] and Menhinick (1964) [44] indices:

$$R1 = (S - 1) \ln(n) \text{ (Margalef index)}$$

$$R2 = \frac{S}{\sqrt{n}} \text{ (Menhinick index)}$$

Where,

- R = Index of species richness
- S = Total number of species
- n = Total number of individuals

3. Species evenness (E) (Pielou, 1966) [47] was determined by using the following expression.

Shannon's equitability (E) can be calculated by dividing H by Hmax (here Hmax = lnS). Equitability assumes a value between 0 and 1 with 1 being complete evenness.

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

- H = Shannon diversity index
- S = number of species in sample

Relative abundance (RA)

$$RA = \frac{\text{Number of individuals of a water bird species}}{\text{number of individuals of all water bird species}} \times 100$$

Results and Discussion

Wetlands are important habitat for avian populations throughout the world. It is greatly significant for being one of the few winter abodes for migratory bird species. Nangal Wetland also treasures a rich diversity of wetland avifauna, including several migratory birds that make the place their winter abode. Survey and counting of bird population at Nangal Wetland was carried out every month from February, 2013 to January, 2015. In all 152 species of birds (resident and migratory) belonging to 46 families under 17 orders, where 29 were migratory (M), 41 were local migratory (LM) and 82 were resident (R) species have been recorded from the wetland during the entire study period.

Out of total 152 bird species, 45 were waterbird species belonged to 10 families under 5 orders. Similarly, out of 45 waterbird species, 23 were migratory (M), 8 were local migratory (LM) and 14 were resident (R) species. These birds were also divided on the basis of their food and feeding habits, 3 were herbivorous (H), 12 carnivorous (C) and 30 were omnivorous (O) (Table 1). Teneson & Ravichandran (2015) [58] reported 43 waterbirds species in Koothapar Periyakulam Wetland in Tiruchirappalli District, Tamil Nadu, India. These waterbird species belonged to 7 orders and 14 families, which accomodate various ecological, residential and feeding groups. Dayananda (2009) [16] reported 218 species of birds at Gudavi Bird Sanctuary, Karnataka. Among these bird species, 99 were insectivorous, 27 piscivorous, 26 omnivorous, 21 carnivorous and 8 nectarivorous birds. Among various waterbird species, Common Coot (*Fulica atra*), Gadwall (*Anas strepera*), Common Pochard (*Aythya farina*), Red-crested Pochard (*Rhodonessa rufina*), Northern Pintail (*Anas acuta*), Ruddy-shelduck (*Tadorna ferruginea*), Northern Shoveller (*Anas clypeata*) were frequently encountered in the present study area. Among these, family Anatidae remained dominant in water bird population followed by family Charadriidae. Giri & Chalise (2008) [23] reported a total of 39 species of waterbirds belonging to 17 families and 5 orders in their study of seasonal diversity and population status of waterbirds in Phewa lake, Pokhara, Nepal. Out of 39 species, 11 species which were winter visitors belonging to the family Anatidae only. Ekhande *et al.* (2012) [19] reported 58 species of birds in and around Yashwant Lake from December 2006 to November 2008. Among these 41 species were waterbirds while 17 were terrestrial.

As per status of Red list of IUCN, 2 species were categorised in the Vulnerable (VU) category, 5 species in the Near Threatened (NT) category and 38 bird species were in the Least Concern (LC) category. Among these, vulnerable species were Lesser White-Fronted Goose (*Anser erythropus*) and Sarus Crane (*Grus antigone*), the Near Threatened species were Ferruginous Duck (*Aythya nyroca*), River Lapwing (*Vanellus duvaucelii*), Indian River Tern (*Sterna aurantia*), Painted Stork (*Mycteria leucocephala*) and Oriental Darter (*Anhinga melanogaster*). Das *et al.* (2014) [15] carried out similar studies at Kapla wetland of Barpeta district, Assam and reported a total of 30 waterbird species under 14 families. As per IUCN status, one species was categorised in the Vulnerable (VU) category, 3 species in the Near Threatened category (NT) and 26 bird species were in the Least Concern (LC) category. Veerwal *et al.* (2014) [62] reported a total of 68 species of waterbirds belonging to 14 families were reported with Anatidae as the

most dominating family with 16 species. They further enlisted, 11 important species in terms of their conservation status. Of these, one species of endangered status, 2 species of vulnerable status and 8 species of Near Threatened status were reported. Mengesha *et al.* (2015) [42] carried out study on abundance and temporal patterns in wetland birds in and around Lake Zeway, Ethiopia and reported a total of 129 waterbird species from 23 families including 2 globally Vulnerable and 6 Near Threatened bird species.

Seasonal fluctuations in the population of waterfowl were highly evident from the findings (Tables 2; Fig. 2 & 3). The diversity of waterbird species was highest during winter compared with other seasons, mainly because of the arrival of migratory birds. A greater number of resident waterbirds were observed when the lakes were filled with water during the monsoon, followed by an influx of migratory waterbirds during winter. In summer, as the water level of the lakes receded, the abundance of waterbirds declined considerably, as many birds moved locally to other suitable habitats. Thus, seasonal changes in water availability strongly influenced the abundance and composition of waterbird communities, with peak populations occurring during periods when suitable aquatic habitats and resources were readily available. Colwell & Taft (2000) [14] reported similar observations indicated that water level and bird abundance were inter-related. Towards the end of winter, most migratory birds began moving, while water levels also started declining in the wetlands. These factors could have contributed to the lower sighting frequency recorded during the summer season across the study wetlands. Maheswaran & Rahmani (2001) [39] also reported that waterbird population fluctuates in relation to changing water level and season from lakes of Dudwa National Park, India. Shanbhag *et al.* (2001) [55] recorded highest abundance of waterbirds in winter months because of arrival of migratory waterbirds in the Carambolim lake of Goa and Raghavaiah & Davidar (2006) [49] from Pulicat lake of Andhra Pradesh in India. Further, fluctuation in water level might alter the habitat characteristics that could cause prompt changes in communities of fishes, amphibians, invertebrates and water birds (Johnson *et al.*, 2007) [30].

Bar-headed Geese were reported in very less number during the second year of study and number of other waterfowls also declined in the second year as compared to previous year. Bird species richness showing an increase from October to January but showing a sharp decrease in the months of February and March. Two waterbird species i.e. Common Shelduck and Lesser-white Fronted Goose (migratory species) were spotted first time from Nangal wetland in February, 2015. Highest number of birds was recorded in the month of January, 2014 (10508.51) during the study period of 2013-14 and in the months of February, 2014 (9996.84) and January, 2015 (7466.02) during the study period of 2014-15. Minimum number of birds was recorded in the month of June, 2014 (607.83) during the study period of 2013-14 and in the month of May, 2014 (473.33) during the study period of 2014-15. The population of the water fowls decrease along with the commencement of return migration of the migratory fowls. Walwert *et al.* (2004) [63] reported that winter-migratory species utilize wetlands as resting and feeding habitats while awaiting favourable conditions in their breeding ranges. During this period, they engage in activities that enable them to

accumulate sufficient fat reserves to support their return journey to Europe.

Migrant water birds have been reported to display a greater sensitivity to human induced disturbances than resident birds (Van der Zande *et al.*, 1980; Burger, 1981; Burger & Gochfeld, 1991; Klein *et al.*, 1995) [61, 12, 13, 33]. Increasing anthropogenic pressure, along with climatic and edaphic factors, has led to the degradation of wetland resources, resulting in a significant decline in wetland fauna, particularly waterbirds, across the globe (Greenwood *et al.*, 1995; Laurence, 1999) [38]. Majority of migratory birds comes from Europe and Siberia to plains of India (Ali, 2005) [4]. Accurate monitoring of bird population size and temporal changes in wetland bird populations is essential for assessing their population status, understanding community structure, and evaluating the ecological condition and quality of wetlands within a given area (Thompson, 2002; De Sanete *et al.*, 2005; Kaminski *et al.*, 2006) [60, 17, 31]. The high avian diversity in this wetland indicates its healthy condition, offering diverse habitats, sufficient food resources, and suitable nesting and roosting sites. This wetland faces relatively lower anthropogenic pressure as it has been designated as a wildlife sanctuary. The rules and regulations governing sanctuaries under the Wildlife Act are stringent; therefore, they provide greater safety compared to other water bodies.

Breeding is a crucial aspect of the life cycle of birds, requiring suitable habitats for successful reproduction. Resident waterfowl also gather at favourable locations that provide appropriate conditions for the completion of their breeding activities (Thomas, 1980) [59]. In the present investigation, among waders, Black-winged Stilts and Red-wattled Lapwings were frequently observed during summer and monsoon. Common Coot and Gadwall were found to be predominant, exhibiting higher populations throughout the winter season. The resident bird species, namely Red-wattled Lapwing (*Vanellus indicus*), Indian Pond Heron (*Ardeola grayii*), Night Heron (*Nycticorax nycticorax*), Common Swamphe (*Gallinula chloropus*), Indian White-breasted Waterhen (*Amaurornis phoenicurus*), Grey Heron (*Ardea cineria*), Purple Heron (*Ardea purpurea*), and Spot-billed Duck (*Anas poecilorhyncha*), were identified as important breeding species within the study area. It was noted that all resident birds established breeding sites at Nangal wetland.

Relative abundance (RA)

Common Coot had the highest relative abundance value during both the years i.e. 24% during 2013-14 and 28% during 2014-15 followed by Gadwall (Table 2). Similar results were also observed by Rais *et al.* (2011) [50] in their study of bird diversity and conservation at Kallar Kahar Lake with special reference to waterbirds.

Species diversity and richness of waterbird

The Shannon-Wiener's diversity of waterbirds was higher during year 2013-14 (i.e. 2.683) than 2014-15 (i.e. 2.606). This could be due to higher species evenness during the year 2013-14. The Simpson diversity index of waterbirds was also higher during year 2013-14 (i.e. 0.8917) than 2014-15 (i.e. 0.8748). The species evenness index was higher during 2013-14 (0.3403) as compared to year 2014-15 (0.301). The Margalef's species richness of waterbirds was higher during the year 2014-15 (i.e. 5.239) than 2013-14 (i.e. 4.846). The Menhinick species richness was also higher during year

2014-15 (i.e. 0.6753) than 2013-14 (i.e. 0.5644) (Table 3). Similar study is carried out by Rajashekara and Venkatesha (2014) ^[51] in their study of eco-spatial and temporal

variation in waterbirds composition and their relationship with habitat characteristics of Urban lakes of Bengaluru city, India.

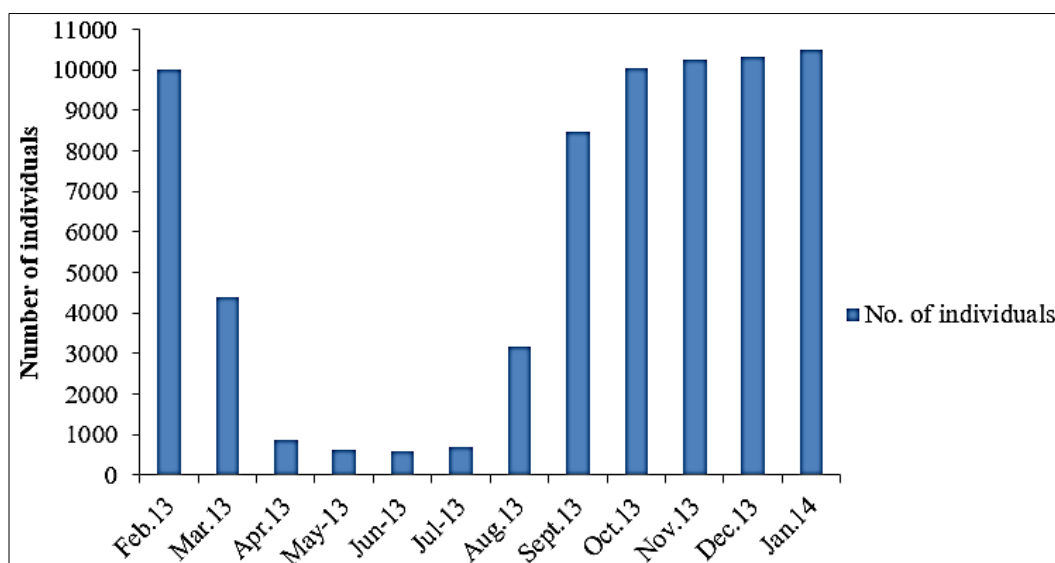


Fig 2: Monthly variation of number of individuals during February 2013-January 2014

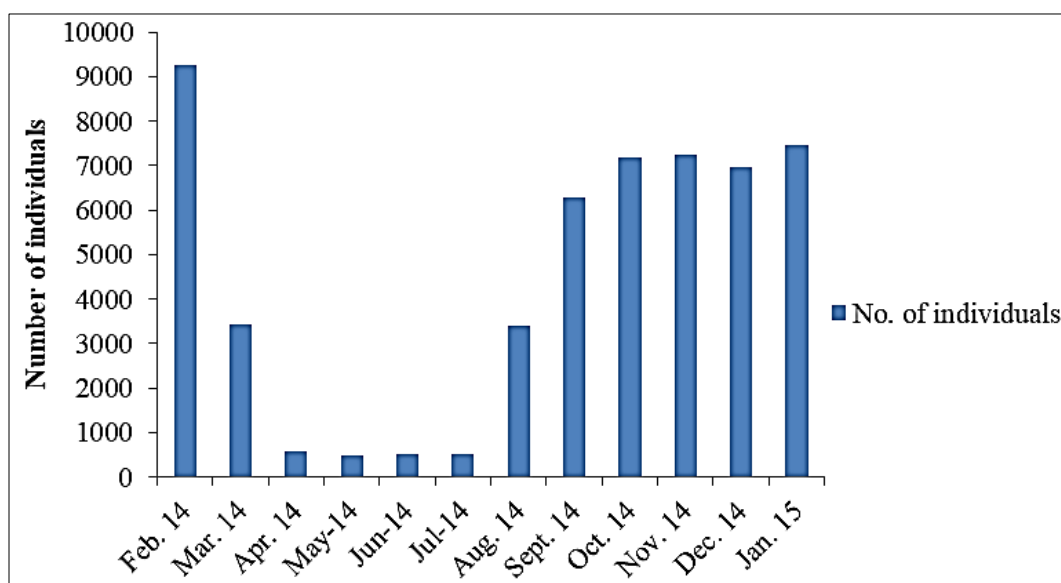


Fig 3: Monthly variation of number of individuals during February 2014-January 2015

Table 1: List of Waterbirds at Nangal Wetland reported during February 2013-January 2015

S. No.	Zoological Name	Common Name	IUCN Status	Status	Food Habit (Ali, 2012)
	Order: Anseriformes				
	Family: Anatidae				
1.	<i>Anas poecilorhyncha</i>	Spot-billed duck	LC	R	Omnivorous
2.	<i>Anas strepera</i>	Gadwall	LC	M	Omnivorous
3.	<i>Aythya farina</i>	Common Pochard	LC	M	Omnivorous
4.	<i>Rhodonessa rufina</i>	Red-crested Pochard	LC	M	Omnivorous
5.	<i>Aythya nyroca</i>	Ferruginous Duck	NT	M	Omnivorous
6.	<i>Anas platyrhynchos</i>	Mallard	LC	M	Omnivorous
7.	<i>Tadorna ferrugenia</i>	Ruddy Shelduck	LC	M	Omnivorous
8.	<i>Tadorna tadorna</i>	Common Shelduck	LC	M	Omnivorous
9.	<i>Anser indicus</i>	Bar-headed Goose	LC	M	Herbivorous
10.	<i>Anser anser</i>	Graylag Goose	LC	M	Herbivorous
11.	<i>Anser erythropus</i>	Lesser White-Fronted Goose	VU	M	Herbivorous
12.	<i>Anas acuta</i>	Northern Pintail	LC	M	Omnivorous
13.	<i>Anas clypeata</i>	Northern Shoveller	LC	M	Omnivorous
14.	<i>Anas crecca</i>	Common Teal	LC	M	Omnivorous, largely Vegetarian
15.	<i>Anas querquedula</i>	Garganey	LC	M	Omnivorous, largely Vegetarian

16.	<i>Aythya fuligula</i>	Tufted Duck	LC	M	Omnivorous
17.	<i>Anas penelope</i>	Eurasian Wigeon	LC	M	
18.	<i>Sarkidiornis melanotos</i>	Comb Duck	LC	LM	Omnivorous
	Order: Charadriiformes				
	Family: Charadriidae				
19.	<i>Vanellus indicus</i>	Redwattled Lapwing	LC	R	Omnivorous, largely Carnivorous
20.	<i>Vanellus duvaucelii</i>	River Lapwing	NT	LM	Omnivorous, largely Carnivorous
21.	<i>Vanellus leucurus</i>	White-tailed Lapwing	LC	M	Omnivorous, largely Carnivorous
22.	<i>Himantopus himantopus</i>	Black Winged Stilt	LC	R	Omnivorous
23.	<i>Actitis hypoleucos</i>	Common Sandpiper	LC	R	Omnivorous
24.	<i>Charadrius dubius</i>	Little Ringed Plover	LC	M	Omnivorous
25.	<i>Charadrius hiaticula</i>	Common Ringed Plover	LC	M	Omnivorous
26.	<i>Sterna aurantia</i>	Indian River Tern	NT	LM	Carnivorous
	Order: Ciconiiformes				
	Family: Ardeidae				
27.	<i>Ardeola grayii</i>	Indian Pond Heron Or Paddy Bird	LC	R	Carnivorous
28.	<i>Nycticorex nycticorex</i>	Night Heron	LC	R	Carnivorous
29.	<i>Ardea purpurea</i>	Purple Heron	LC	R	Carnivorous
30.	<i>Ardea cineria</i>	Grey Heron	LC	R	Carnivorous
	Family: Ciconiidae				
31.	<i>Mycteria leucocephala</i>	Painted Stork	NT	LM	Carnivorous
	Family: Laridae				
32.	<i>Larus brunnicephalus</i>	Brown-headed Gull	LC	M	Omnivorous
33.	<i>Larus ichthyaeus</i>	Palla's Gull	LC	M	Omnivorous
	Family: Phalacrocoracidae				
34.	<i>Phalacrocorax niger</i>	Little Cormorant	LC	R	Carnivorous
35.	<i>Phalacrocorax carbo</i>	Great Cormorant	LC	R	Carnivorous
36.	<i>Anhinga melanogaster</i>	Oriental Darter	NT	R	Carnivorous
	Family: Podicipedidae				
37.	<i>Podiceps cristatus</i>	Great Crested Grebe	LC	M	Carnivorous
38.	<i>Tachybaptus ruficollis</i>	Little Grebe	LC	LM	Carnivorous
39.	<i>Podiceps nigricollis</i>	Black Necked Grebe	LC	M	Carnivorous
	Order: Gruiformes				
	Family: Gruidae				
40.	<i>Grus antigone</i>	Sarus Crane	VU	LM	Omnivorous
	Family: Ralidae				
41.	<i>Gallinula chloropus</i>	Common Swampphen	LC	R	Omnivorous
42.	<i>Porphyrio porphyrio</i>	Indian Purple Moorhen	LC	R	Omnivorous
43.	<i>Amaurornis phoenicurus</i>	Indian White-Breasted Water Hen	LC	R	Omnivorous
44.	<i>Fulica atra</i>	Common Coot	LC	LM	Omnivorous
	Order: Pelecaniformes				
	Family: Threskiornithidae				
45.	<i>Pseudibis papillosa</i>	Red-naped Ibis	LC	LM	Omnivorous

Abbreviations: Migratory (M), Local Migratory (LM), Resident (R), Endangered (EN), Vulnerable (VU), Near Threatened (NT) and Least Concern (LC).

Table 2: Mean, Standard Deviation (S.D.) and Relative Abundance (RA) of birds

S. No.	Species	2013-14		2014-15	
		Mean $\pm$ S.D.	RA	Mean $\pm$ S.D.	RA
1.	Pond Heron	15.72 $\pm$ 4.22	0.269	9.94 $\pm$ 3.29	0.187
2.	Night Heron	9.60 $\pm$ 2.44	0.164	9.18 $\pm$ 2.13	0.155
3.	Purple Heron	2.97 $\pm$ 2.39	0.051	1.5 $\pm$ 1.29	0.025
4.	Grey Heron	2.82 $\pm$ 2.08	0.048	2.05 $\pm$ 1.66	0.032
5.	Sarus Crane	0.84 $\pm$ 0.92	0.012	1.75 $\pm$ 0.35	0.020
6.	Little Cormorant	117.72 $\pm$ 24.30	2.019	111.01 $\pm$ 17.85	1.799
7.	Great Cormorant	37.72 $\pm$ 12.47	0.647	29.71 $\pm$ 17.50	0.578
8.	Oriental Darter	1.40 $\pm$ 1.40	0.037	3.32 $\pm$ 0.82	0.045
9.	White-Breasted Water Hen	388.43 $\pm$ 20.84	6.663	365.74 $\pm$ 25.55	8.225
10.	Red Wattled Lapwing	28.39 $\pm$ 4.01	0.487	21.71 $\pm$ 5.43	0.488
11.	River Lapwing	0.99 $\pm$ 1.11	0.025	0.73 $\pm$ 0.95	0.016
12.	White-tailed Lapwing	0.53 $\pm$ 0.81	0.009	0.38 $\pm$ 0.72	0.008
13.	Black Winged Stilt	52.68 $\pm$ 9.46	0.903	39.94 $\pm$ 9.43	0.898
14.	Common Pochard	267.14 $\pm$ 263.24	4.582	210.06 $\pm$ 162.77	4.724
15.	Red Crested Pochard	406.87 $\pm$ 405.07	6.980	435.63 $\pm$ 327.86	9.796
16.	Spot-Billed Duck	120.63 $\pm$ 48.74	2.069	89.46 $\pm$ 45.08	2.011
17.	Ferruginous Duck	3.27 $\pm$ 3.49	0.041	3.002 $\pm$ 2.49	0.067
18.	Eurasian Wigeon	274.31 $\pm$ 287.52	4.705	128.20 $\pm$ 155.95	2.883

19.	Common Coot	1419.27 ± 1170.59	24.348	1266.75 ± 1019.82	28.487
20.	Indian Moorhen	197.45 ± 126.19	3.387	165.53 ± 117.35	3.722
21.	Purple Moorhen	23.74 ± 15.27	0.407	7.85 ± 6.32	0.409
22.	Great Crested Grebe	6.83 ± 6.12	0.117	5.80 ± 5.02	0.130
23.	Little Grebe	24.04 ± 22.88	0.412	20.64 ± 16.97	0.464
24.	Black necked Grebe	1.12 ± 1.21	0.019	0.94 ± 1.06	0.021
25.	Gadwall	814.46 ± 698.73	13.972	477.79 ± 491.10	10.744
26.	Mallard	50.92 ± 49.93	0.873	38.79 ± 46.35	0.872
27.	Northern Pintail	452.35 ± 380.40	7.760	378.54 ± 349.39	8.512
28.	Ruddy Shelduck	112.84 ± 111.25	1.935	85.98 ± 90.40	2.191
29.	Common Shelduck	-	0	0.134 ± 0.46	0.003
30.	Northern Shoveller	139.15 ± 114.95	2.387	53.91 ± 74.38	1.212
31.	Tufted Duck	103.71 ± 110.48	1.779	95.85 ± 103.88	2.155
32.	Common Teal	117.97 ± 120.38	2.023	114.99 ± 115.72	2.586
33.	Garganey	109.47 ± 115.31	1.878	97.72 ± 101.25	2.197
34.	Brown Headed Gull	7.83 ± 8.51	0.134	4.65 ± 5.14	0.104
35.	Palla's Gull	2.90 ± 3.05	0.049	1.97 ± 2.57	0.044
36.	Bar-headed Goose	385.29 ± 328.25	6.609	63.67 ± 200.66	1.431
37.	Graylag Goose	87.19 ± 85.82	1.495	95.70 ± 92.01	2.152
38.	Lesser White Fronted Goose	-	0	0.05 ± 0.17	0.001
39.	Comb Duck	6.90 ± 4.47	0.118	4.86 ± 3.17	0.109
40.	Common Sandpiper	6.73 ± 4.26	0.115	5.52 ± 4.51	0.124
41.	Little Ringed Plover	3.06 ± 3.24	0.052	1.49 ± 1.64	0.033
42.	Common Ringed Plover	1.95 ± 2.51	0.033	0.76 ± 1.16	0.017
43.	Indian River Tern	2.45 ± 2.57	0.031	1.95 ± 1.90	0.043
44.	Red-naped Ibis	13.75 ± 10.12	0.236	6.12 ± 4.86	0.137
45.	Painted Stork	5.75 ± 6.06	0.099	5.33 ± 5.69	0.119

Table 3: Species diversity indices in different seasons at Nangal Wetland

Indices	2013-14	2014-15
Taxa_S	43	45
Individuals	5804	4440
Simpson Index	0.8917	0.8748
Shannon-Wiener Index	2.683	2.606
Species Evenness	0.3403	0.301
Menhinick Index	0.5644	0.6753
Margalef Index	4.846	5.239

Conservation

Since water depth and trophic structure are key habitat characteristics affecting the abundance and diversity of aquatic birds in wetlands, appropriate and consistent management of wetlands could substantially enhance aquatic bird populations (Maheswaran & Rahmani, 2001; Mukherjee *et al.*, 2002; Farago & Hangya, 2012) [39, 46, 21]. Several investigations have demonstrated that efficient management is essential for improving habitat quality in wetlands used by waterbirds (Erwin, 2002; Balcombe *et al.*, 2005) [20, 6]. To conserve the lake ecosystem and its diverse biodiversity, a management strategy should be developed, providing opportunities for sustainable resource use while safeguarding its ecological values and functions (Ma *et al.*, 2010; D'Souza & Nagendra, 2011; Farago & Hangya, 2012) [41, 18, 21]. The initial measure towards conserving Nangal wetland was its designation as a Wildlife Sanctuary. Owing to strict sanctuary regulations, it can be safeguarded against different external pressures. This initiative can encourage greater migratory bird populations through catchment treatment, afforestation, habitat enhancement, water-depth regulation, and creation of shallow zones to establish roosting habitats for different bird species.

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