Journal of Biodiversity and Conservation Research

ISSN: xxxx-xxxx Vol. 1 (1), pp. 028-036, December, 2013. © Global Science Research Journals

Full Length Research Paper

Physico-chemical factors affecting the distribution of wetland birds of Barna Reservoir in Narmada Basin, Central India

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Accepted 26 September, 2013

The ecology of wetland birds of the Barna Reservoir was studied from March 2009 to February 2011. Species composition, diversity and abundance of birds were assessed. Sixty four (64) species of wetland birds were enumerated. Fourteen (14) environmental variables were correlated with the wetland birds species richness among which most of the variables were positively correlated with bird species richness except water depth, dissolved oxygen, total hardness and chloride. A strong correlation of bird species was noted with benthos density (r = 0.98). Bird species richness was also positively correlated with macrophytic biomass (r = 0.8), orthophosphate (r = 0.75), and conductivity (r = 0.64). It was observed that bird species richness had a strong negative correlation with water depth and dissolved oxygen.

Key words: Barna reservoir, wetland birds, environmental variables, macroinvertebrates, macrophytes.

INTRODUCTION

Birds are important components of our ecosystem and play a major role in maintaining the natural balance in the food chain in nature. There are several importance of birds as they act as browsers, pollinators and seed dispersers (Clout and Hay, 1989).

To study any ecosystem the birds serve as important component as they have the ability to fly away and avoid any obnoxious condition. Hence, they are considered as important health indicators of the ecological conditions and productivity of an ecosystem (Newton, 1995; Desai and Shanbhag, 2007). Birds also play an important role in wetland ecosystem. Wetlands are important especially for bird habitats. Birds use wetlands for breeding, nesting and teaching young, as a source of drinking water, for feeding, resting, shelter and for social interaction. Wetlands provide food for birds in the form of plants, vertebrates and invertebrates.

Some feeders forage for food in wetland soils. Some feed on water column, some feed on the vertebrates and invertebrates that live on submerged and emergent plants. Birds have daily and seasonal dependence on wetlands for food and other life supporting systems (Stewart, 2001).

Distribution and abundance of water birds was affected by several factors. Little change in physical, chemical or biological properties put forth intense effects on bird's habitats (Murphy et al., 1984). Any change in the physical, chemical and biological factors in the catchment exerts severe impact on the wetland as habitat for aquatic communities. These in turn affect the wetland dependent communities as well as the ecosystem attributes such as species richness, its distribution and density (Burkert et al., 2004). Ultimately, these changes alter the corresponding food web structures at the primary and secondary production levels (Wrona et al., 2006). Madhya Pradesh is having a number of small,

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medium and large water bodies (Sugunan, 1995) but very little is known about the avifaunal aspect of these water bodies. Vyas (1992) has initiated a survey on wetland birds of Upper Lake in relation to habitats available to migratory birds.

Vyas et al. (2010) worked on avian diversity of Bhoj wetland of Bhopal with seasonal variation. Recently Balapure et al. (2012) studied the wetland birds of Barna reservoir of Central India, but all these works are done based on spatial and seasonal census of the bird. No work has been done in Madhya Pradesh on the relationship between wetland avifauna and trophic status of the wetland.

No systematic and comprehensive report is available on the avifaunal diversity in any water body of Madhya Pradesh. To fulfill this research gap this study was chosen to conduct the surveys of avifauna and their relationship with wetland characteristics including limnological, macrophytes and macroinvertebrate during 2009-2011.

MATERIALS AND METHODS

Description of the study area

Barna is one of the major irrigation projects of Madhya Pradesh constructed by damming river Barna in Raisen district near Bari village. Barna sub-basin is a part of Narmada river system. The total length of Barna River is 105 km with a catchment area of 1789 km^2. Barna reservoir is located at latitude 22° 50' 23.5" N and longitude 77° 50' 78.20" E and falls in the toposheet number 55 I/4 of Survey of India (Map 1). This is located about 100 km from Bhopal. This reservoir is an important source of fish production in the area. Regular fish stoking is done in this reservoir every year. The water of the reservoir is mainly used for the fisheries and irrigation purpose. The reservoir supports a rich biodiversity and provide habitat for wildlife including migratory birds. A major part of the basin falls under Singhori Wild Life Sanctuary.

Description of the site

For the purpose of the bird study, the wetland was divided into three zones Viz- Zone-I, zone-II and Zone III. This categorization was based on the habitat available for birds. Zone-I comes under Jamner river basin situated at left bank of the reservoir. Maximum runoff of this basin is from Singhori Wildlife sanctuary. The majority area of this zone is with steep slope which creates minimum spread area. Zone II is the central zone of the reservoir which receives runoff from Barna River. This zone is with gentle slope and formed a scattered marshy land when water receded from this part. This area is heavy infested with macrophyte. Plants of seasonal occurrence seen during November to March are *Hydrilla verticillata*, *Vallisneria spiralis*, *Sagittaria sangitofolia*, *Ottelia alismoides*, *Najas graminae*, *Najas minor* and *Jussiaea repens*.

During post monsoon maximum area of this zone is used for paddy cultivation which serves as suitable habitat for wintering birds. Zone III which is on the right side comes under flat area. Some part of this area is used for paddy cultivation. Maximum portion of this area is mudflat. *Hydrilla* sp. and *Najas* sp. are the dominant macrophytes of this zone. Land digging and other human disturbances were noticed in this zone. Each zone is again divided into three subzones based on depth measured during initial survey. In zone-I, there were sites-1, 2 and 3, in zone II, sites-5, 6 and 7 and in zone III, there were sites-7, 8 and 9. Sites-1, 4 and 7 were the shallower part of the reservoir having a depth of 0-2 m, site-2, 5 and 8 with medium depth of 2-4 m and sites-3, 6 and 9 come under deeper part with 4-6 m.

Data collection and analysis

Study of avifaunal diversity of Barna wetland was conducted between March, 2009 and February, 2011. Seasonal observations were made during the study. The study period was divided into four seasons namely summer (March to May), monsoon (June to August), post monsoon (September to November) and winter (December to February). Birds were observed within the transect of 300 m in shoreline when watching from boat. Nikon Binoculars of 10 × 50 were used for observations. The field book of Ali and Ripley (1986), Ali (2002) were used to identify bird species. The checklist was prepared using the standardized common and scientific names of the birds of the Indian subcontinent by Manakkadan and Pittie (2001).

Measurement of hydrological variables

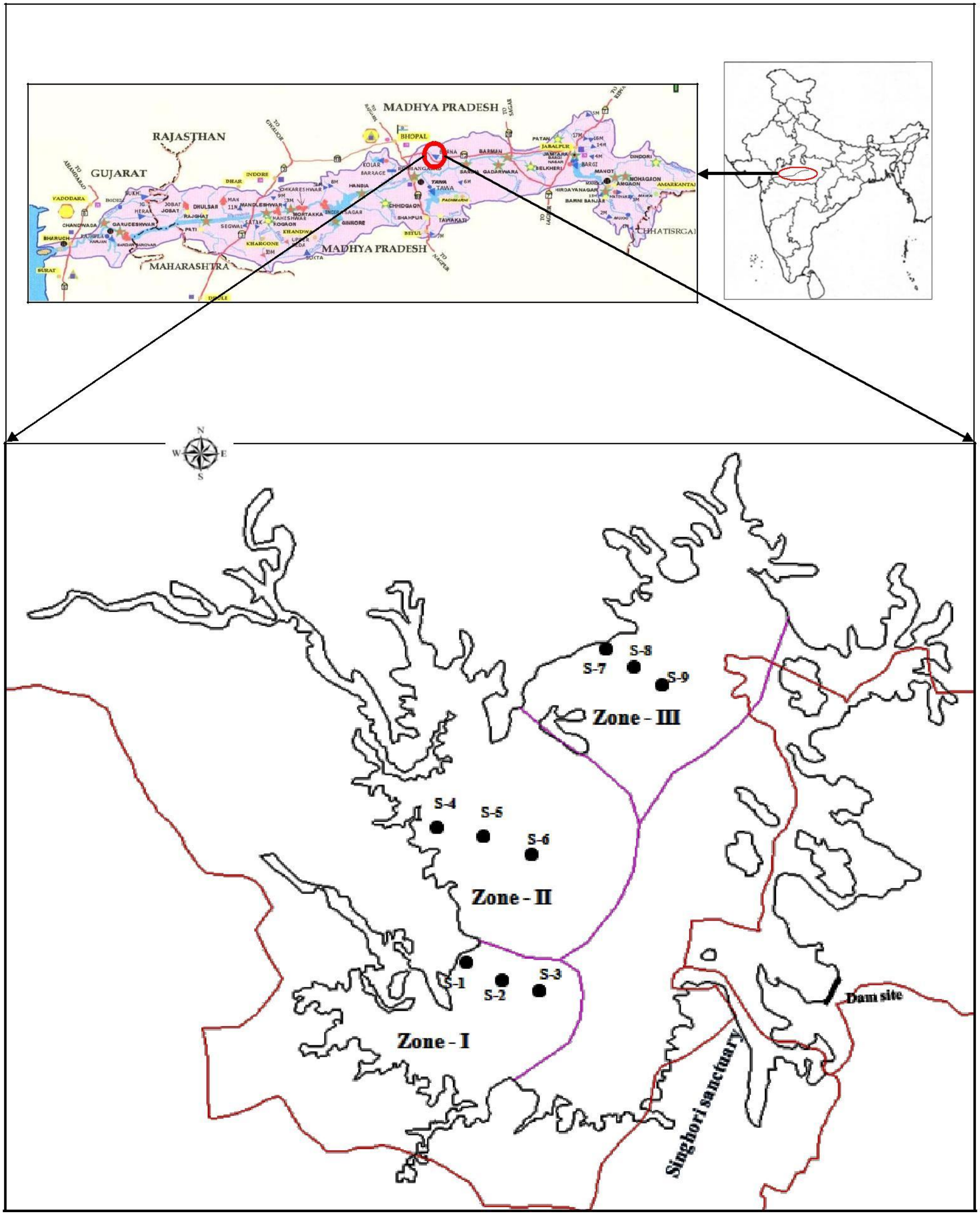
Water samples were collected from the surface of the reservoir for water chemistry. Thirteen physicochemical variables were investigated which directly or indirectly involved macrophytic and benthos growth which ultimately affect the bird population. Analytical techniques as described by standard methods for examination of water and waste water (APHA, 1998; Adoni et al., 1985).

Macroinvertebrate and macrophyte estimation

The benthic samples were collected with the help of Peterson grab, mud sampler. The collected samples were sieved through 2 and 0.5 mm mesh size sieve one after the other (Adoni 1985). The material which retained on sieve were sorted out with the help of forceps and brush and collected in narrow mouthed plastic bottle containing 5% formalin as preservative. Attached fauna from stones and macrophytes were also collected. Identification of all macrofaunal organisms was done with the help of Metzer binocular light microscope by using standard keys of Subba Rao and Dey (1989) and Needham and Needham (1962). Density of macro-inverte-brates was calculated as per Adoni et al. (1985). For collection of macrophytes, a wooden quadrate (50 x 50 cm) was placed at different sites in different habitats and the entire content of the specified area was uprooted. The collected material was washed thoroughly to get rid of adhering material. The extra water of the plants was soaked with the help of filter paper. Plants of each quadrate were separated species wise and fresh weight was noted after weighing them. The samples were transported to the laboratory in polythene bags and sorted out for identification and biomass estimation. Identification of macrophytes was done by using following keys and manuals by Cook (1996) and Biswas and Calder (1984). Biomass estimation was carried out according to Adoni et al. (1985). Correlation matrix and cluster analysis were carried out using software Paleontological Statistics (PAST) version 2.04 (Hammer et al., 2001) and biodiversity professional (McAleece et at., 1999) version.

RESULTS

A total of 64 water birds belonging to 7 orders and 12 families were recorded between March 2009 to February



Map 1. Map of Barna reservoir in Narmada basin of central India where study sites are located zone wise.

2011 (Table 1). Waterbirds counting was done by the Transect methods (Eberhardt, 1968) and point count methods (Ralph et al., 1995). The most dominating family was Anatidae contributing 16 species. Charadriidae formed the second dominant family with 10 species followed by Ardeidae, Rallidae, Laridae, Phalacrocoracedae, Ciconiidae, Threskiornithidae, Alcedinidae, Podicipedidae, Gruidae and Recurvirostridae. The most abundant family was Anatidae, having 53456 individuals which contributed 77.58% of the total bird population. *Anas acuta* (Northern Pintail) and *Anas crecca* (Common Teal) were the most abundant species of this family which formed 36.69% of the total Anatidae percentage.

During the present investigation it was noted that shallower sites (sites-1, 4 and 7) showed maximum bird species richness as compared to the other sites. A maximum of 47 water bird species were recorded from sites-4 followed by 45 wetland birds from site-7 Figure 2. These sites were characterized as shallower zones of the reservoir. Minimum water bird assemblage was noted at sites-8, 9 and 2.

Cluster analysis confirms the findings by making different clusters with similar characters. Den-drogram (Figure 3) is showing the similarity of sites based on the water birds among nine sites of Barna reservoir during two years study period. The arrangement of stations produced by sum-of-squares agglomeration depicts the two main groups, that is, group 1 formed by station 1, 4 and 7. A second group was formed by station 2, 3, 5, 6, 8 and 9 which forms sub groups, that is, 2, 5 and 8 and 3, 6 and 9 (Figure 1). Higher similarity was observed between Site 8 and 5 (84%), 3 and 2 (82%) and 7 and 1 (80%).

During the present study, 14 parameters were taken for correlation analysis between each other including depth, water temperature, conductivity, TDS, pH, D.O., total alka-linity, total hardness, chloride, ortho-phosphates, nitrate, benthos density, macrophytic biomass and bird spe-cies richness (Table 2). Water temperature, conductivity, TDS, total alkalinity, ortho-phosphates and nitrate nitro-gen were positively and significantly correlated with bird species richness where water depth, dissolved oxygen, total hardness and chloride were negatively correlated. The strong correlation of bird species was noted with benthos density

DISCUSSION

Among avian communities, the components of diversity are known to differ between locations and seasons (Kricher, 1972; Bethke and Nudds, 1993). Species richness showed higher ranges in shallower sites (Site-4 and 7) with macrophytic vegetation and lower in deeper zones. Maximum richness was noted at Site-4 having gentle slope and dense macrophytic vegetation. Nelson and Kadlec (1984) described the interactions occurring among macrophytes, macroinvertebrates and water birds in freshwater wetlands as a complex interdependency in which dynamic changes in the abundance and distributional pattern of macrophytes resulting from processes in litter decomposition and macroinvertebrate communities that, in turn, affect avifaunal abundance in water bodies. Species richness, bird abundance and diversity reach higher values in larger and structurally more heterogeneous wetlands (Gonzalez-Gajardo et al., 2009).

Dendrogram show similarity in the number of waterbird species among nine sites of Barna reservoir. Site 4, 7 and 1 which accounted for greater richness of waterbird species belong to one cluster being the marginal part of the reservoir, whereas the rest of the six sites are in the open water with less species richness.

Fluctuation in water level might alter the habitat characteristics that could cause prompt changes in fish, amphibians, invertebrates and waterbird communities (Johnson et al., 2007). In addition to limiting access to foraging habitats, water depth affects the net energy intake of waterbirds because foraging efficiency decreases with increasing water depth. Gawlik (2002) indicated that for wading birds that forage on prey in the water column, the locomotion of the birds might be slowed in deep water because of increased water resistance with depth.

At Barna reservoir, it was noted that temperature and bird richness was positively correlated. Maximum bird richness was noted during winter months with low temperature which was positively correlated. Deshkar et al. (2010) also supports our study. The average water pH was in a slightly alkaline range (7.2-9.2) at our study site during the entire study period.

Longcore et al. (2006) reported that a water pH in the alkaline range supported higher macro-invertebrates and thereby attracted more ducks to the water bodies. Minns (1989) considered pH as an indicator of overall productivity that can cause habitat diversity. He established a significant correlation of pH with species richness of phytoplankton, invertebrates, fishes, amphi-bians and the water birds, which depend on these organisms.

According to Tutle et al. (1984) waterfowl abundance was affected by nitrogen and phosphate fluctuations of water bodies. During the present investigation avifaunal rich-ness showed a positive relationship with nitrate and phos-phate in Barna reservoir.

Hoyer et al. (1994) found a close correlation between the density of aquatic birds and the ortophosphate-phosphorus concentration in the water. According to Pip (1979) alkalinity, pH, dissolved organic matter, nitrogen, phosphorous, chloride, and sulfate all affect macrophyte species distribution.

A linear relation-ship between species richness of bird communities with habitat condition, chloride, total phosphorus, temperature, total nitrogen, ortho-phosphate and nitrate was found by Getachew et al. (2012) in Cheffa wetland.

Table 1. List of birds recorded in Barna reservoir during March 2009 - February 2011

S/N	Common name	Scientific name
	Grebes	
1	Little Grebes	*Tachybaptus ruficollis*
2	Great Crusted Grebes	*Podiceps cristatus*
	Cormorants	
3	Great Cormorant	*Phalacrocorax carbo*
4	Indian Shag	*Phalacrocorax fuscicollis*
5	Little Cormorant	*Phalacrocorax niger*
6	Darter	*Anhinga melanogaster*
	Egrets and Herons	
7	Large Egret	*Casmerodius albus*
8	Little Egret	*Egretta garzetta*
9	Median Egret	*Mesophoyx intermedia*
10	Cattle Egret	*Bubulcus ibis*
11	Grey Heron	*Ardea cinerea*
12	Purple Heron	*Ardea purpurea*
13	Little Green Heron	*Butorides striatus*
14	Black-Crowned Night-Heron	*Nycticorax nycticorax*
15	Indian Pond Heron	*Ardeola grayii*
	Storks	
16	Painted Stork	*Mycteria leucocephala*
17	Asian Openbilled Stork	*Anastomus oscitans*
18	Black-necked Stork	*Ephippiorhynchus asiaticus*
19	White-Necked Stork	*Ciconia episcopus*
	Ibis and Spoonbill	
20	Black Ibis	*Pseudibis papillosa*
21	Oriental White Ibis	*Threskiornis melanocephalus*
22	Eurasian Spoonbill	*Platalea leucorodia*
	Ducks	
23	Greyleg Goose	*Anser anser*
24	Barheaded Goose	*Anser indicus*
25	Brahminy Shelduck	*Tadorna ferruginea*
26	Common Shelduck	*Tadorna tadorna*
27	Comb Duck	*Sarkidiornis melanotos*
28	Lesser Whistling -Duck	*Dendrocygna javanica*
29	Northern Pintail	*Anas acuta*
30	Common Teal	*Anas crecca*
31	Spottbill Duck	*Anas poecilorhyncha*
31	Gadwall	*Anas strepera*
33	Eurasian Wigeon	*Anas penelope*
34	Northern Shoveler	*Anas clypeata*
35	Red Carested Pochard	*Rhodonessa rufina*
36	Common Pochard	*Aythya ferina*
37	Tufted Pochard	*Aythya fuligula*
38	Cotton Teal	*Nettapus coromandelianus*

Table 1 Contd.

	Cranes	
39	Common Crane	*Grus grus*
40	Sarus Crane	*Grus antigone*
	Rails and Coots	
41	Whitebreasted Waterhen	*Amaurornis phoenicurus*
42	Watercock	*Gallicrex cinerea*
43	Common Moorhen	*Gallinula chloropus*
44	Purple Moorhen	*Porphyrio porphyrio*
45	Common Coot	*Fulica atra*
	Waders	
46	Black-winged Stilt	*Himantopus himantopus*
47	Red-wattled Lapwing	*Vanellus indicus*
48	River Lapwing	*Vanellus duvaucelii*
49	Little Ringed Plover	*Charadrius dubius*
50	Kentish Plover	*Charadrius alexandrinus*
51	Marsh Sandpiper	*Tringa stagnatilis*
52	Wood Sandpiper	*Tringa glareola*
53	Common Sandpiper	*Actitis hypoleucos*
54	Curlew Sandpiper	*Calidris ferruginea*
55	Little Stint	*Calidris minutus*
56	Dunlin	*Calidris alpina*
	Gulls and Terns	
57	Brown-headed Gull	*Larus brunnicephalus*
58	Yellow-Legged Gull	*Larus cachinnans*
59	Common Tern	*sterna hirundo*
60	River Tern	*Sterna aurantia*
61	Little Tearn	*Sterna albifrons*
	Partially dependent waterbirds	
62	Whitebrested Kingfisher	*Halcyon smyrnensis*
63	Small Blue Kingfisher	*Alcedo atthis*
64	Lesser Pied Kingfisher	*Ceryle rudis*

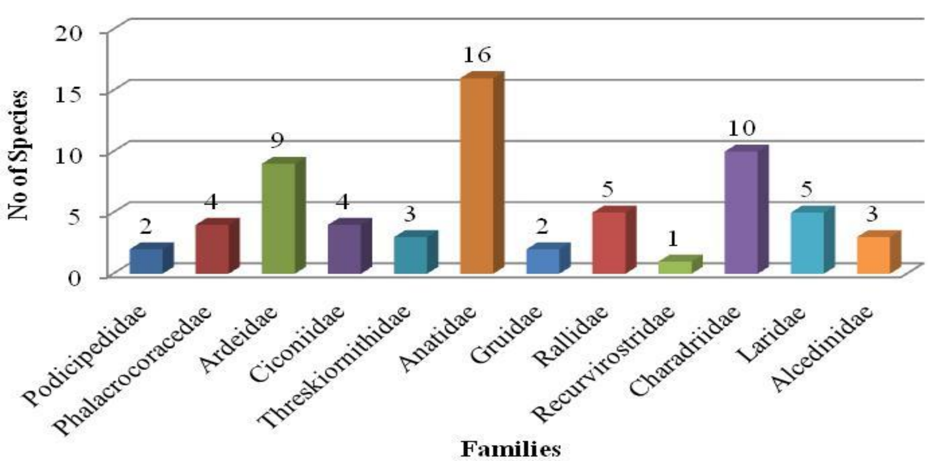


Figure 1. Family wise species composition of water birds in Barna reservoir.

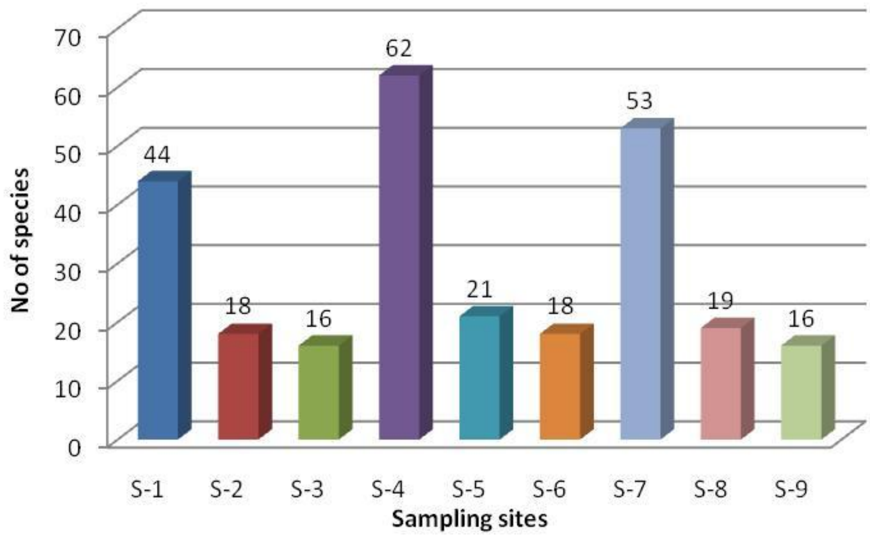


Figure 2. Spatial variation in species richness of wetland birds in Barna reservoir.

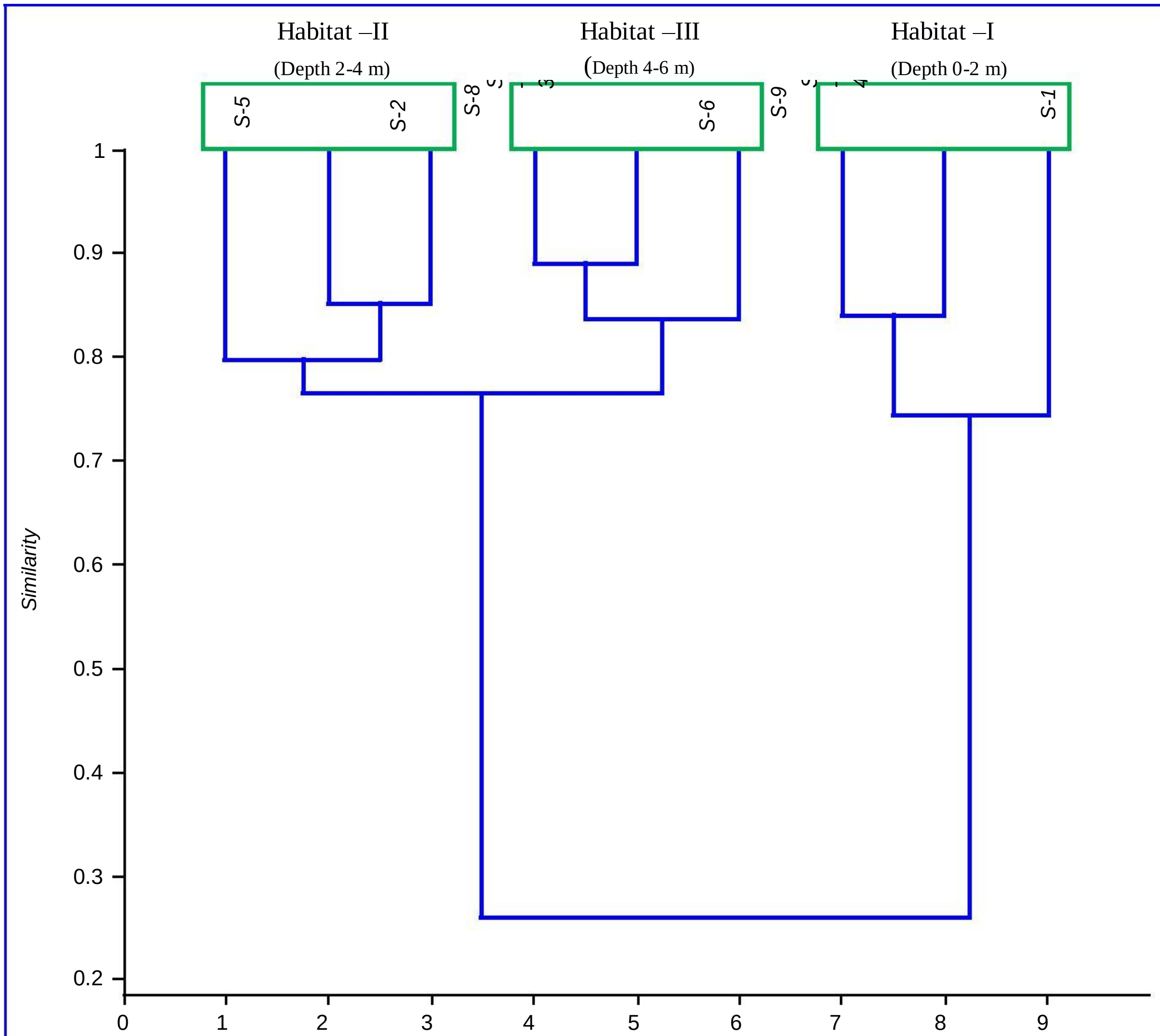


Figure 3. Dendrogram showing Jaccard's similarities between selected sampling sites in Barna reservoir.

Table 2. Correlation matrix for physico-chemical parameters, macrophyte biomass, benthos density and richness of water birds.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1	*	*	*	*	*	*	*	*	*	*	*	*	*
2	0.15	1.00	*	*	*	*	*	*	*	*	*	*	*	*
3	-0.41	-0.10	1.00	*	*	*	*	*	*	*	*	*	*	*
4	-0.23	0.42	0.75	1.00	*	*	*	*	*	*	*	*	*	*
5	-0.20	0.16	0.64	0.90	1.00	*	*	*	*	*	*	*	*	*
6	0.78	-0.18	-0.04	-0.06	0.10	1.00	*	*	*	*	*	*	*	*
7	-0.21	0.22	0.76	0.74	0.65	0.20	1.00	*	*	*	*	*	*	*
8	0.20	0.47	0.07	0.30	0.15	-0.01	0.01	1.00	*	*	*	*	*	*
9	-0.10	0.47	0.20	0.40	0.32	0.04	0.54	0.41	1.00	*	*	*	*	*
10	-0.01	-0.03	0.14	0.17	0.31	0.28	0.10	-0.12	-0.04	1.00	*	*	*	*
11	-0.18	-0.18	0.73	0.35	0.28	0.29	0.70	0.19	0.27	0.25	1.00	*	*	*
12	-0.86	0.11	0.59	0.59	0.51	-0.67	0.49	-0.21	0.10	-0.02	0.18	1.00	*	*
13	-0.70	0.33	0.75	0.82	0.66	-0.53	0.60	0.23	0.38	0.12	0.37	0.85	1.00	*
14	-0.87	0.01	0.64	0.51	0.45	-0.73	0.32	-0.22	-0.07	0.75	0.08	0.98	0.80	1.00

1, Depth (m); 2, water temperature (°C); 3, conductivity (µs/cm); 4, TDS (mg/l); 5, pH; 6, D.O, (mg/l); 7, total alkalinity (mg/l); 8, total hardness (mg/l); 9, chlorides (mg/l); 10, ortho-phosphates (mg/l); 11, nitrate nitrogen (mg/l); 12, benthos density 13, macrophytic biomass; 14, bird richness.

Birds often have correlation with their habitats (Seymour and Simmons, 2008) and have also been used as surrogates for assessing the impact of habitat changes (Yang et al., 2008). Water bird species richness showed strong positive correlation with macrophyte biomass and benthos density in Barna reservoir. A suite of characteristics reflecting higher trophic status, from water quality to inver-tebrate and macrophytic biomass, were correlated with the avifaunal density (Staicer et al., 1994).

Total avi-faunal density has been related positively ($P < 0.05$) with total macrophytic biomass in Santragachi Jheel (Patra et al., 2010). Aquatic macrophytes are important to bird populations that use water bodies and the management of aquatic macrophytes has the potential to affect bird populations.

Nelson and Kadlec (1984) described the interactions occurring among macrophytes, macroinverte-brates and water birds in freshwater wetlands as a complex inter-dependency in which dynamic changes in the abundance and distributional pattern of macrophytes resulting from processes in litter decomposition and macro-invertebrate communities that, in turn, affect avifaunal abundance in water bodies. Well vegetated wetlands seem attractive to wetland bird species (Weins, 1997).

Conclusion

The congregation of large numbers of waterbird species at Barna reservoir for feeding, resting and roosting, is due to the abundance of food (macrophytes, macrobenthic organisms, and free swimming organisms inclusive of fish), accessibility to food resources due to the shallowness in winters, availability of exposed mudflats and shorelines for roosting in an area well protected from human and other disturbances and presence of submerged as well as emergent vegetation patches. Macrophyte diversity is higher in zones II and III than zone I as zones II and III were both having gentle slope which creates maximum mudflat area for the growth of macrophyes.

The different vegetation zones of the Barna reservoir include exclusive zones of individual species such as *Hydrilla verticillata, Cyperus articulatus, Najas minor*, *Vallisneria spiralis* as well as the mixeture of these species at different proportions. Based on the correlation, it was noted that the strong correlation of bird species was noted with benthos density in all zones.

Barna reservoir supports vulnerable endangered and near threatened species of fishes and birds. It supports one vulnerable bird Sarus crane and four near threatened bird, that is, species Darter, Painted stork, Black necked stork and Oriental white Ibis were also found here. So, attention of the concerned agencies is very much needed for the conservation as well as sustainable use of the reservoir.

ACKNOWLEDGEMENTS

Authors are thankful to Dr. Pradeep Shrivastava, Professor, Department of Environmental Science and Limnology, Barkatullah University, Bhopal for his support during the study period by providing laboratory facility. We are thankful to the local people of Bari village who helped during field visits. We are also grateful to the M. P. Fisheries Federation, Bhopal for the boat facility.

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