Фауна і населення	Беркут	19	Вип. 1-2	2010	49 - 59

SPATIAL AND TEMPORAL PATTERNS OF WATERBIRD ABUNDANCE AND SPECIES RICHNESS IN A SEWAGE FED WETLAND, KHODIYAR, GUJARAT, INDIA

J.I. Nirmal Kumar, Manishita Das, Rita N. Kumar, Yamini Verma

Abstract. The structure, composition and abundance pattern of species of waterbird assemblages in sewage fed wetlands has been poorly documented. The study explored censuses of twelve month from January to December, 2008. Overall, 71 waterbird species belonging to 48 genera and 15 families were registered, including 38 species year-round residents and 33 migratory species. Among these, 9 species were considered to be abundant, 38 species common and 24 species rare. The number of species varied among sites and showed seasonal pattern. Abundances were good in number during the winter period due to increased abundance of Anseriformes, Gruiformes and Ciconiiformes. Overall waterbird density was highest where resident species such as Greater Flamingo, Little Egret, Glossy Ibis and Black-winged Stilt were present; some migratory species such as Garganey, Northern Shoveler, Common Coot, Black-tailed Godwit and Ruff contributed to areas with high density during cooler days. The monthly data were pooled to compare various indices of species diversity, i.e. Shannon–Weaver (H'), Evenness (Hill's) Index and Simpson's Index. The Shannon–Weaver (H') varied from 1.813 to 1.531, Evenness (Hill's) Index from 34 to 65 and Simpson's Index from 0.038 to 0.069. The local abundance and composition of waterbird assemblages seemed to be affected by the interplay of several environmental factors.

Key words: fauna, community, number, wetland.

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Пространственные и временные особенности обилия водных птиц и видового богатства на отстойнике Ходияр (Гуджарат, Индия). - Й.И. Нирмал Кумар, М. Дас, Р.Н. Кумар, Я. Верма. - Беркут. 19 (1-2). 2010. - Водно-болотное угодье Ходияр находится возле г. Ананд в центральной части штата Гуджарат. Водоем заполняется муниципальными сточными водами двух городов. Исследования проводились на 3 участках с января по декабрь 2008 г. Птиц учитывали ежемесячно на утренней кормежке – от рассвета до 9^{00}. Всего было зарегистрировано 71 вид гидрофильных птиц. 38 из них встречаются на протяжении всего года, 33 – мигранты. 9 видов были многочисленными, 38 – обычными, 24 – редкими. Количество видов колебалось по участкам и сезонам. Наибольшее обилие птиц отмечалось в зимние месяцы, когда прилетали зимующие виды.

INTRODUCTION

Wetlands represent highly complex environments, and constitute sites where numerous bird species concentrate and have some of the highest biodiversity and biological productivity levels in the world and several globally threatened avian species depend on them (Paracuellos, Telleria, 2004). Waterbirds comprise a large group of species including Anseriformes, Charadriiformes, Ciconiiformes, Gaviiformes, Gruiformes, Pelecaniformes, Podicipediformes and Procellariformes (Nirmal Kumar et al., 2007; Bolduc, Afton, 2008). Waterbird communities experience seasonal and annual fluctuations in abundance and species composition, on a local, as well as on a regional scale (Romano et al., 2005). Variations in bird abundance result from population processes (i.e. birth and death rates), as well as migration among habitats (Poulin et al., 1993). Bird abundance at a local scale depends on morphometric characteristics, availability, distribution and density of food, and the availability of suitable sites for roosting or resting (Wiens, 1989). Moreover, variations in habitat conditions may also produce changes in community species composition (Caziani et al., 2001). The community of waterbirds in sewage ponds has not been documented; where nutrients might be limiting sewage fed environments usually belong to either the eutrophic or hypertrophic categories (Hamilton et al., 2005). Waterbird abundance generally responds to processes of nutrient increases (or decreases) in inland waters (Noordhuis et

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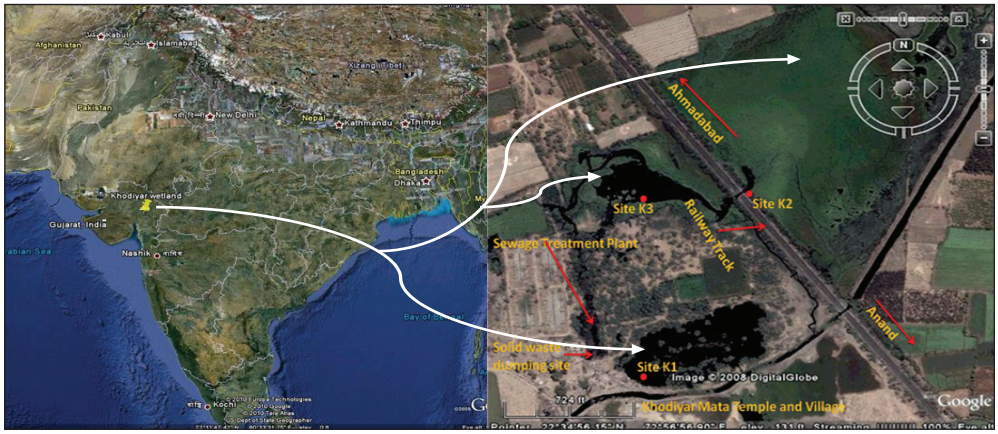

Fig. 1. Map of Khodiyar wetland along with the sampling stations (Courtesy Google Earth).
Рис. 1. Район исследований.

al., 2002), for example some wintering waterbird species respond positively to nutrient inputs during a period of lake eutrophication (Martínez et al., 2005). Therefore, this study highlights spatial and temporal changes in the abundance and distribution of waterbirds, in the sewage fed wetland, Khodiyar, Gujarat, India, from January to December 2008.

MATERIAL AND METHODS

Study Area

Khodiyar wetland is located between 22° 34′ 56.15′′ N latitude and 72° 56′ 56.90′′ E longitude and situated 5 km away from Anand, Central Gujarat (Fig. 1). The wetland is fully down pour of sewage water received from Municipal sewage lines of Vallabh Vidya nagar and Anand Town, so called 'sewage fed wetland'. The sewage fed wetland gains its importance due to the presence of seventy species of waterfowls, especially during cooler months of the year. The acute pressures affecting the bird folk are a railway line which passes in between the wetland, cattle interferences, irrigation, soil excavation and poaching by local folk. Even municipal's solid wastes are dumped here at some extent.

The macrophyte species mainly dominating is *Eichhornia crassipes*, besides, *Alternanthera philoxeoides, Ipomoea aquatica* and *Azolla pinnata* invade the open water areas admist *Eichhornia crassipes*. A small area on the margins is covered by *Typha angustata* and *Ipomoea convolulus.* Terrestrial vegetation like *Prosopis juliflora, Acacia* spp. and *Zizyphus jojoba* are found on the banks of Khodiyar. The vegetation provide the nesting and hatching grounds to many avian species.

This wetland experiences semi arid climate. The summer season started from March and continued till the onset of the western monsoon, and arrived in the third-fourth week of the June. The monsoon season lasted till mid September followed the winter months from November till February. Three sites have been earmarked for the present study.

Study site 1 (K1). This site (Fig. 2) is located near to Khodiyar village with a depth of 7–8 feet, which is highest amongst three study sites. The macrophyte species mainly dominating is *Eichhornia crassipes.* The avian fauna includes Egrets, Jacanas, Ibises, Black-winged Stilts (*Himantopus himantopus*), Purple Swamphens (*Porphyrio porphyrio*) and Herons but density and diversity is poor as compared to other two sites.

Study site 2 (K2). The site (Fig. 3) is located on one side of the railway track. The water depth is lowest (1 to 4 feet). The dominant plant species at this site is *Eichhornia crassipes,* while a small area is covered by

Fig. 2. Study site K1 with waterbirds. Рис. 2. Участок К1 с гидрофильными птицами.

Typha angustata and *Ipomoea aquatica, I. convolulus* on the margins. *Typha angustata* and *I. convolvulus* provide the nesting and hatching grounds to many aquatic avian species. The site is dominated by Flamingos, Egrets, Sarus Cranes (*Grus antigone*), Stilts, Ibises, Jacanas, Herons and many winter visitors like Spoonbills (*Platalea leucorodia*), Garganeys (*Anas querquedula*), Northern Shovelers (*A. clypeata*), Pintails (*A. acuta*), Common Coots (*Fulica atra*), Ruffs (*Philomachus pugnax*), Graylag Goose (*Anser anser*), etc.

Study site 3 (K3). The water depth of this site (Fig. 4) is shallow (1 to 6 feet). The floral species dominating the site is *Eichhornia crassipes* while *Typha angustata* and *I. convolvulus* provide the nesting and hatching grounds to many aquatic avian species. The site is dominated by Flamingos, Sarus Cranes, Egrets, Stilts, Ibis, Ruddy Shelduck (*Tadorna ferruginea*), Purple Swamphens, Herons and many winter visitors like Spoonbills, Garganeys, Shovelers, Coots, Ruddy Shelduck, Ruffs, Pintails, Common Teals (*Anas crecca*), etc.

Waterbird Survey

The enumeration of waterbird abundance and species composition was carried out on monthly basis from January to December 2008. Waterbirds' abundance was calculated during the morning feeding between sunrise and 9^{00} by point count method (Rogers, Breen, 1990). In each census, all birds present at three sites were counted separately and identified to species level using binoculars, (Romano et al., 2005) and species compositions observed were identified with the help of standard literature by Ali (1996), Kazmierczak and Perlo (2000) and Grimett et al. (1999).

Indices

The 12-months of data were pooled to compare various indices of species diversity, Rarefaction and Abundance plot, Species

Fig. 3. Study site K2 with waterbirds. Рис. 3. Участок К2 с гидрофильными птицами.

Fig. 4. Study site K3 with waterbirds and a passing train.
Рис. 4. Участок К3 с гидрофильными птицами, виден проходящий поезд.

Diversity/Species Richness Indices: Shannon–Weaver (H') (1963), and Evenness Index (Hill 1973) index and Dominance (Simpson's Index) (1949), as per the BD pro software. Total bird count recorded with less than 100 individuals during survey were categorized rare; between 100 to 500 individuals as common and that recorded more than 500 individuals were assigned abundant status (GEER, 1998).

RESULTS

24,032 individuals of 71 waterbird species, belonging to 48 genera and 15 families, were recorded in 12 census, carried out on monthly basis. Out of these, 38 (53.5%) species accounted for year-round residents and 33 species (46.5%) are migratory. Species occurrence varied month after month and site by site with K1, being the site with the lowest species richness. Whereas, K2 and K3, species richness was higher especially during the winter, with the inflow of migratory birds.

The most representative families noted were Anatidae with 14 species, Scolopacidae (10 species), Ardeidae (9), Charadriidae (7), Laridae (5), Threskionithidae and Rallidae (4 species each). Nine abundant species encountered and contributed 12.7% which includes resident waterbirds such as Greater Flamingo (*Phoenicopterus ruber*), Little Egret (*Egretta garzetta*), Glossy Ibis (*Plegaldis falcinellus*) and Black-winged Stilt and migratory birds such as Garganey, Northern Shoveler, Common Coot (*Fulica atra*), Black-tailed Godwit (*Limosa limosa*) and Ruff. 38 species (53.5%) of common birds were observed, while 24 species (33.8%) were found to be rare (Table).

Community composition varied in response to change in season and climatic variations. Abundances were higher in wintering period due to increased species of Gruiformes, Anseriformes and Ciconiiformes. The maximum number (100%) of families was recorded during summer and winter, followed by 73.3% during the monsoon period. On the basis of genus, the maximum number (100%) occurred during winter, followed by summer (85.4%) and monsoon (54.2%). Numbers of water birds species was greater in winter (94.5%), followed by summer (72.%) and monsoon (53.2%). Migratory species made their greatest contribution during winter. All species considered to be abundant were documented during winter and summer (100% each), followed by 44.4% during monsoon, while peak values of species of common occurrence occurred during winter (98.0%), and followed by summer (96.1%) and monsoon (78.4%). Among rare species, 90.0% were documented during winter, followed by summer (44.0%) and monsoon (22.0%). Overall, water birds were most abundant during winter (58.5%), followed by summer (32.8%) and monsoon (8.3%). The abundance of water birds recorded at Khodiyar wetland during different seasons largely corresponded to their density. The density of water birds was maximum during

Waterbirds found during study period at Khodiyar wetland
Гидрофильные птицы, зарегистрированные в Ходияре

Species	MS	PS	Overall number (ind.)		
			K1	K2	K3
1	2	3	4	5	6
Podiceps cristatus	2	R	–	–	5
Tachybaptus ruficollis	1	C	186	126	170
Phalacrocorax carbo	1	R	20	32	41
Ph. fuscicollis	1	C	48	79	107
Ph. niger	1	C	111	133	158
Ardea cinerea	1	C	45	29	60
A. purpurea	1	C	42	28	57
Ardeola grayii	1	C	65	72	95
Butorides srtiatus	1	R	–	3	5
Nycticorax nycticorax	1	R	–	7	12
Bubulcus ibis	1	C	147	119	161
Casmerodius albus	1	C	60	40	73
Egretta garzetta	1	A	299	208	380
Mesophoyx intermedia	1	C	152	121	205
Anastomus oscitans	1	C	–	65	36
Ciconia episcopus	1	R	–	14	4
Mycteria leucocephala	1	C	–	39	71
Pseudibis papillosa	1	C	65	43	92
Plegadis falcinellus	1	A	300	216	355
Threskiornis melanocephalus	1	C	116	94	161
Platalea leucorodia	1	C	–	66	35
Phoenicopterus ruber	1	A	–	299	510
Anser anser	2	C	–	265	160
Dendrocygna javanica	1	C	–	303	196
Tadorna ferruginea	2	C	–	55	135
Sarkidiornis melantos	1	C	–	190	308
Anas strepera	2	C	–	160	330
A. penelope	2	C	–	71	43
A. crecca	2	C	84	126	182
A. querquedula	2	A	170	460	780
A. acuta	2	C	40	160	300
A. clypeata	2	A	170	460	950
A. poecilorhyncha	1	C	–	41	95
Aythya ferina	2	C	–	45	115
A. fuligula	2	R	–	14	–
Nettapus coromandelianus	1	C	38	62	124
Grus antigone	1	R	–	14	22
Amaurornis phoenicurus	1	C	155	41	79
Gallinula chloropus	1	C	74	36	49

End of the Table Окончание таблицы

1	2	3	4	5	6
Porphyrio porphyrio	1	C	243	92	159
Fulica atra	2	A	170	440	660
Hydrophasianus chirurgus	1	C	74	25	43
Metopidius indicus	1	C	80	43	29
Vanellus indicus	1	C	141	73	105
V. leucurus	2	R	–	4	15
V. malarbaricus	1	R	–	18	10
Charadrius alexandrinus	2	R	–	3	–
Ch. dubius	2	C	13	36	61
Himantopus himantopus	1	A	1050	670	860
Recurvirostra avosetta	2	R	–	–	2
Gallinago gallinago	2	C	78	250	170
G. stenura	2	R	–	–	9
Rostratula benghalensis	1	R	–	–	6
Actitis hypoleucos	2	C	119	212	168
Tringa glareola	2	C	58	82	149
T. stagnatilis	2	R	–	–	18
T. ochropus	2	R	–	–	20
T. erythropus	2	C	103	157	240
T. nebularia	2	R	–	10	–
T. totanus	2	R	–	–	20
Limosa limosa	2	A	260	470	750
Calidris minuta	2	C	100	230	170
Philomachus pugnax	2	A	490	330	780
Chlidonias hybridus	2	R	–	12	–
Gelochelidon nilotica	2	R	–	–	5
Sterna acuticauda	1	R	–	11	6
S. aurantia	1	R	–	16	7
S. albifrons	1	R	–	–	6
Motacilla alba	2	R	–	9	–
M. citreola	2	R	–	13	–
M. flava	2	R	–	17	30

Migratory status (MS): 1 – resident species, 2 – migratory species;
population status (PS): A – abundant, C – common, R – rare.

winter (69.7%), followed by summer (52.0%) and monsoon (15.6%). Similar observations were made by Romano et al. (2005) in Melincue Lake, Argentina, while studying the seasonal and interannual variation in waterbird abundance and species richness.

The species richness was greater at K3 followed by K2 and K1, as shown by the rarefaction plot (Fig. 5). At site K1, 34 species were identified belonging to 10 families where as site K2 sheltered 62 species and a total of 65 species, belonging to 15 families were documented at study site K3. However the maximum abundance was observed at

study site K3, followed by K1 and K2, (Fig. 6). The water bird populations of Khodiyar wetland fluctuated among sites in different seasons due to local, environmentally dependent factors (Nirmal Kumar et al., 2007). The concentrations of wintering waterfowls were more pronounced at K2 and K3, as compared to K1.

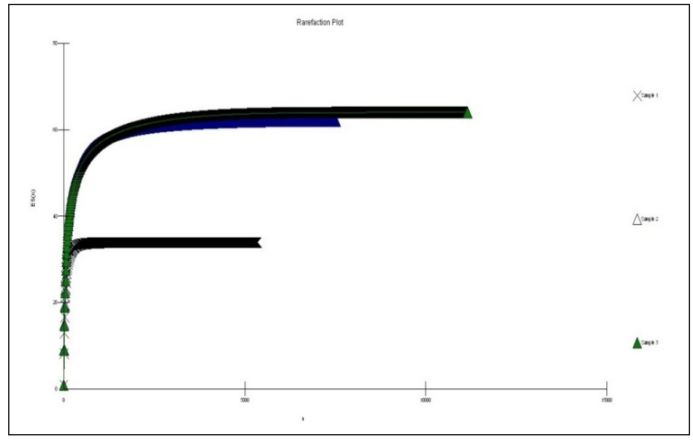

Fig. 5. Rarefaction curves for total species richness for three study sites in Khodiyar wetland.
Рис. 5. Кривые разрежения для видового богатства трех участков в Ходияре.

A total of 34 species belonging to 10 families were identified at K1. The most common was Ardeidae, with seven species. At K2, 61 species were identified, belonging to 15 families. The family rich represented was Anatidae, with 13 species. Northern Shoveler and Garganey were observed on the entire wetland surface as common species, whereas Ruddy Shelduck and Tufted Duck (*Aythya fuligula*) were sighted only in the central part of the wetland. The rest of the species were found on both the central vegetation and the wetland shores. The study site K3 sheltered sixty six species. Avocet (*Recurvirostra avosetta*) was exclusive to this site; which was sighted only twice as transient individual on its way back to north, (Severo et al., 2002). It is worth noting that one of the species Sarus Crane found at both K2 and K3 has a vulnerable status listed in IUCN Red List, 2007 besides White Ibis (*Threskiornis melanocephalus*) a near threatened species as per IUCN Red List, observed in aplenty at this wetland. The spatial and temporal variations of some of the abundant, common, rare and very rare waterbirds have been shown in Figures 7–10.

The various diversity indices for waterfowls are shown in Figure 11. The higher value for Shannon's index was observed at K2 (1.546) followed by K3 (1.524) and K1 (1.353), similar trend was observed for Hill's index (Hill's Number H1) which had a maximum value (244.93) at K2, followed by (227.61) K3, and minimum value (128.97) at K1. It was noticed for Hill's index (Hill's

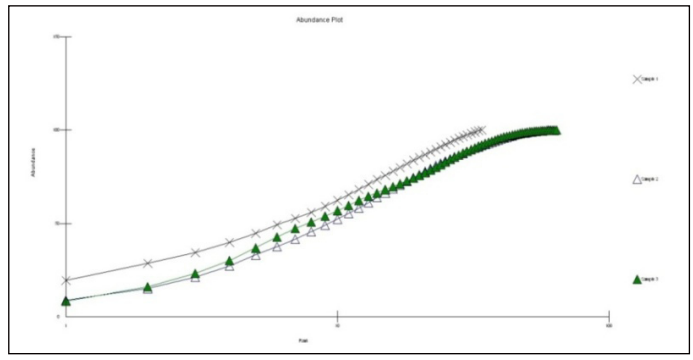

Fig. 6. Abundance plots indicating site wise species richness for Khodiyar wetland.
Рис. 6. Диаграммы обилия для для видового богатства на трех участках в Ходияре.

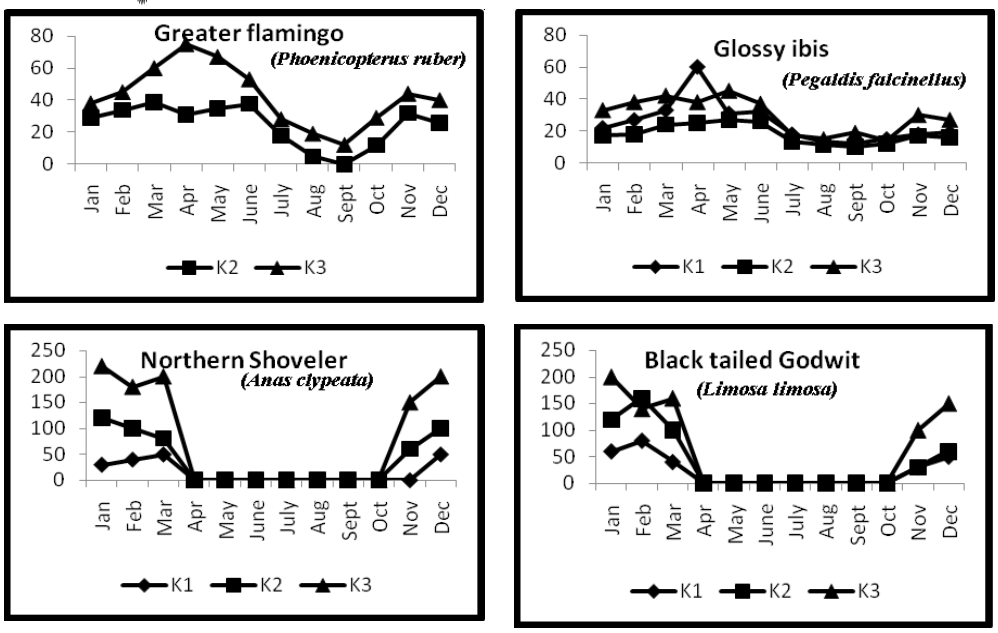

Fig. 7. Spatial and temporal variations of numbers of abundant waterbirds in Khodiyar wetland.
Рис. 7. Динамика численности многочисленных видов птиц на трех участках.

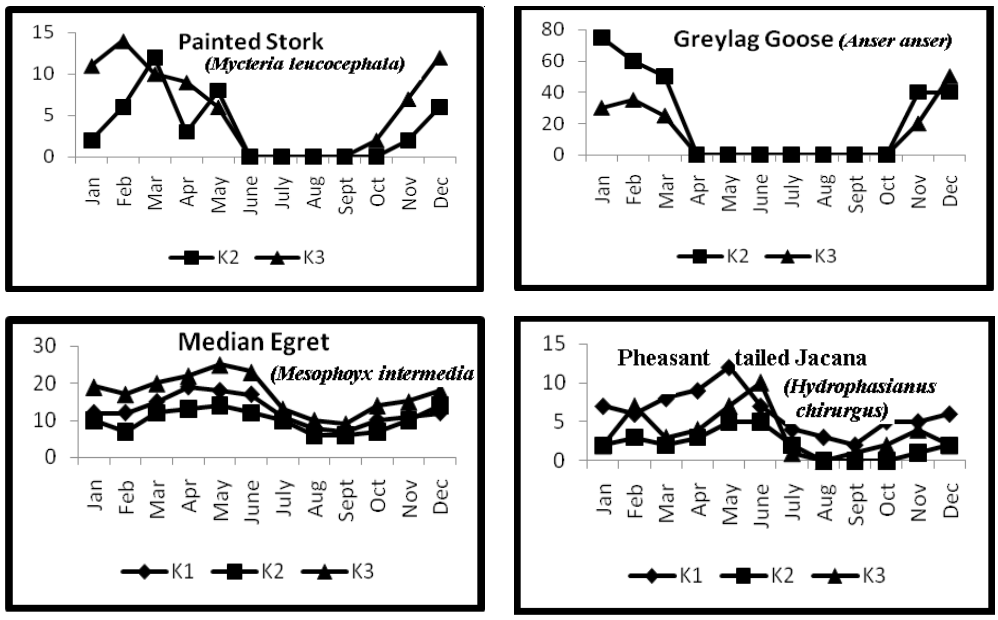

Fig. 8. Spatial and temporal variations of numbers of common waterbirds in Khodiyar wetland.
Рис. 8. Динамика численности обычных видов птиц на трех участках.

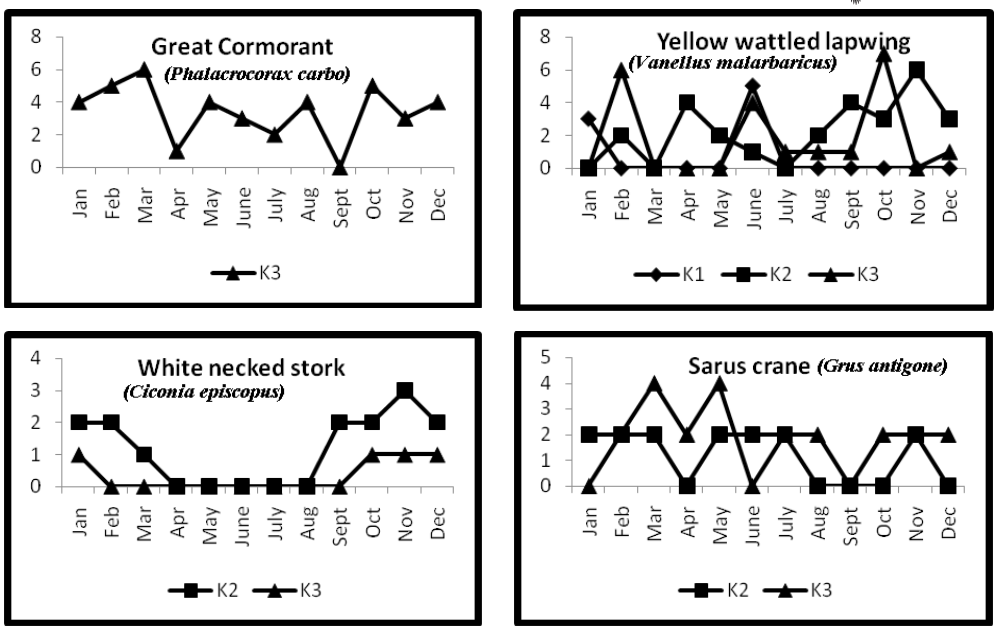

Fig. 9. Spatial and temporal variations of numbers of rare waterbirds in Khodiyar wetland.
Рис. 9. Динамика численности редких видов птиц на трех участках.

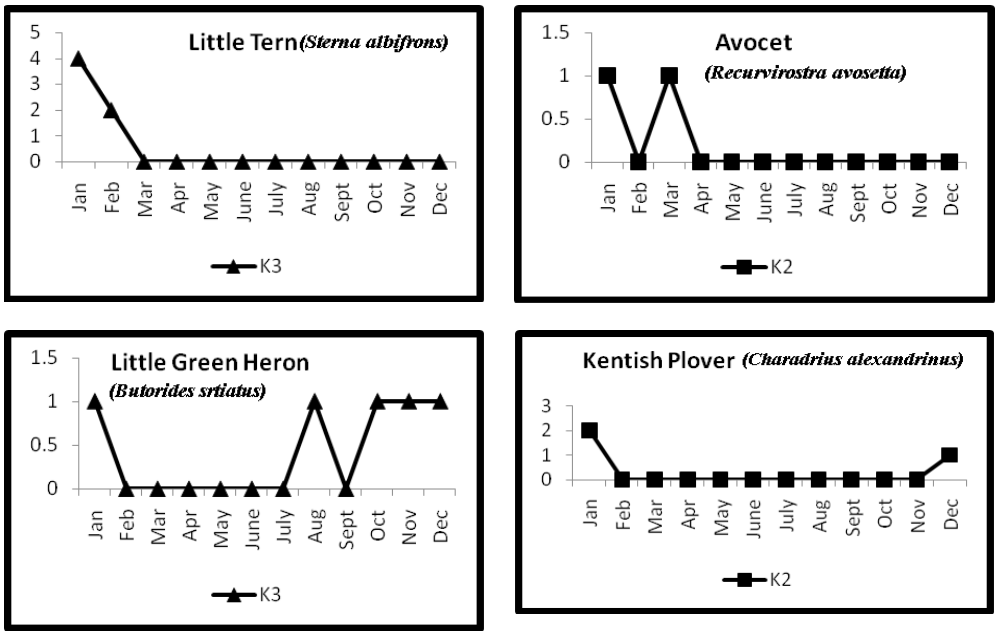

Fig. 10. Spatial and temporal variations of numbers of very rare waterbirds in Khodiyar wetland.
Рис. 10. Динамика численности очень редких видов птиц на трех участках.

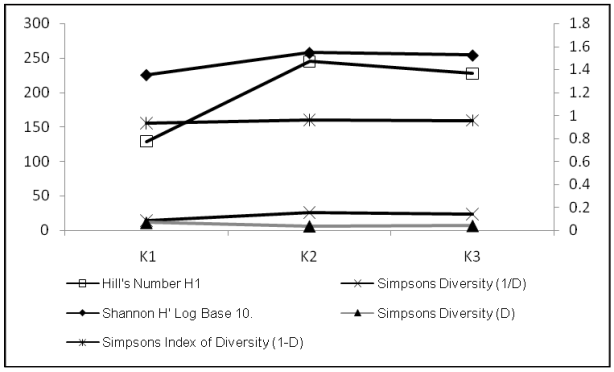

Fig. 11. The variation in site-specific diversity indices among sites at Khodiyar wetland.
Рис. 11. Динамика индексов разнообразия.

Number H0) that K2 (61) and K3 (65) showed more evenness between the sites, as compared to K1(34), whereas lowest value for Simpson's index (D) was observed at K2 (0.038) followed by K3 (0.042) and highest at K1 (0.069). Simpson's Index of Diversity (1-D) signified highest values for K2 (0.962), followed by K3 (0.958) and K1 (0.931), indicating a highest biodiversity at K2. Simpson's Index gives more weight to the more abundant species in a sample and negative relation with Shannon's and Hill's index.

DISCUSSION

During the study period, temporal or seasonal and spatial patterns of waterbirds were found to be distinct and conspicuous. An increase in species richness during the winter was particularly evident at all three sites (Guadagnin et al., 2005). Some species showed very distinct winter and/or migration peaks, but others exhibited a variable seasonal pattern according to winter severity. The seasonal pattern corroborates the expected fluctuations due to movement and migration. Huge wintering aggregations are commonplace in waterbird communities in temperate regions (Kershaw, Cranswick, 2003). Since winter migratory and resident species, predominate in the aquatic bird population of the wetland system, this may be considered an important arrival and refuge area for avian fauna in spite of its small size.

Waterbirds respond locally to the main spatial and environmental gradients of nutrient discharges into the Khodiyar wetland. Site K2 evidently had the highest species richness due to inhabitant characteristic of larger variety of aquatic macrophytes, which provide greater habitat heterogeneity for the avian fauna. Severo et al. (2002) pointed out that birds can be shown to be influenced by many factors, the more relevant ones are the trophic status and the aquatic macrophytes, since they are correlated with an increase in the number of species which probably could exhibit the spatial and temporal patterns of waterfowl community. Similarly, Hoyer and Canfield (1994), examined trophic status, lake morphology, and macrophytes, and found a close correlation between greater trophic status and increase in species richness and abundance of birds. Nirmal Kumar et al. (2008) observed higher nutrient enrichment at K2 in the same wetland which could be the reason for the high waterbird abundance at this site.

Water depth is paramount in explaining waterbird density, and determining whether or not habitat is available; waterbird diversity generally is good at low water depth (shallowness) and correlated to hydrological diversity (Colwell, Taft, 2000; Holm, Clausen, 2006), therefore in our study at site K1 with higher water depth and lower degree of nutrient enrichment could be considered to be the prominent reasons for the low waterbird diversity, however reverse is the condition in site K2 followed by K3.

CONCLUSIONS

It is revealed that overall, 71 waterbird species belonging to 48 genera of 15 families were documented, which included 38 species

year-round residents and 33 species migratory species. Among these, 9 species were considered to be abundant, 38 species common and 24 species rare. It is worth noting that one of the species Sarus Crane, found at both site K2 and site K3 has a vulnerable status listed in IUCN Red List, besides White Ibis a near threatened species as per IUCN Red List, observed in aplenty at this wetland. From the present study it was revealed that existence of various patterns of spatial and temporal segregation among the waterbird reflected the different requirements that are met by these limnologically variables. Higher values of Shannon's and Hill's indices indicated rich waterbird abundance and species richness at site K2 followed by K3 and K1, on the other hand Simpson's indices denotes low waterbirds at site K1.

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