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ASSESSMENT OF WATER QUALITY OF NAGIOPEER AND DANGEWARI WETLANDS AND STATUS OF THE WILDLIFE OF NARA GAME RESERVE, SINDH, PAKISTAN

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ABSTRACT

The Nara Game Reserve area having a number of wetlands and Nara Canal form a Wetland Complex in Desert. In this study selected areas of twenty two important spots of the Nagiopeer and Dangewari wetlands was surveyed and their physico-chemical data was recorded. The samples were taken season wise from both the wetlands and the estimated parameters showed their chemical characters and quality of water. The water of both the wetlands was not suitable for human drinking due to high value of TDS. Seepage from Nara Canal is responsible for making most of the wetlands of the area to have high salt contents making them largely brackish. We also evaluated the status of wildlife of Nara Game Reserve. Hog Deer (*Axis porcinus*) has declined in numbers due to habitat degradation and human disturbance. Fishing Cat (*Prionailurus viverrina*) and Smooth-coated Otter (*Lutrogale perspicillata*) are rare and observed only in Jamrao Head area. The status of large mammals, especially ungulates and carnivores has declined over the past decades due to increase in human population, habitat deterioration, hunting and other ecological changes taking place due to development. Small mammals and rodents are quite common as noticed by their burrow system and direct sightings. The Houbara Bustard (*Chlamydotis undulata*), a winter visitor to the desert areas is under severe hunting pressure. Grey Partridge (*Francolinus pondicerianus*) and some species of ducks such as Mallard and Common Teal are widely hunted. Main threats to the wildlife of the area are human population, hunting, habitat destruction and ecological changes. The Nara Wetland Complex is an important bio-ecological site which needs conservation and management plan for the sustainability of the Nara Game Reserve area.

Keywords: Nara game reserve, water assessment, vertebrate biodiversity.

INTRODUCTION

Natural wetlands of Pakistan have disappeared because of providing lands for housing, agriculture, irrigation and drainage. However, new marshes and lakes have been created near rivers, barrages and dams which provide excellent habitats for water birds. As regards the environmental problems, there has been a severe water shortage in the lower Indus basin. Most of the important wetlands in Sindh are fed by the River Indus and because of reduced flows most of these are drying out or are being degraded. Due to water shortage in the River Indus, several riverine forests have been badly affected and their environment and biodiversity is threatened. The Indus receives huge amount of sewage, untreated industrial effluents and run off from the agriculture lands. This has caused the aquatic biodiversity to decline in numbers and diversity.

Nara Game Reserve having about 200 large, medium and small wetlands forms a Wetland Complex, from which most of them are permanent while some are seasonal. The water of these wetlands is fresh to brackish to saline and these are stretching from the town of Januji in the north to Jamrao head. Nara Canal is the largest canal of Sindh and these wetlands lie on both the sides of Nara having a cultivated area of 108 million hectares. It originates from Sukkur barrage along with Khairpur Feeder West and Rohri Canal. Woodlands, reed beds and vegetations are along these wetlands which provide the habitat for amphibians, reptiles, fishes, avifauna and mammals. Ecologically the area has a great value as far as the

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biodiversity is concerned. Nara Game Reserve was declared as Protected Area in 1981 under the Sindh Wildlife Protection Ordinance, 1972. It is located at 80 km E of Khairpur, 110 km from Sukkur and 515 km from Karachi (Ghalib *et al*., 2006, 2008).

The Nara Canal and associated wetlands form a complex of wetlands in the Nara desert region which extends over parts of Sukkur, Ghotki, Khairpur, and Sanghar districts. It is a part of Thar Desert that extends further south in Tharparkar area. In the area, natural wetlands are unique or rare type (Ghalib *et al*., 2008).

The area supports vulnerable species such as: Smooth-coated Otter (*Lutrogale perspicillata*), Marsh Crocodile (*Crocodylus palustris*) and Marbled Teal (*Marmaronetta anguistirostris*) and it also supports the near-threatened species such as Hog Deer (*Axis porcinus*), Fishing Cat (*Prionalurus viverrina*), White-eyed Pochard (*Aythya nyroca*), Indian Darter (*Anhinga rufa*), Black Ibis (*Pseudibis papillosa*) Long-tailed Grass Warbler (*Prinia burnesii*), Houbara Bustard (*Chlamydotis undulata*) and Indian Pond Turtle (*Geoclemys hamiltoni*). Marsh Crocodile, White-eyed Pochard, Smooth-coated Otter, Hog Deer, Marbled Teal and Houbara Bustard are the key species of the area (Chang *et al*., 2012; Ghalib *et al*., 2004; Rais *et al*., 2009).

Some wetlands of the Nara Canal Wetland Complex are important for supporting significant numbers of water birds during the season. Although regular annual water bird surveys have not been under taken but whatever data is available shows that these wetlands are very important for supporting significant numbers of Anatids and the Waders during the migratory season.

Wetlands of the area are of natural type and formed from the seepage of Nara canal. So, the area is stable around the Nara Canal and the desert area contains sand dunes, having typical flat, bottomed valleys between the dunes termed as “Tarhs” or “Tals”. The Nara Canal is permanent source of water for the agriculture lands extending from 4-5 km on either side of the canal that are recharged by the sides of the canal seepage or rain water. Low rainfall is the dominant feature because of high temperature and absence of high rainfall in rainy season. The total rainfall of the area is less than 250 mm during June to September. In general, range of water table varies from 2.5 m to 5 m. The water table goes down up to a depth of 10 to 18 m with increasing distance from the canal in the eastern and western desert margin.

The catchment area is the Nara desert and the Rohri Hills area. The Nara desert lies between 26^{o} - 28^{o}N and 68 -70 ^{o}E. The altitude is between 50 and 115 meters. It extends from Taluka Ubaro, Daharki, Mirpur Mathelo and Khanpur Mahar of Ghotki district, Rohri and Saleh Pat Talukas of Sukkur district, Nara Taluka of Khairpur district and Taluka Khipro and Sanghar of Sanghar district. Eastern side boundaries of all these talukas are flanked by Rajasthan, India.

The Canal system is composed of the upper Nara Canal lying between Jamrao Head works and Sukkur barrage and the Mithrao, Thar, Jamrao and Khipro Canal system that lie in the south to Jamrao Head works. Sand dunes, the Nara Canal, the agriculture lands and the associated wetland system are the main habitats of the Nara Canal Wetland Complex which provide a shelter to large number of faunal species.

Some wetlands are very rich in salt concentration and crusts of salt deposits are seen in and around such wetlands. Such wetlands are devoid of any aquatic vegetation in them. Fishing in the Nara canal takes place, particularly at the time of canal closure when the fishes are stranded in the deep pools of water left in the canal. It is, however on a small scale, there are no fishing towns as such and the fishermen live in the villages close to the canal. The method and equipment used for fishing is of conventional standing net type.

A number of people of the area depend upon the wetlands of the area, so the Nara Canal Wetland Complex has high social and economical value and functions. The wetlands of the area provide source of water for drinking and for livestock grazing. Fish farms have been made in some of the wetlands. A number of medium and small villages are located near the wetlands with their livestock. Large scale fishing activities are not prominent in the area. These take place downstream in Chotiari Wetland Complex area in Sanghar district.

There has been seven year drought period in Sindh and it had affected the ecological character of the site and the surrounding area as most part of the site lies in the desert area. The desert vegetation was affected adversely and the wetlands shrank in size and most of the wetlands went dry. Drought is still a potential negative factor for the site. Gas exploring activities have been undertaken in the area but these have not made any adverse effect on the environment as mitigation measures have been taken by the gas exploring companies and monitoring has also been done.

As the three important wetland complexes are very close together and form a very large network of wetlands *i.e.*, Nara Wetland Complex, Chotiari Wetland Complex and the Deh Akro Wetlands Complex (Ramsar Site). These have great faunal and ecological importance and are also the potential sites for education and research.

The Nara Game Reserve area is very important due to its biodiversity, and a number of wetlands which support

large population of water birds during the season (Bhaagat, 2005). More than 200 wetlands have been listed. The area also supports some rare, threatened species of wildlife. The area is under environmental pressure due to gas exploration activities, human population pressure, agriculture and Houbara Bustard hunting, which necessitate the carrying out of the ecological studies and timely conservation and monitoring programs to be undertaken. The objective of this study was to assess the water quality of Nagiopeer and Dangewari wetlands and evaluate the status of vertebrate biodiversity of Nara Game Reserve.

MATERIALS AND METHODS

Study Areas

The areas selected for the study are shown in table 1.

Methodology

For water sampling we used large, clean containers, 10 water samples (2 Liter each sample) were collected from 5.5 ft of selected points of the study areas. Al samples were labeled and documented including sample ID, date, location name, quantity and placed into the sample container (one duplicate sample also collected at a random study area and processed by the same Laboratory for double checked).

Total Dissolved Solids, Turbidity, Salinity and pH were analyzed by pH meter, Conductivity was estimated by conductivity meter, Phosphates, Carbon dioxide and Alkalinity were examined by the process of Titrimetric methods (Titration), Magnesium, Calcium, Total Hardness and Chlorides were detected by using complexometric titration (EDTA), Incubation Method-Redox Titration was used for the estimation of Biochemical Oxygen Demand, while Sulphate was examined by Gravimetric method (APHA, 1997), Nitrate was analyzed by Brucine Colorimetric Method and Chromium, Cadmium, Lead and Nickel were analyzed by atomic absorption Spectro-photometric Method (Khan *et al*., 2012, 2014).

Sterilized screw capped glass bottles were used for the collection of protozoan/microorganisms samples. Samples were quickly transferred and readily brought to the laboratory for analysis. Protozoan/microorganisms were identified through shape, body structure, external features, locomotion and behavior (Edmondson, 1966; APHA 1992; Curds, 1982; Curds *et al.*, 1983).

Table 1. Wlidlife Habitats and important Wetlands of Nara Game Reserve area.

S. No.	Name of study area	Co-ordinates
1.	Akanwari Dhand*	27 04 40. 5 N 68 55 57. 2 E 26 31 83. 4 N 68 56 13. 1 E
2.	Akhero Dhand	26 45 53. 5 N 68 53 57. 2 E 26 45 88. 0 N 68 53 95. 1 E
3.	Baboo Dhand	27 13 73. 9 N 69 00 93. 6 E
4.	Berwari Dhand	26 44 50. 9 N 68 58 49. 2 E
5.	Dangewari Dhand	27 00 39. 0 N 68 59 17. 5 E 27 00 53. 0 N 68 58 54. 7 E
6.	Dayran Dhand	26 44 78. 1 N 68 53 24. 5 E
7.	Dholaho Dhand	26 43 02. 9 N 68 58 27. 1 E
8.	Jaari Dhand	27 01 02. 0 N 68 7 01. 9 E 27 00 36. 2 N 68 58 12. 3 E
9.	Jagheer Dhand	26 54 19. 9 N 69 00 09. 4 E
10.	Kinrhi Dhand	26 47 05. 9 N 68 54 22. 6 E
11.	Kirchan	27 05 34. 2 N 68 9 96. 0 E
12.	Lalari	26 40 10. 0 N 68 57 58. 3 E
13.	Manjerka	26 44 07. 1 N 68 59 33. 4 E
14.	Muqamwari	26 42 47. 5 N 68 58 43. 1 E
15.	Nagiopeer	26 43 57. 8 N 68 52 21. 0 E
16.	NARA Canal	26 53 39. 2 N 68 57 38. 8 E
17.	Pallaywari	26 46 40. 6 N 68 54 32. 2 E
18.	Phariaro	27 12 33. 2 N 68 59 44. 8 E
19.	Putkan	26 42 35. 6 N 68 59 04. 9 E
20.	Samabi	26 44 54. 5 N 68 53 44. 3 E
21.	Simni	26 44 06. 9 N 68 58 48. 9 E
22.	Terai Dhand	26 44 51. 9 N 69 02 48. 5 E

*Dhand: Sindi language word means Lake

Survey of Mammals
Following techniques were used to record mammalian occurrence and distribution in the study area:

Roadside Counts
In this method motor vehicles were used along the road trails while the sighted number of individuals of the species estimated was tallied and related to the number of kilometers traveled (Brower *et al.,* 1990). Animals were observed along the road / track from a few meters distance. Count of tracks, footprints, burrows etc.

In this method, the tracks, footprints and burrows of animals were noted and recorded which confirmed the presence of the animals which are nocturnal or secretive in their habits.

Pellet Counts
This technique involved animal use of areas between sampling periods (Brower *et al*., 1990).

Point Count Surveys
In this method, observation points were established at suitable points for viewing the habitat. The observer recorded all sightings at each observation point then an index of abundance of each species was expressed as the number of animals seen per hour of observations (Brower *et al*., 1990). Point surveys were conducted twice daily, once during early morning, i.e. one hour earlier than the sunrise till noon and secondly, in the evening, *i.e.,* half an hour before the sunset till dark.

Line Transects
The line transect or strip census method involves counting the animals seen by an observer traversing a redetermined transect line and recording the distances at which they were seen or flushed. This method is favorable for the sightings of difficult animal's census (Khan *et al*., 2010; Schemnitz, 1980).

Survey of Small Mammals
To investigate nocturnal species, night surveys were conducted. In this method, long boots, sticks, gloves and search lights are used (Khan *et al*., 2013).

Trapping procedure
Sherman traps were used for the collection of rodents. Fifty traps were placed on a line approximately 350 m long and approximately 10m colorful ribbons were used for locating the traps easily. The traps were placed in the afternoon and the specimens were collected into polyethene bags for identification and then released. Fragrant seeds and grains were mixed for attracting the small mammals. Onion, oat, coriander and peanut butter were used with wheat and rice for fragrance.

Survey of Birds
Each major habitat type is identified and surveys are made to record the species of birds found in each discrete habitat such as lakes, canals, ponds, marshes, forest, agriculture fields, vicinity of human habitation and fallow lands. The most commonly used field method in bird surveying is the " Line Transects" which is a common method for bird survey and used for recording bird continually. Re access of birds is good.

Counting the water birds
Binocular and telescope were used for counting water birds from different sites (Grimmett *et al*.,1998, 2008). For accurate counting of water birds summary is given below:

Estimating the numbers of birds within area
It may be taken up when large number of birds are present *i.e.,* >1,000, birds are continually in flight *i.e.,* moving in large flocks; there is lot of disturbance forcing birds to be unsettled and continually taking flight, making prolonged observation on the ground difficult; closely-packed flock of birds, where due to the 'tightness' of the flock counting individual birds is difficult *i.e.,* at a large roost, and due to poor light conditions *i.e.,* viewing into the sun or over a great distance, identification of particular species is not possible (Ghalib *et al*., 2013).

Survey of Reptiles and Amphibians
Various methods have been employed for observation of reptiles and amphibians as given below:

A. Direct counting
B. Indirect counting

A. Direct Counting
Plot Searching
At each site, search was made to detect as many reptiles and amphibian species as possible within a circular central zone. This consists of searching approximately 20 ha (within a 250 meter radius of sampling points) exactly and recording the number of individuals of each species seen.

Spot Lighting or Night Observations
In order to detect and record some nocturnal snakes and lizards, spotlight transects were conducted. Each transect was surveyed after dark with a potable spotlight. Each transect was 3 km long. The same route was traveled on the return trip.

Turning of Stones, Rocks and Rotten Trees
Nocturnal reptiles and amphibians take shelter or rest hiding themselves under the space of stones or rocks. Therefore, in the day time survey, stones or rocks or rotten fallen trees were turned to locate and record the presence of species.

Study of Basking Behavior

In winter, the temperature of the water of the water bodies becomes very low. Crocodiles come outside the lake for enjoying sunshine to keep them warm. Thus, counting of crocodiles becomes very easy at particular area during this season.

B. Indirect Counting

Indirect record of occurrence of species was made by noting the presence of signs like faecal pellets, tracks, den or tunnels (egg laying excavation), evidences from the impression of foot prints, or tail, presence of faecal pellets.

RESULTS AND DISCUSSION

Wetland water can be fully characterized by the three major components: hydrology, physico-chemistry, and biology. A complete assessment of water quality is based on appropriate monitoring of these components.

During the present study, the environmental impacts including the effects of environmental pollution have been studied of the Nara Game Reserve. The two most significant wetlands Nagiopeer and Dangewari wetlands were selected for the environmental studies.

Physico-chemical Parameters of Nagiopeer Wetland

Several physico-chemical parameters were analyzed during the study period to determine the effect water quality on the environment of the lakes. Temperature, Conductivity, Total Dissolved Solids, pH, Turbidity, Alkalinity, Total Hardness, Salinity, Basic Oxygen Demand, Carbon Dioxide, Magnesium, Sulphate, Chloride, Calcium, Nitrate, Phosphate, Cadmium, Chromium, Lead and Nickel were selected for the analysis of water quality. Parameters were analyzed seasonally.

Physico-chemical parameters are effective for change in life processes of aquatic biodiversity like change in water temperature because aquatic biodiversity is sensitive to change in water temperature. Measurement of temperature is quite easy on field during the study, water temperature in pre-monsoon ranged from 33 to 38^{o}C and in post-monsoon it varied from 22 to 31^{o}C. The air temperature varied in pre-monsoon from 37 to 42^{o}C, while in post monsoon it varied from 26 to 34^{o}C. Conductivity varied from 810-1870 (µS/cm), TDS varied from 357-1370 mg/l, pH value ranged from 8.04-8.82, turbidity ranged from 5.29-13.41 NTU, alkalinity ranged from 152-530 mg/l, total hardness varied from 113-429 mg/l, salinity varied from 0.39-1.92 mg/l, Basic Oxygen Demand varied from 4.53 mg/l, Carbon dioxide ranged from 1-2 mg/l, Calcium varied from 31-88 mg/l, range of magnesium varied from 41-82 mg/l, sulphate range varied from 16-156 mg/l, chloride ranged from 39.4-128 mg/l, nitrates range was 0.40-0.78 mg/l, phosphate varied from 0.009-0.053 mg/l, cadmium varied from 0.00 - 0.01 mg/l, varied from 0.02 to 0.05 mg/l, Lead varied from 0.00 to 0.009 mg/l, Nickel in Nagiopeer wetland from 0.006-0.07 mg/l (Table 2).

Physico-chemical Parameters of Dangewari Wetland

Physico-chemical analysis of Dangewari Wetland: water temperature of Dangewari Lake varied from 21 - 40^{o}C and air temperature varied from 24 - 43^{o}C, conductivity of the Dangewari Lake varied from 316 - 942 µS/cm, TDS in Lake varied from 293-1253 mg/L, pH value ranged from 7.91-8.53, turbidity ranged from 5.39 to 18.41 NTU, value of alkalinity ranges from 45 to 118 mg/l, Total Hardness varied from 73 to 253 mg/l, Salinity of Dangewari Lake varied from 0.38 to 1.93 mg/l, Basic Oxygen Demand varied from 3.84 to 6.91 mg/l, Carbon dioxide ranges from 1 to 2 mg/l, Range of calcium varied from 31 to 88mg/l, range of magnesium varied from 54 to 89 mg/l, sulphate varied from 16 to 153 mg/l, chloride ranged from 26.2 to 138 mg/l, value of chloride ranged from 26.2 to 138 mg/l, nitrate range in Dangewari wetland was 0.39 to 0.81 mg/l, phosphate varied from 0.008 to 0.052 mg/l, range of cadmium varied from 0.00 to 0.01 mg/l, range of chromium in varied from 0.02 to 0.06 mg/l, value of Lead varied from 0.00 – 0.01 mg/l and Nickel in varied from 0.00 to 0.09 mg/l (Table 3).

Nagiopeer wetland supports Marsh crocodile (Javed and Rehman, 2004) and Dangewari wetland supports large number of water birds during the migratory season. Moreover, it is the breeding site for Marbled Teal, it is also maintained as a fish pond. The wetlands of Nara Wetland Complex are important because of bird particularly migratory water birds which are the characteristic wildlife of the area (Ghalib *et al*., 2004).

Main habitats also have been identified in the Nara Game Reserve *viz*., the Desert, Farmlands, Nara Canal and the associated marshes, desert wetlands in the periphery of Nara Canal, Forests, Villages and human habitations. Based on present study observations water of these wetlands is not fit for human consumption due to high TDS values as compared to World Health Organization (WHO) standard.

Khan *et al*. (2013) reported 21 species of Mammals, 2 species of Amphibian, 129 species of Birds, 20 species of Reptiles and 37 species of Fishes (Fig. 1). The key species of the Nara Game Reserve include Hog Deer, *Axis porcinus* (Fig. 2), Smooth-coated Otter, *Lutrogale perspicillata* (Fig. 3), Fishing Cat, *Prionailurus viverrina* (Fig. 4), Marbled Teal, *Marmaronetta angustirostris* (Fig.

5), Grey Partridge, *Francolinus pondicerianus* (Fig. 6), Black Partridge, *Francolinus francolinus* (Fig. 7), Houbara Bustard, *Chlamydotis undulata* (Fig. 8) and Marsh Crocodile, *Crocodylus palustris* (Fig. 9) (Azam *et al*., 2002; Ghalib and Nawaz, 2008; Khan *et al*., 2013).

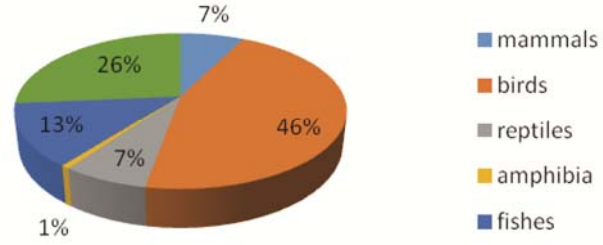

Fig. 1. Wildlife of Nara Game Reserve.

Hog Deer has been reported along the Nara Canal from RD 463 to RD 424. It has mostly declined in numbers due to habitat degradation and human disturbance. Fishing Cat has been reported from around Jamrao Head and presently, it is quite rare. Another study, distribution and population status of Smooth-coated Otter was undertaken in the Nara Game Reserve area and it has also been reported from near Jamrao Head area (Khan *et al.*, 2010; Khan *et al*., 2010).

The status of large mammals especially ungulates and carnivores has declined over the past decades due to increase in human population, habitat deterioration, hunting and other ecological changes taking place due to development. Small mammals and rodents are quite common as noticed by their burrow system and direct sightings (Rais *et al*., 2010).

The study area is a blend of different habitats and supports a variety of avifauna both resident and migratory. The agriculture fields at the edge of desert habitat provide favorable environment to a number of bird species which have adapted to the human settlement.

The Houbara Bustard, a winter visitor to the desert areas, is under severe hunting pressure from the Arab dignitaries who practice large scale hunting of the bird through their trained falcons during November to February each year. In addition to that, Grey Partridge and some species of ducks such as Mallard and Common Teal are widely hunted (Bhaagat, 2005). Marbled Teal is another threatened species of the area. It has been recorded in winter from Kathor Dhand, Jagheer and Simnowahid dhands. Its breeding has been recorded from Dangri and Baboo dhands where the species comes for breeding starting from late March.

Some other rare species have also been recorded from the area, such as Black Ibis was recorded from Nagiopeer, Jerdon's Babbler has been recorded on Phragmites from

Table 2. Water Quality Analysis of Nagiopeer Lake during 2007-2011.

Parameters	**Nagiopeer Lake**									
	Average Pre-monsoon					Average Post-monsoon				
	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Color	A	A	A	A	A	A	A	A	A	A
Odour	O	O	O	O	O	O	O	O	O	O
Water Temperature (^{o}C)	33.33	35.33	36.67	37.67	38	23.33	22.67	24.67	23.33	30
Air Temperature (^{o}C)	36.33	38.33	40.00	40.67	41	26.67	26.00	27.67	26.00	33.33
Conductivity (µS/cm)	1483.33	1140.67	1248.67	1268.00	1142	1726.67	1507.67	1700.33	1609.67	1701.33
TDS (mg/l)	650.00	395.67	403.67	469.33	398	1125.33	841.67	847.33	1099.00	1022.67
pH	8.33	8.68	8.60	8.66	8.31	8.11	8.24	8.22	8.27	8.21
Turbidity (NTU)	7.64	7.19	7.62	5.88	5.29	10.05	10.22	10.12	8.42	8.74
Alkalinity	490.67	457.67	415.00	429.67	458	215.67	217.33	196.33	202.67	198.67
Total Hardness (mg/l)	342.00	300.00	346.67	306.00	342	160.00	129.33	132.33	154.0	141.67
Salinity (mg/l)	1.74	1.79	1.68	1.85	1.52	0.52	0.65	0.49	0.57	0.52
BOD (mg/l)	5.12	5.35	5.06	5.47	4.89	6.30	6.18	5.99	6.31	5.40
Carbon dioxide (mg/l)	1.67	1.33	1.33	1.67	2	1.33	1.67	2.00	1.33	1.67
Calcium (mg/l)	73.00	73.67	76.33	75.67	62	41.67	38.00	36.67	38.00	35.67
Magnesium (mg/l)	53.00	56.33	53.00	68.00	53	60.67	70.33	66.00	76.00	68.00
Sulphates (mg/l)	20.00	18.67	22.00	19.00	20.00	132.67	135.67	142.00	136.6	128.00
Chloride (mg/l)	43.87	41.73	47.13	44.43	41.23	122.67	132.33	132.33	135.0	125.67
Nitrates (mg/l)	0.73	0.70	0.67	0.67	0.71	0.51	0.49	0.48	0.48	0.49
Phosphates (mg/l)	0.05	0.05	0.05	0.05	0.05	0.01	0.02	0.01	0.02	0.01
Cadmium (mg/l)	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01
Chromium (mg/l)	0.02	0.02	0.03	0.04	0.03	0.04	0.03	0.05	0.05	0.04
Lead (mg/l)	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Nickel (mg/l)	0.00	0.02	0.02	0.00	0.00	0.05	0.03	0.06	0.03	0.04

Table 3. Water Quality Analysis of Dangewari Lake during 2007-2011.

Parameters	Dangewari Lake									
	Average Pre-monsoon					Average Post-monsoon				
	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Color	A	A	A	A	A	A	A	A	A	A
Odour	O	O	O	O	O	O	O	O	O	O
Water Temperature (^oC)	35.67	35.67	35	35.33	39.33	24.67	24.67	26.33	22	28
Air Temperature (^oC)	38.67	38.67	38.33	38.67	42.67	28.00	28.00	29.00	25.33	31.67
Conductivity (µS/cm)	562.67	562.67	439.00	554.67	504.00	863.33	863.33	819.33	806.67	611.33
TDS (mg/l)	347.67	347.67	405.00	448.33	374.67	709.33	709.33	781.00	974.33	782.00
pH	8.02	8.02	8.32	8.29	8.32	7.91	7.91	8.06	8.15	8.14
Turbidity (NTU)	12.22	12.22	6.93	8.50	7.71	14.11	14.11	9.71	10.87	11.69
Alkalinity	160.33	160.33	108.67	130.00	106.33	88.67	88.67	53.33	67.00	50.67
Total Hardness (mg/l)	207.67	207.67	148.00	195.00	190.00	115.00	115.00	96.33	114.67	142.67
Salinity (mg/l)	1.36	1.36	1.52	1.54	1.80	0.50	0.50	0.55	0.56	0.63
BOD (mg/l)	4.81	4.81	4.09	5.01	5.04	5.63	5.63	5.01	5.84	6.15
Carbon dioxide (mg/l)	1.67	1.67	1.67	1.67	1.33	1.00	1.00	1.67	1.67	2.00
Calcium (mg/l)	75.33	75.33	77.33	73.33	77.00	37.33	37.33	40.33	39.00	44.67
Magnesium (mg/l)	60.00	60.00	64.67	65.33	69.67	72.33	72.33	79.00	73.33	83.33
Sulphates (mg/l)	21.00	21.00	24.00	19.33	19.00	142.67	142.67	145.33	131.33	124.00
Chloride (mg/l)	34.00	34.00	39.57	42.10	41.40	111.33	111.33	133.00	132.33	122.67
Nitrates (mg/l)	0.63	0.63	0.68	0.76	0.68	0.41	0.41	0.47	0.55	0.50
Phosphates (mg/l)	0.05	0.05	0.05	0.05	0.05	0.01	0.01	0.01	0.01	0.01
Cadmium (mg/l)	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Chromium (mg/l)	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05
Lead (mg/l)	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Nickel (mg/l)	0.01	0.01	0.00	0.00	0.00	0.04	0.04	0.03	0.04	0.02

Nara gate and Striated Babbler was recorded from Bhog Forest.

The most important reptile of the study area Marsh Crocodile has been recorded from 14 wetlands of Nara Game Reserve, in another study, Ghalib *et al.* (2006) already reported about this species. The Threatened/ Near species recorded from the area include: Smooth-Coated Otter (V), Hog Deer (E), Fishing Cat (E), Indian Darter (NT), Ferruginous Duck (NT), Long-tailed Grass Warbler (NT), Marbled Teal (V), Houbara Bustard (V) and Marsh Crocodile (V).

The Threats to the biodiversity of the area included habitat degradation due to poor management practices and fragmentation of the main wildlife habitats due to rapidly increasing human population. There is also impact of 7 Farm-to Market Rural Roads passing through the Protected Area. There is also some disturbance due to gas exploration activities in the area. Two main gas fields viz. Sawan and Kadanwari are located in the area. There are no severe impacts of these projects on the wildlife of the area as EIA studies have been made in the sensitive areas and Environmental Management Plan is already under execution. The principal vegetation consists of *Acacia nilotica, Eucalyptus spp.* and *Zizyphus nummularia*.

More than 200 wetlands have been recorded in the area. Most of them are brackish due to very high percentage of dissolved salts. These are low-lying wetlands and receive water through seepage from the Nara Canal. These wetlands support large numbers of migratory water birds during the migratory season and more than 14 wetlands support Marsh crocodile. As there are no effluents coming to these wetlands, hence, there is no serious issue affecting environmental pollution on the biodiversity.

Very few wetlands contain freshwater which is used for drinking purposes by the local communities. Mostly, the people subsist on water obtained through boring or tube wells.

Chemical analysis of the water in two of the major wetlands of the area *viz*., Nagiopeer, and Dangewari revealed the presence of microbes harmful for human health. But the water of these wetlands, like most others, is not used for human consumption.

The area still presents favorable environment to the animal species particularly the water birds over the majority of wetlands. Dangewari, Nagiopeer, kathor,

Fig. 2. Hog Deer (*Axis porcinus*).

Fig. 3. Smooth-coated Otter (*Lutrogale perspicillata*).

Fig. 4. Fishing Cat (*Prionailurus viverrina*).

Fig. 5. Marbled Teal (*Marmaronetta anguistirostris*).

Fig. 6. Grey Partridge (*Francolinus pondicerianus*)
(Photo Courtesy: wikimediafoundation.org)

Fig. 7. Black Partridge (*Francolinus francolinus*)
(Photo Courtesy: ibc.lynxeds.com)

Fig.8. Houbara Bustard (*Chlamydotis undulate*).

Fig. 9. Marsh crocodile (*Crocodylus palustris*).

Muqamwari, Nagiopeer, Simnowhid have been supporting threatened / rare species such as Ferruginous Duck, Ruddy Shelduck, Black Ibis and Indian Darter. Simni, Jagheer, Berwari and Manjerka Area support gray and Black Partridges. Large scale breeding of Ring Doves has been recorded from Jagheer, while Waders at all times have been observed at Kanni. Recently, Marbled Teal and Ferruginous Duck have been recorded from Dangewari during the AWC 2012 (Chaudhry *et al.*, 2012).

As these wetlands support significant number of water birds during the season, so the study recalls for regular monitoring of water bird populations particularly during midwinter water bird counts. At present, the site is not used for recreation/tourism. But there are possibilities of developing it as a recreation/tourist site. Kathore dhand is a beautiful wetland near Chundko town. It may be developed at a tourist/ recreation site.

Recommendations for Conservation Plan of Nara Game Reserve

1. The boundaries of the Nara Game Reserve are not exactly known. The limits of Nara Game Reserve may be clearly demarcated for proper management of the area.
2. Species of special conservation interest may be studied in particular *viz.*, Hog Deer, Fishing Cat, Smooth-coated Otter, Partridges, Houbara Bustard, Ruddy Shelduck, Ferruginous Duck, Indian Darter, Jerdon's Babbler, Marbled Teal and Marsh Crocodile.
3. Captive breeding programs on Hog Deer and Partridges may be undertaken in the Forest Areas.
4. Regular monitoring of the population status of Hog Deer, Smooth-coated Otter, Fishing Cat and Marbled Teal may be undertaken.
5. Regular Asian Water bird Census may be undertaken on the major wetlands of the Nara Wetland Complex to determine the trends in water bird populations and the record of occurrence of the threatened/rare water bird species.
6. Inventory of the wetlands of the area may be prepared to identify the potential wetlands of high conservation value and as a site having cultural and ecotourism value.
7. Bio-ecological studies may be taken up on some very important wetlands of the area such as Dangewari, Baboo Dhand, Simno Wahid Dhand, Dangree Dhand, Jari Dhand, Jagheer Dhand, Nagiopeer Dhand, Samabi Dhand, Akhero Dhand and Nara Canal.

CONCLUSION

The results of the study determined the threats and problems of the study area. Nara Wetland Complex comprises 200 wetlands in which most of them are natural but some have been made from the seepage of Nara canal. Some wetlands of the area have a great economical and commercial values as well cultural heritage. Two of the wetlands, Nagiopeer and Dangewari are very important because Nagiopeer wetland supports a number of Marsh crocodile and Dangewari wetland is a habitat of resident bird's as well as migratory birds. Dangewari wetland is also a breeding site for Marbled teal and acts as fish pond. Nara Canal, the largest canal in Sindh runs from the Sukkur barrage to Jamrao Head works is the basic source of drinking water, agriculture and live stocks but it is also playing an important role in damaging the area because seepage is the cause of increasing salinity and TDS value in wetland's water and this water is not fit for drinking purpose. The human population is affecting the population of ungulates and carnivores. Main threats to the wildlife of the area are human population, hunting, habitat destruction and ecological changes. The Nara Wetland Complex is an important bio-ecological site which needs conservation and management plan for the sustainability of the Nara Game Reserve area.

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