Chapter 4

Ecological and Environmental Assessment of Nara Desert Wetland Complex (NDWC), Khairpur, Sindh-Pakistan

Muhammad Saleem Chang

Additional information is available at the end of the chapter

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Abstract

The Nara Desert Wetland Complex (NDWC) includes sandy dunes, steep hills and occupies low lying flat zones associated with different natural wetlands formed from the seepage of Nara Canal. These different wetlands are the major perennial source of water to the agricultural lands, local communities, wildlife and for grazing livestock. The NDWC encompasses more than 225 seasonal and permanent small, medium and large sized lakes/wetlands. The total area of Nara Canal is distributed about (108,960 hectares) which starts from Sorah to Head Jamrao. The NDWC was declared in 1972 as a Game Reserve area for the protection of wild animals. The NDWC is also recognized an important potential Ramsar Site. The different floral habitation in the Nara Desert consists of mostly drought resistant vegetation of phytoplankton, reed vegetation, herbs, shrubs and trees. The area is ecologically rich with the faunal biodiversity that includes zooplankton, invertebrates, fishes, amphibians, reptiles, birds, and small and large mammals. The NDWC has received high values for its economic, social, floral and faunal habitat, aquatic biodiversity since the local communities are directly or indirectly dependent on these natural sustainable resources. During the sampling of environmental parameters, most of the wetlands were determined to be seasonal and permanent freshwater, brackish and hypersaline lakes.

Keywords: Nara Desert wetland complex, Nara Canal, biodiversity, ecologically-sustainable resources, environmental parameters

1. Introduction

1.1. Nara Desert wetland complex (NDWC)

The Nara Desert Wildlife Sanctuary is located between 26°28° N and 68°70° N (Elevation 50–115 m) in the province of Sindh, Pakistan. The desert area is approximately 23,000 km^2 semiarid, receiving most of its water 88–135 mm of annual rainfall sporadically during the season of monsoon. These wetlands have rich variety of floral and faunal life such, as various aquatic plant species and different animal species of fishes, amphibians, reptiles, birds and mammals. However, the region is of diverse ecological value for the biodiversity of plant and animal species. These wetlands are distributed in different districts which usually start from Ghotki, Sukkur, Khairpur and ends in Sanghar District [1–4]. In the Nara Canal region, the ground water level usually varies around 76 mm. The capacity of recharging these wetlands in the region is very low due to low rainfall. The level of water table varies between 2.5 and 5 m. In the nearest lands to the Nara Canal, the water level increases up to 10–18 m. Most of the wetlands were developed from sand dunes while a few were developed by deposition of silt [5]. Irrigation system on Nara Canal is contained from upper Nara between Sukkur Barrage to the south Jamrao Headwaters and includes major canals such as Jamarao, Mithrao, Khipro and Thar [1–6]. The area is geographically part of the Indus Basin and is composed of alluvial sediments which are deposited by previous and current different branches of the rivers. The sediments of the area are carried by Indus River which have tertiary shale and limestone basement. The sediments are composed of acolin sands that have previously been deposited during the Pleistocene Epoch. The composition of soil is from sandy to loamy and some part of soil is scarcely made up with the loamy sands. The color of soils is generally from brown to gray brown with the 5–15% mixture of $CaCO_3$. The soil is usually composed of nan-saline, non-sodic mixed with poor organic materials having range of pH from 7.8 to 8.4. The developing hypersaline wetlands are common due to the overflow from Nara Canal [5]. The region is distributed with the sandy and steep hills which are locally famous as “patt”, “Tars” or “Tals”. The main source of water for the agriculture and other activities is Nara Canal which extends up to 4–5 km from both sides of canal [5] (**Figure 1**).

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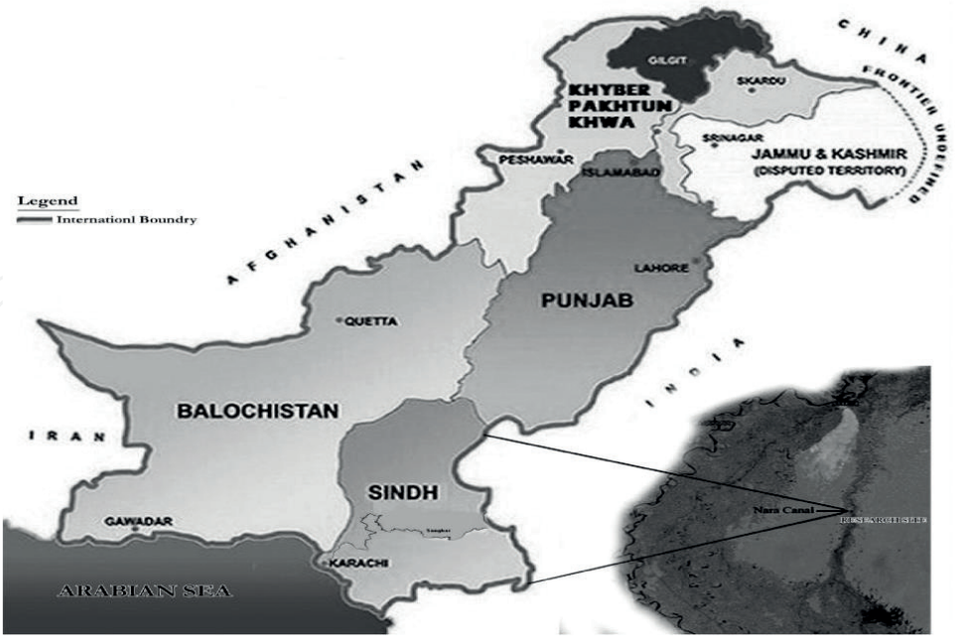

Figure 1. Map of study area of Nara Desert wild life sanctuary.

The area has high wind velocity with the huge amounts of shifting of sand hills and have high temperature with higher soil radiation in the summer and observed very short rainfall and high evapo-transpiration. In the Nara Desert the average minimum temperature is 20°C and the maximum temperature is 45°C. In the summer, the hottest months are from May to July, when the temperature increases from 45 to 51°C. In the winter season, the lower temperature ranges from 20 to 28°C for the months of December to January. In the region, the annual rainfall from 88 to 135 mm occurs during the months from July to September [1–4, 6]. The region of NDWC includes about more than 225 small to medium and some large sized-wetlands; some of these are seasonal and most are permanent. The Nara Canal is the largest canal of Sindh Province and covers more than 108 million hectares. On the both sides of Nara Canal the area is covered with woodland, riverine forest, scrub and desert scrubs. In the region, the source of water for wetlands is the seepage from the Nara Canal [1–4, 7].

The climate of the area is mainly arid having high temperatures and late summer rains observed. The seasonal rainfall is varied and is less than 250–300 mm and rainy season usually starts from June to September. Before the monsoon season, the average temperature is exceeding 45°C in the desert region and in the plains of NDWS the average temperature between 30 and 40°C. The wetland complex is recognized of great hydrological values as 98% Nara Canal water is used for agriculture and only 2% water is used for domestic and drinking purposes. The wetland complex of Nara Canal is 361.6 km long and 90–135 m wide. The maximum water depth of wetland complex is 7.5 m. The highest water discharges of Nara Canal are reported in the months of May–July and the minimum water flow in the August [1, 2, 5].

1.2. Socio-economic status of area

According to the census survey report of 2016, the total population of Nara Taluka is counted 160,985. The target area of Nara Taluka the total population can be estimated to be more than

60,000. The major communities are living in the area study are Baradin, Baloch, Chang, Shard, Syed, Rapper, Dashi, Maleah, Khaskheli, Channa, Sahta, Gopang, Bhurgari, Rind, Nizamani, Mirbahar, Khoso, Wassan, Deewan, Ibupoto, Kakepoto, Rajar, Mirani, and Macchi. From these communities, a few numbers of people are engaged in artisan work, trade, business and job in government departments etc. The Livestock and agriculture are the major source of income of local communities. Cotton and wheat are the main crops cultivated in the Nara while sugarcane, barely, oil seed, pulses, vegetable and fodder are also cultivated. The peoples of the area are living in the worst condition and they have least health facilities, drinking water, education and they do not have available basic life facilities. In spite of low productivity of area, the desert area sustains relatively higher human (1.05 m) and livestock (1.25 m) populations was reported, respectively. The livestock is the major source of income, meat and wool in the area. The overexploitation of vegetation by the grazing animals and the cutting of trees and shrubs for fuel purposes have resulted in environmental degradation that threatens the natural resources in this area. There is no developed transportation system in the Nara Desert. Due to low literacy rate in the area, there is a lack of employment opportunities [5].

1.3. Floristical and faunilistical assessment of Nara Desert wetland complex

In the region of NDWC the richest biodiversity comprises a mosaic habitat of sandy hills, canals, forests, agriculture fields, freshwater and hypersaline wetlands. The area has the richest plant biodiversity consisting of 160 plant species belonging to 118 genera and 45 families were recorded [8–10]. The seasonal crops include sugarcane, cotton, wheat, barley and sunflower. The major vegetation in the sandy habitats are *Prosopis cineraria*, *Acacia niloticus*, *Salvadora oleoides*, *Dalbergia sissoo*, *Tamarix aphylla*, *Melia azedarach*, *Populus spp*. and *Calotropis procera* [5, 6, 11–13]. In the Nara Desert, the various drought-tolerant plant species, such as cactuses and succulents (*Agaves spp*.), *Aerva javanica*, *Calligonum polygonoides*, *Crotalaria burhia*, *Capparis decidua*, *Dipterygium glaucum*, *Tephrosia villosa*, *Aristida adscensionis*, *Cassia*, *Tephrosia uniflora* and *Cassia italic* were recorded [5]. In the zone of Nara Desert, a mixed vegetation of shrubs and plants, such as *Typha spp.*, *Hydrilla verticillata*, *Paspalum distichum*, *Polygonum hyaropier*, *Urticularia lotus*, *Nelumbium nuciferum*, *Desmostachya bininata*, *Phragmites karka*, *Saccharum bengalensis* and *Tamarix indica* were also reported [5, 8–10, 14–23].

The region has been received the high socio-economic values for the local community which is dependent on the agriculture, livestock, fish farms and freshwater wetlands. In this area, the small to medium villages are scattered and their major economies are agriculture and livestock [1, 2, 5, 17, 24]. In this zone, the variety of different wild mammalian species includes *Hemiechnus auritus*, *Caracal caracal*, *Felis chaus*, *Felis margarita*, *Herpestes edwardsi*, *Herpestes javanicus*, *Canis lupus pallipes*, *Vulpes zerda*, *Hyaena hyaena*, *Mellivora capensis*, *Manis crassicaudata*, *Gazella bennettii*, *Hyelaphus porcinus*, *Sus scrofa cristatus*, *Lepus tibetanus*, *Funambulus pennantii*, *Hystrix indica*, *Lutrogale perspicilletta*, *Lutra lutra* and *Prionailurus viverrinus* [5, 25–27]. The NDWC has the richest biodiversity of native and migratory avian fauna of which more than 78 avian species were recorded [5, 7, 24, 25, 28–30]. From this region, two threatened species of Indian-backed vulture and houbara bustard were recorded. The indigenous bird species of myna, crow, sparrow, red-wattled lapwing, white-tailed plover, and stilt were commonly observed. Two bird species of

large-pied wagtail (*Motacilla maderaspatensis*) and rock bunting (*Emberiza cia*) were the first time reported in this region [5]. Some important bird species categorized by International Union for Conservation of Nature (IUNCN) Red List as Least Concern species include the Indian darter, black or red-naped ibis, ruddy Shel duck; as Vulnerable, the marbled teal, and as Near Threatened, the ferruginous duck [5, 23, 24, 28–32].

2. Material and methods

For the collection of data the study was carried out in Nara Desert Wildlife Sanctuary which is located between 26°28° N and 68°70° N (Elevation 50–115 m) in the province of Sindh, Pakistan For the collection of flora species, the direct method/observation was applied during the diurnal period. To collect the faunal species, the direct and indirect methods were applied. For the collection of important ecological data of floristical and faunistical species, the field work for diurnal and nocturnal surveys were conducted randomly.

For the various physicochemical parameters, water from 10 randomly selected stations from a few selected lakes of NDWC were sampled monthly from January to December 2015. The samples were collected from two different sampling sites of upper surface and lower bottom layers and were kept in (Van Dorn Plastic Bottles 1.5 liter) during the collection period.

Parameters	Abbreviation	Units	Procedure
Temperature	Temp	°C	Mercury thermometer
pH	pH	pH Unit	pH meter
Electrical conductivity	EC	Mu/Scm	Conductivity meter
Total dissolved solids	TDS	mg L^{-1}	WTW 320
Turbidity	Turb	NTU	Nephlometric turbidity meter
Calcium	Ca	mg L^{-1}	Titration method (EDTA)
Magnesium	Mg	mg L^{-1}	Titration method (EDTA)
Hardness	Hard	mg L^{-1}	Titration (silver nitrate)
Carbonate	HCO	ppm	Titration (2310)
Bi-carbonate	HCO_3	ppm	Titration (2310)
Alkalinity	Alkal	mg L^{-1}	Titration (silver nitrate)
Chlorides	Cl	mg L^{-1}	Titration (silver nitrate)
Sodium	Na	mg L^{-1}	WTW (320)
Potassium	K	mg L^{-1}	Titration method (EDTA)
Sulphate	SO_4	mg L^{-1}	Titration (2310)
Biological oxygen Demand	BOD	mg L^{-1}	Winkler method
Dissolved oxygen	DO	mg L^{-1}	Winkler method

Table 1. Analytical procedure for physicochemical parameters of NDWC during 2015.

After the samples were kept in 10% nitric acid for 24 hours and rinsed with the distilled water. Water samples were mixed in acid-washed container, rinsed with distilled water, and then stored at 4°C for further analysis. For quality assurance, the samples were analyzed in duplicate through careful standardization and samples examined. Physicochemical analysis was performed by the standardized methods [33]. Chemical properties of water samples including water temperature, depth, and transparency were measured with the Secchi Disk. The temperature was measured by a mercury thermometer immersed into a water depth of 15 cm for 2–5 mins. The pH was measured by of an Orion Model 420 pH meter. The EC, TDS, and Na parameters were measured by a WTW 320 conductivity meter. Alkalinity, hardness, Cl and phosphate were analyses conducted by the standardized methods as recognized by WHO [34]. Titration method (2310) was used to measure Ca, HCO_3 and HCO. Mg and K were analyzed by spectrometry. For the analysis of BOD and DO, the Winkler method and a Jenway Model 9071 Oxygen Meter were used, respectively (**Table 1**).

3. Results

3.1. Ecological assessment: (Flora and Fauna)

Flora: In the region of Nara Desert a variety of different floral species of aquatic as well as terrestrial plants, herbs, shrubs and drought resistant plant species were recorded (**Table 2**).

S. No#	Scientific Name	Common Name	Local Name
1.	*Acacia nilotica*	Thorn mimosa, Bubul	Bubar
2.	*Dalbergia sissoo roxb*	Sisu, Tali	Talehi
3.	*Alhagi maurorum*	Camel-thorn bush	Kandero
4.	*Albizia durraz*	Siris	Sareenhn
5.	*Mimosa pudica L.*	Chui-mui, Lajwanti	Sharam Booti
6.	*Prosopis juliflora*	Mosquite	Deevi
7.	*Prosopis cinreria*	Jamal gotha	Kandi
8.	*Tamarind indica linn*	Imli	Gidaamri
9.	*Trigodela L.*	Proshan, kakpie	Hurbo
10.	*Ocimum L.*	Basil	Nazbu
11.	*Grevia L.*	Phalsa	Pharva
12.	*Azadirachia indica*	Neem	Nim
13.	*Ficus benghalensis L.*	Banyan tree	Barr
14.	*Ficus religiosa L.*	Sacred Fig	Pipal
15.	*Morus alba L.*	White Mulberry	Toot
16.	*Eucalyptus camaldulensis*	Red Gum, Eucalyptus	Safedo
17.	*Zizephus mauritiana Lam*	Berry	Baer

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S. No#	Scientific Name	Common Name	Local Name
18.	*Salvadora persica L.*	Peelu	Khabbar
19.	*Cordia gharaf*	Gondni	Gaiduri
20.	*Tamarix passerinoides*	Tamarisk	Layee
21.	*Pennisatum glaicum L.*	Bajra	Bajhari
22.	*Zea mays L.*	Corn	Makai
23.	*Desmostachya bipinnata*	Dub, Halfa grass	Drubh
24.	*Calotropis procera*	Milk Weed	Akk
25.	*Eruka sativa*	Salad Rocket	Janmbho
26.	*Opentia ficus indica L.*	Cactus	Thohar
27.	*Capparix decidus*	Kapparis	Kirar
28.	*Suaeda fruiticosa*	Shrubby Seablight	Laani
29.	*Citrullus colocynchis L.*	Bitter Apple	Tooh
30.	*Calligonum polygonoides*	Phog	Phog
31.	*Aerva javanica*	Kopak Bush	Booh
31.	*Tamarix aphylla*	Tamarisk	Lao
32.	*Salvadora oleoides*	Jaal	Jaar
33.	*Crotolaria burhia*	Burhia Rattlepod	Soma
34.	*Dipterygium glaucum*	Safrawi	Phair
35.	*Aristida adscensionis*	Sixweeks Threeawn	Lumb Gaah
36.	*Cassia italic*	Cassia, Golden tree	Ghora wal
37.	*Tephrotia uniflora*	Senegal	Siringh/Andhari
38.	*Teophrotia villosa*	Creeping Thistle	Phoodno
39.	*Typha latifolia*	Cattail	Kanahn
40.	*Typha angusta*	Cattail	Kaani
41.	*Paspalum distichum*	Knotgrass	Naru Gaah
42.	*Hydrilla verticillata*	Hydrilla	Hydrilla
43.	*Nyphaea lotus*	White Lotus	Kanwal
44.	*Polygonum hyaropier*	Blake's Knotweed	Anjbar
45.	*Urticulara lotus*	Water Lotus	Kanwal
46.	*Nelumbium nuciferum*	Nelumbium	Kanwal

Table 2. Flora of NDWS.

Fauna: Amphibians: In the Nara Desert three amphibian species belonging from two families of Ranidae and Bufonidae were reported (**Table 3**).

Reptiles: Region of Nara Desert is considered rich in herpeto-fauna with 24 reptilian species belonging to three orders and 12 families. Out of the 24-reptilian species, 2 were herbivores,

S. No#	Scientific Name	Common Name
1.	*Crocodylus palustris*	Mugger crocodile
2.	*Kuchuga tecta*	Saw-back turtle
3.	*Kuchuga smithi*	Brown turtle
4.	*Geoclemys hemiltonii*	Spotted-pond turtle
5.	*Canis aureus*	Asiatic jackal
6.	*Fellis chaus*	Jungle cat
7.	*Prionailurus viverrinus*	Fishing cat
8.	*Felis silvestris*	Desert cat
9.	*Vulpes vulpes*	Red fox
10.	*Lutrogale perspicillata*	Smooth-coated otter
11.	*Herpestes javanicus*	Small Indian mongoose
12.	*Herpestes edwardsi*	Gray mongoose
13.	*Axis porcinus*	Hog deer
14.	*Sus scrofa*	Indian wild boar
15.	*Funambulus pennanti*	Palm squirrel
16.	*Gerbilus nanus*	Balochistan gerbill
17.	*Hemiechinus collaris*	Long-eared hedgehog
18.	*Hystrix indica*	Indian crested porcupine
19.	*Lepus nigricollis*	Desert hare
20.	*Meriones hurrianae*	Indian desert jird
21.	*Mus musculus*	House mouse
22.	*Tatera indica*	Indian gerbil
23.	*Aspiderestes gangeticus*	Indian soft shell turtle
24.	*Lissemys punctate punctata*	Indian flapshell turtle
25.	*Naja naja naja*	Indian cobra
26.	*Echis carinatus*	Saw-scaled viper
27.	*Eryx johni*	Indian sand boa
28.	*Lytorhynchus paradoxus*	Sindh awlheaded sand snake
29.	*Platyceps rhodorchis*	Cliff racer platyceps
30.	*Platyceps ventromaculatus*	Glossy-bellied racer
31.	*Xenochrophid piscator*	Checkered keelback
31.	*Calotes versicolor*	Tree lizard
32.	*Trapelus megalonyx*	Afghan ground agama
33.	*Hemidactylus brookii*	Yellow-bellied house gecko
34.	*Hemidactylus brooki*	Spotted Indian house gecko
35.	*Cyrtopodion scaber*	Keeled rock gecko

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S. No#	Scientific Name	Common Name
36.	*Ophoimorus raithmai*	Three-fingered sand-fish
37.	*Ophoimorus tridactylus*	Indian sand swimmer
38.	*Eutrophis macularia*	Bronze grass skink
39.	*Varanus bengalensis*	Bengal monitor
40.	*Varanus griseus*	Desert monitor
41.	*Acanthodactylus cantoris*	Indian fringetoed sandy lizard
42.	*Bufo stomaticus*	Marbled toad
43.	*Hoplobatrachus tigerinus*	Bull frog
44.	*Rana cyanophlyctis*	Skittering frog
45.	*Tachybaptus ruficollis*	Little grebe
46.	*Podiceps nigricollis*	Black-necked grebe
47.	*Phalacrocorax niger*	Little cormorant
48.	*Phalacrocorax carbo*	Large cormorant
49.	*Phalacrocorax fuscicollis*	Indian darter
50.	*Ardea cinerea*	Gray heron
51.	*Ardea purpurea*	Purple heron
52.	*Ardeola grayii*	Indian pond heron
53.	*Bubulcus ibis*	Cattle egret
54.	*Egretta alba*	Large egret
55.	*Egretta intermedia*	Intermediate egret
56.	*Egretta garzetta*	Little egret
57.	*Egretta gularis*	Reef heron
58.	*Ixobrychus minutus*	Little bittern
59.	*Ixobrychus sinensis*	Yellow bittern
60.	*Tadorna ferruginea*	Ruddy shelduck
61.	*Marmaronetta angustirostris*	Marbled teal
62.	*Anas crecca*	Common teal
63.	*Anas platyrhynchos*	Mallard
64.	*Anas strepera*	Gadwall
65.	*Anas clypeata*	Shoveller
66.	*Aythya ferina*	Common pochard
67.	*Aythya nyroca*	Ferruginous duck
68.	*Aythya fuligula*	Tufted duck
69.	*Aythya collaris*	Ring-necked duck
70.	*Elanus caeruleus*	Blackwinged kite
71.	*Milvus migrans*	Common kite

S. No#	Scientific Name	Common Name
72.	*Haliastur indus*	Brahminy kite
73.	*Accipiter badius*	Central Asian shikra
74.	*Butastur teesa*	White-eyed buzzard
75.	*Circus aeruginosus*	Marsh harrier
76.	*Falco tinnunculus*	Common kestrel
77.	*Pandion haliaetus*	Osprey
78.	*Francolinus pondicerianus*	Gray partridge
79.	*Francolinus francolinus*	Black partridge
80.	*Amaurornis phoenicurus*	White-breasted waterhen
81.	*Gallinula chloropus*	Indian moorhen
82.	*Porphyrio porphyrio*	Purple moorhen
83.	*Fulica atra*	Common coot
84.	*Charadrius leschenaultia*	Greater sand plover
85.	*Vanellus indicus*	Redwattled lapwing
86.	*Vanellus leucurus*	White tailed plover
87.	*Charadrius dubius*	Little ringed plover
88.	*Charadrius alexadrinus*	Kentish plover
89.	*Charadrius mongolus*	Lesser sand plover
90.	*Numenius arquata*	Curlew
91.	*Numenius phaeopus*	Whimbler
92.	*Limosa lapponica*	Bartailed godwit
93.	*Tringa totanus*	Common redshank
94.	*Tringa stagnatilis*	Marsh sandpiper
95.	*Tringa nebularia*	Green shank
96.	*Tringa glareola*	Wood sandpiper
97.	*Tringa hypoleucos*	Common sandpiper
98.	*Gallinnago gallinago*	Common snipe
99.	*Calidris minutus*	Little stint
100.	*Calidris alpine*	Dunlin
101.	*Philomachus pugnax*	Ruff
102.	*Himantopus himantopus*	Blackwinged stilt
103.	*Larus heuglini*	Heuglin's gull
104.	*Larus brunnicephalus*	Brown headed gull
105.	*Larus ridibundus*	Black Headed gull
106.	*Larus genei*	Slenderbilled gull
107.	*Gelochelidon nlitica*	Gull-billed tern

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S. No#	Scientific Name	Common Name
108.	*Hydroprogne caspia*	Caspian tern
109.	*Sterna aurantia*	Indian River tern
110.	*Sterna acuticauda*	Blackbellied tern
111.	*Sterna albifrons*	Little tern
112.	*Sterna sendvicensis*	Sandwitch tern
113.	*Columba livia*	Blue rock pigeon
114.	*Streptopelia decaocto*	Ring dove
115.	*Sterptopelia senegalensis*	Little brown dove
116.	*Centropus sinensis*	Crown pheasant
117.	*Ketupa zeylonensis*	Brown fish owl
118.	*Athene brama*	Spotted owlet
119.	*Ceryle rudis*	Pied kingfisher
120.	*Alcedo athis*	Common kingfisher
121.	*Halcyon smyrnensis*	Whitebreasted kingfisher
122.	*Merops orientalis*	Green-bee eater
123.	*Merops persicus*	Blue-cheeked bee eater
124.	*Corcias benghalensis*	Indian roller
125.	*Upupa epops*	Common hoopoe
126.	*Amomanes deserti*	Desert lark
127.	*Calendrella brachydactyla*	Great short-toed lark
128.	*Galerida cristata*	Crested lark
129.	*Riparia diluta*	Pale sand martin
130.	*Hirundo fuligula*	Crag/rock martin
131.	*Hirundo rustica*	Barn or common swallow
132.	*Lanius isabellinus*	Rufous tailed or Isabelline shrike
133.	*Lanus meridionalis*	Southern gray shrike
134.	*Lanius vittatus*	Bay backed shrike
135.	*Dicrurus adsimilis*	Black drongo
136.	*Acridotheres adsimilis*	Indian myna
137.	*Sturnus vulgaris*	Common
138.	*Phoenicurus ochruros*	Starling
139.	*Oenanthe albonigra*	Hume's wheatear
140.	*Saxicoloides fulicata*	Indian robin
141.	*Saxicola caprata*	Pied robin chat
142.	*Oenanthe isabellina*	Isabelline wheatear
143.	*Oenanthe sdeserti*	Desert wheatear

S. No#	Scientific Name	Common Name
144.	*Corvus splendens*	House crow
145.	*Dendrocitta vagabunda*	Tree pie
146.	*Prinia flaviventris*	Yellow bellied prinia
147.	*Prinia burnesii*	Rufous vented prinia
148.	*Pycnonotus leucogenys*	White-cheeked bulbul
149.	*Pycnonotus cafer*	Red-vented bulbul
150.	*Turdoides caudatus*	Common babbler
151.	*Turdoides earlie*	Striated babbler
152.	*Turdoides striata*	Jungle babbler
153.	*Rhipidura aureola*	White browed fantail
154.	*Phylloscopus collybita*	Common chiffchaff
155.	*Acrocephalous stentoreus*	Clamorous reed warbler
156.	*Sylvia curruca*	Lesser whitethroat sylvia
157.	*Phylloscopus trochiloides*	Greenish warbler
158.	*Motacilla alba*	White wagtail
159.	*Motacilla flava*	Yellow wagtail
160.	*Nectarinia asiatica*	Purple sunbird
161.	*Passer domesticus*	House sparrow
162.	*Passer pyrrhonotus*	Sindh jungle sparrow

Table 3. Fauna of NDWS.

13 were carnivores and 9 were insectivores. A famous indigenous Vulnerable reptilian species of marsh crocodile (*Crocodylus palustris*) was also reported from the Nara Canal and its adjacent territories (**Figure 2**) (**Table 3**).

Birds: In the region of NDWC, these wetlands are recognized as the major habitats for the variety of rare and endangered migratory birds. In NDWC, 118 bird species belonging to 13 orders and 35 families belonging were reported. Fifty-nine birds were native species while 53 birds were migratory species. The important migratory birds were the marbled teal, *Anan angustirostris* (Vulnerable-threatened) and the ferruginous duck, *Aythya nyroca* and the Indian darter, *Anhyinga rufa* (Near-threatened) (**Table 3**).

Small mammals: From the habitat of NDWC the small mammal populations belonging to 3 orders and 5 families were also reported. The small mammals included 5 granivores, 2 herbivores and 1 omnivore (**Table 3**).

Large Mammals: Large Mammals: Twenty-five species of large mammals were reported. From order Carnivora, 10 species included the jungle cat, jackal, small Indian mongoose, gray mongoose, wolf and red fox and from the Order Artiodactyla, the wild boar (**Table 3**) (**Figure 3–6**).

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Figure 2. A view of marsh crocodile.

Figure 3. A view of Lake in NDWC.

Figure 4. A view of plantation in NDWC.

Figure 5. A view of Desert dune in NDWC.

Figure 6. A view of Typha in NDWC.

3.2. Analysis of physicochemical parameters

The highest air temperature of 45°C was measured in July and the lowest of 20°C was measured in January (**Tables 4**, **11**). The highest and lowest water temperatures were 42 and 17°C, respectively (**Table 4**). The highest and lowest values (9.3 and 6.9) for pH were measured in November and December, respectively (**Tables 11**, **12**). The highest and lowest values (9120 and 364 mu/Scm) for EC were measured in November and May, respectively (**Tables 11**, **13**). The highest and lowest values (1042 and 214 mg/L) for TDS were measured in March and May, respectively (**Tables 7**, **13**). The highest and lowest values (186 and 0.20 NTU) for turbidity were measured in the months of January – September, respectively (**Tables 7**, **9**). The highest and lowest values (1214 and 6 mg/L) for Ca were measured in January and November, respectively (**Tables 8**, **10**). The highest and lowest values (876 and 12 mg/L) for Mg were measured in March and May, respectively (**Tables 8**, **13**). The highest and lowest values (5536 and 140 mg/L) for hardness were measured in March and May, respectively (**Tables 7**, **13**). The

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Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temp: Air	20	25	28	32	38	43	**45**	42	32	28	23	20
Tem: Water	17	21	23	28	29	38	33	37	29	24	20	17
pH	8.2	8.1	8.3	8.2	8.0	7.9	7.9	8.0	7.8	7.9	8.0	8.1
EC	985	915	954	885	875	870	850	860	820	890	970	930
TDS	630	618	613	605	590	598	600	620	580	612	640	624
Turb	30	35	32	38	40	42	45	37	28	33	35	41
Ca	40	38	52	50	58	52	65	54	35	34	45	42
Mg	27	30	37	32	35	33	40	25	23	29	24	38
Hard	210	234	270	218	245	240	256	228	205	215	225	220
Alkal	3.5	3.7	3.8	3.9	3.4	3.7	4.0	3.8	3.2	3.5	3.6	3.7
Cl	131	127	122	132	115	142	145	130	120	124	140	135
Na	128	143	145	135	120	128	150	132	110	122	130	137
K	18	20	21	23	19	20	25	21	16	17	20	18
SO_4	128	138	140	98	32	110	116	114	105	118	120	132
HCO	—	—	—	—	—	—	—	—	—	—	—	—
HCO_3	175	152	162	147	150	134	130	170	140	153	165	160
BOD	3.0	3.5	3.2	3.0	2.9	3.3	2.8	3.1	3.5	3.4	3.8	3.7
DO	4.8	4.5	4.9	4.2	**3.7**	4.0	3.9	4.3	4.2	4.6	4.1	4.7

Table 4. Physicochemical analysis of water sample of station 1. Gunjo Bhanbharo Lake.

Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temp: Air	20	25	26	30	32	37	42	38	32	27	23	20
Tem: Water	16	21	23	26	29	33	38	35	29	24	20	17
pH	8.2	8.0	8.1	7.9	8.0	7.7	7.8	8.1	7.6	8.0	7.9	8.2
EC	2860	2478	2730	2380	2595	2517	2370	2678	2173	2594	2436	2247
TDS	1830	1800	16,500	1700	1540	1460	1285	1678	1240	1315	1464	1780
Turb	33	24	30	22	25	19	21	20	18	26	28	29
Ca	140	137	150	145	130	142	120	126	114	118	132	122
Mg	60	48	75	70	52	65	45	44	42	58	53	66
Hard	600	652	680	575	580	638	590	618	563	598	620	640
Alkal	7.0	8.2	12.0	9.1	8.0	8.5	10.0	7.8	6.0	11.0	9.0	8.4
Cl	192	185	210	190	170	192	165	204	154	167	184	180

Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Na	382	370	350	308	315	338	286	268	250	317	375	347
K	32	36	38	32	28	25	24	33	20	24	27	23
SO_4	778	754	725	674	635	653	605	725	582	762	683	697
HCO	—	—	—	—	—	—	—	—	—	—	—	—
HCO_3	350	270	285	315	260	290	250	305	250	360	376	326
BOD	3.5	3.4	3.2	3.6	3.6	3.7	3.8	3.5	3.7	3.3	3.8	3.4
DO	5.0	4.9	4.8	4..7	4.9	4.5	4.8	4.8	4.6	4.3	4.2	4.7

Table 5. Physicochemical analysis of water sample of station 2. Bachal Bhanbharo Lake.

Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temp: Air	21	24	26	30	32	37	43	36	32	27	23	20
Tem: Water	18	20	23	28	29	34	39	32	29	24	20	17
pH	8.0	7.9	7.6	7.7	7.8	7.6	7.5	7.8	7.3	7.5	7.9	7.7
EC	925	876	856	815	814	764	725	780	705	802	883	865
TDS	586	562	547	540	510	487	462	516	443	550	532	580
Turb	9.2	11.4	11.9	10.7	10.4	11.9	12.3	10.9	11.2	11.0	11.6	10.8
Ca	82	74	68	80	54	67	45	56	40	65	75	70
Mg	74	70	62	51	52	58	48	66	42	54	68	62
Hard	538	518	426	487	410	468	430	500	410	485	520	508
Alkal	3.5	3.2	2.6	2.8	2.5	2.9	2.2	2.8	2.1	3.1	3.2	3.4
Cl	168	156	139	141	130	127	118	1162	106	149	156	150
Na	42	33	38	41	34	35	32	36	27	40	38	39
K	40	34	32	29	30	35	34	47	28	37	36	33
SO_4	208	193	195	165	173	182	164	158	153	168	192	187
HCO	—	—	—	—	—	—	—	—	—	—	—	—
HCO_3	142	137	130	129	123	132	120	125	105	139	134	138
BOD	3.9	3.6	3.8	3.8	3.6	3.8	3.7	3.6	3.5	3.7	3.9	3.8
DO	5.2	4.9	5.1	5.0	4.8	4.7	4.8	4.9	4.6	5.1	5.1	5.0

Table 6. Physicochemical analysis of water sample of station 3. Skebi Lake.

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Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temp: Air	21	23	26	31	32	39	44	40	32	26	23	20
Tem: Water	19	20	23	27	29	36	40	36	29	23	20	17
pH	8.5	8.6	9.0	8.5	8.7	8.7	8.5	8.8	8.2	8.9	8.4	8.6
EC	1327	2190	1270	1250	1194	1230	1054	1180	983	1246	1127	1110
TDS	9827	8965	**10,420**	9547	8974	9657	7590	8540	6580	7890	8936	9570
Turb	0.27	0.23	0.29	0.24	0.25	0.27	0.23	0.25	**0.20**	0.26	0.29	0.28
Ca	728	745	772	710	685	715	680	672	582	720	782	730
Mg	838	782	**876**	816	782	725	678	698	645	763	812	804
Hard	5428	5160	**5536**	5096	4528	4826	3974	4976	3792	5120	5265	5380
Alkal	3.8	3.5	3.4	3.3	3.2	3.7	3.1	3.2	3.0	3.7	3.6	3.5
Cl	3329	3289	**3418**	3370	3236	3190	3075	2987	2868	3145	3185	3276
Na	52	50	46	54	58	45	48	47	42	48	49	50
K	**182**	159	170	180	162	150	156	169	140	160	172	157
SO_4	**2980**	2896	2937	2765	2830	2696	2589	2752	2438	2686	2845	2810
HCO	—	—	—	—	—	—	—	—	—	—	—	—
HCO_3	182	153	170	167	162	146	156	149	140	148	172	160
BOD	4.2	4.1	4.0	3.9	4.0	4.0	3.9	3.9	3.8	4.0	4.1	4.0
DO	5.5	5.3	5.4	5.2	5.3	5.4	5.1	5.2	5.0	5.3	5.2	5.1

Table 7. Physicochemical analysis of water sample of station 4. Tooti Lake.

Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temp: Air	21	25	26	33	37	41	42	39	32	26	23	20
Tem: Water	19	22	23	30	33	38	39	36	29	23	20	17
pH	9.2	9.0	9.1	8.7	8.8	9.0	8.5	8.6	8.3	8.4	8.9	8.8
EC	7984	7878	7920	7636	7180	7280	6568	6892	5872	6972	6217	7684
TDS	5123	4976	5068	4783	4837	4690	4287	4528	4027	4686	4839	5074
Turb	38	32	33	37	30	36	28	29	24	31	35	34
Ca	**1214**	1180	1174	1168	1034	1149	983	1084	845	987	1128	1068
Mg	394	376	374	310	345	355	285	367	262	296	312	342
Hard	3985	3884	3923	3810	3812	3792	3529	3626	3428	3590	3782	3888
Alkal	2.9	2.3	2.64	2.4	2.5	2.2	2.1	2.5	**2.0**	2.6	2.8	2.7

Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Cl	147	140	132	130	127	129	120	125	108	134	142	128
Na	75	72	69	71	62	73	56	54	48	66	72	70
K	23	21	18	19	16	20	14	22	15	17	21	22
SO_4	1915	1880	1819	1792	1725	1682	1528	1632	1372	1575	1882	1794
HCO	—	—	—	—	—	—	—	—	—	—	—	—
HCO_3	0.9	0.6	0.8	0.6	0.7	0.8	**0.5**	0.7	0.6	0.7	0.8	0.6
BOD	4.5	4.4	4.2	4.3	4.1	4.2	4.0	4.1	3.9	4.3	4.2	4.0
DO	5.4	5.1	5.3	5.1	5.2	5.3	5.1	5.2	5.0	5.3	5.2	5.1

Table 8. Physicochemical analysis of water sample of station 5. Dangewari Lake.

Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temp: Air	21	24	26	34	38	43	44	38	32	28	23	20
Tem: Water	19	21	23	30	35	40	41	34	29	24	20	17
pH	9.0	8.8	8.9	8.6	8.5	8.7	8.3	8.4	8.1	8.3	8.6	8.8
EC	8912	8842	8720	8254	7837	7632	6865	6540	5392	6934	6836	7894
TDS	5610	5495	5580	5324	4872	4670	4583	4264	3983	4685	4892	4975
Turb	**186**	183	180	172	162	148	152	138	106	162	170	180
Ca	492	471	482	465	385	390	328	387	295	348	412	426
Mg	782	735	757	708	628	615	573	628	412	593	684	710
Hard	4427	4350	4321	4230	4082	4150	3862	3764	3429	3927	4128	4250
Alkal	2.8	2.4	2.6	2.3	2.4	2.5	2.2	2.6	2.1	2.4	2.5	2.7
Cl	142	137	130	120	126	119	114	121	108	133	125	138
Na	54	49	46	44	42	43	37	39	32	46	41	40
K	8.0	8.4	4.0	7.5	5.0	6.8	6.0	8.7	7.0	6.5	9.0	8.9
SO_4	2286	2175	2213	2098	2145	1945	2096	2190	1827	1670	1273	1450
HCO	—	—	—	—	—	—	—	—	—	—	—	—
HCO_3	1.2	1.1	1.06	1.3	1.03	1.2	1.1	1.3	1.0	1.1	1.4	1.2
BOD	**4.6**	4.2	4.3	4.4	4.2	4.5	4.1	4.2	3.9	4.0	4.3	4.2
DO	5.1	4.8	5.0	4.9	5.0	5.0	4.9	4.8	4.7	4.8	5.0	4.9

Table 9. Physicochemical analysis of water sample of station 6. Kharari Lake.

Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temp: Air	20	24	26	30	37	41	44	38	32	27	23	20
Tem: Water	18	21	23	27	34	37	40	34	29	24	20	17
pH	8.0	7.8	7.9	7.6	7.7	7.9	7.5	7.8	7.6	7.8	7.7	7.9
EC	5489	5370	5282	5685	4827	5120	4628	4952	5273	5734	6190	5856
TDS	3186	3256	2973	3080	2863	2965	2682	2792	2854	3124	3340	3260
Turb	12.6	11.8	12.0	11.3	10.0	9.2	8.0	10.4	9.0	9.8	11.9	10.5
Ca	22	18	20	19	18	17	15	21	13	11	6	10
Mg	294	265	240	217	235	247	192	230	205	208	273	253
Hard	1082	978	926	912	884	890	836	992	928	985	1180	1005
Alkal	20.5	19.6	`19.8	18.7	19.2	20.2	16.2	17.6	18.5	19.9	21.4	20.7
Cl	603	568	583	590	535	528	483	610	528	630	666	642
Na	787	740	782	714	739	728	626	775	712	805	821	794
K	38	35	31	34	29	32	26	36	28	30	32	33
SO_4	937	883	826	694	793	782	638	728	875	635	1040	868
HCO	—	—	—	—	—	—	—	—	—	—	—	—
HCO_3	980	940	826	860	793	836	782	872	863	945	1070	984
BOD	3.7	3.6	3.1	3.5	2.9	3.4	**2.7**	3.3	2.9	3.2	3.0	4.4
DO	5.6	5.8	5.4	5.7	5.3	5.5	5.2	5.8	5.7	5.9	**6.1**	6.0

Table 10. Physicochemical analysis of water sample of station 7. Raja Pathan Lake.

Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temp: Air	21	25	26	34	39	42	**45**	40	32	26	23	20
Tem: Water	19	22	23	30	36	39	41	36	29	23	20	17
pH	8.8	8.7	8.4	8.6	8.2	8.4	8.5	8.3	9.0	9.1	**9.3**	8.9
EC	8379	8239	7838	5673	4570	6890	5820	7346	7739	8215	**9120**	8764
TDS	1529	1432	1482	1380	1273	1446	1382	1457	1528	1590	1690	1568
Turb	0.27	0.25	0.26	0.28	0.22	0.23	0.21	0.24	0.25	0.27	0.29	0.22
Ca	49	45	38	46	30	42	36	47	40	51	54	50
Mg	329	348	230	297	186	245	210	305	236	264	397	322
Hard	1626	1486	1327	1336	1182	1479	1268	1504	1529	1545	1770	1654
Alkal	67.4	59	48	51	43	49	50	62	60.2	57	**71.6**	68
Cl	320	316	257	286	216	265	237	248	285	317	397	304
Na	1125	1030	937	879	792	915	845	1056	1026	1187	**1231**	1115

Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
K	67	70	53	56	47	58	52	60	62	57	72	55
SO_4	386	357	274	290	218	287	274	370	326	365	403	378
HCO	—	—	—	—	—	—	—	—	—	—	—	—
HCO_3	3428	3294	3028	3125	2793	2880	2983	3145	3218	3472	**3580**	3356
BOD	3.9	3.6	3.2	3.3	3.4	3.7	3.5	3.8	3.6	3.5	3.8	3.7
DO	5.6	5.5	4.8	5.3	5.0	5.1	5.2	5.0	5.4	5.7	5.8	5.2

Table 11. Physicochemical analysis of water sample of station 8. Old Nara Lake.

Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temp: Air	21	23	26	34	38	41	42	37	32	28	23	20
Tem: Water	19	20	23	30	35	38	39	34	29	25	20	17
pH	7.9	7.7	7.8	7.6	7.3	7.5	7.1	7.4	7.0	7.3	**6.9**	7.2
EC	1263	1143	1172	1092	938	1286	1027	1167	1263	1342	1495	1275
TDS	729	720	628	612	510	664	543	675	692	754	808	785
Turb	31	32	28	29	25	26	27	28	30	27	33	30
Ca	58	55	50	52	40	48	46	50	53	57	64	60
Mg	49	47	46	43	36	44	42	45	47	53	56	51
Hard	328	345	275	263	204	289	232	254	245	316	390	327
Alkal	4.3	4.4	4.0	4.1	3.9	4.7	4.1	4.4	4.2	4.5	4.8	4.6
Cl	152	148	138	119	110	134	126	160	135	145	166	141
Na	141	128	136	130	106	128	124	133	130	140	150	137
K	17	14	16	15	12	13	4	11	5	9	18	17
SO_4	239	215	143	178	137	198	153	232	172	214	260	243
HCO	—	—	—	—	—	—	—	—	—	—	—	—
HCO_3	210	225	189	194	145	178	162	196	186	224	240	210
BOD	3.8	3.7	3.5	3.6	3.3	3.5	3.0	3.4	3.1	3.2	3.6	3.3
DO	5.0	4.8	4.9	4.9	4.8	4.7	4.8	4.8	4.9	4.8	5.0	4.8

Table 12. Physicochemical analysis of water sample of station 9. Saedo Pattan Lake.

highest and lowest values (71.6 and 2.0 mg/L) for alkalinity were measured in November and September, respectively (**Tables 8**, **11**). The highest and lowest values (3418 and 22 mg/L) for Cl were measured in March and May, respectively (**Tables 7**, **13**). The highest and lowest values (1231 and 21 mg/L) for Na were measured in November and May, respectively (**Tables 10**, **13**).

Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temp: Air	21	24	26	33	35	40	43	38	32	27	23	20
Tem: Water	19	21	3	30	31	36	40	34	29	24	20	17
pH	7.6	7.4	7.2	7.3	7.0	7.2	6.9	7.1	7.0	7.5	7.3	7.1
EC	528	512	489	537	**364**	464	387	486	472	515	596	564
TDS	312	302	307	289	**214**	289	230	267	278	307	321	298
Turb	162	157	147	137	117	118	26	127	145	167	180	172
Ca	47	49	53	51	38	45	42	51	48	50	60	54
Mg	18	15	17	13	4	**12**	15	14	16	15	19	17
Hard	210	208	203	198	**140**	212	154	168	182	185	230	217
Alkal	3.5	3.3	3.4	3.2	3.1	3.3	3.0	3.5	3.1	3.2	3.6	3.4
Cl	30	31	29	27	**22**	28	25	26	28	30	32	29
Na	31	28	30	25	**21**	24	27	26	29	28	33	30
K	7.0	6.8	6.0	6.2	5.0	5.4	**3.0**	4.8	5.0	5.9	4.0	4.7
SO_4	61	55	47	44	**38**	43	40	49	46	56	69	62
HCO	—	—	—	—	—	—	—	—	—	—	—	—
HCO_3	171	156	154	128	104	145	120	138	125	167	180	171
BOD	3.9	3.7	3.5	3.8	3.3	3.4	3.1	3.6	3.2	3.5	3.8	3.4
DO	5.0	4.8	4.9	4.8	4.7	4.8	4.6	4.9	4.8	4.7	5.0	4.9

Table 13. Analysis of physicochemical parameters of water sample for station 10. Nara Canal Chundiko.

The highest and lowest values (182 and 3 m/L) for K were measured in January and July, respectively (Tables 7, 13). The highest and lowest values (2980 and 38 mg/L) for SO_4 were measured in November and May, respectively (**Tables 7**, **13**). The highest and lowest values (3580 and 0.5 mg/L) for HCO_3 were measured in November and July (**Tables 8**, **11**) while the value of 0 for HCO was measured in all the months of the study period (**Tables 4**–**13**). The highest and lowest values (4.6 and 2.7 mg/L) for BOD were measured in January and July, respectively (**Tables 9**, **10**). The highest and lowest values (6.1 and 3.7 mg/L) for DO were measured in November and July, respectively (**Tables 4**, **10**).

4. Discussion and conclusion

The Nara Desert Wetland Complex (NDWC) encompasses sandy dunes, steep hills and includes low lying flat zones associated with different natural wetlands formed from the seepage of Nara Canal. These different wetlands are the major perennial source of water for the agricultural lands, local communities, wildlife and grazing livestock. NDWC comprises more than 225 seasonal and permanent, small, medium and large-sized lakes/wetlands. The total area of Nara

Canal is distributed from Sorah (Sukkur) to Head Jamrao about 108,960 hectares and Nara Canal was declared in 1972 as a Game Reserve area for the protection of wild animals. The NDWC is also recognized as an essential potential Ramsar Site [1–5]. The different floral habitation distributed in the Nara Desert includes phytoplankton, reed vegetation, herbs, shrubs and trees. The area is ecologically-rich with the faunal biodiversity which includes zooplankton, invertebrates, fishes, amphibians, reptiles, birds, small and large mammals. The NDWC has received high economic, social, floral and faunal habitats, and aquatic biodiversity values because the local communities are directly or indirectly dependent on these natural sustainable resources [1–4, 7, 29, 35] (**Figure 7**).

In the area the water quality and recharged by the Nara Canal is mainly sweet and acceptable ranges of TDS between 500 and 800 ppm except hypersaline lakes. The hypersaline water of desert area is mainly observed brackish which have TDS between 10,000 and 28,000 pp. [5, 36].

The climate of the area is mainly arid having high temperatures and late summer rains observed. The seasonal rainfall is varied and is less than 250–300 mm and rainy season usually starts from June to September. Before the monsoon season, the average temperature is exceeding 45°C in the desert region and in the plains of NDWS the average temperature between 30 and 40°C. The wetland complex is recognized of great hydrological values as 98% Nara Canal water is used for agriculture and only 2% water is used for domestic and drinking purposes. The wetland complex of Nara Canal is 361.6 km long and 90–135 m wide. The maximum water depth of wetland complex is 7.5 m. The highest water discharges of Nara Canal are reported in the months of May–July and the minimum water flow in the August [1–4, 7].

The assessment of physicochemical parameters such as pH and alkalinity revealed that the lake water has mostly remained alkaline during the whole study period except the Nara Canal station due to its input of rain water. The range of hardness was higher in most of the selected lakes of NDWC. The acceptable level of hardness in lake waters is recognized as 200 mg/L by the World Health Organization [34]. The physicochemical parameters of Na and Mg, as well as

Figure 7. A view of Nara Canal Khairpur.

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the EC, TDS concentrations were found to be higher than the WHO standard. The Na is the major solute that can also affect aquatic biodiversity [37]; Na concentrations during the study period were higher than WHO accepted standard in most of the wetlands in the NDWC. The WHO recommended that the tolerable level of Cl is 250 mg/L [34]. In this study, the various wetlands had higher Cl concentration than the acceptable WHO standard. However, the concentrations of Ca, K, SO_4, HCO_3, BOD and DO were higher than the acceptable WHO standard in the most of selected wetlands during the study period.

In the study area, quality of water is mainly sweet and acceptable for drinking purposes. The range of Total Dissolved Solids (TDS) reported between 500 and 800 ppm. In the area, there are also few brackish wetlands reported and TDS varies between 10,000 and 28,000 due to recharge of insufficient amount of water. The quality of ground water is mainly dominated by sulfate, chloride, calcium and magnesium ions [16, 38, 39]. The conductivity (or TDS) is major parameter along with pH in recognizing the water quality. The values of both parameters is considered acceptable in freshwater lakes while it is otherwise considered the saline lakes. If the value of turbidity is higher than considering alkaline water while above the WHO standard level of 5 NTU. The value of higher turbidity may be due to discharge of waste materials and agriculture run off. The Nara Canal is originates from the Indus River. The water in the Indus River is generally contaminated carrying organic and inorganic polluted particles load from the upstream due to anthropogenic activities. The Sindh Environmental Protection Agency (SEPA 2002) recorded that the value of BOD in Indus River is exceeds more than 6.5 mg/L, which is also recognized by Global Environmental Monitoring System (GEMS) the water of Indus River is highly polluted. According to microbiological analysis of water by WWF-Pakistan (2007) confirmed that in the two sites the presence of fecal coliform. The availability of Fecal coliform in the water system is considering harmful for the human population consumption which may cause water borne disease. In freshwater bodies the availability of Fecal coliform is an indicator of contamination with the human and animal excreta [5, 7, 36, 38, 40, 41].

The parameters of water were only collected to examine the quality of water for the purpose of drinking. Although, it has also been reported that the more than 100,000 fisherman population who were directly associated with the fishery occupation have suffered a lot in the recent decades. In the wetland complexes the higher amount of inflow of saline effluent has causing in the devastation of the lake [7, 40].

5. Threats

Hunting: In the study area, the hunting for recreation is observed common and uncontrolled. However, the region is protected but there is no effective implementation of the wildlife laws for the wild animals. Due to hunting pressure, this is also leading to imbalance between the predator and prey species.

Foraging of Livestock: The large amount of grazing livestock in the area together with the recent climatic changes is degrading the food chain in the ecosystem dynamics.

Cutting trees: In the study area, the cutting of trees in the adjoining desert region for continuous practice of conversion of lands into agricultural fields which is affecting the wild population.

Developmental activities: In this modern era the human population is increasing in higher rate and habitation, the developmental activities in the region and conversion of land for the purpose of agriculture has been damaging the wild habitat and ultimately increasing stress on the existing wildlife.

Recommendation:

Controlled hunting: To control the hunting the check posts should be established for keeping vigilance at important points on uncontrolled hunting. Due to shortage of infrastructure in Sindh Wildlife Department like as transport system and staff failed to stop hunting so that the officials must enhance staff and transport. The Wildlife authorities must consider strengthening of Sindh Wildlife Department in the region.

Ecotourism: The area of Nara Wetland Complex is a best site for promoting ecotourism. For sighting of wildlife and bird watching the watch towers at potential points and other facilities should be developed for promoting community based conservation tourism. The people of local community should be participated and benefited from all this tourism activates. From local community the youth should be trained as a volunteers and co-guides. These health activities will provide the incentives to the local community as a source of income generating activity and an alternative livelihood source.

Promote participatory wildlife management and conservation: For promoting participation in wildlife management and conservation the institutional capacity of community based organizations in the region should be developed.

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Conflict of interest

The research study of "Ecology and Environmental Assessment of Nara Desert Wetland Complex, (NDWC) Khairpur, Sindh-Pakistan"; has there is no conflict of interest.

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Acronyms and Abbreviations

Tem	temperature
pH	pH
EC	electrical conductivity
TDS	total dissolved solids
Tur	turbidity
Ca	calcium
Mg	magnesium
Hard	hardness
HCO	carbonate
HCO_3	bi-carbonate
Alkal	alkalinity
Cl	chlorides
Na	sodium
K	potassium
SO_4	sulfate
BOD	biological oxygen demand
DO	dissolved oxygen
NDWC	Nara Desert wetland complex
WHO	World Health Organization
WWF	Worldwide Fund for Nature

Author details

Muhammad Saleem Chang

Address all correspondence to: saleem_khan74@yahoo.com

Department of Science and Technical Education, University of Sindh Jamshoro, Jamshoro, Sindh, Pakistan

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