Impact of Water Quality and Anthropogenic disturbance on the Relative Resident Abundance and Species Richness of Water Birds at Rawal Lake

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1. Groundwater - Quality

Impact of Water Quality and Anthropogenic disturbance on the Relative Resident Abundance and Species Richness of Water Birds at Rawal Lake

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Submitted in the partial fulfilment of the requirement for the MS degree in the discipline <u>**Environmental Science**</u> with specialisation in **Ornithology in relation to Wetlands Hydrology** at the Faculty of Basic and Applted Sciences, International Islamic University, Islamabad.

Supervisor

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Month, Year

November, 2010

This work of mine is dedicated to

My Mother, who is the reason I am what I am,

My Teachers, who made me, believe in myself,

My Family, for all their support and encouragement,

And

My Husband, who has always been there with me as a source of inspiration .

And to the Rawal Lake birds for all their beauty & cooperation

DECLARATION

I hereby declare that the work presented in the following thesis is my own effort, except where otherwise acknowledged and that the thesis is my own composition. No part of thesis has been previously presented for any degree.

Mamoona Sana Alvi

Forwarding Sheet

The thesis entitled **"Impact of Water Quality and Anthropogenic disturbance on the Relative Resident Abundance and Species Richness of Water Birds at Rawal Lake"** submitted by **Mamoona Sana** in partial fulfilment of MS degree in discipline of Environmental Science with specialisation in **"Ornithology in relation to Wetlands Hydrology"** has been completed under my guidance and supervision. I am satisfied with the quality of student's research work and allow her to submit this thesis for further process as per IIU rules and regulations.

Date: 27/04/2014

Signature:

Name: Dr. Rashid Saeed

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Mamoona Sana Alvi

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Abstract

Rawal Lake not only holds the importance of being a major reservoir of drinking water but is also an urban lake supporting a vast variety of avian diversity. However the Lake so far has been used for recreational and drinking purpose but has been neglected for management of its wild life especially its associated waterfowl abundance and richness. The study carried out in this research has focused on the varied pattern of abundance of resident water birds in relation to anthropogenic disturbance and certain chemical and physical parameters of water quality (phosphates, sulphates, nitrates, turbidity and dissolved oxygen). Time period of the study was five months for observation of water quality and its impact on birds abundance while nine months for observation of anthropogenic disturbance and its impact on birds abundance. Meanwhile another objective of the study was to determine species richness during the whole course of this research.

The chemical parameters were analysed by National Physical Standard Laboratory an accredited Laboratory of Pakistan Council of Scientific and Industrial Research while the physical parameters were determined on-site with Hydro lab MS 5. Variable Point count method was utilized for determination of species richness and abundance of resident bird species of the lake.

Statistical analysis of the study showed significantly negative correlation (0.0257) between resident waterfowl abundance. Similarly regression analysis depicted an inverse relationship between nutrients and turbidity Vs abundance with r square of 0.72 surface and 0.57 subsurface and 0.39 surface and 0.56 subsurface respectively. However R square of dissolved oxygen and abundance (15%) showed a weak relationship between them, suggesting investigation for more time period.

Water Fowl species richness of Rawal Lake was 51 during the nine months study. It includes passage migrant, wintering, summer breeders and resident species of the lake.

Chapter 1 — Introduction

1.1. Research area and purpose

The area under analysis in this study is Rawal Lake. It is located in the catchment area of Murree hills, built on Kurang River within the boundaries of Margalla Hills National park. This artificial reservoir is the first dam built among the series of small dams and reservoirs.

The importance of Rawal Lake does not only dwell in its being an urban lake but is also an important source of drinking water for the citizens of Rawalpindi. Moreover, the lake serves as an important habitat for a diverse species of wintering waterfowls, passage migrants as well as summer breeders. Presently, more than half of the lake is being utilized for sports and recreational purposes.

The purpose of the study is to conduct an avian monitoring survey for determination of resident waterfowl species abundance and species richness of the lake. Furthermore the study aims to work out the possibility of any relationship between bird abundance and water quality.

1.2. Significance of Research

- This study was the first attempt in Pakistan to determine the relationship between water quality and water fowl abundance.
- The study was also carried out to determine specie richness of Rawal Lake.
- This study attempts to cover the gap of six years of Rawal lake bird abundance, survey last conducted in year 2003.

- Moreover, this study provides an opportunity to discover new species and dimensions of studies of water birds.

Chapter 2 — Literature Review

2.1. Part One: Literature Review on Rawal lake

2.1.1. Introduction to Rawalpindi and Islamabad

The urbanite area of Islamabad-Rawalpindi lies between longitudes of 72°45′ and 73°30′ E. and latitudes of 33°30′ and 33°50′ N. This covers approximately an area in three districts of the country; i-e the Islamabad District, the Rawalpindi District of the Punjab, and the Abbottabad District of North-West Frontier Province, Pakistan.

Islamabad being the national capital is the first planned city of Pakistan. It is located at the foot of Margalla hills and is an important center for all governmental activities; while Rawalpindi is much older and bigger city with historical records of being an invasion route for the Alexander, Genghis and Moguls. Later it served as a military base for the British. Nowadays it is still strategically most sensitive area for being a General Head Quarters of Pakistan army.

The geology of this metropolitan area of Islamabad-Rawalpindi consists of plains and mountains whose total relief exceeds 1,175 m. The northern part of this region lies in the mountainous terrain of the Margala Hills that reaches 1,600-m altitude near Islamabad, a part of the lower and outer Himalayas, which also includes the Hazara and Kala Chitta Ranges. In the South of the Margala Hills is a southward-sloping piedmont bench underlain primarily by folded sandstones and shales of Miocene (consolidated sandstone interbedded with unconsolidated sandstone). The West of Rawalpindi, comprises of plains of thick and easily eroded loess are that are extensively dissected into shallow badland valleys while the East of Rawalpindi comprises of the folded ridges of Miocene group of rocks that rise above the alluvial cover to form prominent hills. (USGS report).

The physical framework of Pakistan has been built by two major geomorphic processes that have produced two distinct physiographic provinces.

1. The Western Highlands produced by mountain building movement occurring in tertiary era.
2. The Indus Plains resulting from the deposition of sediments by the Indus River and its tributaries into shallow bays in the Quaternary era.

The western highlands of Pakistan extend from the Makran coast to the Pamir Plateau in the north covering most of Baluchistan, NWFP and the Northern areas and parts of Punjab. These highlands includes

- Potwar Plateau and Salt ranges.
- Mountainous North
- Safed Koh and Waziristan hills
- Sulaiman and Kirthar Mountains and
- Baluchistan Plateau

The Potwar Plateau and Salt ranges region is located to the south of the mountainous north and lies between the Indus River in the west and Jehlum River on the east. Its Northern boundary is formed by Kala Chitta ranges and Margalla hills and southern boundary by gentle slopes of Salt Ranges. Between the northern and southern ranges is located the Soan Basin.

The Kala Chitta ranges rise to a average height of 450-900 meters and extend for about 72 km. Their western part is composed of sandstone and the eastern part of limestone. The ranges are cut deeply by valleys. A few miles north of the eastern extremity of Kala Chitta ranges, the Margalla hills appear and extend eastward into the Kurang River. The average height of Margalla hills is 900 meters with several peaks rising to over 1,200 meters. The south facing slope of the Margalla hills is steep. The main Potwar plateau extends north of the Salt Range. It is an undulating area of 300-600 meters high. Khairi Murat is the largest and most spectacular of the few high hills present there. It is about 39 km long running southwards from the neighbourhood of Rawalpindi. It rises approximately 1,000 meters.

The Soan River dominates the topography. The Soan River and its tributaries have developed gullies and ravines to form typical badland topography. They are called *Khaderas*. The Soan and other rivers have also produced large tracts of alluvial plians where agriculture is practiced.

Soils of the Potwar plateau:

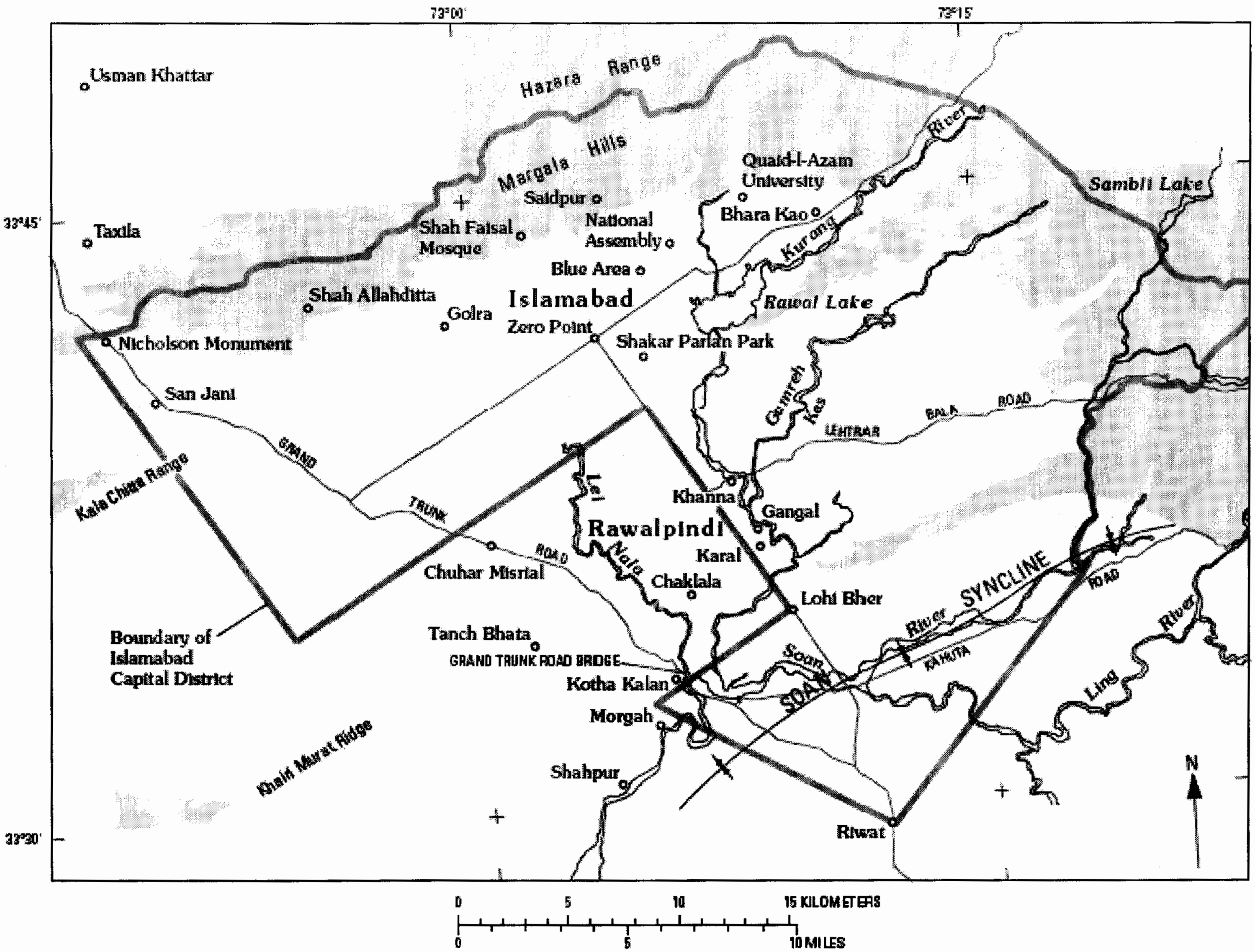
The Potwar Plateau is covered with three types of soils:

1. Loess
2. Alluvial
3. Residual

All the soils are extensively eroded, deeply dissected and badly gullied. The wind deposited loess is brown in colour and moderately alkaline in reaction. They are very fertile but unfortunately do not occupy large areas and are badly eroded. Gully erosion is most extensively typified in the Potwar plateau. It is estimated that more than two million acres of cultivated land have been lost in the upland districts.

The alluvial soils cover the narrower valleys and the alluvial terraces. The soils of the river valleys are fine sands and loams where as those of terraces are clayey loams and loamy clays. They are fertile soils and are suitable for farming.

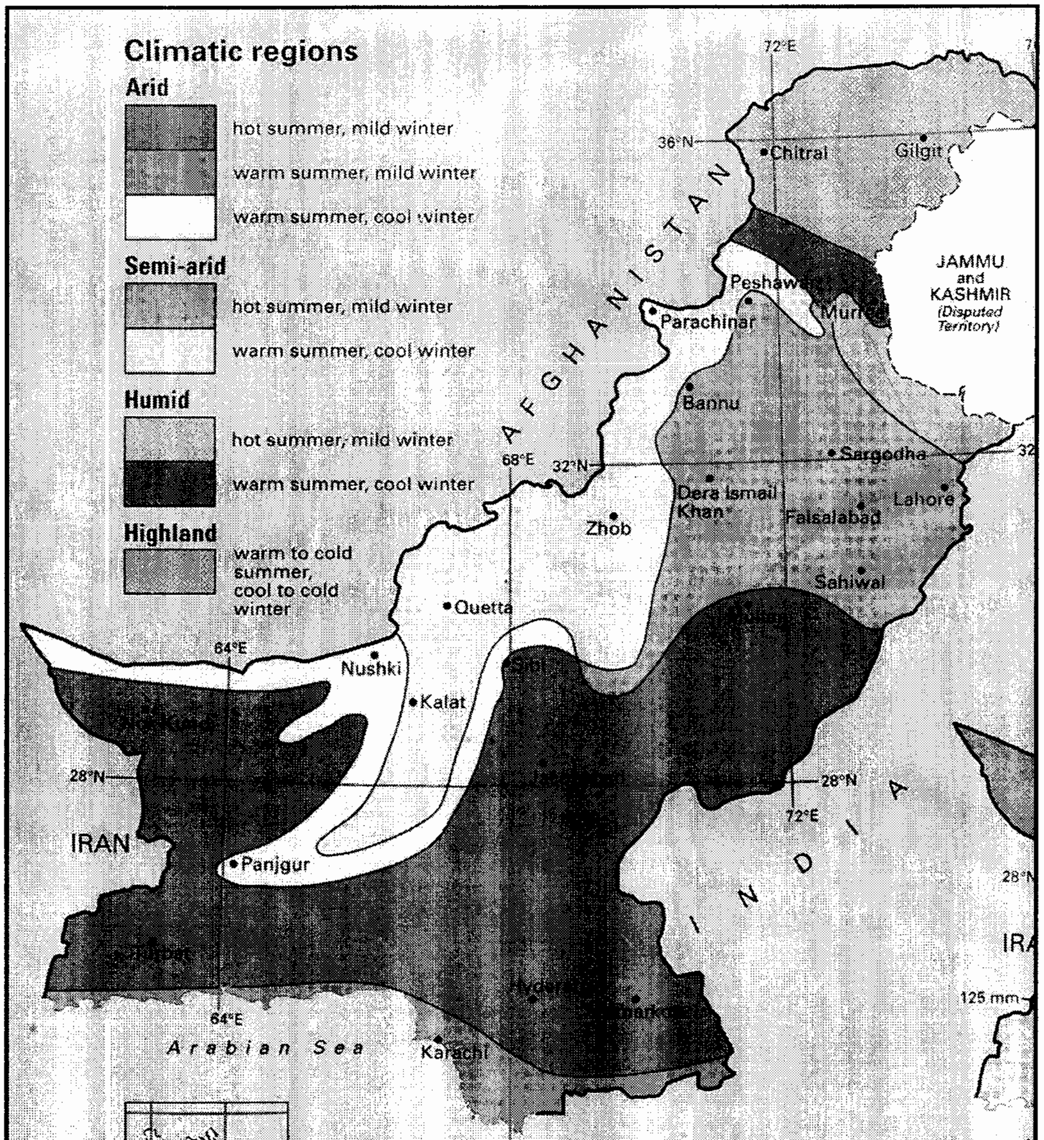
The residual soils of Potwar plateau have been derived from the decomposition of shale and sandstone. They have formed into brown clayey soils. Part of calcium carbonate has been exuviated from surface to foot below. They are poor soils and suitable for pasture (Khan, 1991)



Map 1. Geological Terrain of Rawalpindi and Islamabad. (source: USGS 2007)

The climatic condition of Rawalpindi and Islamabad when classified according to Koppen's method is categorized as Humid mesothermal /subtropical climate with hot/warm summers. This signifies the area with three months of good monsoon rainfall in summers (from the months of July to September) while occasional rainfall is observed in winters with slight peaks in the month of March.

Map 2 shows different climatic regions of Pakistan.



Map 2: Climatic regions of Pakistan

Subsequently the vegetation of Rawalpindi and Islamabad is sub tropical sub temperate dry ever green forest, adapting perfectly to its geological and climatic conditions.

Hydrology of Potwar region is robust. The area is well supplemented with water, having the Soan and Kurang Rivers as the main streams draining through the area. The primary tributaries of the Soan are the Ling River; draining in the northwest and Lei Nala that drains in the South. The Kurang River is fed by Gumreh Kas that drains in the west of the river from the area between the Kurang and Soan. The Kurang and Soan Rivers are dammed at Rawal and Simli Lakes, respectively, to supply water for the urban cities of Rawalpindi and Islamabad.

The headwaters of the Kurang and Soan Rivers were once used to be covered by extensive forest reserves that benefited the consumers via improving the quality and quantity of water supply. However the intensive deforestation in the area for the purpose of various infrastructure constructions has resulted in declined the water quality and its amount. There are also about 26 large and small rain water streams that carry hill torrent and passes through different sectors of the city. Ironically almost all of them have been polluted with the municipal sever, domestic waste and industrial effluent of Islamabad. Furthermore according to CDA officials of Water supply directorate, the ground water table had receded to almost 70 feet in year 2008. The main reason investigated behind the lowering of water table was sporadic percolation of water through the soil, reduced surface area for water absorption and compaction of soil around and near construction and concrete sites. This lesser or very low regeneration of ground water table gas resulted because of massive construction activities and conversion of forested lands to concrete blocks that drains all the rain water into nearby drainage pipes and in streams.

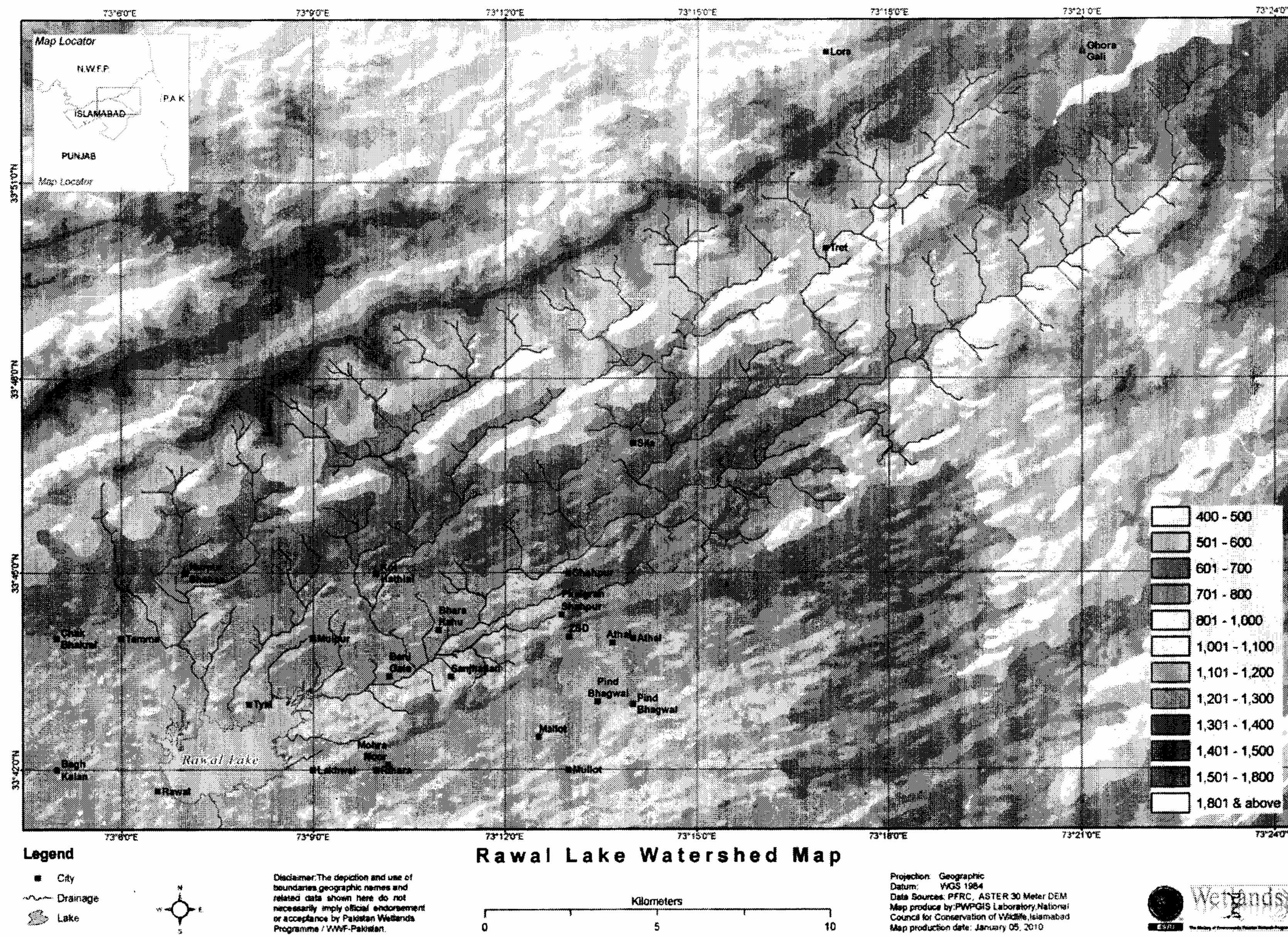
Another reason of degradation and depletion of natural resources in the area is due to the fact of population boom. In accordance with world gazetteers the Federal Capital Islamabad holds the population of nearly 689 249 and about 1 991 656 of people live in its twin Rawalpindi.

Similar is the story of Nullah Leh that runs through the city of Rawalpindi. It carries most of the solid and liquid waste from Rawalpindi and contributes greatly to the pollution of the Soan River. It was once a source of fresh water to the local people and supported a good diversity of soft and hard shelled turtle spices as well as fish species indigenous to the area of Potwar. In brief the solid-waste disposal practices in these twin cities is a continue threat to the quality of ground-water reserves in the area.

2.1.2. Introduction of Rawal lake

Rawal Lake in Islamabad is an important catchment area of Murree (one stream) and Margalla hills (three streams).

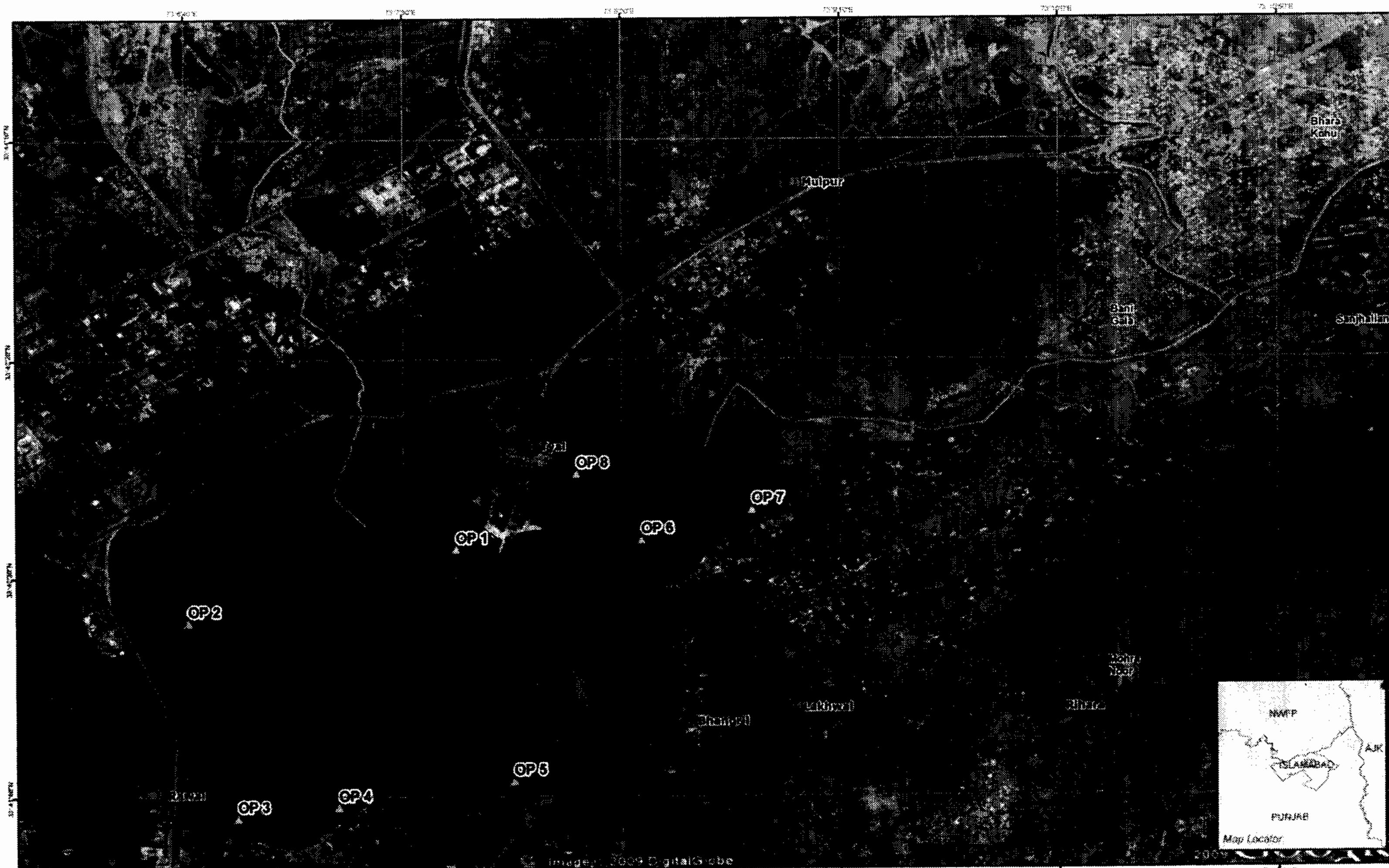
Map 3 shows the watershed region of Rawal Lake in combination of variable topological altitudes of the area.



Map 3 ; Watershed area of Margalla and Murree hills

Rawal Lake is a man made Reservoir build on the Kurang River. It is located at latitude of 33° 41′24″N and longitude 73°44′73″E at an elevation of 520 m above sea level. The Reservoir is of international significance and is protected within an isolated section of the Margalla Hills National Park (Malik and Husain 2006a, b, c; 2007; Bibi et al. 2008). It is a small water reservoir with some associated freshwater marshes.

This artificial lake extends through an area of 8.8 km^2 and is a sole drinking water reservoir for the city of Rawalpindi. The lake also serves as an important habitat for a diverse species of wintering waterfowls. However during study of the lake the most abundant population among wintering fowls was observed of that of mallards (*Anas platyrhynchos*). The lake was designed to be partly "Arched Gravity" type reservoir with a discharge capacity of 2,300 m^3/s and a maximum depth of 31 m. The total storage capacity at the time of establishment was 47,500 acre feet (12994 MG) with the live storage of 43,000 acre feet 11763 MG) and the highest flood level of 1752 feet. (Source: Small Dams and Organisation). However according to the recent survey carried out by PWP team in the month of September 2009 the maximum depth near the dam gates was found to be 17 meters. The most probable explanation of the decrease in the depth can be explained with the results of extreme sedimentation observed during the most time of survey in summer and winter rainfalls. The lake has inlet of four major and 43 small streams with one outlet. The Kurang river stream enters on the northeastern side; Rumli and Quaid-i-Azam University streams enter on the northern side, while the spillway gates are located at the south-western side.



Field Map of Rawal Lake

Draft Map

Legend
- City
- Observation Point
- Roads
- Drainage
- Rawal Lake

Disclaimer: The depiction and use of boundaries,geographic names and related data shown here do not necessarily imply official endorsement or acceptance by Pakistan Wetlands Programme / WWF-Pakistan.

Projection: Geographic
Datum: WGS 1984
Data Sources: Google Earth
Map produce by PWPGIS Laboratory,National Council for Conservation of Wildlife,Islamabad
Map production date: June 10, 2009

Map 4: Rawal Lake and its inlets

The lake reservoir at present serves as an important resource for sports and commercial fishery. It is also a popular area for outdoor recreation especially after the creation of Rawal View Park which is serving as a very popular recreational spot for both the cities. The recreational activities observed at the lake mostly comprises of boating, picnicking and fishing (anchoring). These activities were mostly carried out at three sites of Rawal Lake on the coordinates 33° 42′ 36.5″ N, 73° 07′ 42.0″ E, 33° 41′ 33.2″ N, 73° 06′ 51.9″ E and 33° 41′ 37.6″ N 73° 07′ 15.1″ E

2.1.3. Problems identified by different researchers

Being the major source of drinking water for the residents of Rawalpindi, Rawal Lake has usually been the site to be studied by scientists for its water quality.

Muhammad Ashraf (1992) in the study of annual variation of trace metals in freshwater lake fish, Labeo Rohita, reported maximum concentration of Zinc metal (4.807 μg/g, wet weight) and the minimum for Cd (0.003 μg/g, wet weight) among the assessment of As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Hg in fish. The Author however concluded that the fish alone could not be used as a sole index of environmental pollution and that there was a need to include the sediment-water link to this effect.

Similar study was conducted by Abbas khan and M. Jaffar in 2002, regarding Lead Contamination of Air, Soil and Water in the Vicinty of Rawal Lake. The study brought out that the concentration of Pb was around 33.3 to 338.7 μg/m3 in air, 0.6-21.2 mg/kg in soil and BDL to 170 μg/L in water. Field observation show that almost all the pollution has been generated by automobile exhaust and also that soil and water act as important sink for Pb.

Further research was done by Muhammad Gulfraz in year 2001 on "Concentration Levels of Heavy and Trace Metals in the Fish and Relevant Water from Rawal and Mangla Lakes". The results indicate metals present in the highest concentration were in the order of Fe>Ni>Mn>As>Cu in the water samples of Rawal lake. However higher concentration of metals were present in water samples as compared to fish samples from the lake. The most probable reason of water contamination is the addition of untreated domestic waste.

Tahir *et.al*, 2003, assessed the the distribution of heavy metals (Cr, Co, Cd, Zn, Ni, Cu, Mn and K) in water and liquid waste samples at different stations of Rawal Lake and main streams entering Rawal Lake. The results indicate high concentrations of Ni (0.808mg/l), exceeding the permitted levels set by Environmental Protection Agency of Pakistan.

Work regarding the analysis of pesticide residues in the Rawal lake was performed by Shazia Iram et.al 2009, from the collected samples, 21 pesticides were analyzed and categorized in organophosphates, organochlorines and pyrethroids. Results showed that in Rawal Lake samples average concentration of fenitrothion, 2, 4-DDT and diazinone was higher showing, the potential of toxicity of pesticides to enter the aquatic system. This could also result in possible consequences of bioaccumulation in the food chain.

Study on the assessment of heavy metal contamination using feathers of *Bubulcus ibis* was carried out in 2009 by Naseem and Zeb. The study analyzed concentration of metals like Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Ni, Pb and Zn in the feathers of cattle egret (*Bubulcus ibis)* from River Chenab, Ravi and Rawal lake. The feathers cattle egret collected from Rawal Lake reservoir were least contaminated among the three study areas. The pattern of metal concentration in the three areas shows that Rawal lake contains metal concentration in the following manner: Ca> K > Mg > Zn > Fe > Pb > Mn > Ni > Co > Cr > Cu > Cd > Li.

Sheyla *et.al.* (20010), worked on "Effects of anthropogenic silt on aquatic macro invertebrates and aboitic variables in streams in the Brazilian Amazon". The author and co-scientists concluded that silt has a negative impact on aquatic macro invertebrate density. Thus emphasizing on soil conservation techniques required restore the banks of the stream to their natural condition.

A study was carried out in Monterey Bay, California regarding the effect of water clarity on distribution of Marine Birds in 2004 by Larid A. Henkel. The author concluded that most associations between the distribution of marine birds and water clarity did not have any significantly strong relationship between them.

Quan RC, Xianji W, Yang X (2002) in their research concluded that the distribution of waterbirds was affected by disturbance, with more than one-third of the total species and nearly half of the total individuals occurring at the least disturbed point. Species richness was weakly and abundance was strongly correlated to habitat disturbance, but not to habitat quality. The conservation measures suggested include the cessation of habitat destruction, better plan for the development of tourism, a reduction in the number of canoes and zoning of the non-fishing area.

Results from several studies regarding urbanization of lake have shown that there is a shift in avian species composition, often accompanied with a decrease in water bird species richness and diversity. Decreased habitat availability, vegetative complexity, and food supply, and increased habitat fragmentation, competition, and human disturbance are examples of some of the mechanisms that have been identified as contributing to decreases in richness and evenness in urban bird communities (Marzluff 2001).

Similarly Marzluff (1998) in his work concerning of urban environments and its influences on avifauna and challenges for the avian conservationist states that the process of urbanization may affect birds both through changes in ecosystem processes, habitat structure, and food supply, and through changes in predation pressure, competition, and diseases.

DeGraaf & Wentworth (1981), Tilghman (1987), Blair (1996), Clergeau et al. (1998), Jokimaki 1999, and Rottenborn (1999) have focused on the direct effects of development and habitat alteration on community composition by focusing on changes in avian abundance, species diversity, richness, and evenness. Very few studies have attempted to address how avian abundance is affected by anthropogenic disturbance and water quality of the lake.

2.2. Part Two: Diversity of Rawal lake

Biodiversity:

Rawal Lake possesses a magnificent biodiversity with respect to a healthy wetland categorisation. It could be easily split up into three broad categories

1. Vegetative diversity
1. Fish diversity and
2. Avian diversity

Details of these classes are described below.

2.2.1. Vegetative diversity

Vegetative diversity of Rawal lake can be categorised as

a. Terrestrial

b. Aquatic

 i. Free floating

 ii. Attached Floating

 iii. Submerged

 iv. Emergent and

 v. Wetland weed

2.2.2. Fish diversity

Studies regarding composition and relative abundance of fish composition of Rawal Lake was conducted in 1992 and 1995 by Muhammad Afzal,and colleagues. The study reported thirteen species of nine genera in 1992 and fifteen fish species of eleven genera in 1995 of Rawal Lake. Table regarding the composition and details of fish is given below.

Table 1: List of fresh water fish species in Rawal Lake

#	Technical name	Vernacular name	Commercial desirability
1.	*Catla catla*	Major Carp	+
2.	*Channa auriles*	Snake head	?
3.	*Channa marulius*	Blue eyed snake head	?
4.	*Cirrhinus mrigala*	White Carp	+
5.	*Cirrhinus reba*	Reba carp	-
6.	*Crossocheilus latius diplocheilus*	Kashmir latia	-
7.	*Cyprinus carpio*	Common carp	+
8.	*Hypopthlamichthys molitrix*	Chinese schemer	+
9.	*Labeo calbasu*	Orange fin Labeo	+

10.	*Labeo dero*	Kalabans	-
11.	*Labeo dyocheilus*	Brahmaputra Labeo	-
12.	*Labeo rohito*	Indian Major Carp, Rohu	+
13.	*Ompok bimaculatus*	Indian Butter-Catfish	?
14.	*Ophiocephalus punctatus*	Spotted snake head	?
15.	*Puntius sarana*	Olive barb, Pondicherry barb	-
16.	*Puntius ticto*	Ticto barb	-
17.	*Tor putitoria*	Putitor Mahseer	+

Almost all of the commercially important fishes in Rawal Lake have been artificially introduced by Islamabad Capital Territory (ICT) fisheries department.

2.2.3. Avian diversity

Trends and Population of Rawal Lake bird species

Dr. Anwar in his annual report of PARC 1984 recorded about 6,874 of water fowls at Rawal Lake from the year 1982 to1983. Dildar, *et al.* (2002) conducted two year survey of Rawal Lake water fowl from 1999 to 2001. The study involved determination of migratory pattern and population fluctuation trends.

Ali and Akhtar (2005) represented importance of Rawal Lake for being one of the four sites in Punjab where white headed ducks were observed in year 2003 form January 28th to February 21st.

Following table gives an over review of the specie composition and abundance in years by Anwar (1984) and Dildar, *et al.* (2002)

Table2: List of water bird species of Rawal Lake

#	**Scientific name**	**Common Name**	**1983-1984**	**1999-2000**	**2000-2001**
1.	*Sterna acuticauda.*	Black-Bellied Tern	30	0	60
2.	*Tadorna ferruginea*	Ruddy shelduck	0	14	0
3.	*Larus brunnicephalus*	Brown Headed Gull	264	0	0
4.	*Bubulcus ibis*	Cattle Egret	119	0	0
5.	*Actitis hypoleucos*	Common sand Piper	0	0	116
6.	*Anas crecca*	Common teal	100	0	13
7.	*Fulica atra*	Coots	483	0	15
8.	*Phalacrocorax niger)*	Little Cormorant	8	112	3
9.	*Anhinga melanogaster*	Darter	2	0	0
10.	*Anthropoides virgo*	Demoiselle Crane	6	0	0
11.	*Anas querquedula*	Garganey	250	0	50
12.	*Podiceps cristatus*	Great Crested Gerbe	496	63	0
13.	*Ardea cinerea*	Grey Heron	259	60	69
14.	*Larus argentatus*	Herring gull	0	173	973

#	Scientific name	Common Name	1983-1984	1999-2000	2000-2001
15.	*Egretta alba*	Great Egret	317	235	189
16.	*Egretta garzetta*	Little Egret	0	0	327
17.	*Tachybaptus ruficollis*	Little Grebe	8	0	0
18.	*Clangula hyemalis*	Long tailed duck	0	0	1
19.	*Anas platyrhynchos*	Mallard ducks	1346	2509	183
20.	*Gallinula chloropus*	Common Moorhen	19	0	14
21.	*Clangula hyemalis*	Northern Lapwing	0	0	45
22.	*Anas acuta*	Northern Pintail	1708	120	34
23.	*Ardea purpurea*	Purple Heron	5	0	0
24.	*Netta rufina*	Red crested porchard	256	79	20
25.	*Athya marila*	Scaup Ducks	2	0	0
26.	*Anas clypeata*	Northern Shoveller	172	0	113
27.	*Aythya fuligula*	Tufted ducks	318	0	0
28.	*Ciconia ciconia*	White Stork	9	0	9
29.	*Gyps bengalensis*	White-Rumped Vulture	0	0	0
30.	*Anas penelope.*	Eurasian Wigeon	329	0	4
31.		Yellow vented lapwing	0	0	29

Zulfiqar Ali and Muhammad Akhtar (2003) in their Bird surveys of wetlands in Punjab observed the following species of water fowls and their abundance at Rawal Lake

Table 3: List of water bird species in Rawal Lake in year 2003

#	Scientific name	Common Name	2003
1.	*Nycticorax nycticorax*	Black-Crowned Night Heron	5
2.	*Chroicocephalus ridibundus*	Black-Headed Gull	20
3.	*Himantopus himantopus*	Black-Winged Stilt	100
4.	*Bubulcus ibis*	Cattle Egret	18
5.	*Alcedo atthis*	Common kingfisher	2
6.	*Aythya ferina*	Common Pochard	500
7.	*Anas crecca*	Common teal	15
8.	*Fulica atra*	Coots	450
9.	*Anas penelope*	Eurasian Wigeon	26
10.	*Aythya nyroca*	Ferruginous Pochard	65
11.	*Anas strepera*	Gadwall	185
12.	*Podiceps cristatus*	Great Crested Gerbe	18
13.	*Ardea cinerea*	Grey Heron	6
14.	*Ardeola grayii*	Indian Pond Heron	2
15.	*Egretta intermedia*	Intermediate Egret	18
16.	*Charadrius alexandrinus*	Kentish Plover	1
17.	*Egretta alba*	Great Egret	0
18.	*Egretta garzetta*	Little Egret	65
19.	*Tachybaptus ruficollis*	Little Grebe	35
20.	*Charadrius dubius*	Little Ringed Plover	21
21.	*Anas platyrhynchos*	Mallard ducks	65
22.	*Anas acuta*	Northern Pintail	80
23.	*Anas clypeata*	Northern Shoveler	250

24.	*Ceryle rudis*	Pied Kingfisher	18
25.	*Ardea purpurea*	Purple Heron	1
26.	*Vanellus indicus*	Red-Wattled Lapwing	120
27.	*Tadorna ferruginea*	Ruddy Shelduck	14
28.	*Aythya fuligula*	Tufted ducks	6
29.	*Rallus aquaticus*	Water Rail	6
30.	*Motacilla alba*	White Wagtail	4
31.	*Oxyura leucocephala*	White-Headed duck	7
32.	*Halcyon smyrnensis*	White-Throated kingfisher	6

2.2.4. Wetland Birds and Habitat Resources

Rawal Lake is an urban wetland that has a unique biotic communities involving diverse plants and animals that are adapted to shallow as well as deep and often dynamic water regimes. As water is the key to wetland existence, the commonality of the birds considered here as wetland birds (water fowls) is their response to shallow waters, whether salty or fresh and their use of water-based resources. Wetland birds are extremely diverse, reflecting early anatomical and physiological adaptations to this unique but rich habitat. Many ecologists feel that birds are one of the most visible indicators of the total productivity of such biotic systems. However in case of large group of diverse birds the habitat perspective should be taken in view to explain some of the ecological and evolutionary mechanisms that have dictated bird form and function. Many of the monographs describing species studies during the 1920s to 1960s also included aspects of habitat such as food and vegetation structure, which led to better understanding of the role of water depth and dynamics in the attractiveness and maintenance of such resources (e.g., Allen 1942, Bennett 1938).

Furthermore avian adaptations to utilize wetland and other aquatic systems are diverse and include anatomical, morphological, physiological and behavioural changes.

Anatomically, they include designs for diving and swimming, such as body compression to increase specific gravity (loons and grebes), compressed body structure to allow them to pass between dense vegetation (rails and bitterns), or adaptations for plunge-diving from great heights.

Visual systems must be geared to acuity and protection both in water and air, and to eye accommodation of as much as 50-fold, which allows a quick change of focus from near to far in seeking food, and to binocular vision, which occurs in herons and kingfishers (Campbell and

Lack 1985). Birds that feed at night, like skimmers, have eyes that are better adapted for nocturnal vision compared with diurnal species (Rojas, McNeil and Cabana 1997).

Respiratory physiology differs dramatically in those species that engage in long-term and deep diving. Although amateurs by comparison with large penguins, long-tailed ducks and loons have been recorded in fisherman's nets at 180 and 240 feet (54 and 72 m), respectively, during winter when they may leave wetland fringes for deep water (Schorger 1947).

Morphologically, adaptations include bills that strain, peck, spear, store, and grab, and feet that allow swimming, diving, walking on mudflats, wading, or grabbing and holding fish. Not only do body parts differ in general form, but size of bills, legs, and flight patterns differ across a gradient of wetland edges (Niemi 1985).Additionally, special feathers and plumage designs ensure waterproofing under the most severe conditions.

Water fowls have very diverse food types and demand highly specialized digestive systems: some wetland birds specialize on plant diets, some on animal, some use both, and most switch foods seasonally as induced by needs for breeding or energy for migration.

Moreover wetlands plays the role of sanctuary for the birds from predators, and many water birds capitalize on the protection combined with the rich food resources to molt all their wing feathers simultaneously. Most terrestrial birds or birds that feed on-the-wing must do this annual molt a few feathers at a time, retaining flight capability while reducing energy demands. As a result of these adaptations, birds are better equipped as a group to exploit wetland resources – wherever they occur – than any other animals, except some mobile insects that use similar approaches but on a smaller scale. Because birds are larger, more colourful, fewer in number of species and, therefore, better known, they are more often used as indicators of conditions within a wetland ecosystem.

The environment of an ecosystem also in its way defines the type of birds diversity it can support or favours. Birds distribution often is discussed and compared from a geographic perspective (zoogeography). At one time, emphasis was mostly on a scale of continents and hemispheres rather than regional habitat, but the importance of vegetation zonation and climate has now become a regular factor in descriptions of groups and subgroups of species. At a somewhat smaller scale, identifying where a particular species is found using geographic and large-scale biotic zones is valuable. There is a wide range of adaptation to wetlands among species of water birds of any taxa.

Water birds of the following taxa are found at Rawal Lake:

1. Order Podicipediformes

These are obligate water bird commonly observed at Rawal Lake in this taxa are grebes. They are skilled diving specialists with 21 species worldwide in distribution. However, they are most abundant in cold-temperate climates occurring through either latitude or altitude. Grebes are the aquatic birds adapted for diving from the surface and swimming under the water to catch fish and aquatic invertebrates. All have lobed toes for swimming with great manoeuvrability, and their strong legs are placed near the rear of their almost tail less body making it necessary for them to crawl on their bellies when on land. They can sink underwater without active jump-diving. Species of grebe favour shallower and often well-vegetated wetlands rather than great expanses of open and deep water. In flight grebes have elongated appearance, with the neck extended and feet hanging lower than the humped back. Their bills vary from short and sharp to long and spear-like, dependent upon their aquatic prey. They usually feed singly, but may form loose congregations in the non-breeding season.

They nest mainly in freshwater wetlands, sometimes in sizable colonies, and may build nests of submerged vegetation in open water or of decomposing to fairly fresh emergent vegetation in quite dense marsh vegetation. The precocial young tend to spend a few days on or near the nest, where they are fed by the parents; some are fed until nearly grown and feeding independently. Some species may be double-brooded (i.e., attempt to rear two clutches per breeding season) where temperature and water conditions permit. Adults and young eat fish, amphibians, and large invertebrates. They migrate long distances at night to winter in large freshwater lakes or marine bays.

2. Order Pelecaniformes

The world wide members of this order include Shags (about 14 species) and cormorants (23 species). The shags are well represented in marine and fresh cold waters at high latitudes whereas the cormorants are more tropical and freshwater (Johnsgard 1993). They are common winter migrants in Pakistan while species of little cormorants are resident at Rawal Lake. Cormoramts belong from Family Phalacrocoracidae. They have characteristically long-neck and are medium sized to large aquatic birds, with a hooked bill of moderate length and a long stiff tail. They swim with the body low in the water, with the neck straight and with the head and bill pointing a little upwards. They mainly eat fish that are caught by underwater pursuit and feed in mixed flocks with pelicans and gulls. In flight, the neck is extended and the head is held slightly above the horizontal. Typically, they often perch for long periods in an upright posture, with spread wings and tail, on trees, posts or rocks. Most species are social nesters, often mixed with herons, egrets, ibises, and anhingas in colonies in tree, shrub, or marshy nest sites. Coastal birds nest on cliffs socially or in mixed flocks of seabirds. The young are altricial i-e naked at hatchling, and remain in the nest when small. Most are strongly migratory, often moving in goose-like wedges even in local moves from overnight roosts to feeding areas.

3. Order Anseriformes

Waterfowls like ducks, geese, and swans of the order Anseriformes are a large and cosmopolitan group widely distributed in tropical as well and extreme north and south latitudes (Delacour 1954–64, Johnsgard 1981). They are more conspicuous than many abundant birds because of size, their day as well as night migration, and their large and conspicuous flocks. Species that live at high latitudes are strongly migratory and are, therefore, excellent pioneers at exploring and exploiting new habitats (Weller 1980).

Nest sites vary from cliffs and tree holes to highly aquatic but well-vegetated situations. The young are precocial, downy, and leave the nest to feed with other brood members as soon as they are dry. Young birds are strongly insectivorous except in the true herbivores like geese and swans. Parental care (brooding and predator defense) ranges from long term (geese and swans) to none (the parasitic Black-headed Duck). After breeding, males in particular but sometimes females as well engage in molt-migration, flying a few to hundreds of miles to suitable feeding areas with protective water depths where they lose their flight feathers prior to autumn migration (Hochbaum 1944). A few species molt after post-breeding migration.

Dabbling ducks (Anatini) number between 45 and 51 species and are considered the most ubiquitous and adaptable of all waterfowl and among the most widespread of all waterbirds. Species complexes such as mallard- and pintail-like ducks span both hemispheres and are successful in a great variety of habitats from cold latitudinal and alpine tundra to the tropics. They are flexible in foods, pioneers in new habitats of even temporary water, and are persistent in rearing young under tenuous conditions. Foods of these omnivores include seeds and other plant reproductive parts during nonbreeding seasons and invertebrates during pre-breeding, growth, and molting periods.

Nests commonly are on the ground near water, but clutches are large and re-nesting is common. Bay ducks or pochards (Aythyini) include 17 species and are nearly as widespread as dabblers but require more permanent waters, where they feed seasonally on invertebrates and submergent plant material. Breeding areas usually are on freshwater, but wintering birds may use either saline or freshwater.

Some members of this group nest over water in emergent vegetation, but ground nests near water are common in other species.

4. Order Ciconiiformes (Herons and egrets)

The order **Ciconiiformes** is a large, diverse, and taxonomically complex group of herons, egrets, and related groups. They have worldwide distribution and are among the more visible and attractive wetland birds. Most are characterized by long legs suitable for wading (termed waders in the USA whereas this term is used for shorebirds in Eurasia). Prominent, long bills are characteristic of the group and differ in length and shape through feeding adaptations. Many of these species and groups feed in mixed flocks opportunistically when fish, crustaceans, amphibians, or other prey become vulnerable owing to declining water and oxygen levels. Some members of this order are solitary or loosely social nesters (bitterns and storks, Green Herons) but most are colonial, often in mixed company with anhingas or cormorants. Although many species nest over water or at least near water at elevated sites, many nest on land on islands, and a few like bitterns may nest in upland vegetation when ground predators are absent (Duebbert and Lokemoen 1977). Nest materials are carried some distance or robbed from old nests or other birds nests. Because parents can bring food long distances, they can nest far from water on artificial structures (Great Blue Herons on power-line structures) or groves of trees (many species of herons and egrets).Young are altricial and only sparsely covered with fluffy down;

they are fed by regurgitation. **Herons** (including **egrets** and **bitterns)** have long, straight bills designed for grasping and holding fish, amphibians, reptiles, and sometimes birds and mammals. Bill sizes and shapes vary in herons and egrets, presumably representing adaptations to their usual prey size and behaviour. Moreover, prey size of adults generally is correlated with body size. Some are normally solitary feeders (Great Blue Heron, Grey Heron, bitterns) and others regularly feed in social groups when capturing prey in food-rich pools (Great, Snowy, and Cattle Egrets).

5. Order Gruiformes (rails, crakes, coots, and cranes)

The rails and crakes, coots, and cranes of the large, diverse, and worldwide order Gruiformes range from the more conspicuous cranes and coots to the habitat-shielded rails of emergent vegetation. Rails, Gallinules and coots belong from Family Rallidae. This family includes small to medium sized birds, with moderate to long legs for wading and short and rounded wings. With the exception of Common Moorhen and Common Coot which spend much time in swimming in the open and deep waters, rails are mainly terrestrial. Many occur in marshes. They fly reluctantly and feebly with the legs dangling, for a short distance and then drop into the cover again. The majority is heard more often than seen and is most voluble at dusk and at night. Their calls consist of strident or raucous repeated notes. Foods are highly variable, with seasonal shifts from animal foods (especially invertebrates) to seeds, tubers, and foliage in fall and winter. Coots regularly use open water when feeding on submerged vegetation, and they dive for both vegetation and invertebrates – especially during pre-nesting egg formation and when feeding young. They are equipped with lobate toes effective for diving as well as for walking on mudflats. Coots and probably other members of this family lose the power of flight during their complete and simultaneous wing molt. Rails fly little except when pressed but are capable long-distance migrants and inhabit some of the most remote islands of the world.

6. Order Charadriiformes

The order Charadriiformes is a large, diverse, complex, and important group involving about 14 mostly obligate taxa (families, subfamilies or tribes) of wetland birds best identified by common group names. Best known are the gulls and terns, sandpipers and associates like bog-country snipe, forest dwelling woodcock, phalaropes, stilts and avocets, and plovers.

Plovers and Lapwings belong to Subfamily Charadriinae they are small to medium-sized waders with a rounded head, short neck and short bill. Typically, they forage by running in short spurts, pausing and standing erect, then stooping to pick up invertebrate prey. Their flight is swift and direct •

Godwits, Sandpipers, Curlew and Phalaropes belong to Subfamily Tringinae

The sandpiper family is large and diverse and often separated into tribes. **Sandpipers** are birds of shallow, open or grassy sheet water, mudflat, or sandy shore; they feed on live invertebrates, spawn, or small fish or amphibians most of the year. Many are habitat-specific, with preferences for substrate, water depth, wave height, wind, etc., so that adaptations of leg length, neck length, bill length, and shape differ by species and sometimes by sex. They glean, peck, pick, drill, bore, probe, and sweep, and they demonstrate efficient adaptations in behaviour as well as in structure. Their nesting habitats often differ markedly from their winter or migration feeding areas, and one sandpiper, the Solitary Sandpiper, nests in old songbird nests in stunted trees in the northern forest edge that is interspersed with grassy feeding pools (Kaufman 1996). The young are precocial.

Avocets and Stilts belong to Subfamily Recurvirostrinae they are usually considered either as a separate family or as a tribe of shorebirds. They are worldwide in distribution and are characterized by long bill and longer legs in proportion to the body than any other birds except flamingos. Stilts and avocets inhabit marshes, lakes and pools. They favor saline/soda wetlands and lake shores or estuaries. Stilts have long straight bills and seem more commonly to be running on mudflats than wading, but that tactic depends on feeding opportunities. Avocets have recurved (i.e., upturned) bills ideally suited to sweeping the substrate while wading in shallow water up to belly deep; in fact they sometimes swim. They feed on aquatic invertebrates. They often nest on sites with little vegetation, and the precocial young are well camouflaged for their habitat.

Gulls Tribe Larini Family Laridae

Only subfamily Larinae of family Laridae occurs in Pakistan.

They are medium-sized to large birds with relatively long, narrow wings usually a stout bill, moderately long legs and webbed feet. Immature are brownish and cryptically patterned. In flights gulls are graceful and soar easily in up draughts. Most species are gregarious and all species swim buoyantly and well. They are highly adaptable and are opportunistic feeders with a varied variety diet, including invertebrates.

Terns Tribe Sternini

These tern are small to medium-sized birds aerial birds with a gull like body, but generally more delicately built. The wings are long and pointed, typically narrower than those of the gulls and the flight is buoyant and graceful. Terns are highly vocal and most species are gregarious. Two main groups occur in Pakistan: The *Sterna* terns and the *Chlidonias* or marsh terns. The *Sterna* terns mainly eat small fish, tadpoles and small crabs caught by hovering and then plunge-diving form air, often submerging completely and also by picking prey from the surface. Marsh terns lack prominent forked tail and, compared with *Sterna* terns are smaller, more compact and short tailed. Marsh terns have a more erratic and rather stiff winged flight. Typically marsh terns hawk insects or swoop down to pick small prey for water surface.

Gulls and terns, while closely associated are often nesting together or on similar sites, represent two subfamilies that reflect different feeding strategies involving adaptations of flight and feeding apparatus. Terns are predators on live fish or aquatic invertebrates taken on or near the surface of fresh- or saltwater, while Gulls are more commonly scavengers or kleptoparasites ("hijackers"), harassing and taking food from other birds. The young of gulls and terns typically are precocial but stay in or near the nest while being fed insects or bits of regurgitated fish, crabs, and squid.

Water and other resource influences on wetland birds

Milton W. Weller (2003) discusses the habitat needs of wetland birds. Since the unique and dominant feature for wetland birds is water, and long-term adaptations include genetically selected modifications in anatomy, morphology, and physiology shown in (Table 4).

Shorter-term adjustments, however involves mostly behavioural changes, but we know little about these and they are difficult to study and test experimentally. Birds, like many wetland animals, often are not truly water adapted but retain terrestrial adaptations that allow them to survive with extremes of water regimes and also to exploit resources of both habitats along the wetland edge. Migratory, or at least mobile, birds obviously have greater flexibility in their search for habitat than do flightless, terrestrial vertebrates. It has been suggested that birds logically should follow a hierarchy of selection from large to smaller scale. First, on the largest scale, they either reside in or migrate to large geographic regions with climatic regimes and general landscape or vegetation features attractive to them (either via instinctive preferences or prior experience). Second, a bird could select from various landscape alternatives within this geographic region, such as areas showing certain types, spatial relationships, or sizes of wetlands. Third, a single wetland or complex that provided suitable habitat might be the focus of the bird's search for that season or function (e.g., breeding, non-breeding, feeding, roosting), and, finally, selection of microhabitats, foraging sites, nest site, etc within the chosen wetland or wetland complex will be made to meet its needs. Both the general region and the specific area presumably would meet some innate habitat image, possibly influenced by experience, but some trial-and-error exploration may be involved – especially in case of resource shortages.

Table 4: Adaptations of water birds

#	**Long term adaptation**	**Short term adaptation**
1.	Rear leg placement for swimming and diving	Specific foods
2.	Bone and lung modification for diving	Feeding tactics
3.	Eye modification for nocturnal and underwater	Feeding flights
4.	Flight adaptations for aerial divers	Local Flights
5.	Webbed and lobbed feet	Vegetation species and life
6.	Long legs for wadding	Nest sites and vegetation
7.	Bill specialization for grabbing, straining and	Water depth preference
8.	Water resistant plumage	Roosting patterens
9.	Behavioural adaptation for preening and drying	

#	Long term adaptation	Short term adaptation
10.	Specialization for general types of food	
11.	Physiological adaptation for respiratory and	
12.	Breeding strategies	
13.	Social behaviour: spacing and aggression	
14.	Water depth adaptation	
15.	Wetland types, water dynamics and salinity	
16.	Long-range mobility/resource exploitation	

Water as a resource holds a great significance for all the life forms on earth, yet for the wetland birds it is the psychology of water's presence that seems to be of first importance. It is an attractant, and no habitat is habitat for these species without visually significant bodies of water. Use of a habitat as a source of suitable foods is the next priority, followed by use for body care, such as bathing, thermoregulation, etc. Bathing is regular and often is a group activity. Sometimes it is incorporated into courtship behaviour in obligate water birds that normally mate in and nest on, over, or near water.

Many wetland birds can swim, but some do so rarely. There is a scale of use of water among wetland birds. Facultative species (Kelly and Wood 1996) use wetland edges opportunistically and may feed and nest over water rarely. Most shorebirds are always associated with water but some barely get their feet wet on mudflats. True water birds that swim regularly vary from birds of quiet waters like Moorhens or dabbling ducks to open-water bay ducks like Redheads and Scaup, which often seek the shelter of inland ponds or protected bays when wind and wave velocities exceed a certain level. Such ponds may also provide fresh water (Adair, Moore and Kiel 1996).

Selection of depth of water for feeding is an important and poorly studied behavior, mainly because it is not easy to measure quickly at a distance and perhaps because its significance in habitat segregation has not been appreciated. But each species seems to have a pattern of use geared to the foods and the area, and most are fairly consistent. Some of these tactics vary with season and food.

Although water attracts water birds and provides both food and protection, it has its dangers because it can be a powerful force. It may directly harm or kill, or stress birds through energy demand, thus influencing the species adaptations and ultimately the species composition of birds using certain wetland types. During the breeding season it is common to find more obligate species in productive basin and in fringe wetlands than in river channels. This pattern presumably results both from energy demands of feeding in different wetlands and from the nature and abundance of suitable resources present, which in turn is the product of the physical stresses that influence the basic productivity of each wetland type for example the current in streams and wave action in larger lakes and oceans. These stresses affect water regimes, which in turn influence plant physiology (Riemer 1984, Schulthorpe 1967) and plant succession processes. Except for periodic inflow from sheet water or stream overflow, basin wetlands like lakes lack current and have the least wave energy except as produced by wind. Obviously, the larger the wetland the greater the wind fetch and potential for wave energy to build. Although such wetlands have vertical water movement resulting in water-level changes (Brinson 1993), birds are less influenced by current or wave action. Therefore, these basins are used by a wide variety of birds for breeding and feeding, with less potential for impact of waves on nests, young, or food resources. Many of these species are efficient at building up nests during flooding, and others built nests high in the vegetation, which minimizes loss. Where protective vegetation is lost in larger wetlands between years, wave action increases the potential of loss of nests and eggs and hampers feeding efficiency, with a net loss of energy on the part of the bird. As a result, the habitat becomes less optimal for breeding but might serve other purposes, such as feeding or roosting during calm periods or for species that have different feeding tactics (e.g., underwater diving by grebes as opposed to surface feeding by dabbling ducks).When water levels decline, new dangers of predation may develop, and abandonment of nests and wetlands is common, having the potential result of saving the adults rather than losing both adult and nest.

Salinity

Although most birds seem to have salt-removal glands as well as suitable excretory processes, birds vary in their ability to tolerate high salt intake, ranging from those that perhaps can but rarely do to those oceanic birds that rarely drink freshwater or have salt-free foods (albatrosses, petrels, and auks). Moreover, there is considerable evidence that increased use improves the functioning of salt glands under high salinity (Bradley and Holmes 1972,Cornelius 1977).

Food

Birds require high-energy carbohydrates during the physical stress of migration and during thermoregulation at low winter temperatures. As a result, their diets differ seasonally and by function, and birds move, seek, and vary food choices to meet these needs. Food for young often differs from that of adults unless the adults are in molt or body-growth phases. Young omnivores gradually shift from animal protein in early growth to more seeds and then foliage as they mature. Carnivores or piscivores show shifts more in size or species of prey, often dictated by selection made by the parents during the feeding phase.

Getting food of the correct type and at the right time is one issue, but some birds are not effective until they have the proper feeding conditions. Hence, a feeding perch is preferred or needed by most kingfishers or flycatchers. Aerialists like swallows or plunge divers like Ospreys or Brown Pelicans have greater flexibility, but even these require areas large enough to permit flight manoeuvres, and water of sufficient depth to reduce potential injury. For most species, there are habitat-related issues such as water depth, water clarity, and vulnerability of the prey.Lack of disturbance by potential predators (including people) also may be important.

Resting:

Birds require undisturbed places for rest both during the day and at night to avoid predation or stress. If one observes at a site where various water birds fly in during the day, some land in water and start to drink, some start to feed, and some land on a mudflat or snag, often disturbing other individuals or species to find a place to rest. Some species have very specific requirements for rest sites, presumably based on genetic makeup and social structure. Many swimmers like ducks simply float on open water.

Thermoregulation:

Because of higher body temperature, thermoregulation in birds may seem of less than in other animals, but there is strong evidence that, in addition to migrating to warmer regions during cold periods, they select microhabitats to reduce chilling winds, overtopping waves, or other stressful situations (Burger et al. 1984). Waterfowl are especially able to winter in cold areas because of their compact feathering and heavy down layer.

Mallard ducks demonstrates an additional technique of saving its energy via remaining buried in snow or other heat-preserving shelters rather than to go out and feed on severely cold days, probably which is les than that they could take in (Jorde et al. 1984). Some other ducks conserve heat behaviourally, by tucking their feet into flank feathers and their bill into scapular feathers (Brodsky and Weatherhead 1984), and by selecting sheltering landforms (Longcore and Gibbs 1988).

Escape cover

The need for and use of predator escape cover or conditions vary greatly among groups and species. However be it ducks, wader or walkers these birds gain protection from predation only by the presence of water, and the ability to fly. Thus it is particularly important that rearing areas have water and food to sustain the young during their flightless period, which can be quite long in geese and swans.

Habitat requirements for breeding

Birds also need some very specific habitat features for reproduction, and this varies greatly with the taxonomy and habitat choice of the bird group in question. Breeding for some taxa like songbirds and herons requires territorial sites to proclaim ownership and attract mates (Lack 1968). There are important genetic and evolutionary implications to such habitat choices by males. In colonial waders, territory may be the preliminary nest site where the male has deposited enough sticks or other vegetation to create a mating platform, but the site may be some distance from food. Ducks need open-water areas for on-the-water courtship displays that establish and test pair bonds, much of which occurs on wintering and migration areas. Terns engaging in fish flights need not only a fish to pass to their prospective mate, but undisturbed beach areas where ceremonial feeding occurs. Among wetland birds, nest sites typically are found in microhabitats ranging from highly aquatic to terrestrial.

Habitat requirements for molting:

Adults of those groups (ducks and geese, coots and rails, grebes, loons, auks, anhingas, flamingos, and dippers) that have a simultaneous or near-simultaneous (as opposed to serial) wing molt annually (some ruddy ducks may do this twice a year) are flightless for 2 to 5 weeks and, therefore, have similar resource needs to those of juveniles: foods and protective water or cover must be available in the same wetland. Prior to this event, many adult waterfowl and probably some other groups undergo a "molt-migration" (Salomonsen 1968), seeking large and protective water bodies that are free of major predators for their flightless period (Hochbaum 1944).Some duck species migrate hundreds of miles to special molting areas after breeding: dabbling ducks (Oring 1968), bay diving ducks (Bergman 1973), Paradise Shelducks (Williams 1979), and some geese (Abraham 1980). Food in abundance also is an obvious necessity during an energy-demanding period.

Relationship between wetland types, food niche and foraging strategies of birds:

Food resources within wetlands can be diverse and vary temporally and spatially.

General categories of food resources used by water birds are products of the diversity of vegetation and animals, which are themselves related to hydroperiods (i.e, duration of water in days, weeks, or months per year), timing of biological and environmental events (e.g., seasonal chronology), and water depths in different wetland types.

Vegetation structure of any wetland determines the type of habitat prevailing there for it forms the basis of food chain. However this structure is influenced by adaptations to water permanence, timing, current, and climatic and salinity regimes, resulting in microhabitats with differing vegetation structures such as non-persistent emergents, persistent or robust emergents with sufficient structure that they survive into the next growing season or longer, woody forest or shrub species that may grow continually for many years, or aquatic beds made up of diverse annual or perennial underwater plants that tend to reoccur annually when conditions permit.

Figure 1 shown below describes the influence of water regimes and velocity on vegetation groups and potential plant foods, and on invertebrate and vertebrate (fish, amphibians and reptiles) foods of waterbirds.

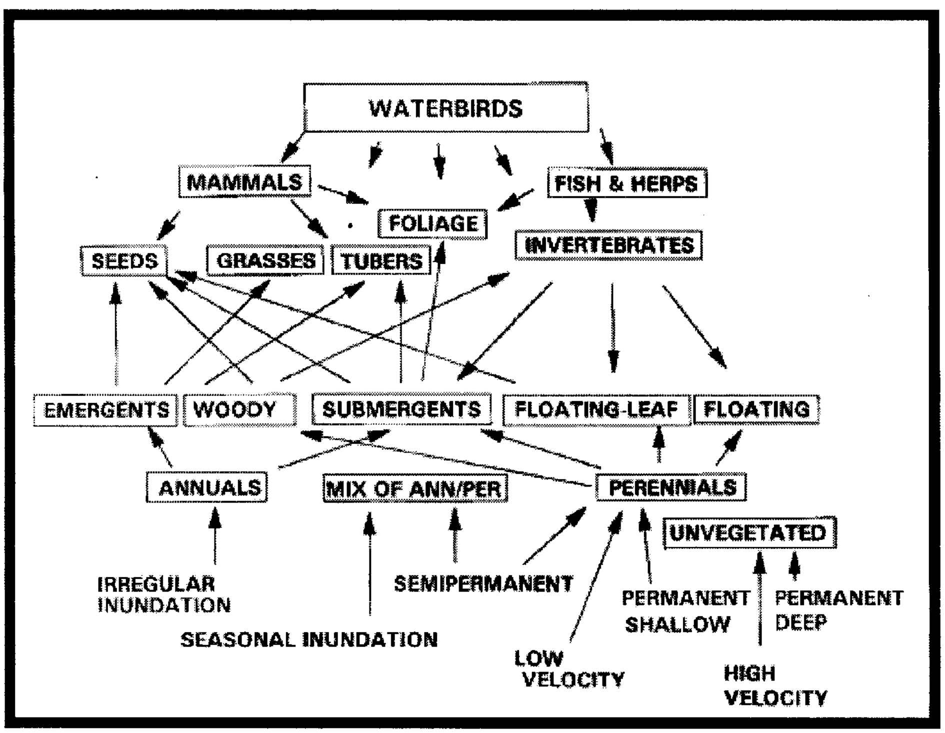


Figure 1: Influence of water regime & velocity on food chain in wetland

Aquatic vertebrates like amphibians and reptiles ("herps"),fish, or wetland mammals like rice rats are major foods of predaceous wetland birds and other vertebrates. But as consumers, they also are linked directly to vegetation, invertebrates, or other smaller vertebrates for food; directly to water for protection; and indirectly to water as the driving force for wetland plant and animal succession over time

Thus the type of food, its presence, rarity or absence in wetlands might influence the bird species that can survive. Furthermore the foraging of water birds is influenced by wetland choice, the microhabitat within the wetland, and food needs for specific stages in the annual life cycle.

The foraging strategies are not simply a matter of choice by the bird but might be fixed by traditional or genetic adaptation that reflects an evolutionary history which maximizes efficiency and ensures resources in these variable environments.

There are several foraging or feeding strategies that might be indicate the complexity and diversity of approaches required to meet annual needs.

Dabbling ducks feed on invertebrates in summer ponds and on seeds or foliage during wintering periods, thus tapping the greatest abundance of each at the peak seasons. Some move to marine habitats, but most favor wintering habitats that are similar to their breeding areas.

Redhead ducks use inland freshwaters for breeding and molting; here, they and their young feed by diving in shallow water for benthic invertebrates. In winter, however, they frequent mainly estuaries or large freshwater lakes, using quite different foods. (Milton 2003)

An interesting technique reflecting good learning ability by the bird has also been noted in several species of heron that take bread or other potential fish food from picnickers and place it in the water where the heron can then capture the attracted fish. Several recent observations of kingfishers and grebes feeding on food seemingly made available by feeding jacanas and other waterbirds (Croft 1996). Egrets, often with conspicuously colored feet, use foot-stirring to disturb or attract prey, and some plovers and sandpipers engage in foot-stamping, seemingly to make their tiny prey surface. Gadwalls and wigeon, both herbivores, do not dive very efficiently but steal from diving coots as they surface. Piracy practiced by frigate birds on gulls, by pelicans on cormorants, and by gulls on smaller birds is commonplace. Response of birds to fish spawn is an opportunistic behavior demonstrating dietary needs for high protein in spring and also flexibility in tactics, causing unusual mixed flocks like brant, scoters, goldeneyes, mergansers, and various gulls. Table 5 shown below presents some examples of food and foraging tactics employed by certain wetland bird species

Table 5: food and foraging tactics employed by certain wetland bird species

Locomotion/ food taken	**Foods**	**Tactics**	**Species/ Example**
Surface swimmers	Invertebrates and seeds	(i) Strain/sweep/grab (ii) Dabble/grab	(i) Shoveler, Green-winged Teal (ii) Blue-winged Teal
Water column divers	Fish/invertebrates	Visual search/grab	Grebes, ducks
Benthic divers	Invertebrates	Benthic straining	Ruddy Duck, Scaup
Flight-feeders	(i) Carrion (ii) Fish/ invertebrates	(i) Surface grab (ii) Shallow dive	(i) Gulls (ii) Terns
Perch-divers	Fish/invertebrates	Plunge-diver	Kingfishers
Walkers/runners (out of water)	Invertebrates	Search, grab	Sandpipers, plovers
Waders/waiters (in water)	(i) Fish (ii) Fish/insects	(i) Search/strike (ii) Stalk	(i) Many herons (ii) Great and Cattle Egrets
Impact feeders	Clams/shellfish	Drop on hard surface	Gulls

Territorial Behaviour in waterbirds

Many waterbirds are highly social in breeding and feeding, and although territories may be clear-cut and violently defended, there is a wide range of territory size and behavior among wetland birds. While there is a positive relationship between body size and territory size in birds (Schoener 1968), it also seems to be dependent upon nesting and feeding strategies.

Species that nest colonially, such as egrets, herons, ibises, cormorants and pelicans, commonly defend only a small area of the tree, shrub, or marsh vegetation or substrate that is a mating site as well as nest site. However, they are attracted to and rarely nest outside colonies, and they obtain foods at some distance from the site, where they may be highly social in feeding. Grebes are good examples of aggressive birds that demonstrate a wide range of behavior by species. Some are solitary (Pied-billed Grebe, Great crested Grebe), and some are colonial (Eared and Western Grebes). There also is a great range of agonistic behavior among ducks, with dabbling ducks typically showing more aggressive behavior than bay ducks (pochards) or sea ducks. Blue-winged Teal and Shoveler are particularly aggressive on relatively small territories where they typically feed on invertebrates (McKinney 1965).

Territorial behavior also occurs on feeding areas for migration and wintering. A number of groups like shorebirds that feed on dispersed foods such as Invertebrates buried in mud or sand, may defend an area year-round (Myers, Connors and Pitelka 1979).

Breeding chronology and Environmental Influence:

Various bird species nest at different times of the year as a result of patterns of environmental seasonality, laying patterns, incubation period, and growth rates of young. But presumably all seasons are influenced by adaptations to available resources in chosen habitats, and how rapidly they are depleted (Wittenberger and Hunt 1985). In an assemblage of birds, there also is the probability of competing with a similar species using similar resources (Cody 1981). If one examines variation in breeding times of the same species at various places, considerable variation is evident, although establishing why is more difficult. Temperature and other seasonal influences are reflected in year-to-year variation in breeding phenology (Rohwer 1992) but regional climatic differences probably produce different mean nest-initiation dates in each region, regardless of habitat..

Wetland diversity and Spatial Patterns

Wetlands are especially known for their abundance of some species or groups of birds as well as for their diversity of species not found elsewhere. The major reason for this abundance presumably is the availability of resources produced by the great primary productivity of wetlands. The diversity of species undoubtedly is linked to diversity of resources produced in the many microhabitats resulting from water-depth gradients and fluctuations.

Wetland types differ in the height, diameter, and robustness of dominant plants as well as in the range of plant species diversity, which with variation in water regimes can result in highly variable and sometime quite complex patterns of habitat diversity. From the completely aquatic to the more terrestrial, these plant life forms result from adaptation to the presence, depth, duration, seasonality, temperature, and chemistry of water. These form different habitats from which a species can chose its microhabitat for particular activities. Various bird species have evolved a different preference, which suggests how habitat diversity can result in habitat sharing of different species in a small area (Weller and Spatcher 1965).

Wetlands diversity Vs Wetlands Size

Some wetland diversity often is a product of size. It has been known for many years that increasing the size of sample plots in plant communities results in increased number of species (i.e., the species–area curve). Increased island size results in increased number of vertebrates, including birds (Duebbert 1982,He and Legendre 1996, MacArthur and Wilson 1967), and wetlands seem to function in the same way. Increased species richness with wetland size has been reported for ducks in small prairie and forested wetlands (Nudds 1992), forested bog wetlands in Maine (Gibbs et al. 1991) diverse waterbirds in lakes and smaller wetlands in Italy (Celada and Boglianai 1993), and Finland (Lampolahti and Nuotio 1993), and estuarine tidal wetlands (Craig and Beal 1992).

Wetlands Habitat Pattern and types of Birds

Birds of deep open water Most birds of deeper, open water with lake-line shorelines are divers that feed on mobile fish, large invertebrates, and occasionally amphibians such as salamanders. These include loons, pelicans, cormorants, certain grebes, and fish eating raptors like Ospreys and Bald Eagles (Esler 1992). Some are benthic divers that feed on clams, worms, or insect larvae, such as Lesser Scaup, Canvasback or Redhead ducks (Bartonek and Hickey 1969, Bergman 1973, Woodin and Swanson 1989). A few species, such as Northern Shoveler, are planktonic feeders and take tiny crustaceans by straining though special bill morphology. They tend to feed in shallow, rich waters in groups or with other birds that stir-up waters and make prey vulnerable. During nesting periods, these species are more closely linked to nesting cover or islands, as reflected in wetland choice by several species of small grebes (Faaborg 1976,) birds of submerged aquatic beds Birds that use submergent plant beds during the non-breeding period are those like American Coots, swans, Gadwall,American Wigeon, or Canvasbacks and Redheads, which feed on the foliage or tubers of plants such as pondweeds, wigeon grass, and seagrasses. Blue-winged Teal and Mallards may strain out floating seeds or surface invertebrates, strip seed from emerging heads, pluck off associated invertebrates such as snails, and bottom feed in more shallow water (Swanson and Meyer 1977). Pied-billed Grebes also feed among the vegetation, seemingly able to move easily through the dense vegetation to capture small fish and large invertebrates that take cover there (Esler 1992).The little Snowy Egret may walk on dense mats of such vegetation or use them as stationary feeding perches.

Birds of robust or persistent herbaceous emergents

Emergent vegetation has the greatest concentration of species, presumably because of its diverse food resources and structural opportunities of cover for different species and different functions during individual life cycles. Use of emergents is especially prominent during the nesting season, when nests of different species may be at various sites. Cover–water patterns are important because species often favour edges, and swimming birds move between patches of vegetation via water channels. Moreover, some birds require sizable areas for taking flight. Therefore, dense stands of single species of plant are less attractive to most species of birds (Kaminski and Prince 1984, Murkin, Kaninski and Titman 1982, Weller and Fredrickson 1974,Weller and Spatcher 1965) and maintenance of balanced cover–water interspersion (i.e., "hemi- marsh") is a management target used by wildlife management agencies. Invertebrates also may be more abundant among these emergents in some seasons (Murkin, Murkin and Titman 1992) and attract birds that use such foods in preparation for egg laying. Herons, egrets, bitterns and ibises may nest among or on top of robust emergents like cattail or California

Bullrush, and some, like bitterns, also feed there during nesting. Such stands of vegetation are excellent waiting sites for stationary feeders like Least Bitterns or Tricolor Herons. Some birds favor the protection of emergents compared with extensive open-water areas that may be influenced by winds or waves but still use the resources of the shallow emergents. Among these are diving ducks like the Ring-necked Duck and Ruddy Duck, which may nest in emergents but feed in the dense submergents often found in these pools. Because they are excellent swimmers and divers, they escape predators by diving and move to adjacent open water to take flight. The swimmers among the rail family, including coots, using deeper water and Moorhens of more shallow water are common in these pools. Black Terns feed on invertebrates at the surface and nest on small mats in such openings. Ibises and large rails use such pools for feeding, and many ducks rear their broods in such sites where cover is adjacent to food. birds of shrub and forested wetlands

Wetland shrubs occur around a variety of wetland types in the seasonally flooded zone or in saturated soils in riparian or alpine habitats. Stream sides or drainages, where wetland vegetation is apparent or where terrestrial vegetation is more abundant and diverse owing to the presence of water, are well known as important riparian areas for birds (Hehnke and Stone 1978, Taylor 1986,Wauer 1977).

Tree- or shrub-nesting passerines and flycatchers are prominent there because of the availability of foods from the stream and from the several layers of vegetation. Water tolerant shrubs like Buttonbush and certain species of willow and alder can survive flooded conditions even during the growing season and are among the plant dominants in areas termed shrub–scrub swamps . Such habitats often are used by herons and egrets as well as by passerines for nest sites. These plant zones commonly are distributed along stream banks, especially in western areas where extensive vegetation is present only because of the increased water table associated with streams. birds of un-vegetated shallow water, mudflats, and sandbars Shallow sheet water over soil, sand, or other non-vegetated or sparsely vegetated substrate may result from rainfall, stream, or tidal flooding of mudflats and shorelines. Plowed fields and other agricultural areas also may be flooded under such circumstances, which often makes available a rich supply of foods. Open-water areas within wetlands form similar new habitats for edge birds when water levels decline below the emergent and sub-mergent zones and expose bare basin bottoms. These offer special habitats for American Avocets, ibis and teal, which specialize in feeding in shallow water, usually by feel or straining rather than sight. Waders often walk such flats in search of fish, amphibians, reptiles, or large invertebrates in the water. Such sheet water areas may be used also during migration or in wintering areas as overnight roosts by cranes and geese; protection of these habitats is a vital management approach to capitalizing on waste grain and other adjacent food resources attractive to such granivores (Hobaugh 1984).

Mudflats are moist and usually unvegetated areas generally not appreciatedby those who do not recognize the abundance and distribution of invertebrates that occur in these habitats and the role the invertebrates play as detritivores in the cycling of nutrients within wetland systems. Thus, the mudflats offer a unique habitat for carnivorous foragers like Killdeers and numerous other plovers and sandpipers (Capen and Low 1980). More fluid mud is the favorite habitat for a number of groups of tiny crustaceans, nematodes and annelids, which are eaten especially by Green-winged Teal, a species often termed "mudder" for its walking and sifting behavior in soupy mud, and by shorebirds. birds of constructed ponds, lakes, and reservoirs Typically, constructed waters are impounded waters that are deep enough that emergent vegetation is either absent or restricted to a narrow fringe, and they sometimes have extensive submerged plant beds in the shore zone that are valuable for waterbirds. These artificial lakes may be important foraging sites for birds that feed on insects over the water, or for swimming birds that eat submergent foliage or resident animals; as a result, they add avian diversity especially in arid regions (Evans and Kerbs 1977). Larger reservoirs may have extensive littoral zones in the upstream area, which may be excellent water bird habitat if they are not subject to rapid and extreme water fluctuations. However, wave action often seriously limits shoreline plant establishment. Because of the abundance of fish, many are excellent areas for cormorants, pelicans, herons, and mergansers. Geese and similar grazers around the world use them as rearing areas in summer because they feed in the uplands and use the water for brood protection. Large reservoirs also may be favoured by wintering flocks of Canada Geese and Mallards, because they are deep and remain open during most winters and the birds can feed in grain fields nearby (Simpson 1988).

Water is the chief driver force in determining the type of Wetland. Most studies and several summaries of information on wetland productivity indicate that diversity and populations of bird species are greatest in those areas with unstable water regimes (Mitsch and Gosselink 1993, Weller 1995). Fluctuations in water or even drawdown periods allow oxidation and enhanced biochemical processes that induce productivity. Food production may subsequently be elevated, but even then, other factors like food availability or concentration influence bird use. It is not surprising that bird populations and bird diversity seem related to the level of eutrophication (Nilsson 1978). Stable wetlands probably have greater stability in population and species variance, but merely at considerably lower levels.

Another study conducted by Mark V. Hoyer; Daniel E. Canfield Jr. (1994) concluded that all trophic state parameters (total phosphorus, total chlorophyll *a*, etc.) accounted for significant portions of the variance in average annual bird abundance, but total chlorophyll *a* concentrations (μg/L) accounted for the highest percentage (47 percent) of the variance.

Chapter 3 — Materials and Methods

3.1. Status of Rawal Lake

Rawal Lake is located within the boundary of Margalla Hills National Park covering the area of 8.8 km^2. However, it fails to enjoy the jurisdictional limits of being in a National Park. There are about 4 broad sections of Rawal Lake while categorising it according to the type of disturbance/activities being carried out there. These include:

1. Sports (canoeing, boating, angling and swimming)
2. Residential
3. Recreational (Rawal view park and banni-galla recreational park)
4. Spill way functioning

It is to be noted here that water area near the spillways is the most undisturbed and seems to enjoy a certain level of protection.

3.2. Research design

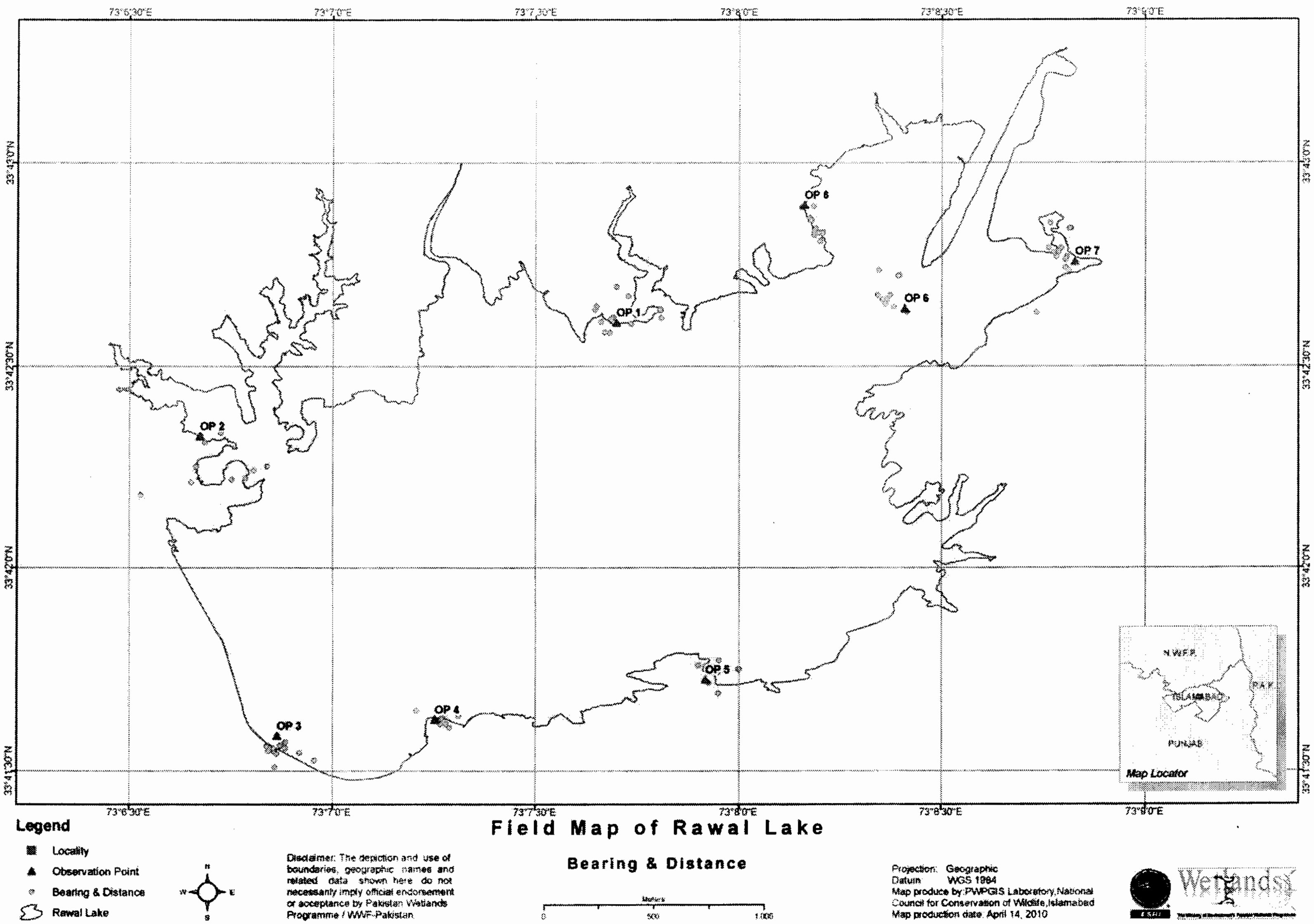
Field Research of the present study comprises of two phases, (a) Water collection and Analysis. (b) Collection of Bird data.

It is important to note that both of the surveys were required to be carried out in the same week, with the gap of maximum 2-3 days in order to reduce any variation.

Both of the phases required quantitative methods for data analysis. However, to calculate the level of disturbance required qualitative techniques for analysis. This set of data was to be collected along with bird data.

3.3.Sampling design.

Eight observation points (OP 1, OP 2,,,,,,,,, OP 8) were set up throughout the lake with the objective to cover the lake uniformly from all sides and were made sure to be true representatives of the area. The points were later marked with coordinates using Garmin GPS Map 76 for the precision of the study area during surveys and sampling. GIS lab of Ministry of environment Pakistan Wetlands was contacted for the configuration of Rawal Lake map 5.



Map 5: Observation points are shown in red triangles and resident bird observation is marked in green circles

3.3.1. Water collection technique

The points of water collection were decided to be 3-4 meters near the bird observation sites.

Physical parameters – dissolved oxygen and turbidity - were measured in the field directly with the use of Hydro lab MS 5.

Turbidity includes suspended solids that come from silt, decaying plant and animals, industrial wastes, sewage, etc. High concentration of suspended solids have various negative effects such as slowing of photosynthesis that in turn can not only slow down the production of dissolved oxygen but also increases the temperature of water resulting in further loss of oxygen. This affects the ability of the fish to survive. Moreover, turbidity impacts the visual ability of fish (and to some extent birds) to hunt and escape from predators. Silt, among the suspended solids which usually results from soil erosion and urban run-off has also been known to clog fish gills leading to imminent death.

Dissolved oxygen is one of the most important aspects of aquaculture. Low levels of dissolved oxygen can usually result in the killing of fish. However, optimum levels result in good growth thus yielding high production. Physical conditions like temperature, altitude and salinity can also affect oxygen level.

Among the chemical parameters nutrient like Phosphorous, Nitrates and Sulphates were taken into consideration. Since nutrients are responsible for eutrophication resulting in lower oxygen level, hence affecting fish productivity.

For the collection of water the bottles were sterilized with 70% methanol solution, were tagged and then sealed before and after water collection.

The bottles were sent to National Physical Standard Laboratory (NPSL) for analysis.

ICT fisheries was contacted for the information of any set freshwater standards in Pakistan. According to the information obtained from the chairman they are following drinking water quality guidelines so far.

Since Pakistan and Australia share the same climatic patterns or zones and have same vegetation. This enables us to use the Water quality criteria and standards of freshwater aquaculture set by Australian Government for their lakes.

Table 6: Water Quality Standard of fresh water aquaculture

Parameters	**Unit**	**Standard**
Dissolved oxygen	mg/l	>5.0
NO_3	mg/l	50
PO_4	mg/l	<0.10
SO_4	mg/l	<100
Turbidity	mg/l	<40

3.3.2. Bird data collection technique

Bird survey was carried out according to standard technique of ***"Variable Point count method"***. Variable point count was used for bird counting on all observation points. Two bands of different radius (0-200 and 200-400 meters) were set at the observation point. Variable bands were created on the basis of recession and advancement of Lake Water with seasonal fluctuations. The decision was supported by two separate studies conducted by Frank, Monica (1995) and Daniel *et.al* (1994) recommending the use of unlimited-radius plots while simultaneously recording individuals relative to a fixed radius for the reason that fewer individuals are detected in small, fixed-radius plots. All the observation points were separated by keeping the least distance of 200 meters in between consecutive Observation Points.

For the observations with the Tahiti 7×50mm West marine binoculars and Nikon fieldscope III ED of 20 x 60mm.

Observation timings of bird counting were set at least 30 minutes before sunrise and 15 minutes before sun set. However the timings were customised according to the visibility and set off of waterfowls in winter. The counting time of birds ranged from 6 to 10 minutes. Maximum of four visits and minimum of two visits to an observation point were carried out to ensure a relatively complete species list.

The study of Bird count was carried for nine months starting from July 2009 till March 2010. Highest counted number of each species was taken into account every month for the period of nine months.

Anthropogenic disturbance was categorised as follows:

High: Includes recreational motor boats and motor scooters, Hunting/ shooting as well as use of dynamite for fishing.

Medium: Moderate construction being carried out along the shorelines, boats for commercial fishing (being run by oars.), Canoeing and rowing boats.

Low to medium: picnicking and angling at a large scale.

Low: Scattered angling along the shoreline.

3.4. Data analyses

Two different statistical analyses were carried out to determine the relationship between bird abundance and anthropogenic disturbance and the physical and chemical parameters of water.

1. Correlation

For *The correlation studies of birds and anthropogenic disturbance* were performed using SPSS statistical software.

For the purpose of correlation studies anthropogenic disturbance was coded as follows:

Table 7

Code	Disturbance
1	Low
2	Low to medium
3	Medium
4	High

Here our Null hypothesis states that there is no significant effect of anthropogenic disturbance in the abundance of resident water fowl. $H_o = O$

While the alternate hypothesis states that is significant effect of anthropogenic disturbance in the abundance of resident water fowl. $H_i = Ø$

2. Regression

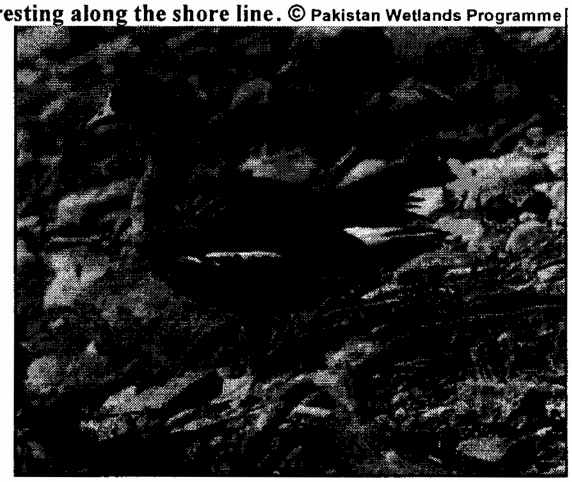
Regression was carried out using SPSS to assess the relationship between nutrients, turbidity and dissolved oxygen with Bird abundance. R Square was taken into consideration in order to determine the degree of variance of the dependent variable that can be explained by the model. Mean of each observation point was taken per month which was then converted into respective log values. Log was taken for the readings of turbidity and nutrients in order to reduce variability and absurdity in the model. Readings of Dissolved oxygen were used without log conversion.

4. Chapter 4 — Results and Discussions

Status of species richness of Rawal Lake:

Around 51 species were identified during the course of this study including Greater white fronted goose, specie that haven't been sighted since 1969 in Pakistan (Grimmet, 2009) (list given in appendix). Hence this study has lead to the discovery of one of the resting sites of Greater white fronted goose and has open options to map its migratory passageway in Pakistan.

Greater white fronted goose flying in flock and an individual resting along the shore line. © Pakistan Wetlands Programme



Analysis of Resident Bird abundance and Anthropogenic Disturbance:

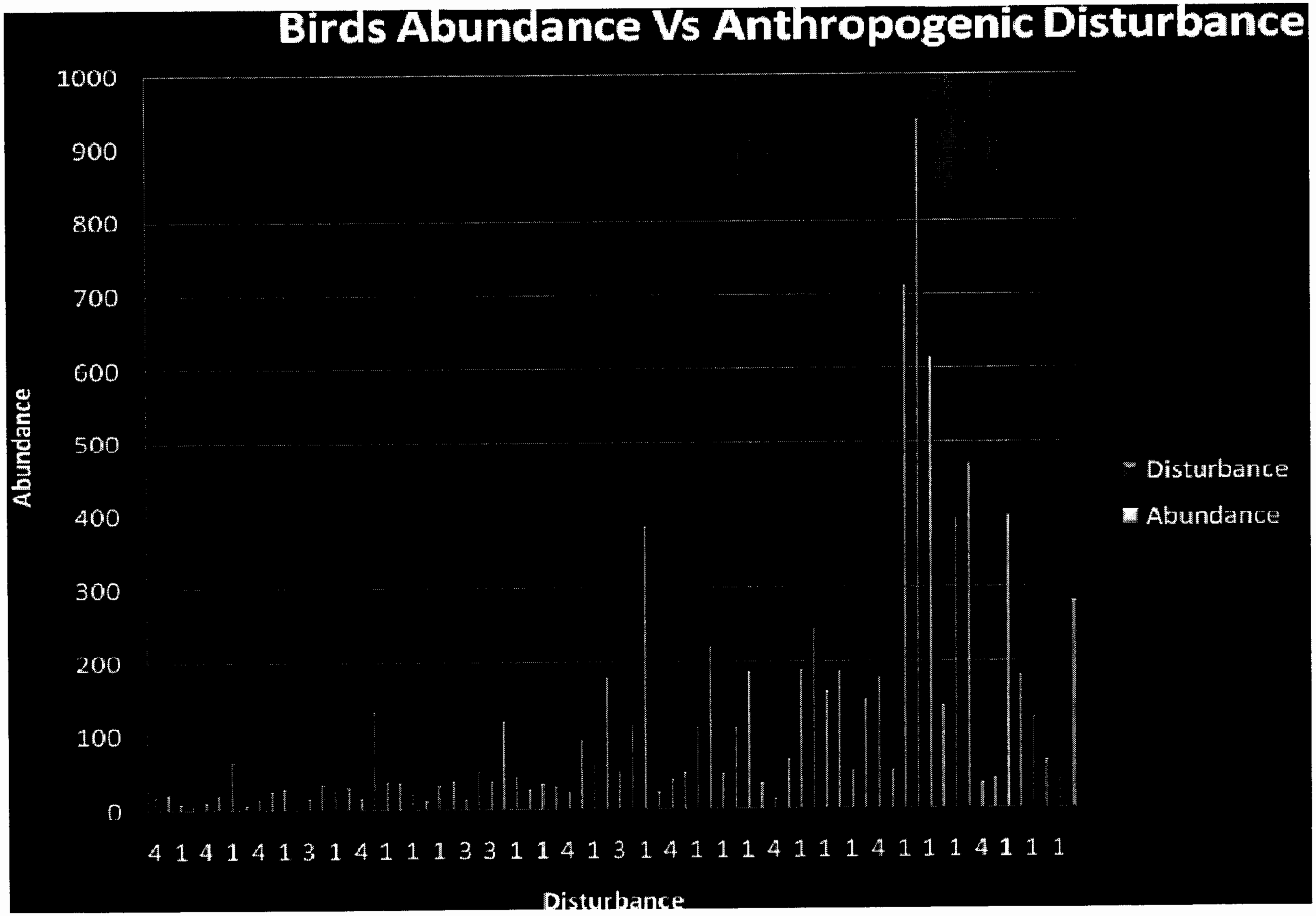
Table 8 shows a significant negative correlation between anthropogenic disturbance and bird abundance indicating that low birds abundance at certain sites was because of medium to high and high anthropogenic disturbance. These results can assist in making decision for the zonation of certain areas of Rawal Lake for the protection of resident and migratory water fowls. Graph 1 proceeded by Box graphs 2, 3 and 4 demonstrates the inverse relation between abundance and anthropogenic disturbance. Similarly Quan RC, Xianji W, Yang X (2002) in their study showed that the distribution of waterbirds was affected by disturbance, with more than one-third of the total species and nearly half of the total individuals

Table 8: The correlation studies of birds and anthropogenic disturbance

		Dist
Abundance	Pearson Correlation	-0.262832302
	Sig. (2-tailed)	0.025711034
	N	72

* Correlation is significant at the 0.05 level (2-tailed).

Since the P value is small and statistically significant so we can reject our H_o and accept our H_i that resident water fowl abundance decreases with increase in anthropogenic disturbance.

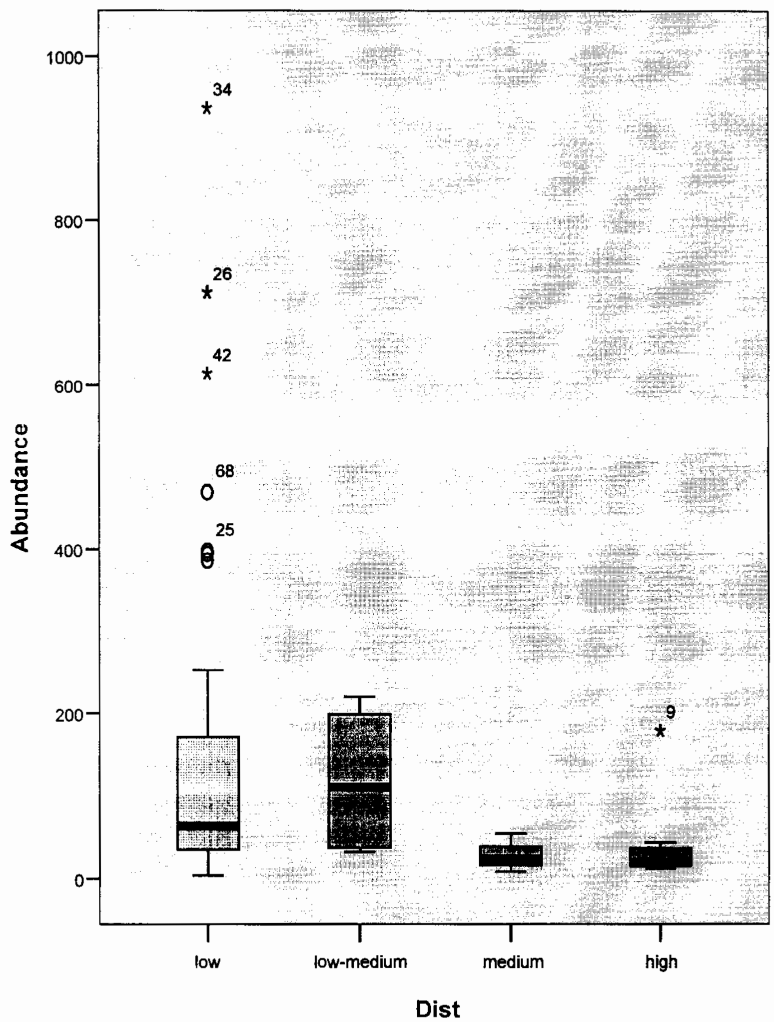


Graph1: The level of abundance in relation to anthropogenic disturbance are shown

*Dist. here and in the following graphs stands for disturbance

Case Processing Summary

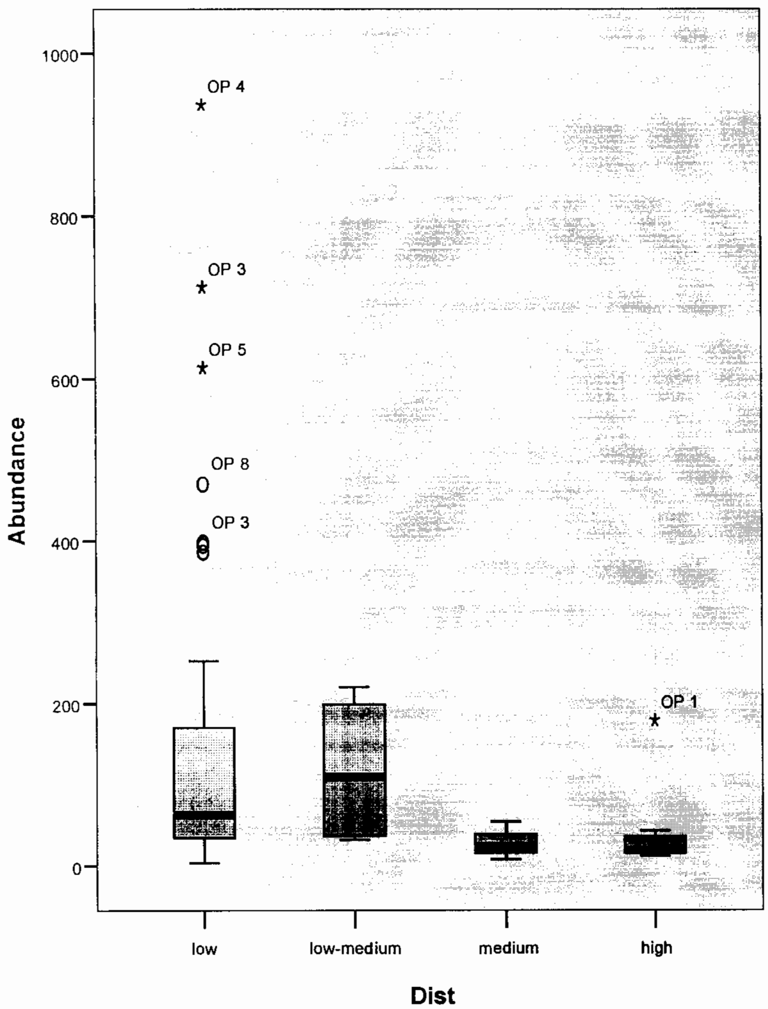
	Dist	Cases					
		Valid		Missing		Total	
		N	Percent	N	Percent	N	Percent
Abundance	low	51	100.0%	0	.0%	51	100.0%
	low-medium	4	100.0%	0	.0%	4	100.0%
	medium	8	100.0%	0	.0%	8	100.0%
	high	9	100.0%	0	.0%	9	100.0%



Graph 2: box graph showing different frequencies for the intensity of disturbance.

Case Processing Summary

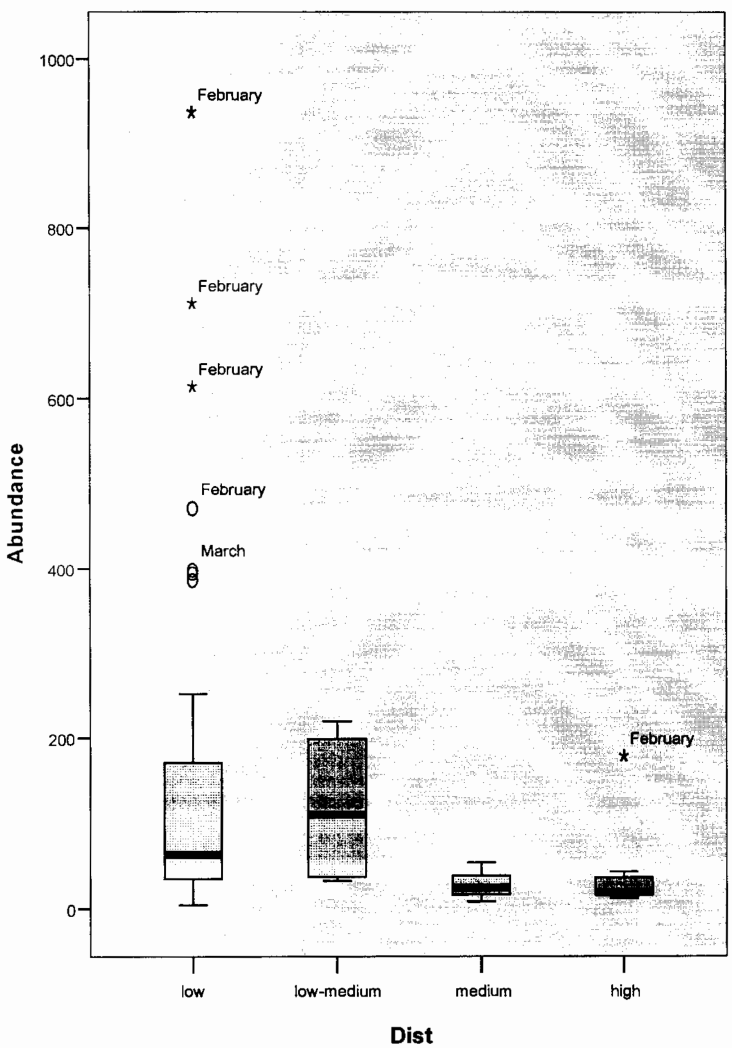
		Cases					
		Valid		Missing		Total	
	Dist	N	Percent	N	Percent	N	Percent
Abundance	low	51	100.0%	0	.0%	51	100.0%
	low-medium	4	100.0%	0	.0%	4	100.0%
	medium	8	100.0%	0	.0%	8	100.0%
	high	9	100.0%	0	.0%	9	100.0%



Graph 3 depicts site wise situation between bird's abundance and disturbance

Case Processing Summary

		Cases					
		Valid		Missing		Total	
	Dist	N	Percent	N	Percent	N	Percent
Abundance	low	51	100.0%	0	.0%	51	100.0%
	low-medium	4	100.0%	0	.0%	4	100.0%
	medium	8	100.0%	0	.0%	8	100.0%
	high	9	100.0%	0	.0%	9	100.0%



Graph 4 shows month wise abundance of birds Vs disturbance

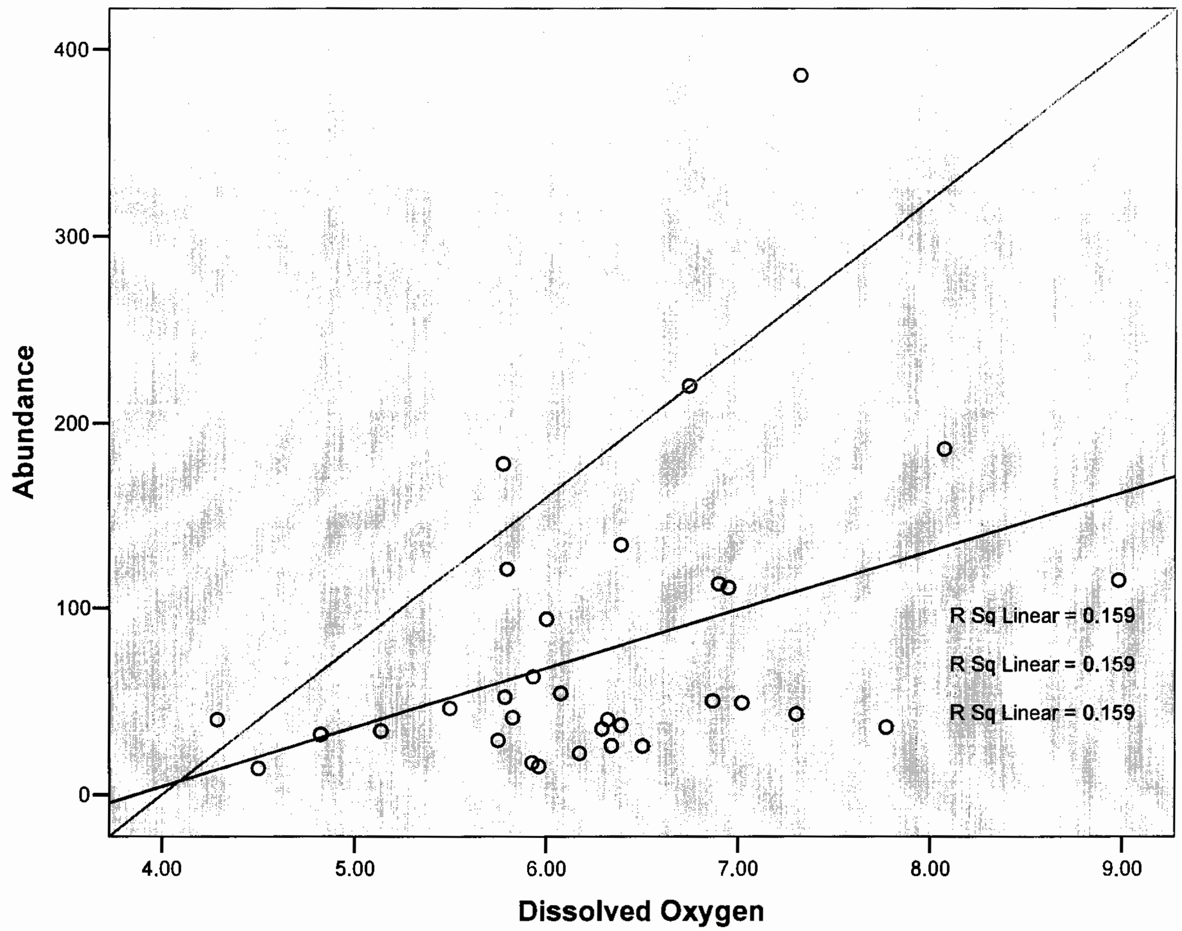
Analysis of Resident Birds abundance and Dissolved oxygen:

Table 9 shows approx 15% of predictors (dissolved oxygen) in relation to dependent variable (bird abundance). The relationship depicted in graph 5 shows that the dependent and independent variables have weak interrelationship and require further investigation.

Table 9:

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.399(a)	.159	.131	72.449

a Predictors: (Constant), Dissolved Oxygen



Graph 5: shows the normal regression line (in yellow) and the line fitted into the equation

Analysis of Birds abundance and Nutrients (surface and subsurface):

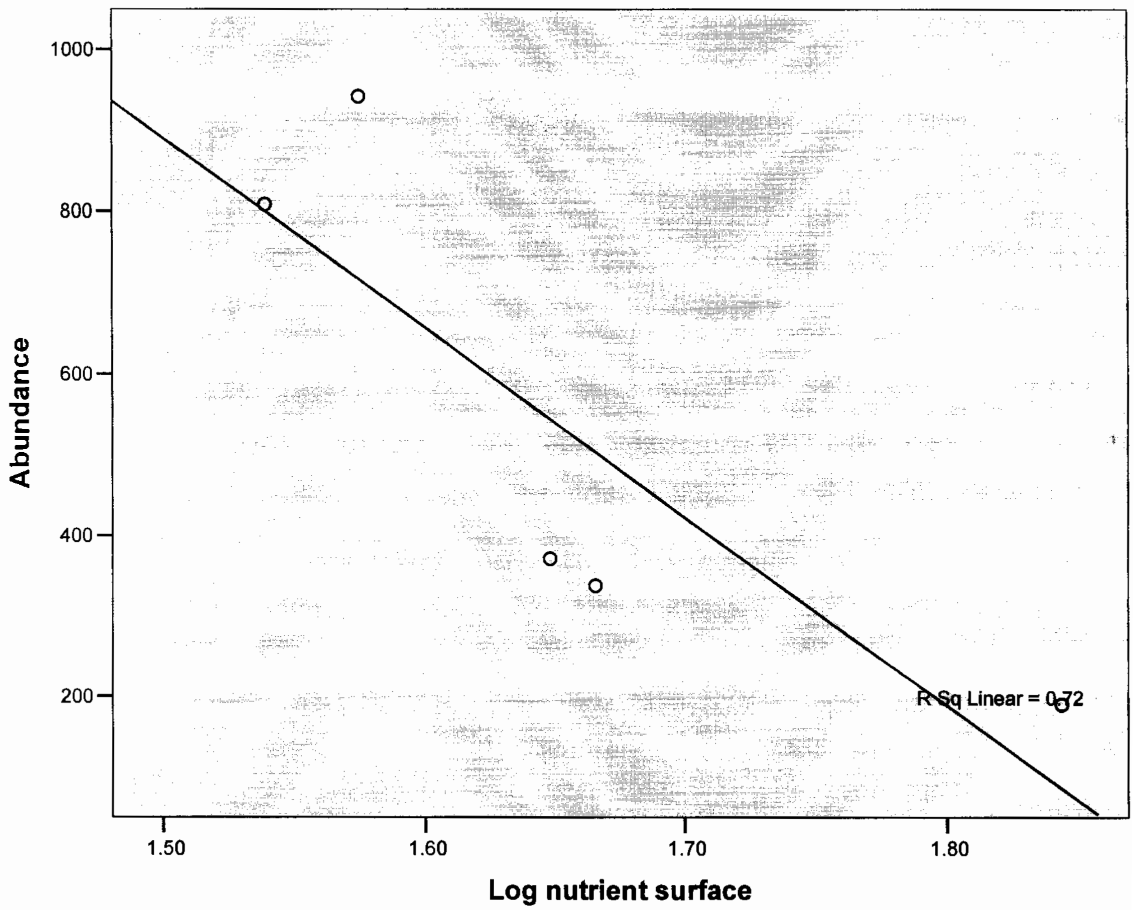
Table 10 and 11 indicate that 72% and 57% of predictors (nutrient) at surface and sub-surface respectively are in relation to and can be explained by dependent variable (birds abundance). Graph 6 and 7 furthermore depict an inverse relation between Birds abundance and Nutrients at surface and sub surface level. This corresponds to the study conducted by Pieter, *et al.* (2003), describing the relationship between parasites and eutrophication. The author reported correlations among eutrophication and low levels of oxygen leading to hypoxic state of water. This results in death of bottom dwellers as well as fish and shrimps. In extreme cases of anaerobic conditions produced by eutrophication, the growth of bacteria namely *Clostridium botulinum* produces toxins deadly to birds and mammals. Zones where this occurs are known as dead zones.

Similarly Friend, McLean and Dein (2001) studied Avian botulism (Clostridium botulinum type C) and avian cholera currently stand out as major problems because of the magnitude of losses they cause, broad spectrum of species affected, annual frequency of epizootics, and their continually increasing geographic area of occurrence. Both strains of these bacteria occur in eutrophic waters. However eutrophication levels in Rawal lake are below the safety lines of Water Quality Standard of fresh water aquaculture to effect resident and migratory birds population.

Table 10:

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.848(a)	.720	.626	199.199

a Predictors: (Constant), Log nutrient surface

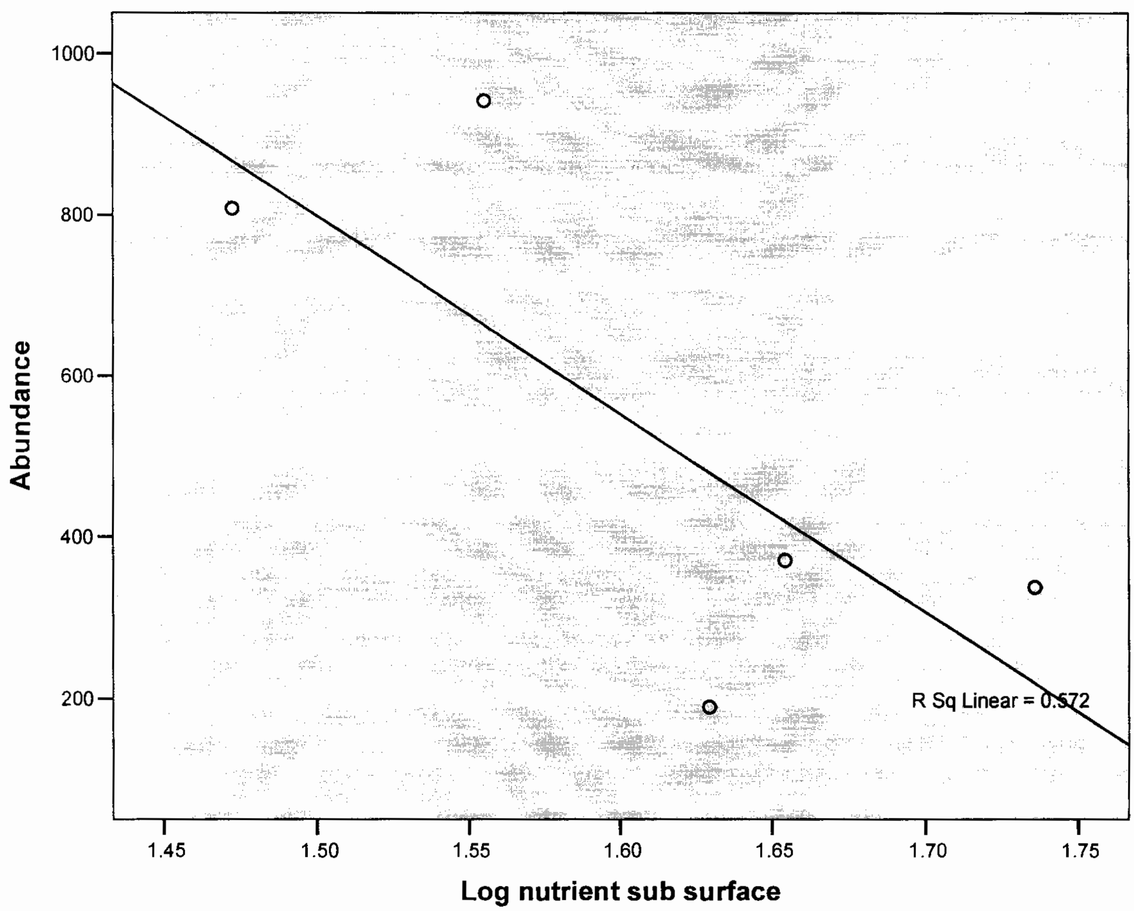


Graph 6 : An inverse relationship between nutrients at surface and birds abundance is shown.

Table: 11

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.756(a)	.572	.429	246.252

a Predictors: (Constant), Log nutrient sub surface



Graph 7 An inverse relationship between nutrients at sub-surface and birds abundance

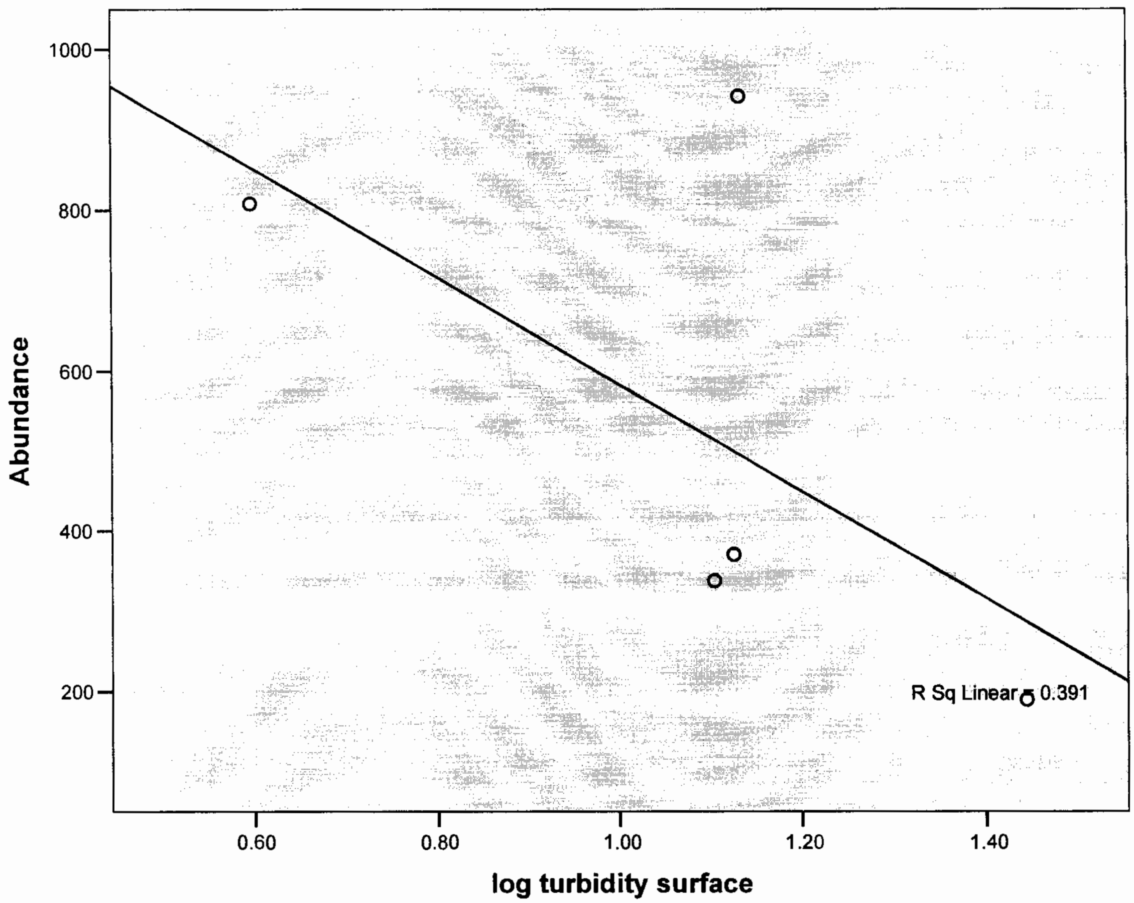
Analysis of Birds abundance and Turbidity (surface and subsurface):

Table 12 and 13 explain that 39% and 56% of predictors (turbidity) at surface and sub-surface, respectively, are in relation to and can be explained by dependent variable (bird abundance). Graph 8 and 9, furthermore, depicts an inverse relation between Birds abundance and turbidity at surface and sub surface level. Since turbidity affects the navigational ability of both deep and shallow water divers, thus affecting their hunting ability. The conclusion is also supported by Henkel in 2004 in Monterey Bay, California as discussed in literature review. Furthermore the results show that turbidity is a prominent problem in the Lake.

Table: 12

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.625(a)	.391	.188	293.729

a Predictors: (Constant), log turbidity surface

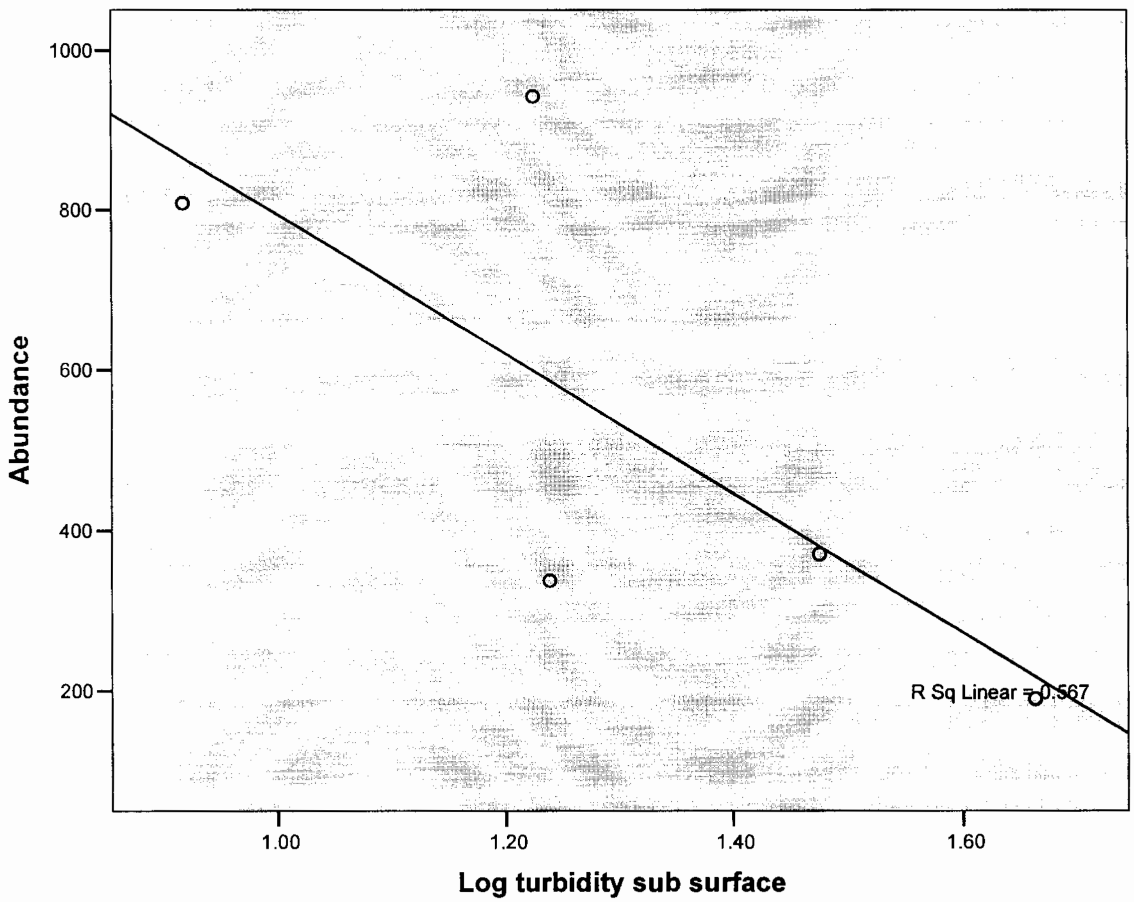


Graph 8 depicts an inverse relationship between turbidity at surface and birds abundance

Table 13:

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.753(a)	.567	.423	247.602

a Predictors: (Constant), Log turbidity sub surface



Graph 9 An inverse relationship between turbidity at sub-surface and bird abundance

Chapter 5 —Conclusions and Recommendations

5.1. Conclusions

Rawal Lake not only serves as a metropolitan lake for drinking purpose but is also a part of National park. Intensive surveys and reviews of previous studies indicate that level of pollution in the lake is far below the permissible limit for fresh water aquaculture. The prominent problem that seems to occur so far is the siltation of lake water especially during monsoon season. Moreover anthropogenic disturbance at certain points along the shore-line has been found to be a major reason besides de-vegetation for low bird abundance and richness. Presently, the Lake requires constant monitoring for lake physical and chemical parameters. Furthermore, zoning of certain areas of the lake as protected ones is required for the provision of safe wintering and breeding grounds to resident as well as migratory birds.

5.2. Recommendations

1. Establishment of shoreline vegetation along the lake as well as along its inlets.
2. Regular de-siltation of the lake.
3. Zonation of the whole forested area (where OP2 is situated) OP3, OP4 and OP5 as a protected area for resident as well as migratory water fowl.
4. Complete control on Hunting, shooting and dynamite as well as chemical fishing.
5. Sturdy regulation on Littering of lake and its shore sides by anglers, visitors and residents.
6. Prohibition of any drainage in resident and recreational spots around the lake.
7. Promotion of Eco-tourism.
8. Clear and transparent ownership of the Lake by cabinet
9. Need for bringing all the stakeholders of Rawal Lake onto one platform and hiring of Wetland guards or inspectors representing each stakeholder.
10. Regular year round monitoring of Lake and its inlet streams by professionals.
11. Year round monitoring an d counting of birds by professionals

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Appendices:

Appendix 1: List of Water fowl species identified at Rawal Lake

#	Common Name	Scientific Name
1.	Black crowned Night heron	*Nycticorax nycticorax*
2.	Black winged stilt	*Haematopus*
3.	Brown headed gull	*Larus brunnicephalus*
4.	Caspian gull	*Sterna caspia*
5.	Citrine Wagtail	*Motacilla citreola*
6.	Common coot	*Fulica atra*
7.	Common green shank	*Trina nebularia*
8.	Common kingfisher	*Alcedo atthis*
9.	Common moorhen	*Gallinula chloropus*
10.	Common pochard	*Aythya ferina*
11.	Common Sand piper	*Actitis hypoleucos*
12.	Common teal	*Anas crecca*
13.	Crested kingfisher	*Megaceryle lugubris*
14.	Eurasian Crag martin	*Ptyonoprogne rupestris*
15.	Eurasian wigeon	*Anas penelope*
16.	Gadwall	*Anas strepera*
17.	Garganey	*Anas querquedula*
18.	Great Cormorant	*Phalacrocorax carbo*
19.	Great Egret	*Egretta alba*
20.	Greater white fronted goose	*Anser albifrons*

#	Common Name	Scientific Name
21.	Green Sand piper	*Tringa ochropus*
22.	Grey heron	*Ardea cinerea*
23.	Grey wagtail	*Motacilla cinerea*
24.	Indian Pond heron	*Ardeola grayii*
25.	Intermediate egret	*Egretta intermedia*
26.	Little Cormorant	*Phalacrocorax niger*
27.	Little egret	*Egretta garzetta*
28.	Little grebe	*Tachybaptus ruficollis*
29.	Little ringed plover	*Charadrius dubius*
30.	Mallard	*Anas platyrhynchos*
31.	Marsh Sandpiper	*Tringa stagnatilis*
32.	Northern Lapwing	*Vanellus vanellus*
33.	Northern pintail	*Anas acuta*
34.	Northern shoveller	*Anas clypeata*
35.	Pale martins	*Riparia paludicola*
36.	Pallas gull	*Larus cachinnas*
37.	Pied kingfisher	*Ceryle rudis*
38.	Plain Martins	*Riparia diluta*
39.	Common Red Shank	*Trigna stagnatilis*
40.	Red-wattled Lapwing	*Vanellus indicus*
41.	River tern	*Sterna aurantia*
42.	Ruddy shelduck	*Tadorna ferruginea*
43.	Temminck's Stint	*Calidris temminckii*

#	Common Name	Scientific Name
44.	Water pipit	*Anthus spinoletta*
45.	White breasted water hen	*Amaurornis phoenicurus*
46.	White browed wagtail	*Motacilla maderaspatensis*
47.	White throated King Fisher	*Halcyon smyrensis*
48.	White wagtail	*Motacilla alba*
49.	Whiskered tern	*Chlidonias hybridus*
50.	Wood sandpiper	*Tringa glareola*
51.	Yellow wagtail	*Motacilla flava*

Appendix 2: Details of Regression analysis between Birds abundance and physical parameters of water

1. **Log Turbidity Surface VS Birds Abundance**

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.625030198
R Square	0.390662748
Adjusted R Square	0.187550331
Standard Error	293.7288379
Observations	5

ANOVA					
	df	***SS***	***MS***	***F***	***Significance F***
Regression	1	165942.9094	165942.9094	1.923381905	0.259567184
Residual	3	258829.8906	86276.63022		
Total	4	424772.8			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1251.487173	536.6984412	2.331825616	0.101977972	-456.526798	2959.501144	-456.526798	2959.501144
X Variable 1	-667.5642499	481.3492594	-1.386860449	0.259567184	-2199.432422	864.3039219	-2199.432422	864.3039219

2. Log Turbidity Sub-surface VS Birds Abundance

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.753003547
R Square	0.567014342
Adjusted R Square	0.42268579
Standard Error	247.6021878
Observations	5

ANOVA					
	df	***SS***	***MS***	***F***	***Significance F***
Regression	1	240852.2699	240852.2699	3.928635966	0.141770651
Residual	3	183920.5301	61306.84338		
Total	4	424772.8			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1665.095827	583.385596	2.854194272	0.064885206	-191.4975076	3521.689161	-191.4975076	3521.689161
X Variable 1	-870.5160378	439.1934783	-1.982078698	0.141770651	-2268.2257	527.1936245	-2268.2257	527.1936245

3. Log Nutrient Surface VS Birds Abundance

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.848382972
R Square	0.719753668
Adjusted R Square	0.626338224
Standard Error	199.1992463
Observations	5

ANOVA					
	df	***SS***	***MS***	***F***	***Significance F***
Regression	1	305731.7808	305731.7808	7.704868028	0.069234693
Residual	3	119041.0192	39680.33972		
Total	4	424772.8			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	4402.954753	1398.187948	3.149043559	0.051303302	-46.70331611	8852.612822	-46.70331611	8852.612822
X Variable 1	-2341.173906	843.4339394	-2.775764404	0.069234693	-5025.35713	343.0093176	-5025.35713	343.0093176

4. LOG Nutrient Sub-surface VS Birds Abundance

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.756123479
R Square	0.571722716
Adjusted R Square	0.428963621
Standard Error	246.2522698
Observations	5

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	242852.2588	242852.2588	4.004807658	0.139163847
Residual	3	181920.5412	60640.18039		
Total	4	424772.8			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	4491.227084	1982.585294	2.265338645	0.108390246	-1818.24416	10800.69833	-1818.24416	10800.69833
X Variable 1	-2461.320236	1229.92121	-2.001201554	0.139163847	-6375.478446	1452.837974	-6375.478446	1452.837974

Appendix 3: Details of Birds abundance in relation to physical parameters of water and anthropogenic disturbance

(i) Readings of Dissolved oxygen in relation to Observation points and Bird abundance

Months	OP	Abundance	LDO
Sep	1	17	5.925
	2	134	6.39
	3	40	6.32
	4	37	6.39
	5	22	6.1725
	6	14	4.5
	7	34	5.1375
	8	40	4.285
Oct	1	15	5.96
	2	52	5.7825
	3	41	5.8225
	4	121	5.7925
	5	46	5.5
	6	29	5.7475
	7	35	6.29

	8	32	4.8225
Nov	1	26	6.34
	2	94	6
	3	63	5.93
	4	178	5.77
	5	54	6.075
	6	115	8.98
	7	386	7.32
	8	26	6.505
Dec	1	43	7.305
	2	50	6.87
	3	113	6.9
	4	220	6.745
	5	49	7.02
	6	111	6.95
	7	186	8.07
	8	36	7.77

(ii) Readings of Turbidity and Nutrients in relation to Observation points and Bird abundance

Months	OP1	OP2	OP3	OP4	OP5	OP6	OP7	OP8	Total	LOG Turbidity		LOG Nutrients	
										Surface	Subsurface	Surface	Subsurface
July	19	22	11	6	12	21	66	8	165				
Aug	16	27	30	4	17	35	28	33	190	1.444591226	1.66312352	1.8439886	1.629545
Sep	17	134	40	37	22	14	34	40	338	1.104913685	1.23904909	1.6658412	1.735826
Oct	15	52	41	121	46	29	35	32	371	1.126192308	1.47548051	1.6482709	1.65432
Nov	26	94	63	178	54	115	386	26	942	1.133265107	1.22521233	1.5747371	1.555157
Dec	43	50	113	220	49	111	186	36	808	0.59641381	0.9179554	1.538984	1.472514

(iii)Readings of Anthropogenic disturbance and Bird abundance at Eight sites

Sites	Months	Disturbance	Abundance
OP 1	October	medium	15
OP 1	January	high	15
OP 1	August	high	16
OP 1	September	high	17
OP 1	July	high	19
OP 1	November	high	26
OP 1	March	high	36
OP 1	December	high	43
OP 1	February	high	179
OP 2	August	low	27
OP 2	December	low	50
OP 2	October	low	52
OP 2	February	low	53
OP 2	January	low	67
OP 2	November	low	94

OP 2	September	low	134
OP 2	March	low-medium	42
OP 2	July	medium	22
OP 3	July	low	11
OP 3	August	low	30
OP 3	September	low	40
OP 3	November	low	63
OP 3	December	low	113
OP 3	January	low	188
OP 3	March	low	398
OP 3	February	low	712
OP 3	October	medium	41
OP 4	August	low	4
OP 4	July	low	6
OP 4	September	low	37
OP 4	October	low	121
OP 4	March	low	182

OP 4	January	low	246
OP 4	February	low	937
OP 4	November	low-medium	178
OP 4	December	low-medium	220
OP 5	September	low	22
OP 5	October	low	46
OP 5	December	low	49
OP 5	March	low	125
OP 5	January	low	160
OP 5	February	low	614
OP 5	August	medium	17
OP 5	November	medium	54
OP 5	July	high	12
OP 6	December	low	11
OP 6	September	low	14
OP 6	July	low	21
OP 6	October	low	29

OP 6	August	low	35
OP 6	March	low	65
OP 6	November	low	115
OP 6	February	low	140
OP 6	January	low	186
OP 7	August	low	28
OP 7	September	low	34
OP 7	October	low	35
OP 7	March	low	40
OP 7	January	low	54
OP 7	July	low	66
OP 7	December	low	186
OP 7	November	low	386
OP 7	February	low	394
OP 8	August	low	33
OP 8	September	low	40
OP 8	January	low	148

OP 8	March	low	252
OP 8	February	low	470
OP 8	October	low-medium	32
OP 8	July	medium	8
OP 8	November	medium	26
OP 8	December	medium	36