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Indus FOREVER

Detailed Ecological Assessment of Fauna, including Limnology Studies at Keenjhar Lake

2007 - 2008

JE MAINTIENDRAI

Indus For All Programme
WWF - Pakistan

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List of Acronyms

A	Abundant
As	Arsenic
BOD	Biochemical Oxygen Demand
C	Capture
C	Common
CAR	Carnivore
Cd	Cadmium
CE	Critically Endangered
CEMB	Centre of Excellence in Marine Biology
CITES	Convention on International Trade in Endangered Species of Flora and Fauna
Cl	Chloride
CMR	Capture-mark-recapture
COD	Chemical Oxygen Demand
Cr	Chromium
DD	Data Deficient
DO	Dissolved Oxygen
DR	Diurnal
E	Endangered
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EIAO	Environmental Impact Assessment Ordinance
EMMP	Environmental Management and Monitoring Plan of Chotiari
FAO	Food and Agriculture Organization.
GEM	Global Environmental Monitoring System
GIS	Global Information System
GPS	Global Positioning Stationing
GRN	Grainivore
Ha	Hectare
HRB	Herbivore
ID	Index of Density
IDER	Indus Delta Ecoregion
IEP	Indus Eco-region Programme
IFAP	Indus For All Programme
INS	Insectivore
IUCN	The World Conservation Union
KB	Kalri Baghar
KTS	Keti Shah
LBOD	Left Bank Outfall Drain
LC	Less common
LC	Least Concern
M	Meters
m	Meters
MAF	Million Acre Feet
Mg	Magnesium
mm	Millimeters
NC	Nocturnal
NC	Nocturnal
NGO	Non Government Organization
Ni	Nickel
No.	Number
NR	Natural Resources

NT	Near Threatened
NTU	Nephlometric Turbidity Units
NWFP	North West Frontier Province
P	Protected
Pb	Lead
PF	Pai Forest
PMNH	Pakistan Museum of Natural History
ppt	particles per thousand
R	Rare
RBOD	Right Bank Outfall Drain
RD	Reduced Distance
RD	Reduced Distance
RNE	Royal Netherlands Embassy
S	Sighting
SEPA	Sindh Environmental Protection Agency
SFD	Sindh Forest Department
SO4	Sulphate
SVL	Snout to Vent Length
SWD	Sindh Wildlife Department
T	Trapping
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
TMDLs	Total maximum daily loads
UMBS	University Marine Biological Station
UNEP	United Nations Environment Programme
viz.	Videlicet; namely
VU	Vulnerable
WAPDA	Water and Power Development Authority
WHO	World Health Organization
WQ	Water Quality
WWF-P	World Wide Fund for Nature – Pakistan

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EXECUTIVE SUMMARY

The 'Detailed Ecological Assessment Study Report' by the Indus for All Programme provides extensive and updated (April 2008) status of various ecological aspects of the Programme's four priority sites. These include a summer survey (June to July) and winter survey (November to February) of vegetation, reptiles and amphibians, avi-fauna, mammals (which have been divided into large and small), fisheries (divided into freshwater and marine) water-quality and limnology which includes phytoplankton, zooplankton and physicochemical properties of the water at the programme sites. The floral aspects of the study is available in a separate report titles

To ensure the authenticity of the reports, maintain the level of scientific approach and install a sense of ownership at government level, a large proportion of the consultancy's were outsourced to Pakistan Natural History Museum, Zoological Survey of Pakistan, Mehran University of Engineering and Technology, University of Karachi and University of Sindh.

This detailed ecological assessment is planned under of the completion of Programme Output A.1.2.2 – "Detailed ecological assessment of Keenjhar Lake"

Keenjhar Lake: Keenjhar Lake is situated at a distance of 113 km from Karachi and about 20 km North and North – East of Thatta town between the longitude of 68 and 69 ^{o} NE and latitude 24 and 25 ^{o}N. It is a freshwater Lake having an area of about 145 km^{2} (Anon 1999). The maximum depth of the Lake is 8m. Keenjhar Lake is located in stony desert, composed of alternating layers of limestone and sandstone. Historically it is formed by the union of two Lakes, Sonehri and Keenjhar through the construction of an embankment on their eastern side in 1950s. Originally these Lakes came into being when River Indus changed its course, cutting-off these Lakes. Before the construction of embankment, the Lakes were fed by a dozen hill torrents on the western side. Now it gets most of its water from Indus River through canal. With this background, Keenjhar may be regarded as semi natural Lake. The Lake is fed by the Kalri Baghar canal originating from Kotri Barrage that enters at the northwest corners, and by many small seasonal streams entering on the western and northern shores. The only outlet is through the Jam branch canal at the southeast corner of the Lake (Anon, 2006). The Lake is known as the largest freshwater Lake of the country and its main source is from Indus River, however, some proportion of water is contributed from the run off from the adjacent hills and torrents. The local villagers residing around the Lake are using water for their daily consumption (Anon, 2006). Keenjhar Lake is the main source of water supply to Karachi and parts of Thatta district.

Large mammals: Almost all the potential sites around Keenjhar Lake as well as in the buffer zone were surveyed and different sampling sites and the distribution of large mammals around Keenjhar were covered. Spending eight days in the field (four days during summer survey and four days during winter survey), a total of 26 animals of nine mammalian species, belonging to three orders (Carnivora, Artiodactyla and Pholidota) were recorded from the study area. Out of nine recorded species of large mammals, six were observed directly while the remaining three were recorded on the basis of indirect evidences like tracks, faeces and interviews of locals and wildlife watchers from Sindh Wildlife Department. Out of the nine recorded species, one is Vulnerable (VU), four Near Threatened (NT) and four Least Concern (LC) according to the IUCN Red List of

Pakistan Mammals 2005. Jungle cat and small Indian mongoose are enlisted as Least Concern (LC) while fishing cat as Vulnerable (VU) in IUCN international Red List 2006. Jungle cat, Fishing cat and Indian pangolin are protected (P) in Sindh. Jungle cat and Fishing cat are listed in Appendix II of the Cities Category 2007.

Small mammals: A total of 17 small mammal species were found in Keenjhar Lake during the whole survey. A total of 14 species were recorded during the summer survey whilst 10 were recorded during winter. The 17 species found in the summer represented 4 orders (Rodentia, Insectivora, Lagamorpha and Chiroptera) and 8 families. Out of the 7 families Muridae was the most abundant (6 accounts in summer and winter) followed by Erinaceidae. The remaining families were represented by only one or two species. There is absence of some families in winter possibly due to migration or hibernation.
Granivores are the most prominent species found in Keenjhar followed by insectivores with herbivores and omnivores having the same representation. The majority of the species were recorded from agriculture land (nine species) with only one being found in open country.

Reptiles and amphibians: Several villages around the Keenjhar Lake were surveyed during June and November 2007 for the presence of amphibians and reptiles including Jhol, Haji Hajab Goth, Khau Makan (Sumar, Jakro), Katian Mori, Goth Bhambroon, Dolatpur, Sonda, Chull, Jhimpir, Chilliya and Amirpir. To precisely account for the amphibians and reptilian population, several of the small islands inside the Keenjhar Lake were also included in winter studies consisting of Dhorarr, Nori Tomb, Gadapirri and Dhor. Both day and night surveys were conducted for the observation and collection of amphibians and reptiles. As most of the areas around Keenjhar Lake are plains dominated by interspersed stones, the author was unable to place pitfall trap in any of the location. Most of the collection was carried out through hand picking or snake-clutches (Snake-rods). The terrestrial vegetation in most of the areas is dominated by *Prosopis juliflora*, *Capparis decidua aphylla*, *Euphorbia caducifolia*, *Salvadora spp*., with small patches of *Acacia nilotica* and *Populus euphratica*. Aquatic flora of the lake is comprised of *Phragmites karka*, *Typha angustata*, and *Persicaria glabra* with submerged and floating vegetation including *Nelumbo nucifera*, *Hydrilla verticillata* and *Potamogeton pectinatus*. In the agricultural fields around the Keenjhar Lake, vegetables, sugarcane, rice and maize are grown.

Birds: The summer surveys in the area were undertaken from 14 June 2007 to 17 June 2007 and the winter surveys from 13 January 2008 to 16 January 2008. The locations visited were the South Western Bank, Western Bank, Southern Bund Side, Southern and Eastern Bank of the lake and the Jhol Dhand.The figures show that the number of species collected was higher in the winter than in the summer. Along with 51 resident birds found in the winter there were 43 winter birds as well.

Zooplankton: The information collected during this survey was also biased by the certain temporal, technical and spatial limitations. An endeavor was however always made to capitalize the available resources and time. Results charted and compiled in this report have therefore been authenticated through technical acumen and scientific expertise.

The prawn species Macrobrachium dayanum found in this area is effectively large in size and, though freshwater basically, it has the physiological capability to

tolerate the increased salinity of the brackish water, is extremely suitable for culturing practices and is therefore abundant in the area. The second freshwater species captured from Keenjhar Lake is the *Macrobrachium malcolmsonii*. This prawn is remarkably well developed and grows up to one foot in length. If sufficient number of eggs of Macrobrachium malcolmsonii are introduced in the lake at appropriate places from the inlet, it can add to the economic value of the lake as well as it will add to improve the ecology of the lake. The only competitor of this huge species can be the other prawn species but as the prawn mainly feeds on detritus mud and sand and only a fraction of the small fish of the lake are affected or harmed by its presence, there is a hope that these two species will be able to coexist successfully in a competitive environment within the lake. The previous prawn culture practices in the area have not been successful because of the fact that people involved in the culturing could not provide the prawns with the required food that involves a good intake of minerals along with sufficient detritus.

Freshwater fisheries: A total of 55 species were recorded from Keenjhar Lake comprising of 9 Orders (Beloniformes, Channiformes, Clupeiformes, Cypriliformes, Mugiliformes, Osteoglossiformes, Perciformes, Siluriformes and Synbranchiformes) and 14 families. Out of the 55 species recorded from Keenjhar Lake the Order Cypriniformes were most abundant with 25 species (45.4% of all species) being represented followed by Siluriformes with 15 species (27.2% of all species) and Perciformes with 7 species (12.7% of all species. The remaining of the Orders were represented by one or two species. Out of the fourteen families recorded during the survey Cyrpinidae with 25 species (45.4%) followed by Bagridae and Chaldidae both with five species (9.1%). Looking at relative abundance across economic brackets, fish having Aquarium value had the highest average, however fish species having Fairly Good and High economic values had the highest maximums. Fish species having the highest economic values had the lowest relative abundance average and maximums, indicating that the pressure on such species is causing the populations to decrease. However, assuming this is the case; species having Low economic should theoretically have high abundance indices which is not the case.

Phytoplankton: During the summer survey total of 65 algal/phytoplankton samples were collected during this period out of which 155 algal species belonging to 53 genera of 7 phyla (Cyanophyta, Volvocophyta, Bacillariophyta, Chrysophyta, Dinophyta, Chlorophyta, Charophyta) and more than 60 algal sample were collected during the autumn/winter survey, out of which 167 species belonging to 60 genera of 8 phyla namely Cyanophyta, Volvocophyta, Bacillariophyta, Dinophyta, Euglenophyta, Chrysophyta, Chlorophyta, Charophyta. Some physico-chemical parameters were also recorded for this site. The water of Keenjhar Lake is rich in primary productivity and as a result several fish species were commonly found due to the abundance of algal and phytoplankton species. The abundance of algal species as a result the ratio of Dissolved Oxygen was high during the field visit, which is beneficial for aquatic organisms, fish, fauna. Water was recorded as alkaline. While different species have various value from point of importance like some species are useful for medicine, nitrogen fixing, vitamins, toxic, for oil, pollution, water quality, hard, soft, alkaline as well as excellent food produced species were recorded.

Physico-chemical properties of water: This wetland is being greatly polluted by increased urban and domestic effluent discharged in the lake particularly through the Kalri Baghar (KB) Feeder canal. The other point sources of possible pollution of the lake are Soneri, Jhampir Nai, Manchri and Shoro drains. The Water quality

assessment shows that the turbidity, BOD and COD were high along with the toxic pollutants such as Cadmium and Lead in Keenjhar Lake water, collected from the vicinity of KB feeder.

Sufficient organic load is observed in Keenjhar Lake as depicted by the high values of BOD and COD, which is causing depletion of Dissolved Oxygen (DO). The 4 mg/l is the lowest DO required for the survival of all types of fish species in fresh water. In present study the DO values are found less than 3 mg/l, which is not favorable condition for the juvenile fish stock and its further growth. This may be the cause of fish decline in recent past.

It was also found that after monsoon, the Lead and Phenol levels have increased. The use of Lead and Phenol containing substances in daily life may be the cause of these types of wastes discharged in to Keenjhar Lake through the storm flow drains and other human activities. The inorganic pollutants represented by hardness, chloride, sulphates, calcium ion, magnesium ion, TDS, etc are, however, found within the acceptable WHO drinking water quality guidelines. In addition, this water quality also meets the FAO guidelines for agriculture and livestock.

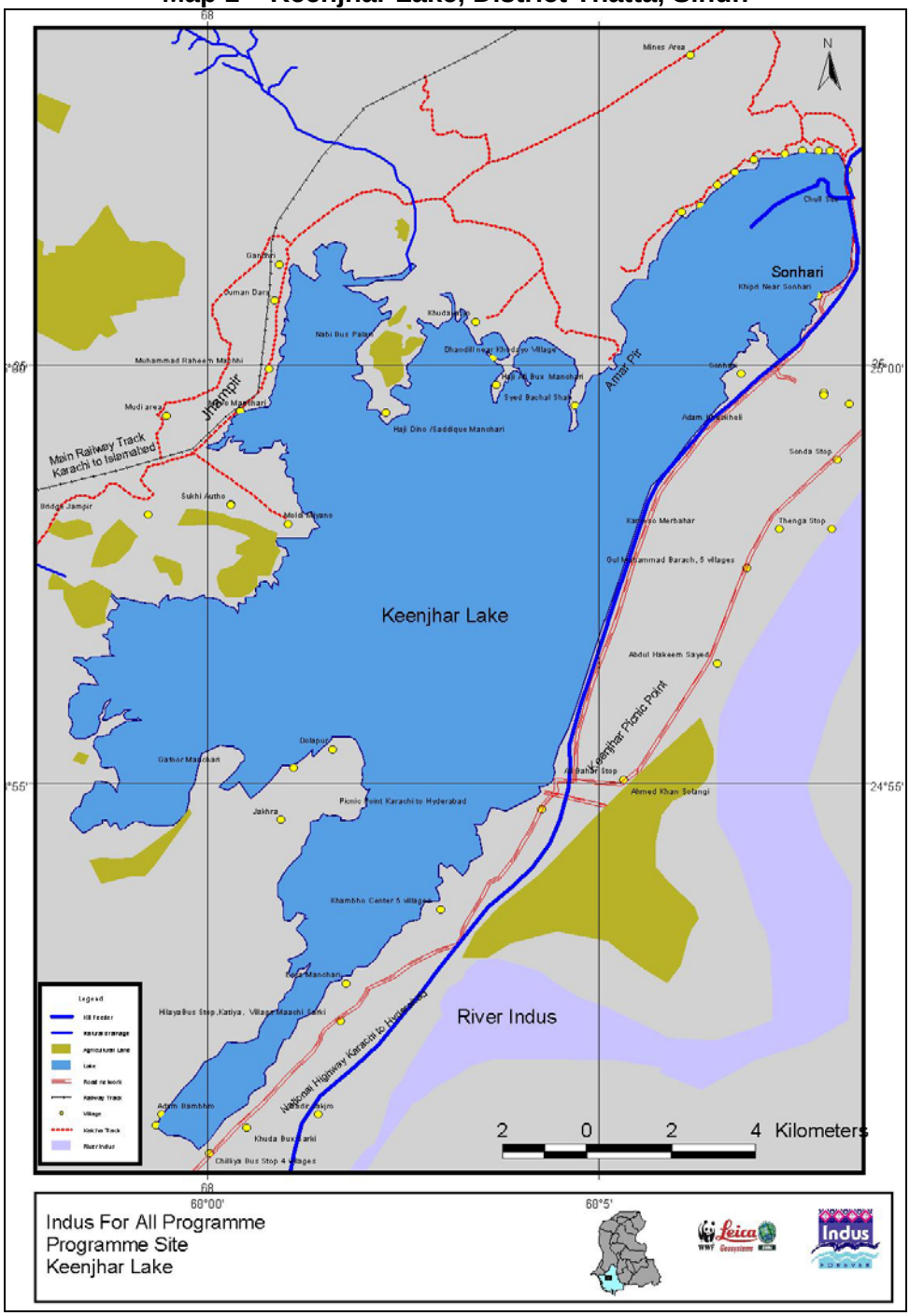
The two time sampling and analysis is limited to reach on concrete water quality assessment and therefore regular water quality surveillance programme is recommended. The public awareness program and training of NGOs/communities is vital to address and arrest the environmental degradation, especially in the picnic/tourist location area.

Chapter 1: Introduction

1.1. Introduction to Keenjhar Lake

Keenjhar Lake is situated at a distance of 113 km from Karachi and about 20 km North and North – East of Thatta town between the longitude of 68 and 69 ^{o} NE and latitude 24 and 25 ^{o}N (see **Map 1**). It is a freshwater lake having an area of about 145 km^{2} (Anon 1999). The maximum depth of the lake is 8m. Keenjhar Lake is located in stony desert, composed of alternating layers of limestone and sandstone.

Map 1 – Keenjhar Lake, District Thatta, Sindh



Historically it is formed by the union of two Lakes, Sonehri and Keenjhar through the construction of an embankment on their eastern side in 1950s. Originally these lakes came into being when River Indus changed its course, cutting-off these lakes. Before the construction of embankment, the lakes were fed by a

dozen hill torrents on the western side. Now it gets most of its water from Indus River through canal. With this background, Keenjhar may be regarded as semi natural lake. The lake is fed by the Kalri Baghar canal originating from Kotri Barrage that enters at the northwest corners, and by many small seasonal streams entering on the western and northern shores. The only outlet is through the Jam branch canal at the southeast corner of the Lake (Anon, 2006). The lake is known as the largest freshwater lake of the country and its main source is from Indus River, however, some proportion of water is contributed from the run off from the adjacent hills and torrents. The local villagers residing around the lake are using water for their daily consumption (Anon, 2006). Keenjhar Lake is the main source of water supply to Karachi and parts of Thatta district.

Anon (1999) described that at its initial stage the lake was around 18.5 meters deep, however, due to subsequent siltation from River Indus the depth has reduced to 5-6.5 meters. There are about 62 small and large villages around the lake which fall in four Union Councils viz: Sonda, Oongar, Jhimpir and Chatto Chan of Tehsil and District Thatta.

Sonahri, Chill, Ghandri, Chakro, Moldi, Dolatpur, Chilliya, Khambo, and Hilllaya are the major villages. Jhimpir town is also situated on the north western bank of the Lake. Before partition, it was surrounded by a population of about 40, 000 fishermen living in the villages mentioned above. However, with the construction of link canal and gradual shortage of water the population of fishermen communities started declining as evident from the table 12 (Anon 2006).

Table 1 – Comparison of fishermen population and fish production

Year	Population	Fish Production (Metric Tons)	No. of Boats
1988-89	24355	58000	2200
1998-99	11900	27000	1710
2005-06	10320	15650	820

Source: Anon (2006).

About 50,000 people are dependent on the lake. There are four fish-landing centers at the Lake *Viz.,* Khumbo, Chilya, Sonheri and Jhimpir. A total of 800 fishing crafts are operating in the area. The fishermen have their own fishing territories and the local community defined them properly (Anon, 2006). For example, the people from the Sonheri village have their own fishing grounds and they never fished in the territories of the Jhimpir areas (Anon 2006).

The main casts/tribes present are Palari, Shora, Kapai, Gandara, Hilaya, Turk, Katiyar, Khaskheli and Sarki etc. The major occupation of the community is fishing and agriculture. People belonging to Palari, Shora, Hilaya and Turk tribes are involved in agriculture around the lake. Pesticides are widely used in the cultivated area. People have livestock especially buffaloes, goats and cows etc. and they graze them in the buffer zone and around the lake. Other casts are involved in fishing and commonly known as Mirbahar. The fishing practices of the local communities are generally sustainable. The locals hardly use small mesh size nets to catch the fish. The permanent circular nets placed in the lake locally known, as “Gol Jaar” is also sustainable way of fishing.

Due to decline in fisheries some people are also involved in the mining of stones from the nearby stony hills. Some communities are also earning income from the local tourists coming from Karachi, Hyderabad and Thatta for recreational purpose. They have the speedboats and they usually charge Rs. 1000 to Rs. 1500 per day based on the time and trip. These boats do not have any safety gears on them, therefore lots of accidents have been occurring in the past and many people lost their lives. Sindh Tourism Development Corporation has developed a Tourist Center there with air-conditioned lodges and visitor's facility. The facility has been developed in a stretch of about 2 km towards eastern side of the lake and they charge an entrance fee from vehicles and/or visitors into this area. The Irrigation Department has a small set up and has a rest house. Towards south-western side of the lake the Karachi Water Sewerage Board has its own set up to regulate the outlet of the lake. Pakistan Army has also established a rest house on the eastern side of the lake. Fisheries Department is also active in the area; it has established a modest facility over Keenjhar Lake and owns a large set up in Chillya, which is about 10 km away from there. At Chillya, the Fisheries Department has training centre and a hostel along with fish hatchery.

1.1.1 State of natural resources

Keenjhar Lake was declared Wildlife Sanctuary in 1977 under Sindh Wildlife Protection Ordinance, 1972. The sanctuary has a buffer zone of 5 km. It has also been designated as Ramsar site during 1976 (Anon 1999).

- **Flora:** The Lake has a rich flora of submerged, floating and emergent aquatic plants such as *Potamogeton spp., Najas minor, Nelumbo nucifera, Nymphaea spp., Cyperus spp., Phragmites spp., Typha spp.,* etc. These provide both food and shelter to fauna species. Many birds reside in the thick growth of *Typha* and *Phragmites*. The land around the lake has a rich diversity of semi aquatic to dry land plant species.

- **Fauna:** Keenjhar Lake is rich in fish fauna. It includes *Ambassis nana*, *Badis* spp. *Puntius sarana, Puntius ticto, Catla catla, Channa* spp. *Cirrhinus mrigala, Ctenopharyngodon idellus, Gadusia chapra, Glossogobius spp. Labeo rohita, Labeo gonius, Notopterus notopterus and, Rasbora rasbora,* etc. The livelihood of the local communities mainly depends on these resources. Anon (1999) mentioned an annual production of about 700 metric tonnes of fish but there is a potential of producing around 10, 000 metric tonnes. There has been reduction in the fish stock due to overexploitation.

  Keenjhar Lake is an important breeding and wintering and staging area for a wide variety of terrestrial and migratory birds. About 65 species of waterfowl have been recorded. Amjad and Kidwai (2002) (gave following account of annual waterfowl census at Keenjhar Lake.

Table 2 – Population of migratory birds over different years

Year	Total Number of birds recorded
1970s	50,000 – 150,000
1987	135,000
1988	205,000
1990	89,784
2000	30,220
2001	38,958
2002	30,610

Source: Amjad & Kidwai (2002)

Breeding birds include Night-heron, Cotton teal, Pheasant tailed jacana, Purple Moorhen, besides some passerines. The Cotton teal has disappeared in the recent years and has not been seen on the lake for few years. Mammals include Jackals, Fox, Porcupine, Mongoose and small rodents. Pangolin has also been recorded. Among reptiles snakes like Cobra and Saw-scaled viper are common. Monitor lizards, Spiny tailed lizard are also found here.

- **Agriculture:** Rice, sugarcane, maize and vegetables are grown in buffer and adjacent areas of the Lake. An account of cultivated plants (woody perennial and herbaceous) is provided in **Table 3** below.

Table 3 – Cultivated plant species recorded at Keenjhar Lake

S.no	Family	Plant species	Life form	Habit
1	Boraginaceae	*Cordia myxa* L.	Phanerophyte	Small tree
2	Caesalpiniaceae	*Cassia alata* Linn.	Phanerophyte	Shrub
3	Caesalpiniaceae	*Parkinsonia aculeata* L.	Phanerophyte	Tree
4	Fabaceae	*Sesbania bispinosa* (Jacq.) W.F. Wight	Phanerophyte	Subshrub
5	Mimosaceae	*Leucaena leucocephala (Lam.) ed Wit.*	Phanerophyte	Tree
6	Moraceae	*Ficus benghalensis*	Phanerophyte	Tree
7	Moraceae	*Ficus religiosa*	Phanerophyte	Tree
8	Pedaliaceae	*Sesamum indicum* L.	Phanerophyte	Shrub
9	Verbenaceae	*Clerodendrum inerme* Gaertn	Phanerophyte	Shrub

1.1.2 Socio-economic status of communities around Keenjhar Lake

Keenjhar Lake is one of the major fresh water reservoirs located at Thatta district of Sindh province, covering an area of about 14,000 ha. The lake is rich in fish fauna and support the livelihood of about 50,000 people. Keenjhar is the major source to provide domestic and industrial water supplies to cosmopolitan city of Karachi. The communities are living in the settlement of the different sizes of villages and hamlets in the programme area. Thirty eight villages are located with two kilometers radius having population of 18,792 members with 2,610 households and average household size is 7.2. Housing infrastructure around the Lake is very poor, 73.3% of the houses are Kacha houses made up with thatch material and consisting of one to two rooms. The communities at Keenjhar Lake, in general, practicing same cultural norms and Sindhi is the predominate language of the area. Gandhra, Mirbahar, Manchri and Machhi casts are fishermen, Hillaya, Dars, Autha and Katiar are farmers, while Palari Jakhra are the herders.

1.1.3 Infrastructure and social services

The lake is the main source of drinking water for the communities; about 78% people are getting their drinking water from the Lake; whereas 14% people are getting water from nearby canal. The area is deprived of sewerage facility, whereas only 27 houses have toilet facilities in their houses. About 44% villages have access to the electricity; no gas facility is available in the entire Lake area.

- **Education**: About 60% population around the lake is illiterate; however the ratio of primary education is reported as 30%, which is indicating that primary schooling has been available there in recent years. Only 5% people are educated up to middle and 3% up to matric and graduation level, whereas female illiteracy is 88%. 63% villages have primary boy's schools with average 2 rooms building and two teachers for 83 students. About 2.6 % villages have middle school facilities with 6 rooms building and 4 teachers for average 50 students, there is no high school for boys and girls in lake area. Thirty six percent villages have primary girl's schools with 2 rooms and 2 teachers, where as 2.6% villages have facility for the girls middle school with 6 room building, but no female staff is appointed yet for these girls' middle schools.

- **Health:** Health and hygiene condition of the area is very pathetic. Incidence of malaria, diarrhea, skin disease, typhoid and jaundice were reported in all programme villages at Keenjhar Lake, but the incidence of the skin disease and malaria was found at alarming level. There is dearth of health infrastructure, only 3% villages have dispensaries and one village has Basic Health Unit, no Rural Health Centre or hospital is available in the program site, 60 % people are visiting private clinics. On an average the private clinics and other health facilities are available at a distance of 10 km from their villages. Professional maternity services are also missing in the area and 87% births are being attended by local birth attendants. Only 1% cases are being handled by the trained Lady Health Visitors (LHVs) and about 12% cases are being handled at hospitals and private clinics due to some complexities. Child and mother mortality rate is reported 7 % and 1%, respectively

- **Livelihood sources and poverty level:** There is mix of four major occupations around the lake, fishing, agriculture, stone mining and mat making. However fishing is continued to be dominant occupation of the programme area. About 44% community members are engaged with fishing, followed by 22% as agriculture laborers and 8% engaged in stone mining. Poverty has remained one of the most serious problems of the area. Decline in fish catch, poor infrastructure, lack of employment opportunities, lack of productive assets, inadequate technical capability and use of inappropriate technology is the main factors responsible for their poverty level. Using the poverty line of Rs. 1000 per capita income (2004-5 national poverty line of Rs.878 and adding inflation rate of 7.5 per year) about 62 % people around Lake are living below poverty line with average per capita income of Rs. 971.

1.2 Rationale and Objectives

1.2.1 Large Mammals Survey

1.2.1.1 Rationale

The Indus Eco-region is one of the forty biologically richest eco-regions in the world, as identified by WWF. The Indus Eco-region Programme (IEP) is a 50 years long (2005 - 2055) initiative of WWF - Pakistan and the Government of Sindh that will address poverty and natural resource degradation in the Indus eco-region. In the Biodiversity Visioning and Eco-region Conservation Planning Workshop for the Indus Eco-region, held in Karachi in July 2004, participants identified fifteen prioritized areas within the Indus eco-region (WWF – P 2008). An *Indus for All Programme* of the IEP has been implemented on five out of fifteen prioritized landscapes with support from Royal Netherlands Embassy (RNE) in

July 2006 for a period of six years. The five sites are Keti Bunder (coastal), Keenjhar Lake (fresh water ecosystem), Pai Forest (irrigated forest), Chotiari Reservoir (desert ecosystem) and Keti Shah Forest (riverine forest). The Programme aims to work with all relevant stakeholders at field, district, provincial and national levels to build capacity, support and influence planning and mainstreaming of poverty-environment nexus.

The detailed ecological assessment of the project sites has been initiated as an output of the Programme to establish a baseline in and around the project sites. The baseline will determine key livelihoods interventions of *Indus for All Programme* by identifying the gaps and opportunities.

As a part of the detailed ecological assessments and to study the mammalian fauna of the project sites, the study sites were visited twice; firstly during summer in June 2007 and secondly in winter during January 2008. Each visit of all the five sites was of 3-5 days duration.

1.2.1.2 Objectives of the study:

a. Identify various large and medium sized mammals in the study area, develop a checklist and estimate the populations of some key mammalian species.
b. Assess the major threats that are likely to affect the survival of large mammals and suggest mitigation measures to those threats.
c. Identify key habitat and associated features of the large mammals habitat.

1.2.2 Small mammal survey

1.2.2.1 Rationale

Small mammals are an indispensable component of fauna and they play an important role in determining the holding capacity and maintenance of the number of animals in the higher trophic level of the food chain. They not only maintain ecological balance in an ecosystem, but also play a specific role in biological control, necessary for a self sustained ecosystem. These small animals fill niches and depend upon the submerged roots, fallen seeds, rhizomes and bulbs, insects, snakes, scorpions, spiders and beetles for their food. They are in turn eaten by larger animals like foxes, jackals, cats, owls, eagles, kites, falcons and wolves living in the particular ecosystem. To determine the status of large mammals it is necessary to obtain data on small mammals.

Role of small mammals usually stem from perceived negative values associated with their role as pest and disease spreading animals. Small mammals, however, play an important and perhaps indispensable role in the functioning of an ecosystem. They should not be viewed separately from other components in the ecosystem. Rather, they must be viewed in terms of their interrelationships with other components. Small mammals influence the structure and function of ecosystems as consumers of plants and small animals, as movers of soil and soil nutrients, and as the primary prey of raptors, snakes, hawks, eagles, owls and carnivorous mammals. Because of their intermediate trophic position and high dispersal abilities, small mammals may track changes in biotic and abiotic environment that result from shifts in land-use practices and other human activities.

Researchers have proposed various ways in which small mammals interact with plant communities. The main interactions can be categorized as those relating to primary productivity, plant species composition, plant stature and reproduction, and decomposition rates of plant materials. Small mammal herbivores may consume as much as 60 % (Migula et al. 1970) of the total annual primary plant production. They may have localized, large-scale impacts on primary productivity during population explosions. However, the effect of direct consumption of plants by herbivores must be evaluated in terms of what portion of the primary production is actually available to the animal. Estimates of vegetation consumption by small mammals ranged from <1% in short grass and mid grass sites to as much as 20% in desert grasslands (French et al. 1976). Harris (1971) has estimated that 0.17-5.01% of the net primary production was transferred to the rodent trophic level.

Small mammals have been credited with changing plant community composition and species distribution. Plant communities in many parts of USA have been altered by extensive damage to big sagebrush during cyclic population peaks of voles. Control of pocket gophers in western Colorado resulted in an increase of perennial forbs (Turner 1969) while grass and sedge densities were higher in areas where gophers were present. Small mammals can also alter plant community composition and species distribution by consuming and caching seeds. They can also influence plant community composition by heavily grazing or damaging plants, and thus reducing their ability to produce seeds.

Seed caching activities of small mammals can alter plant distribution by either increasing or decreasing survival of plants. Yet, dispersal of seeds by small mammals can result in increased germination and survival. Some organisms may be dependent on small mammals for seed or spore-dispersal. Many fungi and nitrogen-fixing bacteria and yeast depend on small mammal mycophagy for spore dispersal (Fogel and Trappe 1978).

The rate of plant succession may be affected by small mammal burrowing and feeding activities. The mounds of small mammals disrupt grass associations and provide bare soil for the invasion of lower succession plants, thereby increasing the diversity of plants. Selective herbivore by small mammals can also alter plant succession rates. Rodents may aid in the recovery of overgrazed grasslands by selectively grazing on weedy plant species (Gross, 1969).

Small mammals can influence the rate of decomposition of organic materials by adding green herbage and excrements to the litter layer and by reducing the particle size of vegetative material. They are more efficient in effecting the mineralization of organic matter than either insects or ungulates (Golley et al. 1975). Voles affect decomposition rates by altering microclimatic conditions in the litter layer and by deposition of excrements and vegetative cuttings into litter layers, which increases micro-organism growth (Zlotin and Kodashova 1974). Reduction of particle size of living and dead vegetative material by small mammals also increases decomposition rates.

Soil structure and chemical composition are affected by the activities of small mammals. Burrowing activities largely influences soil structure. Burrowing and the addition of faeces and urine to the soil influence soil chemical composition through changes in nutrient and mineral cycling rates and pathways. Soil structure may be altered as small mammals burrow, bringing large quantities of mineral soil to the surface. Pocket gophers are reported to excavate 18 metric

tons of soil material per hectare per year (Hole 1981). Abaturov (1968) estimated that mole burrows covered 36% of woodland ground surface, which resulted in increased soil porosity and drainage, and altered soil water holding capacities. Soil mounds resulting from small mammal burrowing are strongly heated, and the surface crust that rapidly forms prevents evaporation. As a result, at depths of 5-20 cm the water content of the soil under mounds is 7-82 higher than that at corresponding depths in virgin soil (Zlotin and Kodashova 1974).

The most significant role of small mammals may be their effect on the chemical composition of soils, particularly the addition and incorporation of nitrogen. Soil chemical composition can be altered by the addition of excreta and by the upward displacement of nutrients through the soil profile.

Small mammals function as secondary consumers in the ecosystem by preying on invertebrates and on other mammals, which may have direct impacts on prey production. Insectivorous species may exert a regulatory effect on invertebrate populations; small mammals consumed a high percentage of invertebrate populations in nearly all grassland sites studied by French et al. (1976). Carnivores have been shown to influence prey species densities. Hayward and Phillipson (1979) estimated that weasels consumed as much as 14% of the small mammal production, resulting in a reduction in the impact of small mammals on the rest of the ecosystem. Secondary consumption may indirectly influence primary production. Plant consumption by invertebrate herbivores may be reduced by the insectivorous feeding habits of small mammals. Destruction of large numbers of insect larvae by shrews has been reported by Buckner (1964). Small mammal predation may serve to reduce invertebrate species that are themselves predators of phytophagous insects. Small mammals also affect Land bird species. Nest predation by small mammals is the major cause of nest failure in passerines and nesting success of land birds.

Small mammals serve as a food supply for a large number of predators and can exert significant influence on predator population cycles. Small mammals, especially rodents, are characterized by high productivity rates, and thus, even at relatively low densities, are an important source of food for predators. Densities of small mammals can have profound impacts on the reproductive potential of some predators. For example, the proportion of tawny owls that bred each year in England varied from 0 to 80%, according to the number of mice and voles present (Southern, 1970). Several authors have documented cases where population levels of predators can be traced to small mammal densities. For example, population declines in black-tailed jackrabbits (*Lepus callfornicus)* induced significant decreases in numbers of coyotes (*Canis latrans*) in north-western Idaho and southern Idaho (Clark, 1972) and kit foxes (*Vulpes macrotis*) in western Utah (Egoscue, 1975). Raptors, such as the great-horned owl, may increase as much as five-fold during years of high densities of snowshoe hares in Alberta (McInvaille and Keith, 1974). Further, population outbreaks of small mammals can induce predators to switch from preferred prey, thus reducing predation on some game species.

1.2.2.2 Objectives of the study:

a. To provide a detailed ecological assessment and systematic account of small mammal of the programme sites and their buffer zones.
b. Collect data from the field on species occurrence, abundance and diversity in the study areas;

c. Collect and review secondary data on the small mammal species of the study sites, using the available literature and knowledge of local inhabitants.
d. Prepare a taxonomical checklist of all the species with their English and local names and their status in the study sites.
e. Identify threatened mammalian species in the Indus for All Programme, WWF Pakistan sites and recommend conservation measures;
f. Study the behaviour of various species of rodents and other associated groups in relation to habitat and diet in the study sites.
g. Assessment of impacts of environmental changes and human population pressure on potential mammalian species and their habitats. Associated mitigation steps are also to be suggested.
h. Provide photographs, where possible, of the small mammal species.
i. Compile a report on the consultancy addressing all the above-mentioned issues.
j. To identify the key species of small mammals inhabiting the area.
k. To identify impact of small mammals on the overall livelihood of the people.

1.2.3 Reptiles and amphibians survey

1.2.3.1 Rationale

Amphibians and reptiles are very important animals among the vertebrates. Amphibians show the transition from aquatic to terrestrial life. Reptiles, the animals that invaded land, were the first fully terrestrial forms of life. Apart from their impressive evolutionary history, they beautifully demonstrate different concepts of physiological and behavioral adaptations to different climates, from tropical forests to hot deserts and marine to fresh -water. They do not have the ability to travel long distances like birds and mammals. In response to any local environmental changes they respond quickly and therefore may act as excellent biological indicators.
Amphibians and reptiles are important components of any living system and play a key role in the interlocking web of nature. At one end they prey upon insects and other invertebrates and therefore regulate the population of these animals and on the other hand they are also a major source of food for other carnivore species (birds and mammals). Their position in the ecological niche is so vulnerable that the survival and collapse of the whole energy cycle depends upon the presence and absence of the amphibians and reptiles. The existence and sustainable use of this biological resource is therefore imperative around the study sites.

Despite the fact that amphibian and reptiles are an important biological resource, very little attention has been paid to them, in Pakistan. The major hurdle presumably is the lack of expertise and awareness in this particular field. Moreover, our society in general and rural folk in particular is mostly repulsive and afraid of reptiles. The results of the present study will enable us to know about the natural wealth of all the Programme sites in terms of amphibians and reptiles. Furthermore, the status of all the species of Amphibians and Reptiles will be evaluated so that in any adverse circumstances the conservation strategies could be suggested.

1.2.3.2 Objectives of the study

The study was envisaged to provide for the first time, a comprehensive ecological and systematic account of the amphibians and reptiles of the Programme sites and their buffer zones. The prime objectives of the study were to:

a. Collect and review secondary data on the reptile and amphibian species of the study sites, using the available literature and local inhabitants.
b. Collect data from the field on species occurrence, abundance and diversity in the study areas.
c. Prepare a taxonomical checklist of all the species with their English and local names and their status in the study sites.
d. Identify threatened amphibian and reptile species in the Indus For All Programme sites and recommend measures to improve the situation.
e. Study the behavior of various species of amphibians and reptiles in relation to habitat and diet in the study sites.
f. Assessment of impacts from environmental changes and human population pressure on potential reptilian and amphibian species and their habitats and to suggest associated mitigation measures.
g. Provide photographs, where possible, of the amphibian and reptile species.
h. Compile a report on the consultancy addressing all the above-mentioned issues.

1.2.4 Birds survey

1.2.4.1 Rationale

The species of birds and number of birds of species observed have been recorded during summer and winter. Population studies on the birds of the area were not undertaken because of time constraints. The overall status of each species observed has been given categories such as common, seasonal and rare. It was not possible to predict trends in the population of key species of birds, as it requires at least ten years data.

This consultancy portfolio aims to conduct a series of detailed ecological assessments in order to establish a baseline in and around the four Programme areas plus Keti Shah. The survey will adopt recognized scientific methodologies. The baseline will determine key livelihoods interventions of Indus for All Programme by identifying the gaps and opportunities.

1.2.4.2 Objectives of the study

a. Conduct a review of literature on bird fauna of the study area.
b. Develop a species inventory of the resident and migratory birds with notes on relative occurrence and distribution of each program area.
c. Conduct a site specific study on main habitats important to bird species including habitats of critical importance.
d. Record program area specific study of human impacts to resident and migratory bird population.
e. Assist the GIS lab in developing GIS based information regarding occurrence and distribution of bird fauna for each Programme area.
f. Document and describe bird species of “Special Concern” with economical and ecological perspective both in resident and migratory avifauna found within each program area.
g. Conduct studies to describe and assess anthropogenic impacts on bird species found in each program area.
h. Record photographs and other information collected and compiled on the avifauna of each Programme area.
i. Submit detailed assessment report for each Programme area.

1.2.5 Freshwater Fisheries
1.2.5.1 Objective

a. Enlist and describe existing resident and migratory fish resources, their abundance, diversity and habitats in the study area
b. Prepare a taxonomical checklist of all the species with their English and local names and their status in the core and buffer zones
c. Help in developing GIS based information regarding occurrence and distribution of fish fauna.
d. Document the anticipated changes to resident and migratory fish population in the study area.
e. Document and describe fish species of "special concern" regarding the economic and ecological perspectives found in the study area
f. Suggest suitable methods of monitoring fish in the core and buffer zones of the study area.
g. Conduct a local survey of the fishermen to assess the trends of fish production for the last ten years.
h. Develop simple indicators for assessing the population trends of the fish that can be applied by the local staff in future.
i. Study the suitability or otherwise of the conventional fish ladders used in barrages and recommend the suitable measures for safe passage of all and critical fish fauna including Blind Indus dolphin.
j. Describe and assess potential anthropogenic impacts on fish species found in the study area
k. Submit a comprehensive baseline reports and monitoring plan to the team Leader.

1.2.6 Phytoplankton
1.2.6.1 Rationale

Qualitative and quantitative determinations of algae is essential for determining the aquatic productivity, as algae is the chief source of food for aquatic animals including the important group of Cryptogamic flora. Some species are excellent whilst others are good producers of food in the food cycle of aquatic ecosystems. Algae is widely distributed and is an important component of various ecosystems like marine, rivers, ponds, streams, dams, lakes etc. Algal flora can also be used as a good indicator of pollution (Patrick & Reimer, 1966).

Algae are among the most important and prime segment of the aquatic environment. The quantity and quality of algal flora is affected by many ecological factors, which influence the diversity of algae directly or indirectly. The main factors determining algal diversity are temperature, availability of nutrients, light, CO_2 and oxygen. In lake in the subtropical region, water temperature plays an important role for the production of algae up to a certain limit. Carbon dioxide is critically important and only those water bodies abundantly supplied by this gas can support sufficient growth of algae. The excess amount of CO_2, however, causes water-blooms which is a growth of algae at or near the surface of a body of water; followed by a series of disturbed biological conditions. Oxygen is one of the primary limiting and determining factors in phytoplankton ecology. Algae produces abundant oxygen during the daytime, which is, consumed both by the fish and by the algae itself. The amount of oxygen produced by algae determines the quantity and kinds of aquatic life which a water body may support at different levels. Light and nutrients also play a direct role for qualitative and quantitative growth of algae. Extraordinary high concentration of nutrients is, however, associated with eutrophication resulting in algal blooms.

It is believed that the first living cell that appeared on planet earth emerged from the ocean. In all its form, life has developed from the growth of mono-cellular algae. About 90% of the species of marine autotrophs are algae and about 50% of the global photosynthesis is algal derived thus every second molecule of oxygen we inhale come from algae and algae reuse every second molecule of carbon dioxide we exhale (Melkinian 1995). The importance of algae and their consumption for human is well known since 300 BC in China and Japan. These two countries are the major algae/sea weed cultivators, producers and consumers in the world such as the Indian Ocean region countries like Malaysia, Indonesia, Singapore, Thailand, and Korea. Algae/sea weeds are used in salad, jelly, soup. In Pakistan algae/sea weeds consumption is negligible so there is need for awareness of algae as a source of health, basic food as they are rich and an easily available source of vitamins, minerals and trace elements.

1.2.6.2 Objectives of the study:

a. Collection and identification of phytoplankton/algal samples using latest techniques.
b. Preservation according to standard method.
c. Document the changes to algae and other aquatic plants in study area.
d. Document and describe algae and other aquatic plants species of “special concern” regarding the economic and ecological perspective found in the study area.
e. Suggest suitable species of algae and other aquatic plants used by fish in study area.
f. To submit a comprehensive baseline reports and monitoring plan.

1.2.7 Zooplankton

1.2.7.1 Rationale

Invertebrates have complicated and imperative roles in maintenance of biotic communities. They are integral to nearly every food chain, either directly, as food for fishes, amphibians, reptiles, birds, mammals, or indirectly, as agents in the continuous recycling of nutrients in the soil. Almost all food webs are dependent on invertebrate species that are performing vital ecological functions such as pollination or seed dispersal. A world without invertebrates would be impoverished and fragile, and ecosystems would collapse. Also the sheer number and mass of invertebrates reflects their enormous ecological impact. Though some invertebrates have a negative impact on humans, either by harming them directly as disease agents or attacking some of their interests, still all adverse effects combined are insignificant compared to their beneficial effects.

Invertebrates have been recognized as sensitive biological indicator species of environmental conditions in rivers and streams. These bio-indicators are increasingly being depended as tools for monitoring health of ecosystems, especially that of wetlands. Aquatic macro-invertebrates comprising annelids, mollusks, crustaceans, arachnids and insects are considered reliable indicators of wetland health. The sensitivity and tolerance of invertebrate species make these organisms an excellent group to provide information on overall wetland condition.

Invertebrates live in a vast range of habitats, from forests and deserts to caves and seabed mud. In oceans and freshwaters they form part of the plankton, which comprise of an immense array of tiny living organisms that drift in the surface currents. Invertebrates are also found in the soil beneath and in the air above our heads. Some use wings to propel but others, particularly the smallest

invertebrates, float on the slightest breeze. These tiny invertebrates form clouds of aerial plankton that drift unseen through the skies. (Hawking, J.H et al 2006)

Aquatic invertebrates are an important source of food for birds, mammals, amphibians, reptiles, fish, and other invertebrates. Changes in terrestrial and aquatic habitats lead to changes in invertebrate assemblages, which in turn increase, decrease, or change food supplies for other animals. As impacts occur in a stream, species richness (number of species) decreases but the population size of some species may increase. Further, large-sized species are usually replaced by small species (e.g., Wallace and Gurtz 1986). Conversely, when the stream condition improves, larger invertebrate species replace small species (Grubaugh and Wallace 1995). Such changes can have critical impacts on species that depend on invertebrates for a food supply.

Aquatic benthic invertebrates are a diverse group of relatively long-lived sedimentary species that often react robustly and mostly predictable due to human disturbance of aquatic systems. This capability to demonstrate a strong reaction makes them a cost-effective and comprehensive tool for the monitoring of stream water quality. Benthic invertebrates are therefore among the most common group of organisms used to assess water quality in a good number of wetlands worldwide.

A taxonomic investigation of aquatic invertebrates is essential to assess the status of biodiversity in any area. Monitoring of invertebrates at a higher taxonomic level (genus, family, order) can be useful in indicating changes in invertebrate assemblages in response to some impact if proper controls are established, but such monitoring usually cannot determine loss of species.

The Indus Delta comprises more than of 95% of the total mangrove areas of Pakistan and has the seventh largest mangrove forest in the world. This area has been famous for its mangrove forests and some 129,000 hectares of mangrove. These mangrove forests form a habitat of a large number of migratory and residential bird species and serve as a huge nursery of various fish species. Keti Bunder is part of the Indus delta and is located in the mouth opening of the Indus in the Province of Sindh, Pakistan. It consists of main River Indus, various creeks, estuaries, mud, sand, salt flats, mangrove habitat, marshes, riverine forests, fresh and salt-water lakes, riverbanks and channels. It falls under largely arid and semi-arid climatic conditions and is characterized by river discharge and moderate tides. Mangroves cover in the Delta has decreased by about 70% over the last thirty years (although recently stabilized), which must be reflected in the declining stocks of key coastal/marine species, which are also over hunted, in any case, especially prawn.

1.2.7.2 Objectives of the study

The study was formulated to provide a comprehensive ecological and systematic account of the Invertebrate fauna of Keti Bunder, Keenjhar Lake, Chotiari Reservoir, Pai forest and Keti Shah. The prime objectives of the study were to:

a. Collect and review secondary data on the invertebrates of the above-mentioned area, with the help of available literature and local community.
b. Collect data from the field on species occurrence, abundance and diversity in the study areas.
c. Prepare a taxonomical checklist of the invertebrate groups found in the desired reservoir

d. Study the ecology and behavior of various groups of invertebrates with special reference to crustacean fauna of the desired area (if any)
e. Assessment of impacts from environmental changes and human population pressure on economically important invertebrates and their habitats.
f. Provide photographs, where possible, of the impetrative invertebrate species collected from inside and around the Reservoir.
g. Compile a report addressing all the above-mentioned issues.

1.2.8 Physicochemical properties of water

1.2.8.1 Objectives of the study:

a. Review and compile baseline surface hydrological conditions, baseline ground water conditions, baseline of water quality levels in the Programme area;
b. Study seasonal flow patterns (pre and post monsoon) for each site
c. Collect accurate field measurements for pH, Zinc, TDS, Ammonia, DO, Cyanide, B.O.D, Nitrate, C.O.D, NH_4N_2, oil and grease, conductivity of Phenolic compounds, light transparency/turbidity, total Coli forms, CO_2, Fecal E.Coli, hardness, fecal Enterococci /Streptococci, Ca^{++} Mg, Phosphate, Chlorides, Arsenic, temperature and alkalinity according to approved procedures;
d. Analyze data to identify water quality contaminants of concern, levels and extent of contaminating to determine ambient conditions, trending and cause/effect relationships for each area.

1.3 Literature Review

1.3.1. Large Mammals

The mammalian fauna, particularly the species of large mammals have always been of interest to wildlife managers and researchers alike. Ellerman and Scot (1951), Ellerman (1961) and Prater (1965) in their publication referred to the species found in Pakistan. Siddiqui (1969) published a booklet on the Fauna of Pakistan that included the Mammalian species. Ahmad and Ghalib (1975) published a Checklist of Mammals of Pakistan. Ahmad and Khanam (1986) published a booklet on the Ungulates of Pakistan, in Urdu language. Ahmed (1997) dealt with the distribution and status of ungulates in Pakistan. Roberts (1997) provided a comprehensive detail on mammals of Pakistan. Roberts (2005) published Field Guide to the Large and Medium sized mammals of Pakistan.

The creeks in Keti Bunder are a part of the North Arabian Sea and lies within the Indian Ocean Sanctuary, set up by the International Whaling Commission to protect cetacean population. Information on marine cetaceans along Pakistan coast is very sparse and very little data has been published. Ahmed & Ghalib (1975) reported occurrence of nine mammalian species. Roberts (1997) lists thirteen species of marine cetaceans from coastal waters of Pakistan based on personal communications with different people on sightings. Further evidence suggests that there is an undocumented high diversity of cetaceans in Pakistani waters. There has been no comprehensive survey of cetaceans in Pakistan and only recently University Marine Biological Station (UMBS), University of London, Millport, U.K. in partnership with WWF – P and Centre of Excellence in Marine Biology (CEMB); University of Karachi started cetacean surveys on Pakistan coast and offshore. WWF Pakistan is undertaking surveys of dolphins and

porpoise in Korangi – Phitti creek system in Karachi with support from the Ocean Park Conservation Foundation.
No study on terrestrial mammals has been undertaken in the area. Roberts (1997), Ahmad and Ghalib (1978) have worked on the distribution and status of mammals in Pakistan but did not mention particular occurrence in Keti Bunder area. Ahmad et al (1988) worked on the vertebrate fauna of mangrove swamps of Sindh and recorded 5 species of mammals, including marine and terrestrial mammal but they did not describe the mammals occurring exclusively in the nearby terrestrial area of mangrove forests.

No researchers or wildlife managers have exceptionally dealt with the mammal fauna of Chotiari Reservoir or its environs. However, WAPDA carried out an Environmental Impact Assessment of the area through Consultants in 1992 (EIA Report 1993). Later, they also conducted studies for Environmental Management and Monitoring Plan of Chotiari through Consultants MMP – NESPAK – ACE in 1997 (EMMP Report 1998). These studies made a situation analysis of the wildlife including mammals in Chotiari area. Azam (2002) gave distribution and population Hog Deer in Sanghar district.

A number of workers have studied the fauna of Indus River. Ahmad and Ghalib (1978) gave the distribution of the Mammals of Pakistan including mammals found in the Indus River. Pilleri (1970, 1977), Niazi and Azam (1988), Reeves and Chaudhry (1998), Bhaagat (1999) and Braulik (2006) studied the distribution, population and status of Indus dolphin. However, no work has been done on the mammalian fauna of riverine forest of Keti Shah and the present surveys are the first efforts to study the mammalian fauna of the forest.

1.3.2 Small Mammals

There are several reports on the study of small mammals of Pakistan (Ahmad and Ghalib, 1979; Akhtar, 1958-60; Anthony, 1950; Baig et al, 1986; Banerji, 1955; Beg, et al., 1975, 1986; Frantz, 1973; Fulk et al., 1981; Mehmood et al., 1986; Mian, 1986; Mirza, 1969; Parrack, 1966; Roberts, 1972, 1973; Siddiqui, 1970; Thomas, 1920a,b,1923; Wagle, 1927; Walton, 1973 and Wroughton, 1911,1920) but the most comprehensive and consolidate work is that of Roberts (1997). Roberts (1997) compiled all the information available on the mammalian fauna of Pakistan. After that Woods *et al*. (1997 a, b) gave a detailed account on the small mammals of Pakistan but their work was restricted to the northern mountain region of Pakistan. None of these studies has specifically addressed the mammals of lower Sindh.

The role of small mammals has not been properly studied in Pakistan but it has been a subject of special concern all over the world. Effect of small mammals on vegetation pattern has been studied by Migula et al. (1970), French et al. (1976), Harris (1971), Turner (1969), Fogel and Trappe (1978), Gross (1969), Golley et al. (1975) and Zlotin and Kodashova (1974). Their affect on soil composition and chemistry has been highlighted by Abaturov (1968), Hole (1981) and Zlotin and Kodashova (1974). Small mammals have a very strong interaction with the other animals of the ecosystem and the interactions between small mammals and other animal have been studied by French et al. (1976), Hayward and Phillipson (1979), Buckner (1964), Southern (1970), Clark (1972), Egoscue (1975) and McInvaille and Keith (1974).

1.3.3 Reptiles and amphibians

The herpeto-fauna of Indus for All Programme, WWF Pakistan areas was little studied by early herpetologists (Murray, 1884, 1886; Boulenger, 1890, 1920; Smith, 1933, 1935, 1943; Minton, 1966; Mertens, 1969; Dubois & Khan, 1979; Khan, 1979, 1980). Comprehensive studies have not been undertaken and herpeto-fauna remains marginally explored. This is because the areas are very wide, extremely difficult with very limited infrastructure and other facilities. The conditions were even worse in the past and did not encourage the scientists to venture for studies. Amphibians and reptiles are cold-blooded animals and therefore are more sensitive to the environmental conditions as compared to birds and mammals. However, in the recent past, Khan (1989, 1992, 1993, 1997, 1998, 2006), Baig (1988 a, b, c; 1989, 1990, 1992, 1996, 1997, 1998, 2001 a, b, 2002); Khan and Baig, (1988, 1992); Khan and Tasnim (1989, 1990); Baig & Böhme (1991, 1996); Baig and Gvozdik (1998); Auffenberg & Rehman (1993); Woods *et al*. (1997) and Shah and Baig (2001) attempted to explore the herpeto-fauna of different areas of Pakistan and published their findings, which were surprisingly, either new to the science or extended the range of several species which were reported only from the neighboring countries of Pakistan.

Although no extensive studies on the amphibians and reptiles have ever been conducted in the Programme sites but as per preliminary Baseline report of the Indus for All Programme sites, conducted by Dr. Hafeez-ur-Rehman in 2006, 23 species of amphibians and reptiles from Keti Bunder, 31 species from Keenjhar Lake, 35 species from Chotiari Reservoir and 23 species from Pai Forest, were reported, based on collection, observation or as a result of interviews with local people or cited by the earlier authors. The site of Keti Shah, District Sukkur, was not included in those studies hence; baseline report regarding the herpeto-faunal assessment of the area is not available.

Detailed herpeto-faunal (amphibians and reptiles) assessment studies conducted during June 2007, in all the Programme sites recorded through observation and collection, 20 species of amphibians and reptiles were collected or observed from Keti Bunder, 17 species from Keenjhar Lake (District Thatta), 28 species from Chotiari reservoir (District Sanghar), 13 species from Pai forest and 11 species from Keti Shah. While in discussion with the locals and some earlier literature citations, the number of amphibian and reptilian species is expected to be much more than this. Therefore the species likely to be present in the areas have also been included in the checklist prepared. Keti Shah riverine forest was for the first time surveyed in terms of amphibian and reptile biodiversity. The studies were repeated in November 2007 to add species not represented in the earlier studies to the existing records.

The studies focused on different aspects of amphibian and reptilian biology, ecology and systematic and also addressed the issues like illegal live reptile trade, illegal poaching of freshwater turtles and lack of implementation of Government policies to meet these issues. Measures are also suggested to keep intact and conserve these vital biodiversity resources in a sustainable manner for future.

1.3.4 Birds

Data regarding water birds and wetlands of Pakistan mainly comes from Midwinter waterbed Census conducted regularly from 1987 onwards and published by IWRB/AWB in the following publications. Perennou and Mundkur, 1992, Perennou et al. 1993; Mundkur and Taylor 1993; Lopez and Mundkur 1997 and Li and Mundkur 2004.

Directory of Asian wetlands by Derek A. Scott (1989) is a remarkable achievement as it gives a series of national reports covering all countries from Pakistan in the west, China, the Koreas, Japan, The Philippines, Indonesia, and Papua New Guinea in the east.

The Pakistan section of the directory, 52 wetland sites have been described. These have been selected on the basis of criteria developed through the Ramsar Convention. Although it lacks information about the wetlands of the Nara Desert Wetland Complex, Deh Akro Wetland Complex, Rann of Kutch, sites in Baluchistan such as Ormara, Jiwani, Hingol Hor, Ras Malan etc. but it is still a sole reference book on the wetlands of Pakistan.

Roberts et al (1986) have given a checklist of Birds of Karachi and Lower Sindh. Tom Robert's two volumes of Birds of Pakistan comprise of the first complete account of the avifauna of the country. The first volume contains detailed descriptions of 347 non-passeriformes and the second volume deals with 313 species of passerines.

Later, Ghalib et al (1999) listed the Birds of Chotiari Wetland Complex based on their study during 1997. They gave the preferred habitats of the various species, threats to avifauna and proposals for management of the site. Ghalib and Bhaagat (2004) dealt with the wetlands of Indus Ecoregion. They gave the list of important wetlands along with the species of avifauna recorded.

Hasan et al (2005) have listed the fish and birds of Keti Bunder, Shah Bunder and other parts of the Indus delta. They have recorded 51 species of birds. Khan and Ghalib (2006) have given the bird population and threats to some selected important wetlands in Pakistan.

1.3.5 Freshwater Fisheries

Many diverse studies have been conducted on many aspects of fish and fisheries of the coastal areas of Pakistan. The major bulk of literature is on the biodiversity of various parts of the coastal areas. The significant work in this regards is that of Ahmed *et al.* (1976), Ali and Jafri (1986), Iqbal *et al.* (1999), Jafri *et al.* (1999), Jafri *et al.* (2000), Jalil and Kamaluddin (1981), Kazmi and Kazmi (1979), Leghari *et al.* (1999), Mirza (1986), Niazi (1976), Parashad and Mukerjee (1930), Qureshi (1965), Siddiqui *et al.* (1973), Sufi (1957, 1962). Some work on the commercial fishes has been conducted by Ahmed and Niazi (1988), Bianchi (1985) and Khan (1999). The limnological aspects of various water bodies have been covered by Baig and Khan (1976), Baqai *et al.* (1974 a, b), Dewani *et al.* (2002), Mahar *et al.* (2000) and Nazneen (1995). The water pollution in the coastal area has been documented by Amjad *et al*., (1998), Monawar *et al.* (1999) while aquaculture aspect is badly lacking and the only work documented is that of Yaqoob (1994).

1.3.6 Phytoplankton

Phytoplankton community structure in lakes appear to be well studied (Smith, 1990). Unfortunately in Pakistan except the work on Nazneen (1974) and Bri and Nazneen (1979), most of the research works concern with phytoplankton algae of temporary and permanent ponds. More over these studies are devoted only to the one species richness and many do not cover the entire seasonal variability. Many studies on phytoplankton of water bodies of this region appear not to be well

documented from an ecological point of view. The knowledge of temperate lakes and their phytoplankton is much greater that that of tropical and sub-tropical lakes. Tropical lakes appear to have different plankton community structure from temperate lakes and are mostly populated by submerged and emergent macrophytes.

Nitrogen was reported as the main limiting factor for production in tropical waters (Payne, 1986). But the shallow lakes of Salado River Basin are rich in both nitrates and phosphates (Quiros, 1989) and limitation by nutrient is not evident contrary to most tropical aquatic eco-systems where nutrients are rapidly mineralized (Fisher, 1978; Junk & Furch, 1991); sediments of these lakes store high amount of organic matter, mainly derived from macrophytes. Macrophytes appeared as the main factor influencing structure and abundance of phytoplankton (Izaguirre & Vincour, 1994)/. Lakes with a greater biomass of higher plants showed lower phytoplankton densities. The influence of macrophyhtes on phytoplankton communities has been discussed by several authors and attributed to different factors, shading allelopathy and competition for nutrients (Welch and Cooke, 1987: Engel, 1998 and Mitchell, 1989)

In temperate region the blue green algae often dominates summer phytoplankton of both shallow and deep lakes (Sommer *et al*, 1986). In other Danish lakes poor light conditions and continuous circulation lead to the dominance of blue green algae (Chorus & Shlag, 1993). Nutrient limitation did not fulfill any obvious role, the annual pattern of phytoplankton dynamics appeared to have been dominated by hydrological and climatological features (Barone & Flores, 1984). More over the coupling of hydrological and algal seasonability is well seen in other man made lakes (Talling, 1986) and the hydrodynamic control of phytoplankton growth has been discussed by Harris (1986)

In tropical and sub-tropical lakes, seasonal cycle of phytoplankton seems to be strongly related to the water level fluctuations and the climatological features and it seems reasonable to agree with the results of Harris (1986) & Barone & Flores (1994), that abiotic factors such as flooding, dewatering, light, and mixing mainly affect the phytoplankton dynamics and also by inhabiting or delaying the development if biotic relationships (i.e. fry predation efficiency) which commonly takes place in aquatic environment.

The construction of dams creates large bodies of standing waters which may be the subject to chemical and biological changes symptomatic of eutrophication. Among the most dramatic consequences of eutrophication results in the formation of water blooms of blue green algae (Goldman & Horne, 1983). Blue green algae can release allelopathic substances which are toxic to humans (Lawton & Codd, 1991) and to other organisms (Feuillade, 1992). The occurrence of blue green algae's in Indian lakes and reservoirs has been well studies by Gopal *et al.,* (1998) and Houk, (1989).

Baker Lake is a shallow, eutrophic lake that also serves as a reservoir. The knowledge gained through this piece of work will provide a clear picture of the phytoplankton composition of the lake. Changes in water levels played an important role in the structure of phytoplankton communities. The distinct increase of secchi disc depth in lake is the main factor responsible for change in cynaphyta compositions. The improved light condition at bottom made it possible for Gloeotrchia and Amphanizomenon to establish lake population in the sediment. The migration of Amphanizomenon and Gloeotrichia transfers particularly phosphorus and nitrogen from sediment to the lake (Osgood 1988 and Barbieror & Welch, 1992). Istvanovics *et al.,* (1993) and Pettersson *et al.,* (1993) clearly confirm the phenomena.

Physical and chemical and biological features are strongly conditioned by surface level fluctuations, due to flooding and dewatering (Thornton *et al* 1990). This phenomenon is clearly operative in Bakar Lake. During summer season reservoir water is intensively used for agriculture purpose. The deep outlets may also interfere with stratification pattern (*Calvo et al., 1984*). In addition the reservoirs often become so shallow that they can no longer accommodate a stable thermocline (Calvo *et al,*. 1993), such instable conditions tend to affect the dynamics of planktonic communities (Barone et al., 1991, Flores and Barone, 1994). Due to out flow of water and in absence of in-flow a marked interfere with stratification pattern and effect on the dynamics operative of composition of the planktonic operative in composition of planktonic

1.3.7 Zooplankton

A review of literature shows that some works on morphology, anatomy, larval development, breeding and fecundity, zoogeography, parasitism, associations, ecology, bionomics, distribution, food, fisheries, biochemistry, nutritive value, bioassay, biotechnology and some other issues relating to invertebrates has have also been carried out in Pakistan though in inadequate quantity. Some important works Include Ali (1983), Baqai and Ishrat (1973), Baqi (1975), Jafri (1995), Jafri and Mahar (2003a, 2003b), Jafri (1999), Leghari (1999) on the zooplankton.

Some work on crustaceans include Ahmed (1985), Ahmed and Khan (1971), Ahmed and Moazzam (1982), Ahmed (1973), Kazmi and Siddiqui (1992, 2001, 2006), Kazmi and Tirmizi (1990, 1995b, 1999), Kazmi and Yousuf (2005), Kazmi (1973, 1975, 1990, 1991, 2000, 2001), Keenan (1998), Kemp (1917), Khan (1975a, 1976b, 1977b), Khan and Ahmad (1975), Kholi (1992, 2004), Moazzam and Rizvi (1985), Moazzam (2003), Mustaquim (1972), Mustaquim and Rabbani (1976), Niazi and Hoque (1974), Nayeem (1993), Qadri (1960), Siddiqui and Kazmi (2003), Siddiqui and McLaughlin (2003), Siddiqui (2004), †Stoliczka (1871), Tirmizi (1962, 1967, 1968, 1970a, 1970b, 1974, 1976, 1977, 1978, 1980), Tirmizi and Ahsanullah (1966), Tirmizi and Bashir (1973), Tirmizi and Ghani (1978, 1982a, 1982b, 1983, 1986, 1988a, 1988b, 1992a,

In Pakistan there is still a dearth of specific literature and information regarding most of the zooplankton groups and for most of them the taxonomic investigations have not been scratched though there are examples of fragmented efforts including Haq and Rehman (1973), Haq (1973), Ali (1983), Biswas (1971), Iqbal and Baqai (1976), Jafri (1999), Leghari (1999). The quantum of work done and being done on zooplankton seems diminutive as compared to the huge scope and diversity of the invertebrate fauna in Pakistan. Most of the zooplankton fauna of Pakistan is therefore still uncharted and requires insightful and devoted scientific attention. Qadri and Baqai (1956) and Jafri and Mahar (2002) made some endeavors in order to explore the Branchiopod fauna of Pakistan including the riverine and terrestrial species.

1.3.8 Physico-chemical properties of water

In Pakistan, there are several potential sources to contaminated water. Bacteriological contamination of drinking water has been reported to be one of the most serious problems throughout the country in rural as well as urban areas (Abid & Jamil, 2005; Kahlown, Tahir, & Sheikh, 2004; Jehangir, 2002; Sun-OK, Shin-Ho, Nasir, & Noor-us-Saba, 2001). Another strong source for ground water and ponds / wetlands contamination is chemical pollution from toxic substances from the industrial effluents, pesticides, nitrogenous fertilizers, arsenic and other chemicals (Din, Hussain, Naila, Shabbir, Rana, Anwar, Saeed, & Zumra, 1997;

Tahir, Chandio, Abdullah, & Rashid,1998; Sajjad & Rahim,1998; Hussain & Mateen, 1998; Sial & Mehmood,1999; Latif, Akram, & Altaf,1999; Chandio,1999; and Tahir, 2000). In addition, excessive monsoon rains, floods, herbicides, fungicides, untreated municipal waste, sewage breakdowns, and coastal water pollution due to waste discharges and oil spills are extremely hazardous which pollute water.

An abundant supply of good, clean water must support a variety of beneficial uses. These include drinking water for domestic use and stock watering; industrial, commercial, agricultural, irrigation, and mining use; fish and wildlife maintenance and enhancement; recreation; generation of electrical power; and preservation of environmental and aesthetic values.

Water quality factors are important in freshwater aquaculture systems. Water quality determines not only how well fish will grow in an aquaculture operation, but whether or not they survive. Fish influence water quality through processes like nitrogen metabolism and respiration. Some water quality factors are more likely to be involved with fish losses as dissolved oxygen, temperature, and ammonia. Others, such as pH, alkalinity, hardness and clarity affect fish, but usually are not directly toxic.

Fish are important not only for ecosystem function, but also may provide socioeconomic value in the form of fishery resources for people. Loss of fish species due to changes in water quality or over-fishing may result in dramatic shifts in ecosystem dynamics, as grazing pressure on invertebrates and algae can be released, enabling rapid growth and potential blooms of algal populations.

The majority of the subtropical and tropical coastline is dominated by mangroves, estimated to cover an area of 22 million hectares. However, over the past several decades, the global area in mangroves has increasingly diminished as a result of a variety of human activities, such as over harvesting, freshwater diversion and conversion to other uses" (Snedaker, S. C.,1993).

Pakistan is largely arid and semi-arid, receiving less than 250 mm annual rainfall, with the driest regions receiving less than 125 mm of rain annually. It has a diverse landscape, with high mountain systems, fragile watershed areas, alluvial plains, coastal mangroves, and dune deserts. The flora and fauna are mainly Paleartic and Indo-malayan. Forests cover approximately 4.58 million ha (5.7 percent) in Pakistan. (Government of Pakistan, 1996) Of these, 0.132 million ha (less than 3 percent) are coastal mangrove forests. Pakistan is divided into 18 habitat types, among them mangrove forests, which occur mainly in the Indus Delta and in a few patches westward along the Baluchistan Coast.

There has been considerable qualitative and quantitative loss of mangrove forest in Pakistan over the last 50 years. A significant reduction in the river water supply and increased marine water pollution in the Indus Delta as well as over harvesting of mangroves by the local communities, sedimentation, and coastal erosion are generally considered to be the proximate causes of this loss. Another threat is emerging in the form of over harvesting of fish resources, largely provoked by increased pressure for exports with little or no consideration for the existing environmental laws and regulations. Policies and decisions made at the national and international levels have determined these proximate causes.

Chapter 2:
Material and methods

2.1 Large Mammals

2.1.1 Team composition

Apart from the permanent team members from WWF Pakistan, different professionals, field biologists and supporting staff members from different site offices of *Indus for All Programme*, Sindh Wildlife Department, Sindh Forest Department and Karachi University accompanied the study team. The study teams comprised of 6-9 members for different sites during summer and winter surveys. Details of study teams for each site are given in Appendix I.

Most of the large mammals reported from the sites are mostly nocturnal whereas few diurnal medium sized and larger mammals are also distributed in the area. The aquatic mammals are reported only from Keti Bunder and Keti Shah. Therefore, different direct and indirect methods of detection were applied; first to locate various mammalian species and secondly, to estimate the populations of some mammals of concern. The following direct and indirect observation methods applied during the survey included;

2.1.2 Point surveys

In this method, observation points were established along roads, edges of ponds or marshes, at a higher place or at any other location suitable for viewing the habitat. For a period of 15 to 60 minutes at each observation point, the observer recorded all sightings of the mammals at that site and then calculated an index of abundance of each species as the number of animals seen per hour of observation (Brower *et. al* 1990).

2.1.3 Roadside counts

Roadside counts technique was applied at Keenjhar Lake mostly for the nocturnal mammals like foxes, jackals and cats. Additionally this technique was used in Keenjhar Lake as a means to locate different nocturnal mammals using search lights on 4x4 jeeps as well as diurnal mammals like mongooses.

2.1.4 Track counts

Tracks can be the first indication of the presence of animals in an area. Track counts especially after rain can be useful in identifying different animals especially those which are nocturnal and secretive in habits. A fresh rain eliminates the previous tracks and the recent tracks of animals entering or leaving the study area can be used as a measure of their abundance. During the survey period, track counts technique was applied at all the five study sites and at Keenjhar Lake this technique was applied just for the confirmation of the presence of nocturnal mammals.

2.1.5 Line transects

The line transect or strip census method of population estimation involves counting the animals seen by an observer traversing a predetermined transect line and recording the distances at which they were seen or flushed. The average of the flushing distance is determined and used to calculate the effective width of the strip covered by the observer. The population for the entire area then is considered to be the number of animals flushed, divided by the area of the strip and multiplied by the total area (Schemnitz 1980).

P = AZ / 2XY	**P** = population **A** = total area of study **Z** = number of animals flushed **Y** = average flushing distance **X** = length of strip

Line transects or strip census method is a particularly useful technique when animals are difficult to see and must be flushed to be counted. This methodology was applied at Keenjhar Lake for Jackals.

2.1.6 Pellet counts

Pellets' counting in a specific area is a good technique for locating large mammals and assessing their populations. This technique involves removing all pellet groups from plots and then estimating from subsequent observations on those plots the number of groups per hectare to compare animal use of areas between sampling periods. In some cases it is not possible to remove all the pellet groups from an area therefore under such circumstances; an observer with a little practice can identify the fresh pellets depending on the color and dryness of the pellets. Ten to fifteen 100 m² plots (7.07 x 14.14) can be used for this purpose. These plots should be checked every three to seven days and the periods between samplings should not be so long that feces will decompose or be destroyed by weather or insects. A random selection of plots in the study area and the number of pellet groups in each plot is tallied and summed (Brower *et. al* 1990). An index of density (ID) of the number of pellet groups per unit area is then determined as;

$$ID = n / A$$

Where n is the sum of pellet groups counted over all plots and A is the total area sampled (i.e., the sum of the areas of all the plots). This method is effective in the habitats with dry weather and little or no dung beetle activity where pellet groups remain preserved between sampling periods. After counting pellets, one must be assured that they will not be counted on successive sampling periods so they should be removed by the observer. Defecation rates for the species under the study are closely estimated if it is desired to convert pellet counts to number of animals.

At Keenjhar Lake as most of the area is covered by stony desert therefore this method was applied to confirm the existence of the mammals reported by locals and not for the estimations of their populations.

2.1.7 Interviews with local residents

Interviews with local residents are valuable not only for the survey site selection but also in identifying the potential areas and a good source of primary data about the existing wildlife of the area. This method was very helpful in locating different mammal species in all the five study sites. However, despite the effectiveness of this method, minimal emphasis was placed on this source regarding the populations of different animals as it is assumed that the data regarding the population estimates could be biased.

2.1.8 Capture-mark-recapture

This method is applied by using vocalization frequency to estimate the size of different animals' populations is also an effective method. The technique involves walking along fixed transects to disturb all animals present on a study plot, potentially provoking a vocal response. Those animals heard to vocalize (whether observed or not) are then considered the total number of "marked" individuals in the population. The proportion of "marked" individuals in the population is estimated from the proportion of animals that vocalize in the sub sample of individuals observed (the vocalization frequency). Population size is estimated by dividing the number of marked individuals by the vocalization frequency. If the assumptions are met, this method provides estimates of absolute population size at low cost and with little material investment, because physical capture and marking of animals is not necessary (Reby 1998). Using this technique at Keenjhar Lake, the populations of Jackals were estimated.

2.1.9 Live trapping of nocturnal mammals

It was difficult to confirm the existence of some carnivores through above methods because most of the carnivores found in study sites are nocturnal and difficult to locate and observe during day time. Since it is difficult to differentiate between some mammals belonging to Felidae family on the basis of their pug marks techniques for trapping some carnivores were applied and traps were made for trapping live animals such as jungle cat, grey mongoose etc. Such specially designed traps were set for the animals and the trapped animals were released after having been photographed. The traps were designed in such a way that there were no chances of any damage to the animals. This technique was applied near Jaakhra fish ponds at N 24 52 282 and E 68 02 693

Image 1 – Small mammals trap being set for Jungle cat

Image 2 – Small mammals trap being set for Jungle cat

2.1.10 Equipments and Field Kit

Equipments and field kits used for watching different mammals and assessing their populations in different sites of the Indus for All Programme included;

1. Digital camera to record the photographic evidences of the mammals.
2. Search lights for night vision of nocturnal mammals on 4x4 vehicles.
3. Measuring tape to record the size of foot prints and fecal droppings.
4. Binoculars (10x 50) to observe the diurnal large mammals.
5. Geographical Positioning System (GPS) to record the coordinates.

6. Field guide books for assistance in quick identification of mammals.
7. Note book and pencils for recording field notes.
8. Satellite maps of the study sites.

2.2 Small Mammals

One effective way to survey small mammals is active searching, particularly during the daytime. This method is equally applicable to both nocturnal and diurnal species. The study area was actively searched for potential and suitable microhabitats along the canal banks, open plains, bushy areas and agriculture fields. Active searching is very effective for inventory of *Gerbilus, Meriones, Hystrix,* and *Hemiechinus*. This method is most effective for those small mammals which can not be trapped easily e.g. Hedgehog.

To investigate nocturnal species, night surveys were conducted in exposed areas of potential habitats on the ground. This methodology involved the use of a powerful torch light, sticks, long boots, gloves etc

Table 4 – Locations used for sampling in Keenjhar Lake

Keenjhar Lake		
Northing	**Easting**	**Location name**
24 50 817	67 57 117	Jhangli Kooa
24 50 817	67 57 117	Jhangli Kooa
24 50 817	67 57 11	Noriro/Nor
24 50 81	67 57 117	
24 50 817	67 57 117	Karo Kooa
25 03 955	68 07 36	Sehar
24 46 295	67 56 457	Fusli Kooa
24 46 295	67 56 457	Fusli Kooa
25 01 898	68 03 939	Kundyara Kooa
24 52 262	67 59 288	Makli graveyard

2.2.1 Bait

A mixture of different food grains mixed with fragrant seeds was used as bait for the attraction of the small mammals. Wheat and rice were used as food grains while peanut butter, coriander, oats and onion were used for fragrance. This bait was found highly successful in the study area probably due to the overall food shortage and fragrance. Freshly prepared bait was used on every trapping day. Only small amounts of bait were put on the rear side of the traps. Care was taken to make sure that the bait was placed on the platform fitted on the rear side of the trap.

2.2.2 Traps and trapping procedure

Sherman traps were used for the present studies to collect the live specimens. Fifty traps were set at a specific area on a line approximately 500 m long and traps were set approximately 10m apart. Each trap was marked by a colorful ribbon to locate the traps easily. The traps were set in the afternoon and checked early in the morning. The specimens were transferred into polythene bags and were identified in the field and released. The specimens with some doubt were preserved in 10 % formalin and were sent to the laboratory and identified using identification keys. At least one specimen of each species was preserved for reference.

2.2.3 Data collection

The species of the trapped animal was noted as was the net weight, gender and other relevant information such as date, habitat, location, elevation and weather conditions

2.3 Reptiles and amphibians

2.3.1 Survey Method

The activities of amphibians and reptiles are highly seasonal and are influenced by the variation of weather even on a daily basis due to their exothermic and cryptic nature. It is more fruitful to survey them during their activity periods. Amphibians are usually most active just after dusk during their breeding season; many diurnal reptiles such as skinks and some lizards are active in mid-morning whereas nocturnal reptiles such as certain snakes and geckos would be active only at night.

Most amphibians and reptiles go into hibernation during winter. They would be under-estimated if surveys were carried out during this time. As such, it would be essential to survey herpeto-fauna at appropriate timings in order to collect a representative baseline for assessment. Many reptiles such as snakes and lizards are timid, secretive, fast-moving and cryptically colored. This renders survey on reptiles difficult. The reptiles therefore tend to be under-represented in ecological surveys in general. More intensive surveys with appropriate survey methodologies would rectify such limitation.

There are standard methods for the studies of amphibians and reptiles (Foster and Gent, 1996; Hayek and Martin, 1997). All these techniques have been summarized in the EIAO Guidance Note, 2004.

2.3.2 Active searching

An effective way to survey amphibians and reptiles is by active searching, particularly during the daytime. This method is equally applicable to both nocturnal and diurnal species. The study area was actively searched for potential breeding areas of amphibians (e.g. marshes, small water pools, water channels) and suitable microhabitats for both amphibians and reptiles (e.g. stones, pond bunds, crevices, leaf litter/debris, rotten log).

Image 3 – searching for reptile species

These places were deliberately uncovered to search for the eggs and tadpoles of amphibians in aquatic habitats or to reveal the presence of the amphibians and reptiles hiding under these covers. Active searching was carried out in all the locations with a focus on suitable microhabitats. In winter, studies were conducted, prior to the start of the hibernation period of most of the amphibians and reptiles. Most of the active searching was only possible and limited to the pre-dusk time in winter, as the low night temperatures hindered the activities of the herpetiles.

Searching for the nocturnal species of amphibians and reptiles was carried out in exposed areas of their potential habitats on the ground, along the path or the pond/stream bank. Night survey in some of the rocky terrain around the Keenjhar Lake was difficult as there was always a likelihood of venomous snakes, as the author did face; so, long shoes, hand lamps and powerful torches were used for this purpose.

2.3.3 Signs

Presence of signs like impression of body, tail or footprints, faecal pellets, tracks, dens or egg laying excavations, were also some of the suitable methods to find out the existence, range and rough population of amphibian and reptilian fauna.

2.3.4 Collection

Hand picking (through bare hands or with the help of long forceps or snake clutch), adopted for the present studies, has always been the most efficient way of collecting different species of amphibians and reptiles. However, for larger species like monitor lizard and rock-agama, noose traps or other appropriate techniques were used. For handling snakes, especially poisonous ones, snake clutches/ sticks were used. In addition to Hand picking, “Scoop nets” for shallow water and “Cast nets” in large water bodies were used for aquatic reptiles and amphibians. For frogs and toads, auditory detection of mating calls at the breeding sites is considered as an efficient method to find out the species; particularly the more vocal species and therefore a large number of toads were spotted with this method.

2.3.5 Data records

The species collected or observed during the survey were photographed with a digital camera and necessary field data were recorded. The coordinates and elevations were recorded with the help of GPS. The voucher specimens collected were subsequently transported to the Pakistan Museum of Natural History (PMNH) laboratory for future reference.

2.3.5 Preservation

The amphibian or reptile specimens were arranged in a tray or ice-cream container in a position, which showed the features important for identification, e.g. mouth wedged open, one hind leg extended and fingers and toes spread.

Preservatives such as 10 % formalin solution or 50-70 % alcohol or methylated spirits solution in water was added to just cover the specimens, and the container was then covered and left until the specimens were set. In case of larger specimens, a slit was made in the belly and preservative injected to preserve the internal organs. This step was omitted in case of frogs as they have thin and permeable skins, but in case of reptiles, the preservative was injected into their bodies as their skin is impermeable and does not allow any solution to get into. For this purpose normal syringes were used.

The specimen was stored in the same preservative in a watertight jar. A waterproof label was added to the jar, giving details of place, date and collector’s name. A label was tied to the specimen written with permanent Indian ink or simple carbon pencil. The same details were stored with tadpole specimens, which don’t need to be set, just dropped into preservative.

2.3.6 Identification of species

The specimens were identified with the help of most recent keys available in literature (Khan, 2003, 2006).

2.3.7 Data analysis

There are several numerical indices in use, which quantitatively describe different levels of diversity and evenness in samples collected from different localities or at different times from the same environment. One such commonly used diversity index is called “Shannon-weaver” index of diversity, which combines the number of species present and evenness into a single index. The formula is given as: D = -Σ pi in pi where “i” stands for an index number for each species present in a sample, “pi” can be calculated through “ni/N” in which “ni” represents the number of individuals within a species divided by the total number of individuals “N” present in the entire sample and “ln” stands for natural log. In this way the proportion “pi” of each species in the sample times the natural log of that same value “ln pi” the values for each species and finally multiplied by –1. The value of “D” is always higher when species are equally abundant. Similarly species evenness is calculated by the formula as: E = eD/s, where “e” is the Shannon-weaver constant valuing 2.7, “D” is the value of Shannon-weaver index and “s” represents the number of total species in a sample. Species evenness, thus, separates the effect of different population sizes (number of individuals within species) from number of species (species diversity).

2.4 Birds

2.4.1 Survey method

Each major habitat type in the study area was identified and records were kept of species of birds found in each discreet habitat such as lakes, canals, ponds, marshes, coastal areas, creeks, forest, agriculture fields, mangrove areas, vicinity of human habitation and fallow lands. The number of birds observed in each habitat type was also recorded with particular emphasis on the key species and to relate the data to other components of the study area such as vegetation, water and soil etc.

The most commonly used field method in bird surveying is the “Line Transects” method. It is based on recording birds continually along a predefined route within a predefined survey unit. It can be used in terrestrial, freshwater, and marine systems to survey individual species, or group of species. It is used to examine bird-habitat relationships and to derive relative and absolute measures of bird abundance.

Line Transects are suitable for extensive, open and uniform habitats and for large and conspicuous species. Double counting of birds becomes a minor issue as the observer is continually on the move. Line Transects are suited to situations where access is good and these are very useful for bird-habitat studies (Gregory et al 2004).
In the present studies, each sample area was transversed / examined by 2 observers, separately. Birds were searched on each side of the strip for 150m so that each study strip was 300m wide. Use of binoculars and telescopes was made to identify bird species, count or assess bird numbers, particularly in case of water-birds.

2.4.2 Evaluation of water-bird numbers

To evaluate the numbers of water-birds utilizing a site, whether from a stationary point or by moving through the area, binoculars or telescopes are used. Below is a summary of when to count accurately or estimate the number of water-birds present:

a) Counting individuals birds within an area

- Small number of birds present i.e.) <1,000.
- Limited inter-or intra – site movement by water-birds i.e. the birds are stationary at a roost site.
- No on-site disturbance i.e. people, birds of prey, which may force birds to fly frequently within the site.
- The birds are well spaced out i.e. foraging in an open area.

b) Estimating the numbers of birds within an area

- Large numbers of birds present i.e. >1,000.
- Birds continually in flight i.e. moving along the coast to a roost site in large flocks.
- A lot of disturbance forcing birds to be unsettled and continually take flight, making prolonged observation on the ground difficult.
- A closely-packed flock of birds, where due to the "tightness" of the flock counting individual birds is difficult i.e. at a large roost.
- Due to poor light conditions i.e. viewing into the sun or over a great distance, identification of particular species is not possible.

c) Methods of accurate count

- Close viewing of individuals with binoculars or a telescope. Counting 1, 2,3,4,5,6,7…… etc.
- Distant viewing of an evenly distributed flock. Counting 1,2,3,4,5,6,7……..etc.
- Visually dividing birds into small groups and counting each group individually, i.e.) when there is an uneven distribution of numbers. Totals for each group are then added to form the final total.
- Counting flocks in multiples i.e. 3,6,9,12,15…….. Etc or 2,4,6,8,10……etc. This method can be used for either evenly or unevenly distribution of water-birds. (Howes, J. and Backwell, D. 1989).

2.5 Freshwater fisheries

2.5.1 Fish surveys:

There are five techniques for fish surveys viz., Bank-side counts, trapping, cast netting, gill netting and electro fishing (Environment Impact Assessment Ordinance Guidance note no. 10/2004, Singhanouvong and Phouthavong, 2002). Bank-side counts are only done on the banks of clear shallow streams, Trapping is done by using specific baits for specific species, Gill netting is only for commercial fishes while electro fishing is done only in wade able streams with limited width. The cast netting technique is, therefore, the most appropriate technique for large rivers and reservoirs while studying the fish biodiversity.

2.5.2 Cast-netting technique

A general survey of the reservoir area was conducted to identify different habitats in the study area. Field stations were selected covering all the representative habitats of the study area. Long/Lat of all the field stations was noted to make it more accessible during the study period. Fish will be collected using cast nets of two different mesh sizes, (small one having mesh size of 1cm X 1cm and having a circumference of 30 ft. and the large one with mesh size of 2.5cm X 2.5cm and

with a circumference of 45ft.) so that the fish fauna of all the age classes could be collected. Ten nets of each mesh size were cast in each stations along a line transect of about 500 meters. The collected material was numbered according to stations and the effort no. and mesh size. The fish specimens were preserved in 10% formaldehyde solution in the field. Large specimens were given an incision in the belly to ensure proper preservation. The specimens were identified in the laboratory and taxonomical checklists along with English and local names were compiled.

The status of each species (common, rare, fishery value, maximum size etc.) was determined on the basis of relative abundance of each species in the project area. The data on fish species collected in each station and of every habitat along with their long./lat. was available for developing GIS based information regarding occurrence and distribution of fish species in the lake. Any possible change in the last ten or so years in fish population fish was anticipated on the bases of data collected, previous studies carried out in the area and on the basis of interviews of the fishermen and local people, agro-forestry practices and irrigational pattern in the area and conservational measures that could be expected in future. The fishes of special concern i.e., fishes of economic value and fishes of ecological concern were given special attention and were documented and enlisted on the basis of the first hand information collected by the actual data and the information already available through previous studies.

2.6 Phytoplankton

2.6.1 Collection methodology

Algal and phytoplankton species were collected in June and November 2007. A small boat was used along with a phytoplankton net of 5-10 µm mesh to collect samples. Water samples were collected each time using a water sampler (Nansen bottle) commonly unused for studying physico-chemical features, using standard methods (APHA, 1985) and for identification of phytoplankton. Samples were preserved in 4% formalin solution (Mason, 1967). The species composition was determined by utremohal method (Lund, 1958). The micro algae (ultra nanoplankton) were not counted as Gorham et al (1974) considered these algae comparatively un-important in high productive water-bodies. Identification and counts were done using inverted light microscope (BH-2 Olympus using objectives 10^X, 20^X, 40^X, 100^X but usually 20^X and 10^X eye piece was used) and identified with the help of available literature (Tilden, 1910; Husted, 1930; Majeed, 1935; Smith, 1950; Silva, 1954; Desikachary, 1959; Prescott, 1962; Siddiqi & Farooqi, 1964; Patrick, 1966; Philpose, 1967; Islam & Tahmida, 1970; Tiffany & Briton, 1970; Vinyard, 1979; Akiyama & Yamagishi, 1981; Shameel, 2001).

2.7 Zooplankton

2.7.1Collection protocols and standardizing procedures

Specimens belonging to diverse groups of Invertebrates were collected from the various localities of the prescribed areas using a variety of collection protocols and techniques.

2.7.2 Aquatic invertebrate fauna - Plankton net and drag nets:

The most widely used apparatus for collecting zooplankton is the plankton net. This, despite many minor variations in pattern, consists essentially of a cone of bolting silk, (or equivalent material) mounted on a ring or hoop to which are attached three thin bridles spliced on to a smaller ring by means of which the net can be shackled to a towing rope or warp. The end of the cone is left open and is reinforced by strong material, tapes or cords are sewn to this so that a small metal

or glass jar can be tied into it. The jar receives most of the plankton as the net is towed along, but some always remains on the wall of the net and is removed by turning the net inside–out and washing it in a wide- mouthed receiving jar, holding about a liter of water. The sample was then preserved in the preservative chemicals.

The plankton net was towed slowly behind the boat and mostly a five-minute or even less haul was usually sufficient to give an adequate amount of zooplankton. The mesh size of the material of which the net is constructed influences the kind of plankton caught. As the focus of the present study has been the macro-zooplankton, therefore, plankton net of mesh size 0.03 mm was selected. (G. E.Newell and R. C Newell, 1963)

2.7.3 Random sampling

The distribution and abundance of invertebrates are strongly influenced by abiotic factors, such as light, depth, temperature, salinity, tides and time of year (i.e. seasonal effects). Zooplankton, for example, is unevenly distributed over wide space and time scales in the water bodies. As it was not possible to sample all of the zooplankton from the lakes and other reservoirs using a single collection method, random sampling was therefore used as the probable procedure in which each and every species has the equal chance and probability to be caught during sampling. Each individual is chosen entirely by chance and the likelihood of a biased data collection is thus reduced.

2.7.4 Precautions in field

i. Sample labels are properly completed, including sample ID, date, stream name, ample location, and collector's name, and placed into the sample container. The outside of the container should be labeled with the same information.
ii. After sampling at a given site, all nets, pans and trays are rinsed thoroughly, examined and picked free of organisms or debris. Any additional organisms found should be placed into the sample containers.

2.7.5 Precautions in taxonomic investigation

i. A voucher collection of samples is maintained. These specimens are properly labeled, preserved, and stored in the invertebrate repository for future reference.
ii. The reference collection of each identified taxon is maintained and specimens sent out for taxonomic validations are also recorded with the label information and the date sent out. Upon return of the specimens, the date received and the finding are also recorded with the name of the person who performed the validation.
iii. Information on samples completed (through the identification process) is recorded in the log register to track the progress of each sample. A library of basic taxonomic literature is maintained and frequently revitalized to ensure accurate identifications.

2.7.6 Hand picking and use of forceps

Hand picking, through bare hands or with the help of long forceps, which has been adopted for the present studies, is by far the most productive method for collecting different groups of terrestrial invertebrates especially arachnids (spiders, solifugids) and myriopods etc. The specimens collected or observed during the survey were photographed with digital camera and significant field data were recorded. The

voucher specimens collected were transported to the PMNH laboratory for future reference.

2.7.7 Preservation and storage of the specimens

All invertebrate specimens including the zooplankton were preserved by the addition of grades of formaldehyde and 70 % ethyl alcohol. These fluids suffice to preserve the samples indefinitely and also have the effect of sending all the plankton to the bottom of the jar. All zooplankton are delicate and easily get damaged, so sample handling was gentle. It is advisable not to concentrate the sample too much. Zooplanktons were sub-sampled by adding water to bring the samples to a known volume (500 or 1000 ml). The concentrated samples were then stored in suitable bottles and plastic screw tapped jars. The date, place of origin, mesh-size of the net, length and depth of the haul were written in Indian ink on quality paper and placed in the jar as the labels outside usually peel off after some time.

2.7.8 Counting and studying the zooplankton

The volume of the zooplankton is determined by the displacement method. First the total volume of the concentrated sample plus the preserving fluid is measured. Then the plankton is filtered off, using a filter paper in a funnel, and the volume of the filtrate is measured. The volume of the plankton is then obtained by the difference between the two volumes. A measure of the total catch is also made by weighing the filtered plankton. One ml of the concentrated sample may contain so many organisms that it would be very difficult to count them. One ml of the concentrated sample was therefore diluted to 100 ml and out of this diluted sample, one ml was taken. Identification and counting the samples was done under a dissecting microscope with dark-field illumination. Staining was not required although a drop of glycerin was put on each individual specimen isolated from the jar in order to avoid any damage to the samples.

2.8 Physico-chemical properties of water

The samples were collected in clean acid rinsed bottles for the general water quality parameters such as pH, temperature, conductivity, TDS, Total Hardness, Chlorides, Phenol, Sulphates, turbidity, ions and four heavy elements. The BOD and COD water samples were collected in separate colored water bottles and kept in ice box for preservation. All samples were properly sealed under specific codes/labels and dispatched to the water quality laboratory on next days with proper custody protocol.

The sampling strategy was designed according to the site conditions and in consultation with the WWF team deployed at the study area. The sampling was designed to cover all the sources of pollution for example municipal and industrial waste water discharging in to Keenjhar Lake through KB Feeder. The location points and their significance are highlighted in **Table 5**.

Water samples were drawn from the sources considering full depth of standing water or flowing water. In many cases the mixed water (top-bottom) were taken so that the samples are representative of the available environment.

The sample location points were marked on map through GPS. These points will be used as reference points for future studies.

Table 5 – Details of water-quality samples taken from Keenjhar Lake

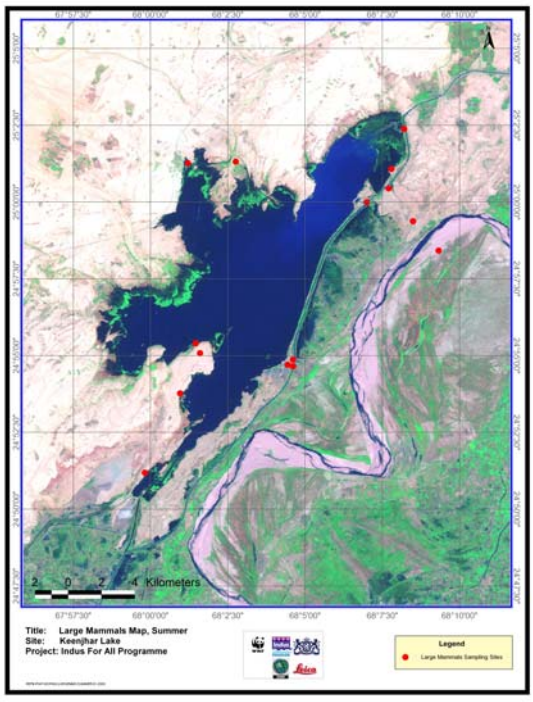
S.no	Sample No	Geographical location	Location /Significance
1	KL-B1	N2459.819 E6806.578	Soneri-1 (biological waste)- Buffalos entry point
2	KL-B2	N2500.399 E6806.240	Soneri-2 (algal growth)
3	KL-B3	N2509.819 E6804.578	Soneri-3 (Drinking Water pumping station)
4	KL-B4	N2501.406 E6806.611	Mid point of the Lake
5	KL-B5	N2459.819 E6803.618	1 km down from head regulator of Keenjhar lake. (KB Feeder is main source of water supply to Keenjhar Lake).
6	KL-B6	n/a	Downstream head regulator of Keenjhar lake
7	KL-B7	n/a	Upstream of Keenjhar lake head regulator
8	KL-B8	N2500.097 E6806.578	Ali Bux Manchhari village.(Observe human activities and drain entry into Keenjhar Lake).
9	KL-B9	N2500.528 E6801.450	Jhampir Nai. (See effect of industrial waste like coal, Dolomite mining, silica sand etc coming with rainwater into the Lake.)
10	KL-B10	N2457.180 E6801.335	Shoro village drain (This drain brings storm water into the Lake).
11	KL-B11	n/a	Picnic point. (Every weekend during summer huge number of people visit the lake as picnic place where solid waste is thrown into the lake and frequent washing of motor vehicles take place)
12	KL-B12	n/a	KB Feeder outlet(Karachi Water supply source)

Chapter 3:
Findings and discussion

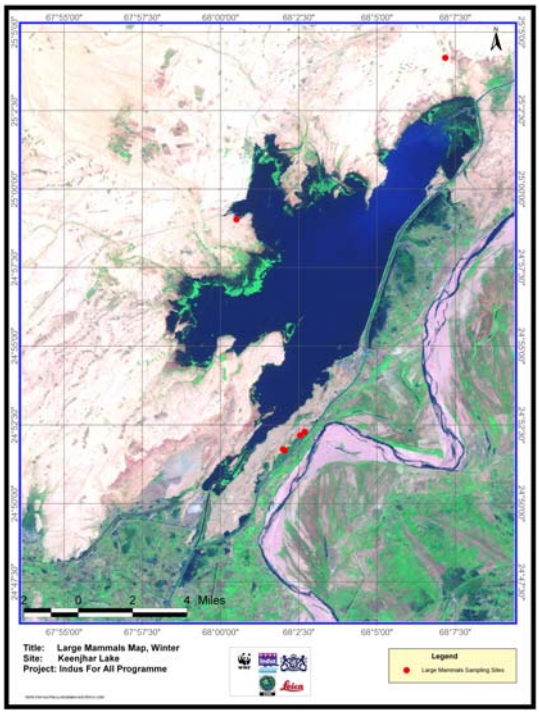
3.1 Large mammals

3.1.1 Sampling Sites

Almost all the potential sites around Keenjhar Lake as well as in the buffer zone were searched to locate the existing large mammals and the GPS coordinates at different locations were noted. Different sampling sites and the distribution of large mammals around Keenjhar are given in **Maps 2 and 3**. GPS coordinates taken during summer and winter surveys are given in the annex document.



Map 2 – Sampling points at Keenjhar Lake (summer)



Map 3 – Sampling points at Keenjhar Lake (winter)

3.1.2 Species identified

During eight days in the field at Keenjhar Lake (four days during summer survey and four days during winter survey), a total of 26 animals of nine mammal species, belonging to three orders (*Carnivora, Artiodactyla* and *Pholidota*) were recorded from the study area as given in the **Table 6**.

Table 6 – Mammal species recorded from Keenjhar Lake

Sr. No.	Common Name	Scientific name	Order	Animals observed
1	Asiatic jackal	*Canis aureus*	Carnivora	5
2	Jungle cat	*Felis chaus*	Carnivora	2
3	Fishing cat	*Prionailurus viverrinus*	Carnivora	-
4	Bengal fox	*Vulpes bengalensis*	Carnivora	-
5	Desert fox	*Vulpes vulpes pusilla*	Carnivora	1
6	Small Indian mongoose	*Herpestes javanicus*	Carnivora	12
7	Grey mongoose	*Herpestes edwards*	Carnivora	4
8	Indian wild boar	*Sus scrofa*	Artiodactyla	2
9	Indian pangolin	*Manis crassicaudata*	Pholidota	-

3.1.3 Observation records

Out of nine recorded species of large mammals, six were observed directly while the remaining three were recorded on the basis of indirect evidences like tracks, faeces and interviews of locals and wildlife watchers from Sindh Wildlife

Department. The observation records of different mammal species at Keenjhar Lake are given in **Table 7**.

Table 7 – Observation records of different mammals at Keenjhar Lake

Sr. No.	Species	Direct Observations	Indirect Observations		
			foot prints	fecal material	Interviews with locals
1	Asiatic jackal	✓	-	-	✓
2	Jungle cat	✓	-	-	✓
3	Fishing cat	-	✓	-	✓
4	Bengal fox	-	-	✓	✓
5	Desert fox	✓	-	-	✓
6	Small Indian mongoose	✓	-	-	✓
7	Grey mongoose	✓	-	-	✓
8	Indian wild boar	✓	✓	-	✓
9	Indian pangolin	-	-	-	✓

3.1.4 Conservation status of different mammal species

Out of the nine recorded species, one is Vulnerable (VU), four Near-threatened (NT) and four Least-concern (LC) according to the IUCN Red List of Pakistan (mammals) 2005. The Jungle cat and small Indian mongoose are enlisted as Least Concern (LC) while the fishing cat is listed as Vulnerable (VU) in IUCN international Red List 2006. The Jungle cat, Fishing cat and Indian pangolin are protected (P) in Sindh. The Jungle cat and Fishing cat are listed in Appendix II of the CITES Category 2007. The conservation status of mammal species found at Keenjhar is given in **Table 8**.

Table 8 – Conservation status of mammals found at Keenjhar Lake

Sr. No.	Mammal Species Recorded from Keenjhar	IUCN International Red List 2006	IUCN Pakistan Red List 2005	Sindh Wildlife Protection Ordinance 1972	CITES Category 2007
1	Asiatic jackal	-	NT	-	-
2	Jungle cat	LC	LC	P	Appendix II
3	Fishing cat	VU	NT	P	Appendix II
4	Bengal fox	-	NT	-	-
5	Desert fox	-	NT	-	-
6	Small Indian mongoose	LC	LC	-	-
7	Grey mongoose	-	LC	-	-
8	Indian wild boar	-	LC	-	-
9	Indian pangolin	-	VU	P	-
Legend: VU = Vulnerable, NT = Near Threatened, LC = Least Concern, P = Protected					

3.1.5 Population Estimations:

3.1.5.1 Population of Asiatic jackal

Population of Asiatic jackal was estimated at Keenjhar to be 46 animals. This estimation was based on records of howling of jackals at three different sites of the study area. Howling was recorded during 6:00 pm and 7:30 pm by three different survey teams during night surveys on 14 June 2007.

During summer survey, in total 14 animals were directly observed. These included three animals around Dolat Pur village on northern side of the lake at (N 24º 50’ .190”, E 68º 06’ .081”), four animals near Jhimpir village at (N 25º 01’

.254", E 68º 01' .215") and seven animals near Sonehri on southern side of the lake at (N 24º 59' .989", E 68º 07' .002"). Records of howling and observations of Jackals at Keenjhar Lake during summer survey are given in **Table 9** and **Table 10** respectively.

Table 9 – Records of howling of jackals around Keenjhar Lake

Survey Team No.	Animal groups Observed	Estimated animals	Total Animals
A	3	04 + 05 + 04	13
B	4	03 + 05 + 06 + 04	18
C	3	04 + 05 + 06	15
Total Animals observed around 3 different sites			**46**

Table 10 – Records of direct observations of jackals around Keenjhar Lake

Sr. No.	Location	Animals Directly Observed
1	N 24º 50' .190", E 68º 06' .081"	03
2	N 25º 01' .254", E 68º 01' .215"	04
3	N 24º 59' .989", E 68º 07' .002"	07
Total Animals directly observed		**14**

3.1.5.2 Population of wild boar

Two dead specimens of Indian wild boar killed by hunters with the help of hunting dogs were observed along southern side of the lake at N 25º 02' .375", E 68º 08' .209". Based on the information provided by the hunters and locals regarding the number of wild boar in the area, it is estimated that about 15 animals are present around and within the buffer zone of Keenjhar Lake.

3.1.6 Threats and recommendations

3.1.6.1 Threats

- **Presence of feral dogs:** Presence of a large number of feral as well as hunting dogs kept for wild boar hunting in the area is a threat for wild animals. It is also a causal factor for the disappearance of hog deer and Indian otter from Keenjhar. Feral dogs have no natural threat on them and are provided with good shelter by humans, has caused severe damage to Indian otter as young otters are attacked which are now extinct in Keenjhar.

- **Hunting:** Scores of hunters particularly during winter season visit the lake to shoot migratory birds. This definitely poses a threat to the wild animals around Keenjhar. Similarly, wild boar hunting with dogs and guns also disturbs the existing wildlife in the study area.

- **Persecution of large mammals:** In some areas of the Indus Eco-region, Indian otter is considered a blessing among the poor fishermen. The otter helps in catching fish in the nets. Due to this positive role, some fishermen keep tamed otters but now these are extinct in Keenjhar. Despite all this, the fish farmers don't like the existence of otters near fish ponds as it attacks and steals the fish from fish ponds.

3.1.6.2 Recommendations

- **Ban on hunting around Keenjhar:** There are still some chances of existence of Indian otter in KEFL canal near Chul Side (near inlet of the

lake) as observed while interviewing the locals. The major threat to Indian otter is trapping and poaching for its skin. Secondly, the fish farmers kill this animal and get the dual benefit by selling its skin. There should be a complete check on its hunting so that it could survive in Keenjhar;

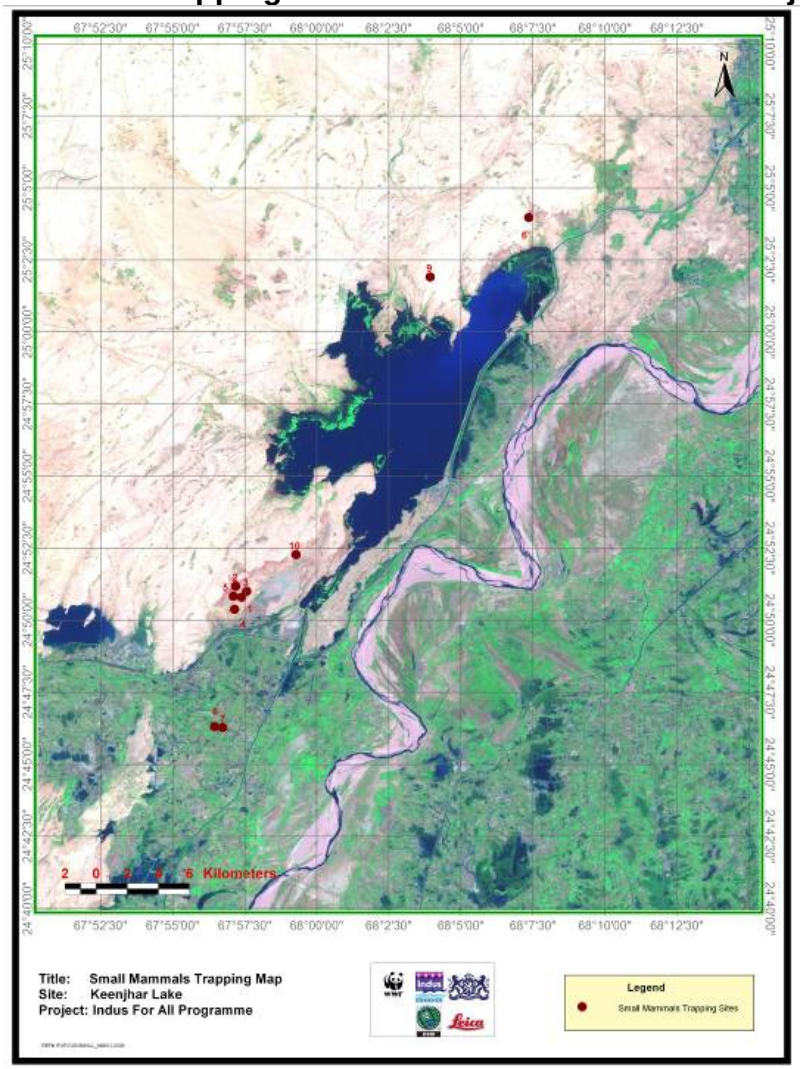
- **Reintroduction of Indian otter:** Indian otter should be reintroduced in Keenjhar. Presence of an active predator will definitely affect the fish populations and fittest and healthy fish will be available in the Lake. Introduction of Indian otter in Keenjhar Lake may add to the efforts of eco-tourism development in the area.

3.2 Small Mammals

3.2.1 Sample locations

Map 4 shows the location of small mammals trapping sites for Keenjhar Lake. Details of the sampling sites can be found in the annexure document.

Map 4 – Details of trapping sites for small mammals at Keenjhar Lake



3.2.2 Species account

A total of 17 small mammal species were found in Keenjhar Lake during the whole survey. A total of 14 species were recorded during the summer survey whilst 10 were recorded during winter. The 17 species found in the summer

represented 4 orders (*Rodentia, Insectivora, Lagamorpha and Chiroptera*) and 8 families. **Table 11** gives an account of the species recorded at Keenjhar Lake along with their conservation status, feeding habits and activity habits.

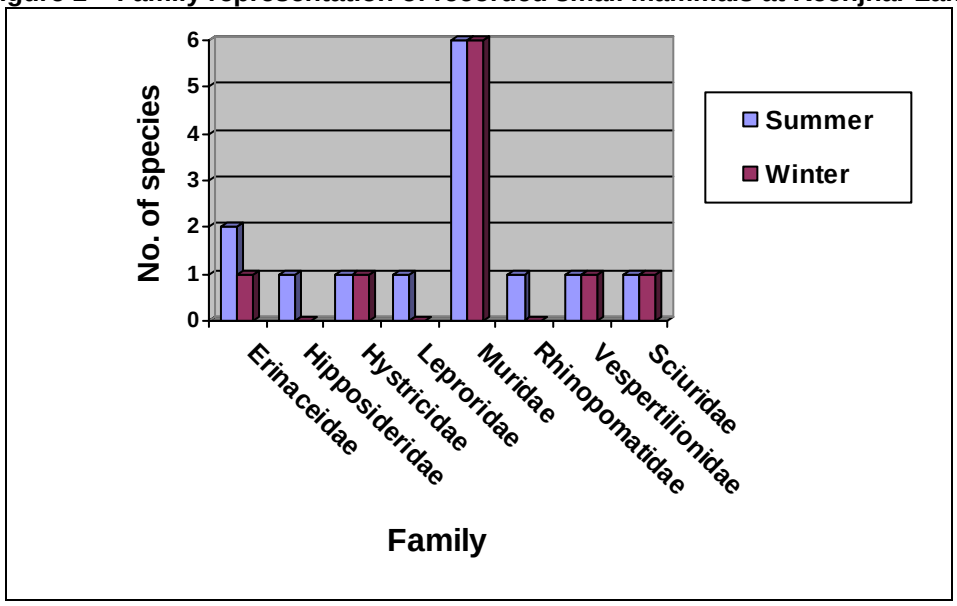
Table 11 – Total species recorded at Keenjhar Lake along with conservation status, feeding habits and activity habits

S. no	English Name	Scientific Name	Feeding Habit	Behavior	Status	Summer	Winter
1	Cairo spiny mouse	*Acomys cahirnus*	GRN	NC	LC	+	-
2	Leaf-nosed bat	*Asellia tridens*	INS	NC	LC	+	-
3	Sindh Rice Rat	*Bandicota bengalensis*	GRN	NC	C	+	+
4	Palm Squirrel	*Funambulus pennantii*	GRN	DR	C	+	+
5	Balochistan Gerbil	*Gerbilus nanus*	GRN	NC	C	-	+
6	Long-eared Hedgehog	*Hemiechinus collaris*	OMV	NC	LC	+	-
7	Indian crested porcupine	*Hystrix indica*	HRB	NC	C	+	+
8	Desert hare	*Lepus nigricolis*	HRB	NC	C	+	-
9	Indian Desert Jird	*Meriones hurrianae*	GRN	DR	LC	-	+
10	House mouse	*Mus musculus*	GRN	NC	C	+	-
11	Grey spiny mouse	*Mus saxicola*	GRN	NC	C	+	+
12	Short-tailed rat	*Nesokia indica*	GRN	NC	C	-	-
13	Indian Hedgehog	*Paraechinus micropus*	INS	NC	C	+	+
14	Kuhls' bat	*Pipistrellus kuhlii*	INS	NC	C	+	+
15	Common Rat	*Rattus rattus*	OMV	NC	C	+	+
16	Large mouse tailed bat	*Rhinopoma microphyllum*	INS	NC	LC	+	-
17	Indian Gerbil	*Tatera indica*	GRN	NC	C	+	+

3.2.3 Orders and families

Out of the 7 families *Muridae* was the most abundant (6 accounts in summer and winter) followed by *Erinaceidae*. The remaining families were represented by only one or two species. There is absence of some families in winter possibly due to migration or hibernation.

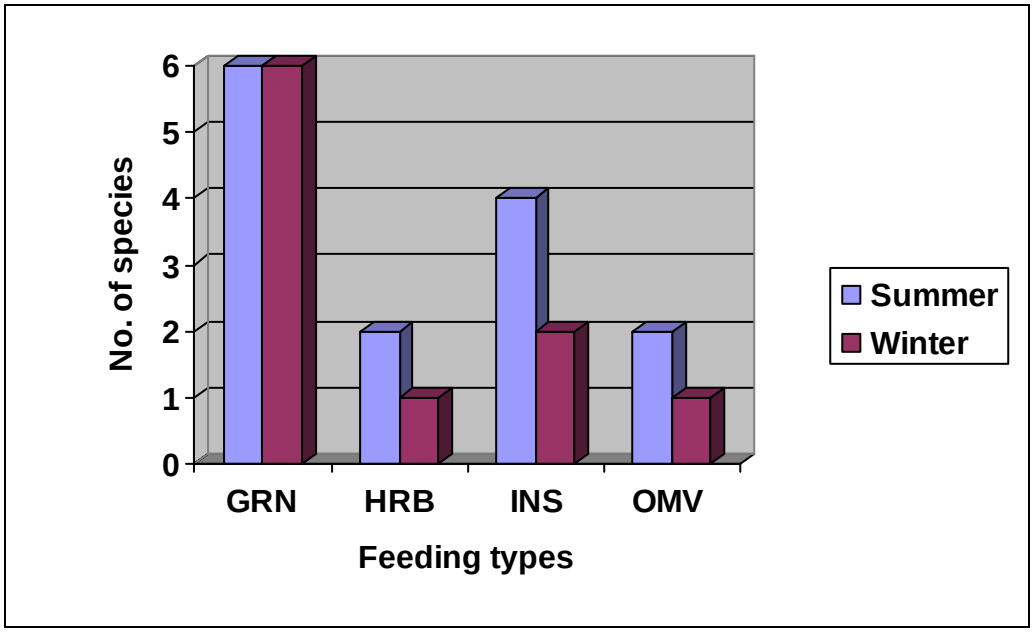
Figure 1 – Family representation of recorded small mammals at Keenjhar Lake



3.2.4 Feeding habits

Granivore's are the most prominent species found in Keenjhar followed by insectivores with herbivores and omnivores having the same representation. The majority of the species were recorded from agriculture land (nine species) with only one being found in open country.

Figure 2 – Distribution of feeding types across the species recorded at Keenjhar Lake



3.2.5 Habitat and conservation status

The areas around Keenjhar Lake are dominated by small mammal species adapted to desert conditions. The burrowing mammals are less in number and restricted to the alluvial patches of agricultural lands and along the bed of the Indus River. Small hills with loose rocky slabs provide natural home for non burrowing small mammal species like Indian bush-rat *Golunda ellioti* and Spiny mouse *Acomys cahirinus*. Some vegetation patches in the riparian areas provide shelter to hares and mongooses and human settlements provide breeding grounds for many species like Black rat and Indian field-mouse. Many bat species feed around agriculture areas and presumably roost in nearby trees.

Figure 3 – Number of species recorded from main habitat types at Keenjhar Lake

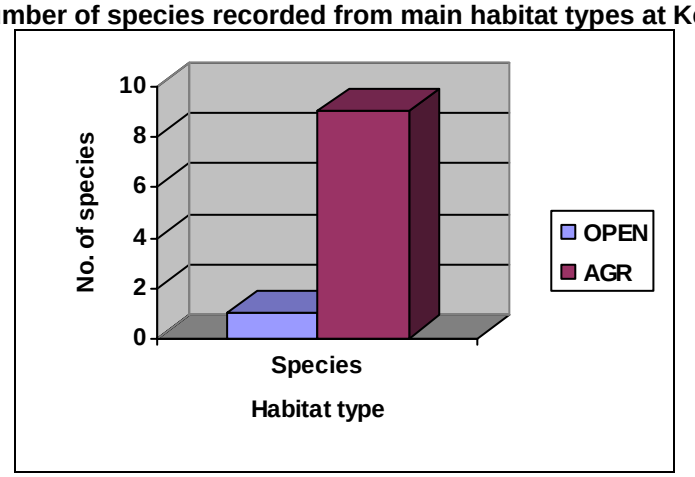
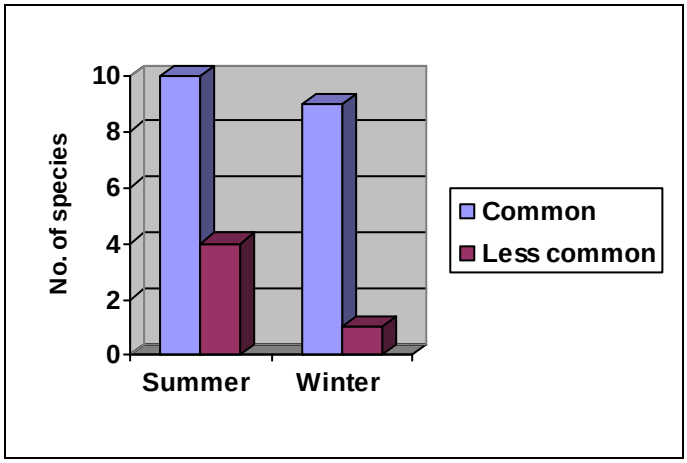


Figure 4 shows the number of species that fall under two local status categories i.e. common, less concern and common. Most of the species came under common (10 in summer and 9 in winter) followed by less frequent (4 in summer and 1 in winter).

Figure 4 – Distribution of small mammal status over the species and season at Keenjhar Lake



3.2.6 Threats and recommendations

3.2.5.1 Threats

- Coal mining and the associated disturbance near Chul is removing or degrading the habitat of species such as Little Indian field-mouse and Cairo spiny-mouse;

- Extraction of stone and quarrying around the lake peripheries are destroying the habitat of many of the non-burrowing species;

- The Jogi, Bheel and Bar communities are involved in trapping small mammal species, especially Desert Hare and Indian Porcupine;

- The current heightening of the lakes embankment is increasing the disturbance of the area. It is also envisaged that increased water levels will also increase the water-logging of adjacent areas resulting in flooding of burrowing mammal habitats.

3.2.5.2 Recommendations

- The relevant authorities should ensure that any illegal mining is stopped (Keenjhar Lake is a designated Wildlife Sanctuary). If these activities are to be carried out then they should be only in prescribed areas and that some areas are left undisturbed from any such activity;

- The Sindh Wildlife Department should strictly enforce the Wildlife act and discourage the hunting of small mammals. Alternatively, community managed game reserves could be initiated and hunting of such species could be brought under licensing controlled by the local communities which in turn with provide financial incentives for community to protect wildlife;

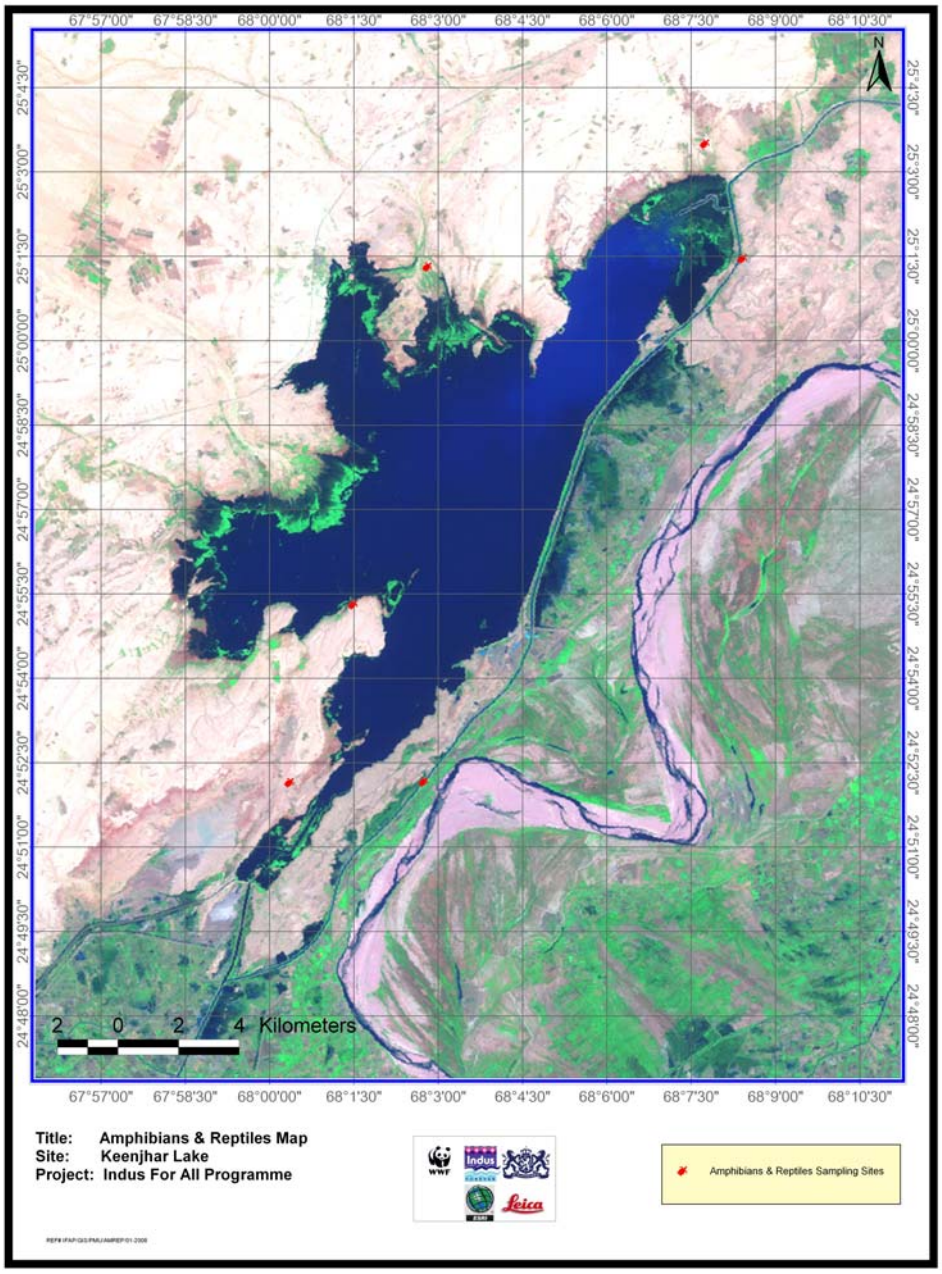
- Sindh Wildlife Department and/or Sindh Environmental should monitor the affects of the heightened embankments and create similar habitats to replace any lost or degraded habitats

3.3 Reptiles and amphibians

3.3.1 Sampling locations

Map 5 below shows the locatios of trapping sites for reptiles and amphibians at Keenjhar Lake. Details of the sampling points can be found in the annexure document

Map 5 – Showing sampling locations for reptiles and amphibians at KeenjharLake



3.3.2 Species account

In the summer studies, 17 species out of 48 possibly distributed species of amphibians and reptiles were observed or collected. To add to the number of species recorded during the summer, the author repeated the survey in the beginning of the winter season and observed and collected 6 additional species including 2 species of freshwater turtles i.e. *Lissemys punctata andersoni* and *Aspideretes gangeticus,* one species of gecko i.e. *Cyrtopodion kachhense kachhense*, lacertids *Ophisops jerdonii*, Boa i.e. *Eryx conicus* and a species of colubrid snake *Spalerosophis atriceps*, all of which were not represented in the previous survey. Thus 23 species of herpetiles were recorded out of all possible 48 species from the study area. The amphibians are represented by 3 species belonging to 3 genera and 2 families. Among the reptiles, chelonians are represented by 6 species belonging to 5 genera and 2 families. Lizards outnumber all the groups of reptiles, represented by 21 species belonging to 13 genera and 7 families. Snakes are the second dominant group of herpetiles in the study area and are represented by 19 species belonging to 15 genera and 6 families. A comprehensive list of species collected both in summer and winter is provided in the annex document.

Image 4 – Reptile habitat at Keenjhar Lake

Image 5 – Reptile habitat at Keenjhar Lake

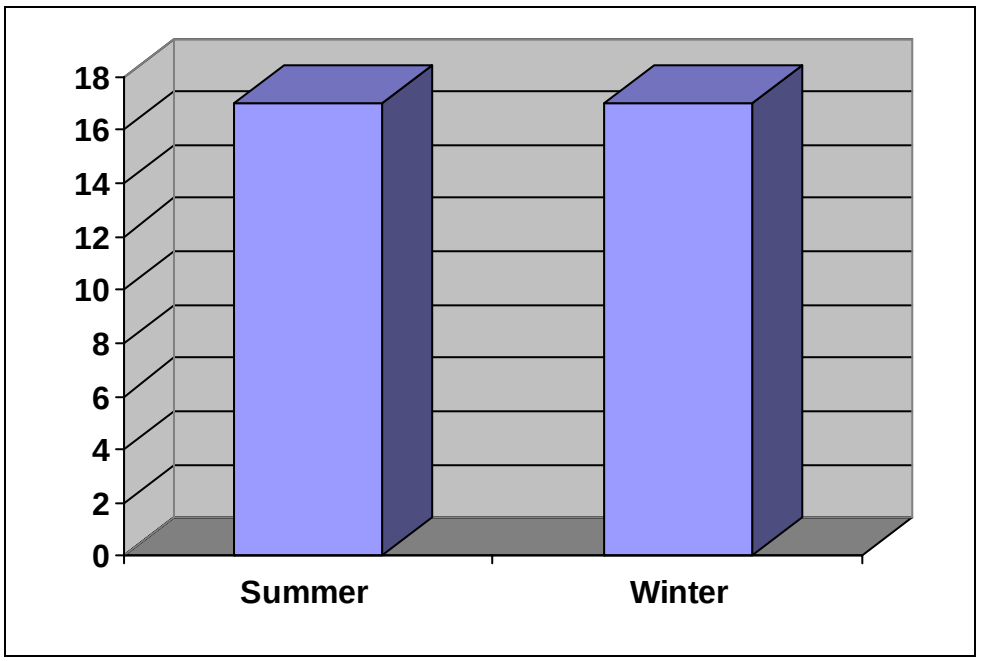
The comparison of various diversity parameters shown in **Table 12** is indicative of higher diversity of herpetiles in summer studies. Though the richness of both summer and pre-winter observation and collection of herpetiles is equal yet the Shannon diversity index and the evenness of summer studies is somewhat higher than the pre-winter studies. Figure 5 gives an account of number of species recorded over winter and summer.

Table 12 – Comparison of amphibian and reptilian diversity during summer and pre-winter studies at Keenjhar Lake

S. No.	Species Name	Total	Summer	Winter
1.	*Bufo stomaticus*	74	74	0
2.	*Euphlyctis c. cyanophlyctis*	32	26	06
3.	*Hoplobatrachus tigerinus*	50	45	05
4.	*Lissemys punctata andersoni*	04	0	04
5.	*Aspideretes gangeticus*	02	0	02
6.	*Eublepharis macularius*	13	13	0

S. No.	Species Name	Total	Summer	Winter
7.	*Uromastyx hardwickii*	22	08	14
8.	*Calotes v. versicolor*	28	28	0
9.	*Trapelus megalonyx*	12	12	0
10.	*Trapelus agilis pakistanensis*	49	35	14
11.	*Trapelus rubrigularis*	08	08	0
12.	*Cyrtopodion scaber*	25	17	08
13.	*Cyrtopodion k. kachhense*	07	0	07
14.	*Hemidactylus flaviviridis*	70	54	16
15.	*Acanthodactylus cantoris*	24	19	05
16.	*Ophisops jerdonii*	04	0	04
17.	*Varanus bengalensis*	48	26	22
18.	*Eryx johnii*	08	08	0
19.	*Eryx conicus*	01	0	01
20.	*Ptyas m. mucosus*	13	11	02
21.	*Spalerosophis atriceps*	04	0	04
22.	*Xenochrophis p. piscator*	11	09	02
23.	*Echis carinatus sochureki*	22	18	04
	Total (number of individuals collected)	**531**	**411**	**120**

Figure 5 – Number of reptile and amphibian species recorded from Keenjhar Lake over winter and summer



3.3.3 Species diversity

Figures 6 and 7 give details of the species diversity and evenness of reptiles and amphibians over summer and winter.

Figure 6 – Evenness of reptile and amphibian species at Keenjhar Lake

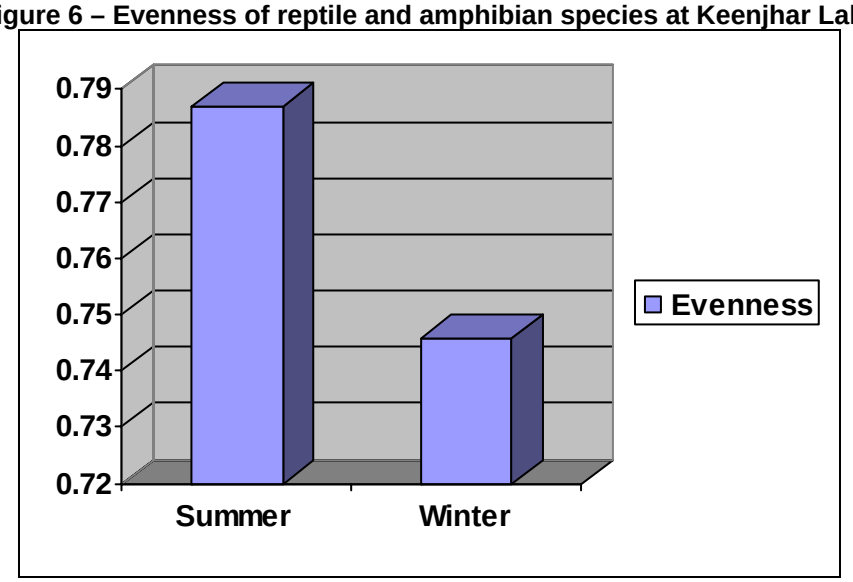
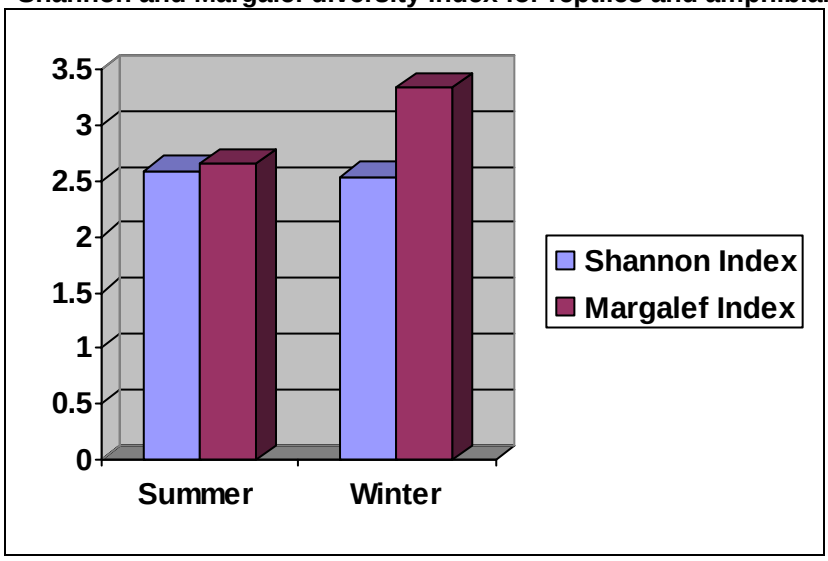


Figure 7 – Shannon and Margalef diversity index for reptiles and amphibians



It can be inferred that species diversity over summer and winter are quite similar. However evenness is much less in winter, which given the nature of reptiles (being cold-blooded) is acceptable.

3.3.4 Threat and recommendations

3.3.4.1 Threats

- The lake is facing the scarcity of freshwater over the years due to which the population of freshwater turtles is adversely affected, thus the natural balance of aquatic ecosystem is disturbed;

- Local people are heavily engaged in deforestation and logging activities. This is leading towards the habitat destruction for the associated herpetofauna.

- Pollutants from various sources including pesticides from agricultural lands and effluents from different industries pose serious threats to the precious freshwater turtles of the lake. The lake being tourist spot is triggering the situation through water contamination.

- Locals regard all the lizards and snakes as their enemy and so they kill every individual that they encounter, to show their enmity.

- A large number of reptiles are being collected and illegally exported to different countries by snake charmer groups, depleting their population in the environs of the lake.

- Road-kills of *Varanus* species (Monitor lizards) are very common around this lake.

3.3.4.2 Recommendations

- Lack of awareness and education among the locals is the major threat to the amphibian and reptilian fauna. This could be avoided by educating the locals and Wildlife officials through trainings, workshops, pamphlets and brochures, highlighting the importance of amphibians and reptiles of the area;

- There should be a complete ban on the collection of reptiles for un-scientific purposes including its illegal trade. The collection of venomous snakes for the scientific purposes should only be allowed after its permission from the concerned quarters.

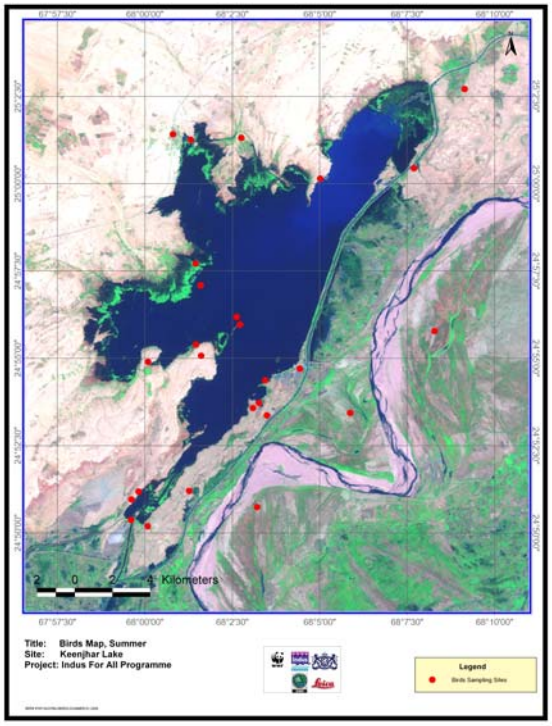
- A comprehensive and regular survey for at least a period of two years of freshwater turtles population is necessary to evaluate the current status and suitability for captive breeding. This in turn could be one of the alternate sources for the livelihood of local communities.

- To protect and conserve the vital species of amphibians and reptiles, there should always be the signboards on the roads, depicting the importance of nearby heavily populated amphibian or reptile species and the speed of vehicles must remain within limits accordingly.

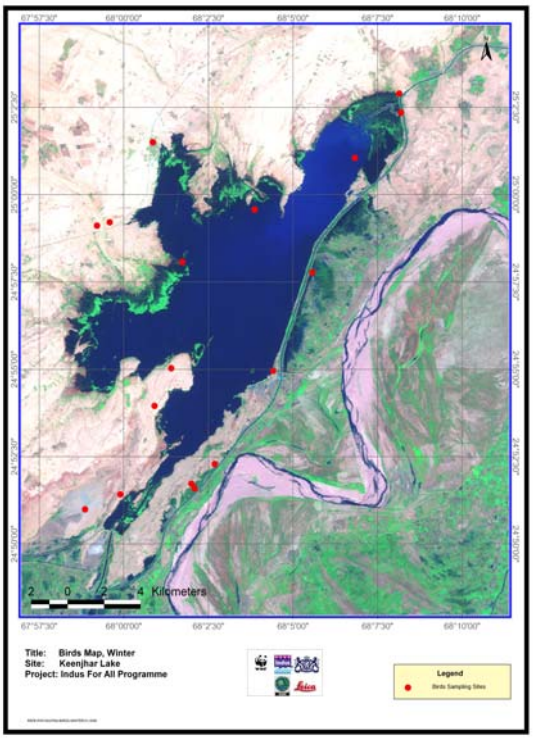
3.4 Birds

3.4.1 Sampling sites

Maps 5 and **6** show the summer and winter observation points for birds at Keenjhar Lake. Details of the sampling points can be found in the annexure document**.**



Map 6 – Bird observation points for Keenjhar Lake in summer



Map 7 – Birds observation points for Keenjhar Lake in winter

3.4.2 Species accounts for summer

A total of 57 species were recorded during the summer survey. **Table 13** shows the species with their status, occurrence and number recorded at Keenjhar Lake.

Table 13 – List of avifauna recorded from Keenjhar Lake during summer

No.	Common Name	Scientific Name	Status	Occurrence	Observed Number
1	Little Grebe/Dabchick	*Tachybatus ruficollis*	Common	Resident	446
2	Little Cormorant	*Phalacrocorax niger*	Common	Resident	136
3	Yellow Bittern	*Ixobrychus sinensis*	Scarce	Resident	09
4	Black Bittern	*Ixobrychus flavicollis*	Scarce	Summer breeder	06
5	Indian Pond Heron	*Ardeola grayii*	Common	Resident	209
6	Cattle Egret	*Bubuleus ibis*	Common	Resident	59
7	Little Egret	*Egretta garzette*	Common	Resident	101
8	Purple Heron	*Ardea purpurea*	Scarce	Irs-year round visitor	05
9	Black Shouldered	*Elanus caeruleus*	Scarce	Resident	05

	Kite				
10	Brahminy Kite	*Haliastur Indus*	Scarce	Resident	10
11	Osprey	*Pandion haliaetus*	Scarce	Winter visitor	01
12	Indian Grey Partridge	*Francolinus pondicerianus*	Scarce	Resident	04
13	White-breasted Water hen	*Amaurornis phoenicurus*	Sarce	Resident	05
14	Black winged Stilt	*Himantopus himantopus*	Common	Resident	36
15	Red-wattled Lapwing	*Hoplopterus indicus*	Common	Resident	201
16	Indian River Tern	*Sterna aurantia*	Common	Resident	283
17	Black-bellied Tern	*Strena acuticanda*	Rare	Resident	05
18	Whiskered Tern	*Chlidonias hybridus*	Scarce	Irs-year round visitor	06
19	Little Tern	*Sterna albifrons*	Common	Summer visitor	12
20	Chestnut-bellied Sand grouse	*Pterocles exustus*	Common	Resident	10
21	Blue Rock Pigeon	*Columba livia*	Common	Resident	126
22	Collared Dove	*Streptopelia decaocto*	Common	Resident	121
23	Little Brown Dove	*Streptopelia senegalensis*	Common	Resident	127
24	Common Koel	*Eudynamys scolopacea*	Common	Summer visitor	08
25	Common Crow Pheasant	*Centropus sinensis*	Common	Resident	27
26	White-breasted Kingfisher	*Halcyon smyrnensis*	Common	Resident	33
27	Pied Kingfisher	*Ceryl rudis*	Common	Resident	42
28	Little Green Bee-eater	*Merops orientalis*	Common	Resident	124
29	Ashy-crowned Finch Lark	*Eremopterix grisea*	Common	Resident	20
30	Desert Lark	*Ammomanes desert*	Scarce	Resident	02
31	Crested Lark	*Galerida cristata*	Common	Resident	34
32	Common/Barn Swallow	*Hirundu rustica*	Common	Winter visitor	19
33	Wire-tailed Swallow	*Hirundu smithi*	Common	Resident	53
34	Paddy-field Pipit	*Anthus rufulus*	Scarce	Resident	01
35	White-cheeked Bulbul	*Pycnonotus leucogenys*	Common	Resident	56
36	Red-vented Bulbul	*Pycnonotus cafer*	Common	Resident	13
37	Pied Bush Chat	*Saxicola caprata*	Common	Resident	43
38	Indian Robin	*Saxicoloides fulicata*	Common	Resident	36
39	Plain Coloured Prinia	*Prinia inornata*	Common	Resident	33
40	Common Babbler	*Turdoides caudatus*	Common	Resident	58
41	Striated Babbler	*Turdoides earlei*	Common	Resident	08
42	Purple Sun Bird	*Nectarinia asiatica*	Common	Resident	64
43	Bay-Backed Shrike	*Lanius vittatus*	Scarce	Resident	02
44	Great Grey Shrike	*Lanius excubitor*	Scarce	Resident	03
45	Black Drongo	*Dicrurus macrocercus*	Common	Resident	42

46	Indian House Crow	*Corvus splendens*	Common	Resident	324
47	Common Myna	*Acredotheres tristis*	Common	Resident	250
48	Bank Myna	*Acredotheres ginginiamus*	Common	Resident	251
49	Indian House Sparrow	*Passer domesticus*	Common	Resident	636
50	Yellow-t throated Sparrow	*Petronia xanthocollis*	Common	Summer breeder	39
51	Streaked Weaver	*Ploceus manyar*	Common	Resident	155
52	Indian Tree-Pie	*Demdrocitta vagabunela*	Scarce	Resident	01
53	Green Sandpiper	*Tringa ochropus*	Scarce	Winter visitor	02
54	Oriental Sky Lark	*Alanda gulgula*	Common	Resident	10
55	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	Scarce	Resident	04
56	Yellow- bellied Prinia	*Priniaflaviventris*	Scarce	Resident	02
57	Little/House Swift	*Apus affinis*	Common	Resident	54
Total					4282

3.4.3 Species account for winter

During the winter surveys, the main lake, associated marshes, agricultural fields, vicinity of villages, fish farm areas, grass fields, bands of the lake and another Wetland viz Jhol Dhand were surveyed. A total of 98 species of birds were recorded. Out of which 51 were resident, 42 winter visitors, 03 were irregular year-round visitors and 02 passage migrants. Most of the birds were found on or near the wetland habitats. A pair of Pallas's fishing eagle was found nesting on Eucalyptus near Jakhro fish form. Among the threatened species, the black-bellied tern which is a near threatened species was recorded. On the nearby wetland called Jhol Dhand, some important species such as greater flamingo, Pallid Harrier, Common Kestrel, Imperial Eagle, Steppe Eagle and Chestnut bellied sandgrouse were recorded.

A total of 13,419 birds from the area were recorded. The major threats to the birds of the area particularly the water-birds, is large scale disturbance and hunting activities over the lake. There also were a lot of fishing nets and bird nets in the lake.

Table 14 – Avifauna of Keenjhar Lake recorded during winter surveys

S.no	Common Name	Scientific Name	Status	Occurrence	Obser. No.
1	Little Grebe	*Tachybaptus ruficollis*	Common	Resident	82
2	Little Cormorant	*Phalacrocorax niger*	Common	Resident	41
3	Black-Crowned Night Heron	*Nycticorax nycticorax*	Less Common	Resident	05
4	Indian Pond Heron	*Ardeola grayii*	Common	Resident	89
5	Cattle Egret	*Bubulcus ibis*	Common	Resident	16
6	Little Egret	*Egretta garzetta*	Common	Resident	129
7	Intermediate Egret	*Mesophoyx intermedia*	Common	Year-round Visitor	31
8	Great White Egret	*Casmerodius alba*	Common	Winter Visitor	131
9	Purple Heron	*Ardea purpurea*	Less Common	Year-round Visitor	02
10	Gadwall	*Anas strepera*	Common	Winter Visitor	09
11	Common Teal	*Anas crecca*	Common	Winter Visitor	124
12	Pintail	*Anas acuta*	Common	Winter Visitor	71

13	Shoveller	*Anas clypeata*	Common	Winter Visitor	400
14	Common	*Aythya ferina*	Common	Winter Visitor	291
15	Tufted Duck	*Aythya fuligula*	Common	Winter Visitor	467
16	Black-sholdered Kite	*Elanus caeruleus*	Less Common	Resident	07
17	Black Kite	*Milvus migrans*	Common	Resident	60
18	Brahminy Kite	*Haliastor indus*	Less Common	Resident	02
19	Pallas's Fishing Eagle	*Haliaeetus leucoryphus*	Scarce	Resident	02
20	Eurasian Griffon Vulture	*Gyps fulvus*	Common	Winter Visitor	10
21	Marsh Harrier	*Circus aeruginosus*	Common	Winter Visitor	22
22	Greater Spotted Eagle	*Aquila clanga*	Less Common	Winter Visitor	04
23	Steppe Eagle	*Auila nipalensis*	Common	Resident	46
24	Osprey	*Pandion haliaeetus*	Less Common	Winter Visitor	03
25	Common Kestrel	*Falco tinnunculus*	Less Common	Winter Visitor	03
26	Indian Grey Partridge	*Francolinus pondicerianus*	Common	Resident	11
27	White-breasted Water-hen	*Amaurornis phoenicurus*	Less Common	Resident	02
28	Common Moor-hen	*Gallinula chloropus*	Common	Resident	40
29	Common or Black Coot	*Fulica atra*	Common	Winter Visitor	5162
30	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	Less Common	Resident	16
31	Black-winged Stilt	*Himantopus himantopus*	Common	Resident	30
32	Little Ringed Plover	*Charadrius dubius*	Less Common	Winter Visitor	04
33	Red-wattled Lapwing	*Hoplopterus indicus*	Common	Resident	81
34	White-tailed Lapwing	*Chettusia leucura*	Less Common	Winter Visitor	06
35	Little Stint	*Calidris minuta*	Common	Winter Visitor	34
36	Common Snipe	*Gallinago gallinago*	Less Common	Winter Visitor	02
37	Marsh Sandpiper	*Tringa stagnatilis*	Less Common	Passage migrant	02
38	Green Shank	*Tringa nebularia*	Less Common	Winter Visitor	02
39	Green Sandpiper	*Tringa ochoropus*	Common	Winter Visitor	12
40	Wood Sandpiper	*Tringa glareola*	Less Common	Winter Visitor	03
41	Common Sandpiper	*Actitis hypoleucos*	Less Common	Winter Visitor	07
42	Great Black Headed Gull	*Larus ichthyaetus*	Common	Winter Visitor	112
43	Black-headed Gull	*Larus ridibundus*	Common	Winter Visitor	1543
44	Herring Gull	*Larus argentatus*	Common	Winter Visitor	291
45	Gull-billed Tern	*Gelochelidon nilotica*	Common	Winter Visitor	11
46	Indian River Tern	*Sterna aurantia*	Common	Winter Visitor	50
47	Little Tern	*Sterna albifrons*	Common	Winter Visitor	07
48	Whiskered Tern	*Chlidonias hybridus*	Common	Year-round Visitor	199
49	Blue Rock Pigeon	*Columba livia*	Common	Resident	67
50	Indian Collared Dove	*Streptopelia decaocto*	Common	Resident	85

51	Little Brown Dove	*Streptopelia senegalensis*	Common	Resident	49
52	Rose-ringed Parakeet	*Psittacula krameri*	Less Common	Resident	06
53	Crow-pheasant	*Centropus sinensis*	Less Common	Resident	04
54	Syke's Nightjar	*Caprimulgus mahrattensis*	Less Common	Resident	07
55	White-throated Kingfisher	*Halcyon smyrnensis*	Common	Resident	13
56	Common Kingfisher	*Alcedo atthis*	Less Common	Resident	03
57	Small Pied Kingfisher	*Ceryle rudis*	Common	Resident	30
58	Little Green Bee-eater	*Merops orientalis*	Less Common	Resident	04
59	Indian Roller	*Coracias benghalensis*	Less Common	Resident	05
60	Hoopoe	*Upupa epops*	Less Common	Winter Visitor	04
61	Desert Finch-lark	*Ammomanes deserti*	Less Common	Resident	06
62	Crested Lark	*Galerida cristata*	Common	Resident	20
63	Plain Sand Martin	*Riparia paludicola*	Common	Resident	179
64	Common Swallow	*Hirundo rustica*	Common	Winter Visitor	327
65	Paddy-field Pipit	*Anthus rufulus*	Common	Resident	36
66	Yellow Wagtail	*Motacilla flava*	Common	Winter Visitor	28
67	White Wagtail	*Motacilla alba*	Common	Winter Visitor	19
68	White-cheeked Bulbul	*Pycnonotus leucogenys*	Abundant	Resident	34
69	Blue-throat	*Luscinia svecica*	Less Common	Winter Visitor	03
70	Pied Bush-chat	*Saxicola caprata*	Less Common	Resident	05
71	Desert Wheatear	*Oenanthe deserti*	Less Common	Winter Visitor	08
72	Eastern Pied Wheatear	*Oenanthe picata*	Less Common	Winter Visitor	03
73	Indian Robin	*Saxicoloides fulicata*	Common	Resident	20
74	Cettis Warbler	*Cettia cetti*	Scarce	Winter Visitor	02
75	Tawny /Plain Coloured Prinia	*Prinia, prinia inornata*	Scarce	Resident	02
76	Paddy-field Warbler	*Acrocephalus agricola*	Scarce	Winter Visitor	02
77	Clamorous Reed Warbler	*Acrocephalus stentoreus*	Less Common	Winter Visitor	04
78	Lesser Whitethroat	*Sylvia curruca*	Less Common	Winter Visitor	04
79	Plain leaf Warbler	*Phylloscopus neglectus*	Less Common	Winter Visitor	07
80	Eurasian Chiffchaff	*Phylloscopus collybita*	Common	Winter Visitor	43
81	White-browed Fantail Fly catcher	*Rhipidura rhipidura*	Less Common	Resident	02
82	Common Babbler	*Turdoides caudatus*	Common	Resident	47
83	Striated Babbler	*Turdoides earlei*	Less Common	Resident	03
84	Jangle Babbler	*Turdoides striatus*	Less Common	Resident	12
85	Purple Sunbird	*Nyctarinia asiatica*	Less Common	Resident	05
86	Isabelline Shrike	*Lanius isabellinus*	Less	Winter Visitor	02

			Common		
87	Bay-backed Shrike	*Lanius vittatus*	Less Common	Resident	02
88	Great Grey Shrike	*Lanius excubitor*	Less Common	Summer Visitor	05
89	Black Drongo	*Dicrurus macrocercus*	Common	Resident	22
90	Indian Tree-pie	*Dendrocitta vagabunda*	Less Common	Resident	03
91	Indian House crow	*Corvus splendens*	Common	Resident	50
92	Common Starling	*Stumus vulgaris*	Common	Winter Visitor	35
93	Common Myna	*Acridotheres tristis*	Common	Resident	37
94	Bank Myna	*Acridotheres ginginianus*	Common	Resident	100
95	Indian House Sparrow	*Passer domesticus*	Common	Resident	131
96	White-throated Munia	*Eodic malabarica*	Less Common	Resident	08
97	House Bunting	*Emberiza stiolata*	Less Common	Resident	13
98	Black bellied Tern	*Sterna acuticauda*	Scarce	Winter Visitor	02

3.4.4 Summer and winter comparison

The summer surveys in the area were undertaken from 14 June 2007 to 17 June 2007 and the winter surveys from 13 January 2008 to 16 January 2008. The locations visited were the South Western Bank, Western Bank, Southern Bund Side, Southern and Eastern Bank of the lake and the Jhol Dhand.

Figure 8 shows that the number of species collected was higher in the winter than in the summer. Along with 51 resident birds found in the winter there were 43 winter birds as well. **Figure 9** shows the number of orders, families and species recorded during winter and summer from Keenjhar Lake.

Figure 8 – Species occurrence in the study area showing their seasonal status

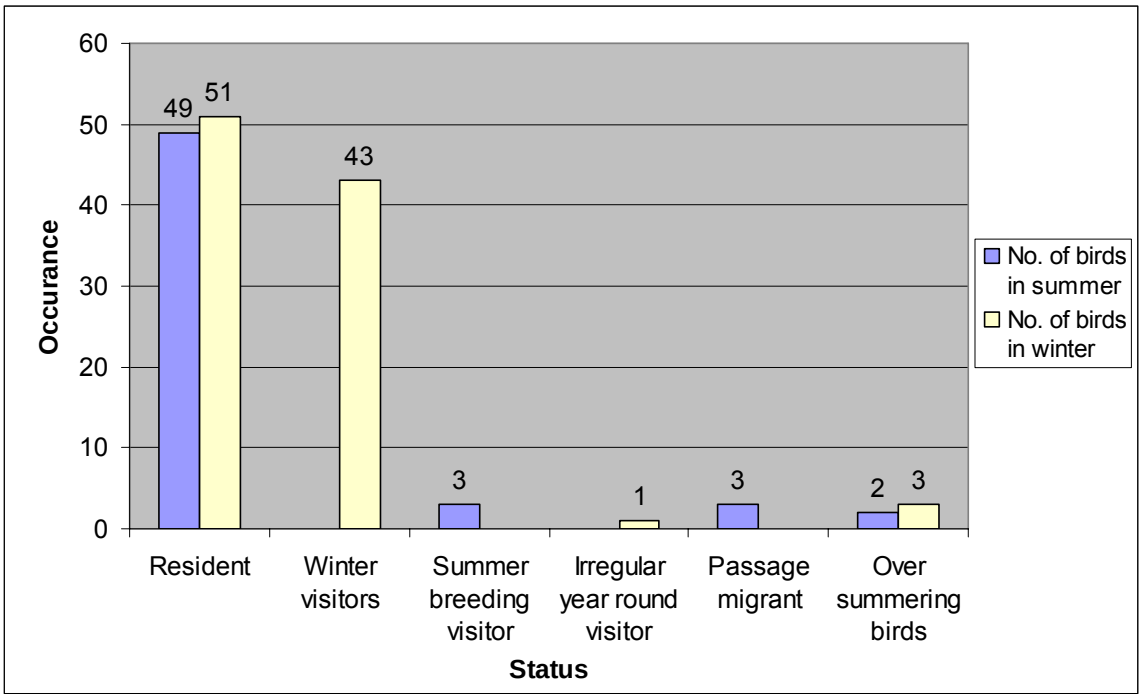
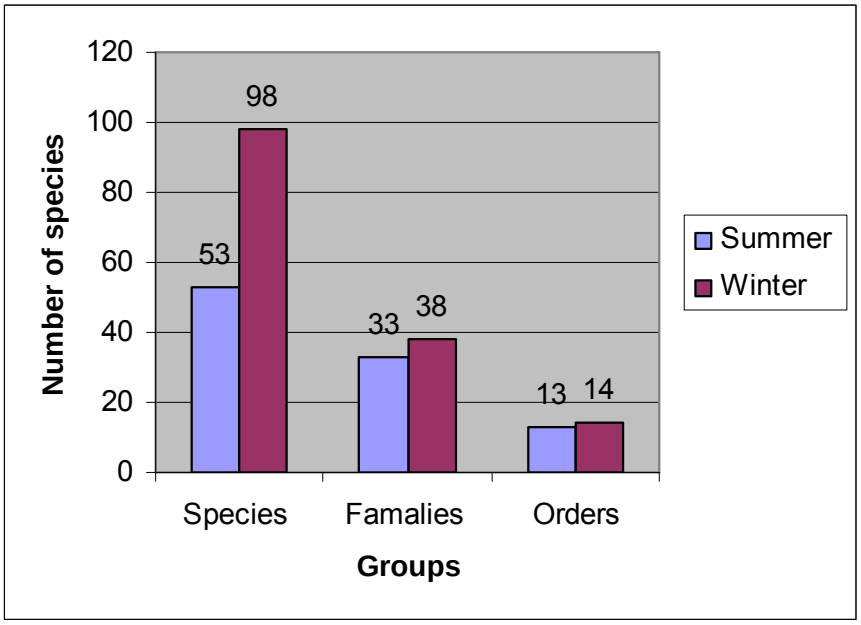


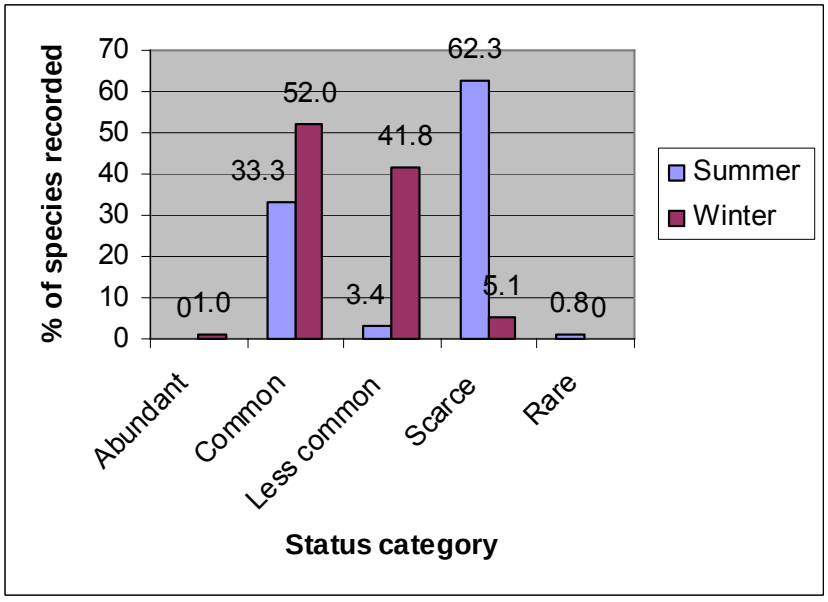
Figure 9 – Number of species, families and orders recorded during summer and winter seasons



3.4.5 Conservation status

Figure 10 shows the percentage of species under different status categories during winter and summer.

Figure 10 – Percentage of species recorded across status categories



In summer most of the bird species recorded was scarce or common whereas in winter they were common or less common.

3.4.6 Habitats:

The important bird habitats were the main lake, associated marshes, and

agricultural fields, vicinity of villages, fish farm area, grass fields and bunds of the lake. A total of 57 species of birds were recorded in the summer surveys while 98 species of birds were recorded in the winter surveys. Most of the birds were found on or near the wetland habitats. Among the threatened species, the Black-bellied tern which is a near threatened species was recorded. On the nearby wetland called Jhol Dhand, some important species such as Greater flamingo, Pallid Harrier, Common Kestrel, Imperial Eagle, Steppe Eagle and Chestnut bellied sandgrouse were recorded. A total of 13,419 birds from the area were recorded. The major threats to the birds of the area particularly the water-birds are large scale disturbance and hunting activities over the lake. Fishing and birds nets were also found in the lake.

3.4.7 Threats and recommendations

3.4.7.1 Threats

- There is eutrophication in the northern and western side of the lake as a result there is heavy growth of *Typha* and *Phragmites* along with exotic plant species which may be changing the habitat preferred by certain birds e.g. waders.
- Excavation of building material and quarrying is common on the banks of the lake. This is causing a high level of disturbance especially to shore birds. Both wintering and breeding activities may be affected by this activity;
- Likewise, the disturbance caused by tourism activities on the lake may can be causing the birds to migrate to other less-disturbed areas or move to other water bodies;
- Hunting and trapping of birds is very common is most areas of the lake, hunting of birds by hunters with guns and trapping of birds for sale on the roadside is probably one of the largest causes in bird population decline at the lake over the last few years
- There is lack of solid waste management and general quality of the lake may be declining, which may have a knock on affect to wintering and breeding birds that inhabit the lake
- The Sindh Wildlife Department has very staff at the lake to patrol and tackle this issue of hunting and trapping.

3.4.6.2 Recommendations

- There is a need for a conservation management plan for the long-term administration the lake, which is also a Wildlife Sanctuary and Ramsar site.
- Jhampir, Ameer peer and Daulat pur areas of the lake should be developed for ecotourism so that communities can get a direct benefit from the lake and therefore feel a vested interest in the conservation of the area. Eco-tourism would depend heavily on the presence of both bird diversity and sizable populations
- There is a need to establish an information centre and research conservation centre. Sign boards on the public areas and roads need to be placed to indicate the limits of Wildlife Sanctuary and importance of the wetland as a Ramsar site.

3.5 Freshwater fisheries

3.5.1 Species account

A total of 55 species were recorded from Keenjhar Lake comprising of 9 Orders (*Beloniformes, Channiformes, Clupeiformes, Cypriliformes, Mugiliformes, Osteoglossiformes, Perciformes, Siluriformes* and *Synbranchiformes*) and 14

families. Table 15 below gives an account of each species recorded along with ecological aspects.

Table 15 – Ecological aspects of fish fauna of Keenjhar Lake

S.no	Species	Feeding habit	Habitat	Max. size (cm)	Commercial value	Country status	Status in study area
1	*Gudusia chapra*		Middle and upper reaches of rivers	20	Low	Common	Less common
2	*Chitala chitala*	Aquatic insects, mollusks, shrimps and small fishes	Freshwater rivers, lakes	120	High	Less common	Less common
3	*Notopterus notopterus*	Insects, fish crustaceans	Standing and sluggish waters of lakes, floodplains, canals and ponds	25	Low	Common	Common
4	*Chula cachous*	Insect larvae and plant matter	Ponds, ditches and rivers	6	Low	Common	Common
5	*Salmophasia bacaila*	Larvae and adults of insects	Slow running streams, rivers, ponds	15	Low	Common	
6	*Securicula gora*	Insects, insect larvae and crustaceans	Rivers and canals	22	Low	Common	Less Common
7	*Amblypharyngodon mola*	Insects, insect larvae and crustaceans	Ponds, canals, slow-moving streams, nullahs and paddy fields	20	Low	Common	
8	*Aspidoparia morar*	Phytoplanktons, insect larvae	Streams and ponds	17	Low	Common	Common
9	*Barilius vagra*	Phytoplanktons, insect larvae	Hill streams with gravelly and rocky bottom	12	Low	Common	Common
10	*Esomus danricus*		Ponds, weedy ditches	9	Low	Common	Common
11	*Rasbora daniconius*	Aquatic insects and detritus.	Ditches, ponds, canals, streams, rivers	15	Low	Less common	Less common
12	*Cirrhinus mrigala*	Juvenile omnivorous, adults herbivorous, feeds on plankton, but also grazes on algae	Rivers, lakes	100	Very high	Common	Common
13	*Cirrhinus reba*	Planktons, insect, plant material	Rivers, lakes, canals	30	Fairly good	Common	Common

14	*Gibelion catla*	Aquatic and terrestrial insects, detritus and phytoplankton	Rivers, lakes	180	Very high	Common	Less common
15	*Labeo calbasu*	Filamentous algae and diatoms	Slow-moving waters of rivers, and ponds	90	High	Common	Common
16	*Labeo dero*	Filamentous algae, diatoms and phytoplankton's	Shallow and slow moving waters of rivers	60	Fairly good	Common	Common
17	*Labeo dyocheilus pakistanicus*	Omnivorous fish depending upon phytoplankton's, zooplanktons and larvae of aquatic insects	Active currents of large rivers	90	Fairly good	Less Common	Less common
18	*Labeo gonius*	Plants, benthic algae, weeds	Rivers and lakes	150	Fairly good	Common	Common
19	*Labeo rohita*	Feeds on algae, Phytoplankton	Rivers and lakes	200	Very high	Common	Common
20	*Osteobrama cotio*	Feeds on aquatic insects	Rivers and lakes	15	Low	Common	Common
21	*Puntius chola*	Worms, crustaceans, insects and plant matter	Shallow water of streams, rivers, canals, beels, haors, ponds	15	Aquarium	Less Common	Less common
22	*Puntius sophore*	Phytoplanktons and algae	Rivers, streams and ponds	17	Aquarium	Common	Common
23	*Puntius ticto*	Crustaceans, insects and plankton	Still, shallow, marginal waters	10	Aquarium	Common	Common
24	*Systomus sarana*	Aquatic insects, shrimps, algae	Rivers, streams, lakes	40	Fairly good	Less Common	Common
25	*Cyprinus carpio*	Aquatic insects, crustaceans, annelids, mollusks, weed and tree seeds, wild rice, aquatic plants and algae	Slow flowing or standing water	120	Very high	Common	Common
26	*Hypophthalmichthys molitrix*	Phytoplankton and zooplankton	Standing or slow-flowing water of impoundme	100	Very high	Less common	Common

			nts				
27	*Hypophthalmichthys nobilis*	Phytoplankton and zooplankton	Lakes and impoundments	90	Very high	Less common	Less common
28	*Ctenopharyngodon idella*	Higher aquatic plants and submerged grasses; takes also detritus, insects and other invertebrates	Lakes, ponds, pools and backwaters of large rivers	150	Very high	Less common	Less common
29	*Sperata sarwari*	Small fish, crustaceans, insect larvae	Lakes and rivers	150	Very high	Less common	Common
30	*Mystus bleekri*	Crustaceans, insect larvae	Lakes, tanks, rivers, canals	15	Low	Common	Common
31	*Mystus cavasius*	Crustaceans, insect larvae	Rivers and lakes; also beels, canals, ditches, ponds, and inundated fields	40	Fairly good	Common	Common
32	*Mystus vittatus*	Shrimps, insects, mollusks	Standing and flowing waters of lakes and swamps	21	Fairly good	Common	Common
33	*Rita rita*	Insects, mollusks, shrimps and fishes	Rivers and estuaries	150	Very high	Less common	Rare
34	*Bagarius bagarius*	Insects, small fishes, frogs and shrimps	Rapid and rocky pools of large and medium-sized rivers	250	Very High	Common	Common
35	*Gagata cenia*	Insect larvae	Stagnat side pools of rivers	15	Low	Common	Common
36	*Nangra nangra*	Insect larvae	Shallow running waters with thick sand layer	7	Low	Rare	Rare
37	*Ompok bimaculatus*	Fish crustaceans and mollusks	Shallow streams and rivers with moderate currents	45	Low	Common	Common
38	*Wallago attu*	Smaller fish, crustaceans, and mollusks	Rivers, lakes and tanks	240	Very High	Common	Common
39	*Heteropneustes fossilis*	Omnivorous	Ponds, ditches, swamps and marshes	30	Low	Common	Common
40	*Ailia coila*	Insects and shrimps	Large rivers and connected waters	30	Low	Common	Common
41	*Clupisoma*	Insects,	Fresh water	60	Very high	Common	Rare

	garua	shrimps, other crustaceans	and tidal rivers				
42	*Clupisoma naziri*			24	Very high	Rare	Rare
43	*Eutropiichthys vacha*	Small fish and insects	Rivers, canals	40	High	Less common	Less common
44	*Sicamugil cascasia*	Small insects and phytoplanktons	Rivers pools and shallow running waters	14	Low	Common	Less common
45	*Xenentodon cancila*	Crustaceans, small fishes, insects	Rivers, ponds, canals	40	Fairly good	Common	Common
46	*Channa marulia*	Fish, frogs, snakes, insects, earthworms and tadpoles	Deep pools of rivers and lakes	180	Very high	Common	Common
47	*Channa punctata*	Worms, insects and small fish	Ponds, swamps, brackish water ditches	30	Low	Common	Common
48	*Chanda nama*	Zooplanktons, insect larvae	Standing and running waters; clear streams, canals, ponds	10	Aquarium	Common	Common
49	*Parambasis baculis*	Zooplanktons, insect larvae	Standing and running waters; clear streams, canals, ponds	5	Aquarium	Common	Common
50	*Parambasis ranga*	Invertebrates worms and crustaceans	Sluggish and standing water	8	Aquarium	Common	Common
51	*Glossogobius giuris*	Small insects, crustaceans and small fish	Freshwater and estuaries	35	Aquarium	Common	Rare
52	*Colisa fasciata*	Zooplanktons, insect larvae	Weedy environment of rivers, estuaries, ditches, ponds and lakes	12	Aquarium	Common	Common
53	*Colisa lalia*	Zooplanktons, insect larvae	Weedy environment of slow moving streams, rivulets and lakes	9	Aquarium	Common	Rare
54	*Oreochromis mossambicus*	Carnivorous /omnivorous, herbivorous or detritus feeders	Reservoirs, rivers, creeks, drains, ponds swamps and tidal creeks	39	High	Common	Common
55	*Mastacembelus armatus*	Benthic insect	Streams and rivers	90	Aquarium	Common	Common

		larvae, worms and some submerged plant material	with sand, pebble				

3.5.2 Orders and families

Out of the 55 species recorded from Keenjhar Lake the Order *Cypriniformes* were most abundant with 25 species (45.4% of all species) being represented followed by *Siluriformes* with 15 species (27.2% of all species) and *Perciformes* with 7 species (12.7% of all species. The remaining of the Orders was represented by one or two species. Out of the fourteen families recorded during the survey *Cyrpinidae* with 25 species (45.4%) followed by *Bagridae* and *Chaldidae* both with five species (9.1%). **Figures 11 and 12** give a graphical representation of the distribution of species of Orders and Families respectively.

Figure 11 – Number of species recorded over Orders at Keenjhar Lake

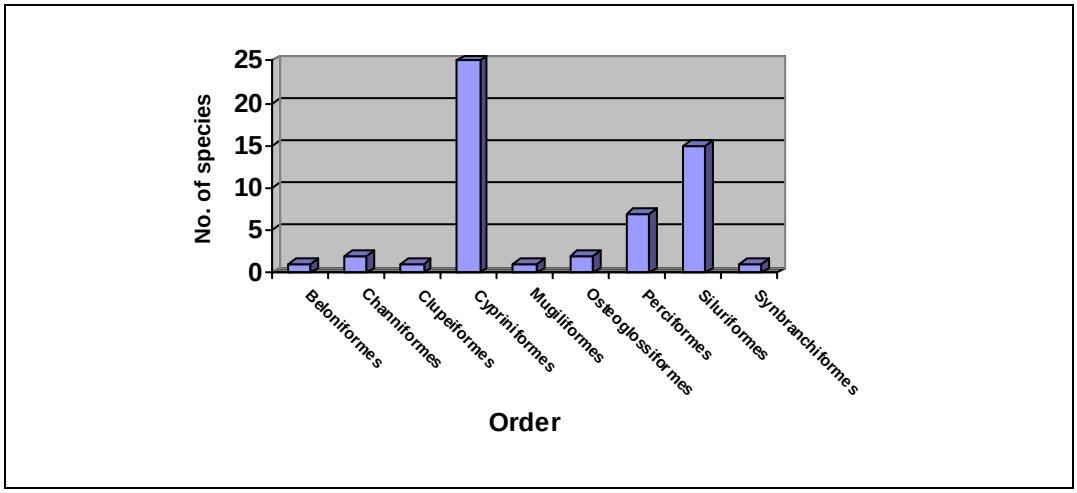
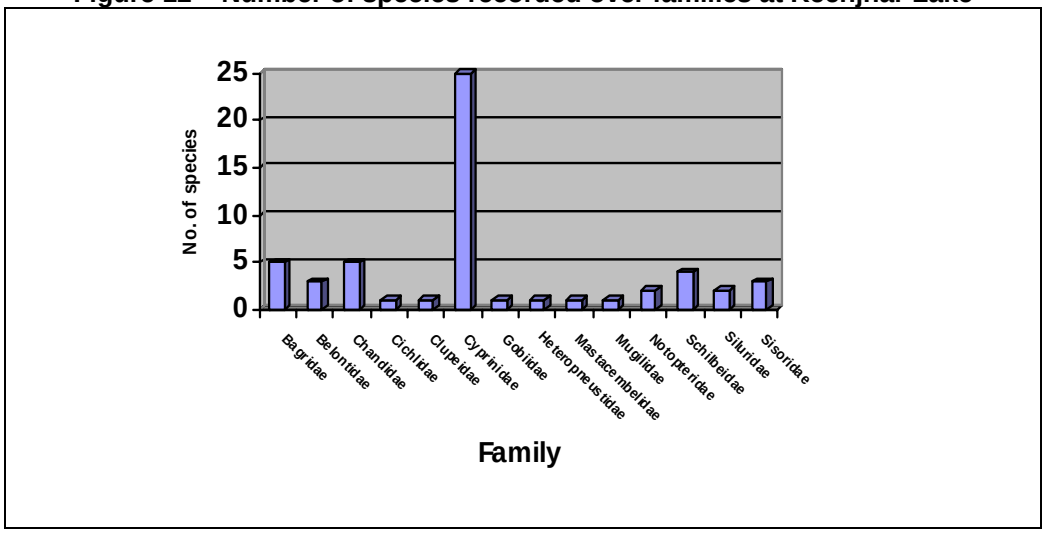


Figure 12 – Number of species recorded over families at Keenjhar Lake



3.5.3 Relative abundance and status

Relative abundance has been calculated on catch effort (per 100) and divided into four categories, Rare, Less Common, Common and Very Common. Table 16

below gives the relative abundance of each species along with local (relative) status and country status.

Table 16 – Relative abundance and status of fish fauna in Keenjhar Lake

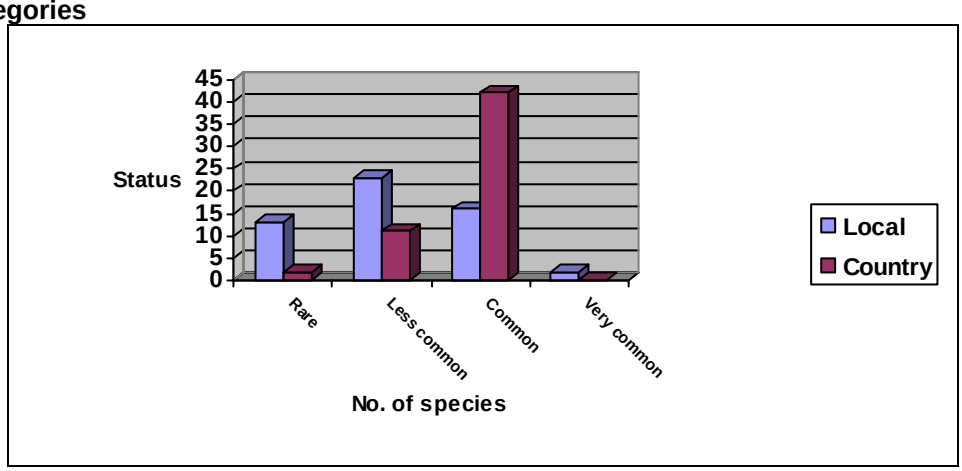
Sr. No	Fish Species	Catch per 100 efforts	Relative abundance*	Status in Keenjhar Lake	Status in country
1	*Gudusia chapra*	3	0.63	Rare	Common
2	*Chitala chitala*	2	0.42	Rare	Less common
3	*Notopterus notopterus*	8	1.69	Less common	Common
4	*Chela cachius*	5	1.06	Less common	Common
5	*Salmophasia bacaila*	6	1.27	Less common	Common
6	*Securicula gora*	5	1.06	Less Common	Common
7	*Amblypharyngodon mola*	4	0.85	Rare	Common
8	*Aspidoparia morar*	7	1.48	Less common	Common
9	*Barilius vagra*	7	1.48	Less common	Common
10	*Esomus danricus*	5	1.06	Less common	Common
11	*Rasbora daniconius*	4	0.85	Rare	Less common
12	*Cirrhinus mrigala*	7	1.48	Less common	Common
13	*Cirrhinus reba*	9	1.90	Less common	Common
14	*Gibelion catla*	4	0.85	Rare	Common
15	*Labeo calbasu*	6	1.27	Less common	Common
16	*Labeo dero*	5	1.06	Less common	Common
17	*Labeo dyocheilus pakistanicus*	7	1.48	Less common	Less Common
18	*Labeo gonius*	10	2.11	Common	Common
19	*Labeo rohita*	7	1.48	Less common	Common
20	*Osteobrama cotio*	16	3.38	Common	Common
21	*Puntius chola*	3	0.63	Rare	Less Common
22	*Puntius sophore*	18	3.81	Common	Common
23	*Puntius ticto*	15	3.17	Common	Common
24	*Systomus sarana*	3	0.63	Rare	Less Common
25	*Cyprinus carpio* Linnaeus	8	1.69	Less common	Common
26	*Hypophthalmichthys molitrix* (Valenciennes)	5	1.06	Less common	Less common

27	*Hypophthalmichthys nobilis*	4	0.85	Rare	Less common
28	*Ctenopharyngodon idella*	6	1.27	Less common	Less common
29	*Sperata sarwari*	10	2.11	Common	Less common
30	*Mystus bleekri*	15	3.17	Common	Common
31	*Mystus cavasius*	14	2.96	Common	Common
32	*Mystus vittatus*	11	2.33	Common	Common
33	*Rita rita*	8	1.69	Less common	Less common
34	*Bagarius bagarius*	12	2.54	Common	Common
35	*Gagata cenia*	7	1.48	Less common	Common
36	*Nangra nangra*	1	0.21	Rare	Rare
37	*Ompok bimaculatus*	14	2.96	Common	Common
38	*Wallago attu*	13	2.75	Common	Common
39	*Heteropneustes fossilis*	9	1.90	Less common	Common
40	*Ailia coila*	12	2.54	Common	Common
41	*Clupisoma garua*	3	0.63	Rare	Common
42	*Clupisoma naziri*	4	0.85	Rare	Rare
43	*Eutropiichthys vacha*	5	1.06	Less common	Less common
44	*Sicamugil cascasia*	6	1.27	Less common	Common
45	*Xenentodon cancila*	24	5.07	Very common	Common
46	*Channa marulia*	6	1.27	Less common	Common
47	*Channa punctata*	8	1.69	Less common	Common
48	*Chanda nama*	15	3.17	Common	Common
49	*Parambasis baculis*	16	3.38	Common	Common
50	*Parambasis ranga*	21	4.44	Very common	Common
51	*Glossogobius giuris*	3	0.63	Rare	Common
52	*Colisa fasciata*	8	1.69	Less common	Common
53	*Colisa lalia*	3	0.63	Rare	Common
54	*Oreochromis mossambicus*	24	5.07	Common	Common
55	*Mastacembelus armatus*	12	2.54	Common	Common
Total Specimens		473			

Rare = 0.00-1.00, Less Common = 1.10-2.00, Common = 2.10-3.50, Very common = > 3.5
*** No. of specimens of a particular species/ Total specimens*100**

Relative abundance was calculated and categorized into five divisions (Rare, Less Common, Common and Very Common). At country level Common species were the most abundant category (42 species, 76.4%) followed by Less Common (11 species, 20%) with very few representation from Rare or Very Common categories. Abundance at local (relative) level was dominated by Less common (23 species, 41.8%) followed by Common (16 species, 29%) and then Rare (13 species, 23.6%). Very common was only represented by two species (3.6%). **Figure 13** gives an account of both local and country status.

Figure 13 – Number of species recorded in local (relative) and country status categories



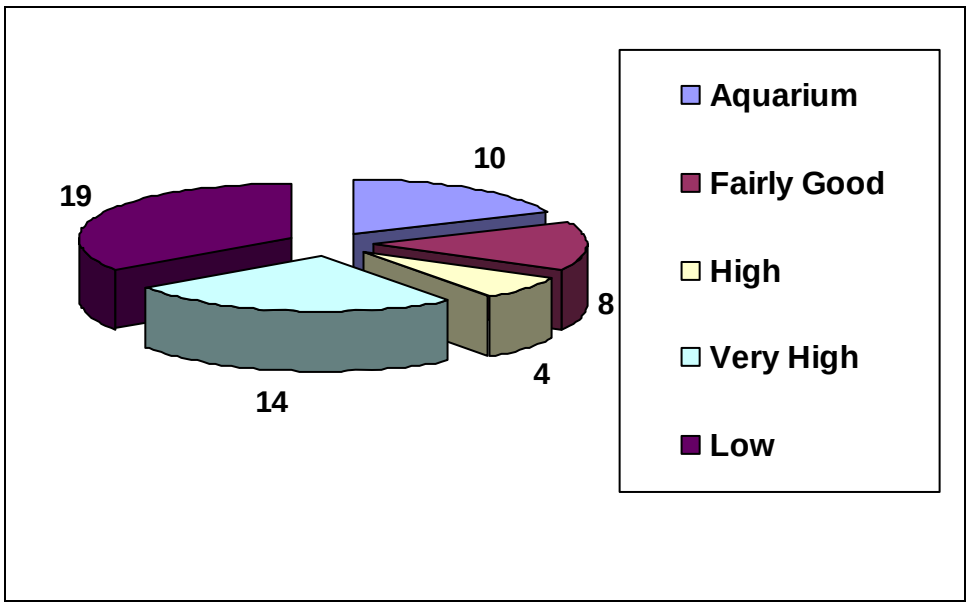
3.5.4 Economic status of fish species recorded from Keenjhar Lake

The majority of the fish recorded from Keenjhar Lake belongs to the low economic bracket (19 species, 34.5%), Very High (14 species, 25.5%) followed by Aquarium (10 species, 18.2%). Species with High or Fairly Good economic vales were represented by 12 species (21.8%). **Figure 14** gives an account of the distribution of species over the economic brackets.

Image 6 – Traditional fishing practices at Keenjhar Lake

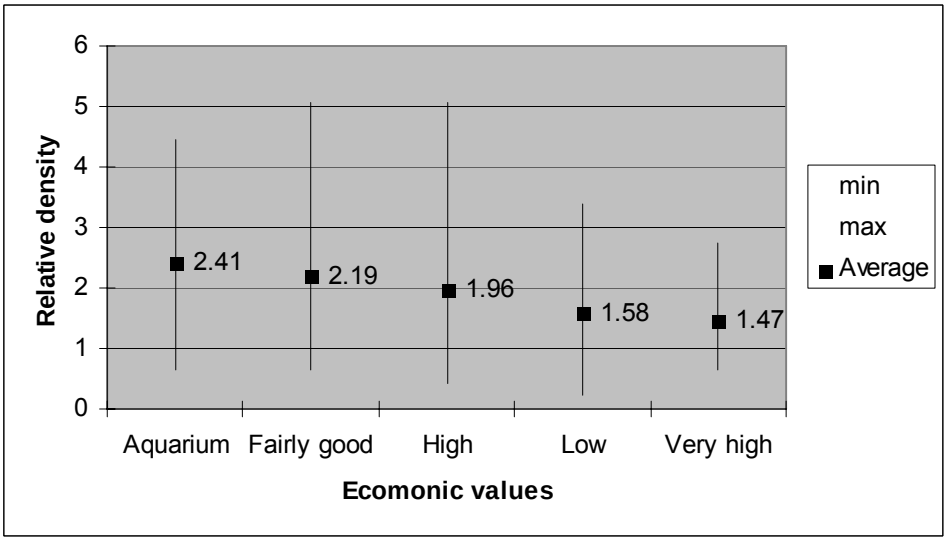
Image 7 – Local fishing nests at Keenjhar Lake

Figure 14 – Number of fish species recorded from each economic bracket



Looking at relative abundance across economic brackets, fish having Aquarium value had the highest average, however fish species having Fairly Good and High economic values had the highest maximums. Fish species having the highest economic values had the lowest relative abundance average and maximums, indicating that the pressure on such species is causing the populations to decrease. However, assuming this is the case; species having Low economic should theoretically have high abundance indices which is not the case. **Figure 15** shows the minimum, maximum and average of the relative abundance across the economic brackets.

Figure 15 – Minimum, maximum and average of the relative abundance across the economic brackets.



3.5.5 Brief on licensing system in Keenjhar Lake

The licensing system was introduced in Keenjhar Lake along with other four-water area of the Province during 1977 for betterment of Fishermen Community on one hand and to eliminate middlemen exploitation on the other. The fishermen

gave so poor response to the licensing system that the income never crossed rupees five lace. During the period 1992-93 to 1997-98 licenses system was abolished as per speech of then Finance Minister. Besides lake was also declared as wildlife sanctuary form 1993-94 and it was under the possession of Agriculture, Livestock Department where the fishing was completely banned up to 1996-97, when the possession of water area was transferred back to Fisheries department for introduction of mole system under the order of the then Chief Minister of Sindh.

After failure/cancellation of 'moles' system, licensing system was restored which remained operative up to 1998. Thereafter the lake was put into open auction in Rs. 688,000/= for the period 01.1.1999 to 30.06.2000 but on the agitation of Fishermen against auction system, it was decided in the meeting held by Director General, Livestock and Fisheries, deputy Commissioner, Thatta that Rs. 688.00/= be recovered from the fishermen and licenses be issued to them, as a result the Fishermen got the licenses of Rs. 519,000/= only.

The lake was put into open auction for the period 2000-2001 with Government bid of Rs. 27,52.000/= at 400% increase (enhanced by the then Minister) & fetched the bid of Rs. 15,65,00/= but same was not approved being a low bid. On the non-approval of lease 7 by the passage of the time the contractor backed out from his offer and demanded refund of Rs. 3,50,000/= deposited by him. Again the water area was put into open auction on 23.11.2001 for the period 2000-2001 & fetched bid Rs. 13,80,000/= against Government bid of Rs, 13,76,000/= (at 100%) out of which Rs. 10,80,000/= were recovered only

Again the lake was put into open auction for 2001-02 along with other water areas but fetched no bid.In the light of verbal instructions of the then Secretary, Agriculture Livestock & Fisheries Department during the visit of Keenjhar lake on 05.07.2001 the departmental operation was carried out with share of 1/4th to Fishermen, which is still in operation.

The lake was repeatedly put for open auction the year 2003-04 & on 21.05.2003, 09.06.2003, 28.06.2003, 05.07.2003, 23.4.2003 & 21.03.2004, after wide publicity, through newspapers but could not fetch any did due to political interference and acute shortage of commercial carp fishes because of drought conditions which affected the breeding and propagation of fishes in River Indus. Looking to the shortage of major commercial fishes in the lake, Fisheries Department stocked 250,000/= fish seed in to the lake during 2002-03. The department has prepared the scheme namely "Improvement & Restoration of Lake Ecosystem and Control of Eutrophication & Vegetation in the Lake" under which fish seed production capacity of Chillya fish Hatchery is being enhanced and on completion 1000,000 fingerlings will be stocked in the lake annually.

Table 17 – Fish production in monetary terms over the years

S. NO	YEAR	AMOUNT	REMARKS
1	1979-80	402450	-do-
2	1980-81	355850	-do-
3	1981-82	384700	-do-
4	1982-83	298400	-do-
5	1983-84	305950	-do-
6	1984-85	164432	-do-
7	1985-86	302751	-do-
8	1986-87	316931	-do-

9	1987-88	333483	-do-
10	1988-89	-	-do-
11	1989-90	192453	-do-
12	1990—91	246855	-do-
13	1991-92	85800	-do-
14	1992-93	-	License Fee abolished by finance Minster Sindh
15	1993-94	-	-do-
16	1994-95	-	-do-
17	1995-96	-	-do-
18	1996-97	-	Mole System
19	1997-98	-	License fees was exempted by Govt: vide No 20(1)SO (Fish)97/dated: 16-7-1999
20	1998-99	-	-do-
21	1999-2000	519000	-do-
23	2001-2002	388173	D.O. Amount
24	2002-2003	226258	D.O. Amount
25	2003-2004	127348	D.O. Amount
26	2004-2005	47454 Up to October 2004	D.O. Amount

3.5.6 Threats and recommendations

3.5.6.1 Threats

- **Reduction in Fish Landings:** Due to a number of factors, the fish production in the Keenjhar Lake has substantially reduced and the number of fishermen and the fishing boats has been reduced in the last 20 years. The following table provides an estimate of this trend. The causes of this large scale migration of fishermen communities from the lake are the shortage of fish production in the lake due to continuous shortage of water in Kotri downstream, pollution of the lake with the growth of parasitical plants and useless grasses causing deoxygenating of the water and affecting the growth of fish, non installation of iron nets on the faces of canals running out of the lake causing the outflow of fish seed form the lake, mismanagement in the process of releasing the fish seed in the lake by fisheries department, absence of substitute income generating activities for the fishermen communities and non provision of education, health and infrastructure facilities;

- **Water Pollution:** There are many sources of pollution in the Keenjhar Lake. One of the causes of fish shortage in Keenjhar Lake is the material expelled by the industrial areas of Kotri and Nooriabad. Local industries of Kotri dispose off their wastes in Kalri Baghar (K.B.) Feeder which is the feeding source of Keenjhar, Moreover; growth of Australian un-rooted parasitical plant is another source of Pollution affecting the growth of fish. Most of the cities and towns of Punjab and Sindh discharge their municipal and industrial wastewater into the Indus River. Another major problem in Keenjhar Lake is the eutrophication. The lake water is being enriched with nutrients, causing abnormal plant growth. Runoff of chemical fertilizer from cultivated fields may trigger this phenomenon. Use

of this lake as a tourist spot is another source of pollution for this lake. More than 15000 people of Karachi visit this lake weekly. These tourists not only throw garbage into Keenjhar but also bring communicable human diseases to the local people and aquatic system by bathing/swimming in the lake;

- **Multiple ownership of the Lake:** At present five Government Departments are performing different functions at the lake which are Sindh tourism departments, Irrigation department, Wildlife department Fisheries department and the local government. The tourism department promotes the tourism activities, irrigation department looks after the embankments, link canal, and water quantity in the lake. The wildlife department takes care of the wildlife and fisheries department takes care of the fishing activities. The local government influences the auction of fishing rights in the lake. All these departments are working independently without consulting to each other and without considering the interests of the other departments. Activity of one department is often the problem for the other as tourism can be problem for wildlife species and fishing activities. It is important to reconsider this arrangement and a Keenjhar lake development authority be established so that all the activities could be performed in a coherent manner;

- **Construction of Link Canal:** Historically, the Keenjhar Lake was receiving water from the main river Indus by the K B feeder canal. It was bringing turbid water of the Indus to the lake. To avoid this turbidity to be mixed in the lake, a link canal was constructed to divert the water directly to the canal feeding Karachi bypassing the Keenjhar Lake during monsoon months. The commercial fishes in the main river Indus in monsoon season. The K. B. canal was a seed bank for the commercial fishes in the Keenjhar Lake. It was bringing millions of fingerlings and fries of the fish that was breeding in the main river Indus and each year the lake was recruited by the new stocks of fish seed and the depletion of fish stocks due to fishing activities in the lake was compensated each year. By construction of Link canal the Keenjhar Lake is not stocked by this natural fish seed and the fish production in the lake is severely affected;

- **Over fishing due to auction system/license system:** A major cause of decrease in the inland fisheries is the auction system under which Govt. has auctioned the fishing rights of the lake to the local people or the influential contractors. In Keenjhar lake area there is license system. Both these systems are highly controversial. The contractors as well as people having License, both take it for granted to get as much catch as possible to have maximum profit. They do not bother about any rule or regulation. Any means of fishing, whether legal or illegal, is being adapted and any size of fish is being caught. The Keenjhar Lake is the worse example of overexploitation of fisheries resource in the country. If this situation continuous, there will be no fish in the years to come and more and more fishermen will be left jobless;

- **Conflicts with Fishermen community and Fisheries Department:** There is a conflict between local fishermen and fisheries department regarding the auction system or the license system. Consequently fisheries department is not putting required quantity of fish seed in the

lake which is urgently required at the moment as the fish stock is depleted and there is no natural recruitment through K. B. branch. The lake requires 2,500,000 mixed fish seed annually to meet the present fishing pressure;

- **Escape of fish seed from the Lake:** The lake has an open out let in the form of the canal supplying water to the city of Karachi. Most part of the fish seed that is put in the lake by the fisheries department is escaped from the lake through this canal. As the lake is not being naturally recruited and a major part of the seed stocked by the fisheries department is also escaped, then where from the fish will come in the lake and it will definitely result into a situation which is presently being faced by the fishermen community in the Keenjhar Lake;

3.5.6.2 Recommendations

- **Direct flow of the Canal into the lake:** The faces of link canal should be separated from the lake and in the, breeding season and water from the main Indus River should be directly released into the lake. Plenty of natural fish seed is neral1y present in the river water during this season, which is healthy and suitable to grow easily than the artificial seed;

- **Prevent lake from industrial Waste:** To prevent the lake from the pollution and supplying the pure drinking water to Karachi, it is necessary to prevent lake from the toxic material of Kotri and Nooriabad Industrial area. If the toxic material released by these industrial area keeps on continuously mixing with the water of Keenjhar lake, it can cause great harm to the human population on one hand and the aquaculture and the live stocks on the, other hand;

- **Elimination of water weeds/useless grasses:** With the growth of Australian parasitical plant and other useless grasses water is deoxygenated causing great loss to the aquaculture and fish growth and health. An increase in pollution in the lake will decrease the fish which will cause a decline in the number of migratory birds;

- **Establishing fish nurseries on the banks of lake:** It is necessary to build the fish nurseries on the banks of lake and annually five million fish seed must he released into the lake because many fish species have almost become extinct. Fishermen communities do not find the fish species even for eating purpose which in past was regularly exported to England, Kuwait, Saudi Arabia and other countries. It is necessary that the fish nurseries be established on the banks of the lake to release a substantial quantity of fish seeds every year in the lake so that a sustainable exploitation of the resource could be made possible;

- **Installation iron nets at the outlet:** Installation of iron nets are important on the outlet of the canals running out the lake because if some of the seed from the river comes into the canal by chance or if some seed is stocked by the fisheries department, it is escaped from the lake.

- **Awareness through community:** An awareness about the wise use of fish resources, consequences of overexploitation of fisheries resources, use of illegal fishing gears, fishing in breeding season and rehabilitation of lake needs to be started through the mosques, community based organizations, fisher folk organization and through the local governments.

3.6 Phytoplankton

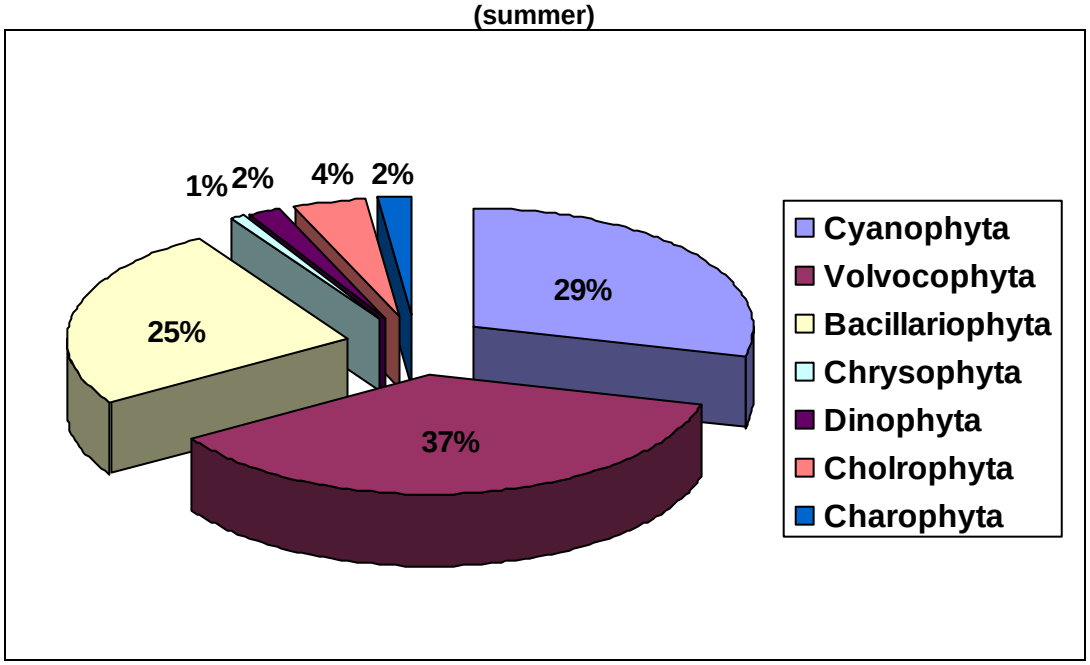
3.6.1 Summer Flora

The following species of phytoplankton were recorded from Keenjhar during the summer season. **Table 18** gives the list of phytoplankton recorded and **Figure 16** gives the graphic distribution of species over phylum.

Table 18 – Distribution of Phytoplankton/Algal species in Keenjhar Lake (summer)

Kingdom	Phylum	Class	Order	Families	Genera	Species
MONERA	Cyanophyta	2	2	2	13	45
PROTISTA	Volvocophyta	2	2	5	13	58
	Bacillariophyta	1	2	9	17	38
	Chrysophyta	1	1	1	1	2
	Dinophyta	1	1	2	2	3
PROTOCTISTA	Chlorophyta	3	5	5	6	6
	Charophyta	1	1	1	1	3
Total: 3	7	11	14	25	53	155

Figure 16: Percentage of species against phylum recorded in Keenjhar Lake (summer)



The ecological study of algal flora of Keenjhar Lake was conducted 14 to 16 June 2007. A total of 65 algal/phytoplankton samples were collected during this period out of which 155 algal species belonging to 53 genera of 7 phyla (Cyanophyta, Volvocophyta, Bacillariophyta, Chrysophyta, Dinophyta, Chlorophyta, Charophyta).

Physical and chemical parameters of the lake show the effect of temperature on the algal species. High air temperature (33-38^{o}C) changes the climate, directly affecting glacier, snow, water form and water surface temperature (21-31^{o}C). High temperature of water surface helps in dissolving the organic and inorganic matter and temperature often controls the horizontal distribution of many algae. The photosynthetic rate of phytoplankton has increased with the increase of temperature. pH (7.7-8.2) shows that the water is alkaline, pH increases due to high concentration of dissolved organic and inorganic matter, temperature and

algal species. the Total Dissolved Solids Was measures at 242-287 ppm, making the water quite productive for aquatic life. The Total Suspended Solids (TSS) is 2-5 mg/L, the high TSS value shows that high concentration of non living particulates originate as catchment, derived silts, clay, mud, organic matter are present in the water. This high value is due to flood, rain and other waste materials. They are the major disturbance in water affecting composition and biomass of the plankton/algae. The lake is highly turbid with a value of 1-8.2, high concentration of a-biogenic turbidity, whether disturbance or not, water column mixing as such or in combination with in organic turbidity cause changes in the light field over time. Consequently, vertical mixing and suspended solids significantly affect phytoplankton photosynthesis and productivity in aquatic environment. Conductivity value 50-58.8 M. ohmsx^{10} shows the current ions for production showing algal vegetation production in the lake. The salinity of the lake is 0.1-0.3 ppt and the presence of Orthophosphate is (0.02-0.03 ug/L). Only those species with a high tolerance level are able to grow at these levels. High Humidity (55-60%) value shows that Fungus, Bacteria, Cyanobacteria, Aerial algae could be present as humidity directly affects light and temperature. Light transparency was (3.3-4.5 meter). At one meter the water is too much turbid which affect the light limit as a result algae/phytoplankton photosynthesis and therefore restrict biomass development from inlet of water. Dissolved oxygen (7.5-8.8 mg/L) was in sufficient quantity for production of aquatic life like fish, fauna but this high concentration of dissolved oxygen was due to inlet and outlet of water and abundance of Phytoplankton/algae. Carbon dioxide CO_2 (40-80 ppm) was in sufficient quantity for the growth of phytoplankton/algal species as increase in CO_2 causes increased algal species. Blue green algae were found in colonies like *Microcystis, Oscillatoria, Phormidium* etc. and green algae making mats like *Cladophora, Spirogyra,* and *Chara* as well as layer of *Cosmarium*. A High value of CO_2 shows availability of rock carbonaceous. High Nitrate value of 0.7-2.6 ug/L in summer season increased chlorophyll-a distribution and alternate high value in cold water, low chlorophyll-a, which means that both nitrate and temperature plays significant role in chlorophyll distribution. Phosphate (0.3-0.9 ug/L) plays significant role to control the algal growth. Total hardness (120-155 ppm) concentrations show that sufficient quantity of blue green algae was available in this water. Increase in Calcium hardness (76-78 ppm) increases the production of green algae. Increase in the concentration of Magnesium hardness (45-78 ppm) results in the production of colonies of Cyanophyceae. Higher wave (2-12 inch) reading was due to wind. Taste, odor, and color of the water showed that it was tasteless, odorless and sometime fish and aquatic vegetations. The color of the lake in the summer season was gray/ greenish and colorless during the monsoon season. The water is rich in algal species, which is beneficial for fauna and fish. Some aquatic vegetation were found in and near surrounding lake water *Ceratophyllum, Equisetum fluviatiles* L., *Lemna minor, L. gibba, Phragmites maximus* (Forsk.) Chiov., *Potamogeton pectinatus, Scirpus debilis, Utricularia inflata* var. *minor, Prosopis glandulosa* Torr.*, Typha angustifolia* var. *elongata* Dudley Wiegand, *T. latifolia* L., *Cyperus, Cynodon dactylon* (L.) Pers.*, Alhaji maurorum* Fisch.*, Capparis deciduas* (Forssk.) Edgew.*, Acacia modesta* Wall*, Euphorbia, Amaranthus, Chenopodiums*, *Meliaazadrachta indica,* dates, calotropis were recorded.

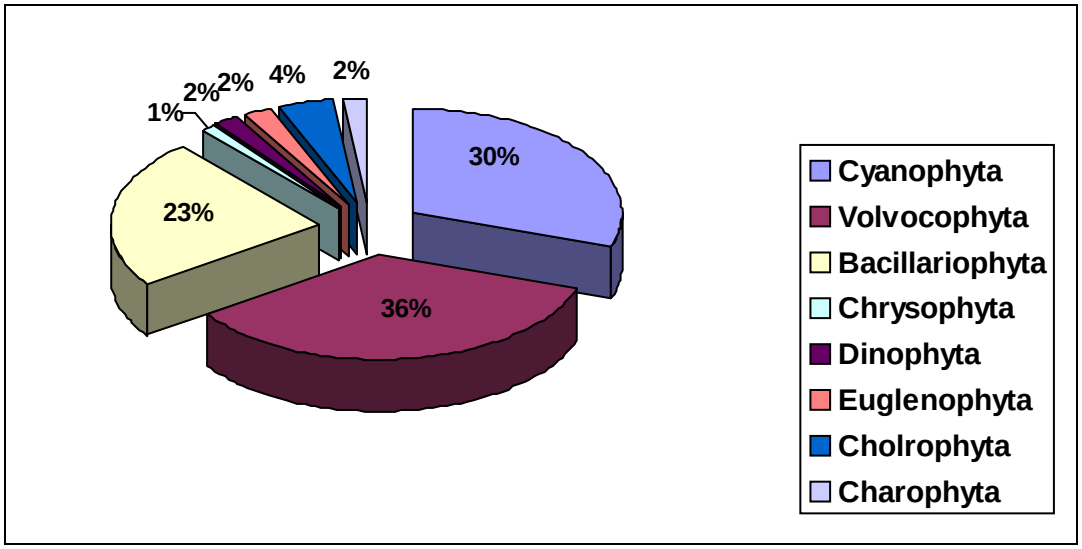
3.6.2 Winter Flora

The following species of phytoplankton were recorded from Keenjhar during the winter season. **Table 19** gives the list of phytoplankton recorded. **Figure 20** shows the distribution of species across phyla.

Table 19 – Distribution of phytoplankton/algal species in Keenjhar Lake (winter)

Kingdom	Phylum	Class	Order	Families	Genera	Species
MONERA	Cyanophyta	2	2	4	17	51
PROTISTA	Volvocophyta	2	2	4	14	59
	Bacillariophyta	1	2	9	17	338
	Chrysophyta	1	1	1	1	2
	Dinophyta	1	1	2	2	3
	Euglenophyta	1	1	1	2	4
PROTOCTISTA	Chlorophyta	3	5	5	6	7
	Charophyta	1	1	1	1	3
Total	8	12	15	27	60	167

Figure 17 – Percentage of species against phylum recorded in Keenjhar Lake (winter)



More than 60 algal samples were collected during 13-15 November, 2007 from Keenjhar Lake, out of which 167 species belonging to 60 genera of 8 phyla namely Cyanophyta, Volvocophyta, Bacillariophyta, Dinophyta, Euglenophyta, Chrysophyta, Chlorophyta, and Charophyta were observed.

- **Blue green algae:** 51 species were belonging to 17 genera of the phyla Cyanophyta, in which 10 species of the genus Microcystis, 7 species of the genus Oscillatoria, 5 species of the each genus Aphanocapsa, Merismopedia, 3 species of the each genus Chroococcus, Gomphosphaeria, Lyngbya, 2 species of the each genus Gloeocapsa, Phormidium, Spirulina, Nostoc, Rivularia, one species of the each genus Aphanothece, Eucapsis, Pseudoholopedia, Anabaena, Calothrix were respectively observed. Initially growth of blue green algal species protects other plants in their growth by supplying moisture and other nutrients. Blue green algal species have much resistance power to survive in any condition.

- **Green algae:** 59 species were belonging to 14 genera of the phyla Volvocophyta, in which 14 species of the genus Cosmarium, 10 species of the genus Scenedesmus, 9 species of the genus Pediastrum, 5 species of the genus Closterium, 4 species of the each genus Euastrum,

Staurostrum, 3 species of the genus Coelastrum, 2 species of the each genus, Ankistrodesmus, Tetraedron, Spondylosium, one species of the each genus Crucigena, Arthrodesmus, Cosmocladium, Desmidium, were recorded. All the species are used as primary source of food for aquatic life. Arthrodesmus, Cosmoeladium, Desmidium, Closterium, Cosmarium reduces the hardness from water. Scenedesmus, Pediastrum and Crucigena are included in medicinal group.

- **Golden brown algae:** 38 species belonging to 17 genera of the phyla Bacillariophyta in which 5 species of the genus Cymbella, 4 species of the genus Epithemia, 3 species of the each genus Synedra, Gomphonema, Gyrosigma, Navicula, Surirella, 2 species of the each genus Cyclotella, Cocconies, Mastogloya, Nitzschia, one species of the each genus Melosira, Fragiloria, Diplonies, Pinnularia, Rhopaldia, Cymatopleura, were recorded.

- **Dinophyta:** 3 species belonging to 2 genera of the phyla Dinophyta 2 species of the genus Peridinium and one species of the genus Ceratium, were observed.

- **Flagellales group:** 4 species belonging to 2 genera of the phyla Euglenophyta 2 species belonging to the each genus Euglena and Phacus, were observed.

- **Chrysophyta:** 2 species belonging to one genus Dinobryon of the phyla Chrysophyta were recorded. These species indicate cold temperature of water.

- **Grass green algae:** 7 species belonging to 6 genera of the phyla Chlorophyta, 2 species belonging to the genus Oedogonium and one species belonging to the each genus Cladophora, Coleochaete, Spirogyra, Zygnema, Ulothrix were observed.

- **Charophyta:** Three species belonging to the genus Chara of the phyla Charophyta were observed. The species of Chara produce crop these species are excellent food producers. The species show natural indication for alkaline water. The species were used as food for cattle. When they are mature they release some smell to kill the mosquitoes. Chara is very common in our region. The climate conditions are favorable for this genus. This genus is included as cosmopolitan, the species of this genus were found from coastal area to near Khunjerab Pass and from Keenjhar to Karounger.

3.6.3 Comparison of summer and winter

Table 20 below shows the algal species were recorded from Keti Bunder over summer and winter.

Table 20 – Genera and their species along with percentage at Keti Bunder and its adjacent areas (summer and winter)

Name of Genera	Summer		Winter	
	Number of species	Percentage%	Number of species	Percentage %
Kingdom: MONERA				
Phylum: Cyanophyta				
Class: Chroocophyceae				
Order: Chroococcales				
Family: Chroococcaceae				
1. *Aphanocapsa*	5	10.6	1	0.7
2. *Aphanothece*	1	2.1	1	0.7
3. *Gloeothece*	4	8.5	1	0.7
4. *Gomphosphaeria*	0	0	1	0.7
Class: Nostocophyceae				
Order: Oscillatoriales				
Family: Oscillatoriaceae				
1. *Lyngbya*	3	6.3	2	1.3
2. *Oscillatoria*	7	14.8	2	1.3
3. *Phormidium*	2	4.2	1	0.7
4. *Trichodesmium*	0	0	1	0.7
Order: Nostocales				
Family: Nastocaceae				
1. *Anabaena*	0	0	3	2
Kingdom: PROTISTA				
Phylum: Volvocophyta				
Class: Volvocophyceae				
Order: Chlorococcales				
Family: Oocystaceae				
1. *Oocystis*	0	0	1	0.7
2. *Tetraedron*	0	0	1	0.7
Family: Coelastraceae				
1. *Coelastrum*	3	6.3	2	1.3
Family: Dictyosphaeriaceae	0	0	0	0
1. *Dictyospherium*	0	0	1	0.7
Family: Hydrodictyaceae	0	0	0	0
1. *Pediastrum*	0	0	2	1.3
Family Scenedesmaceae	0	0	0	0
1. *Scenedesmus*	0	0	2	1.3
Order: Volvocales				
Family: Chlamydomonadaceae				
1. *Chlamydomonas*	0	0	1	0.7
Class: Desmidiophyceae				
Order: Desmidiales				
Family: Desmidiaceae				
1. *Closterium*	0	0	1	0.7
2. *Cosmarium*	0	0	3	2
Phylum: Dinophyta				
Class: Dinophyceae				
1. *Amphisolenia*	0	0	1	0.7
2. *Ceratium*	1	2.1	27	18
3. *Dinophysis*	0	0	4	2.7
4. *Gonyoulax*	0	0	2	1.3
5. *Nactiluca*	0	0	2	1.3
6. *Ornithocercus*	0	0	1	0.7
7. *Prorocentrum*	0	0	4	2.7
8. *Podalampas*	0	0	1	0.7
9. *Protoperidinium*	0	0	5	3.3
Phylum: Bacillariophyta				
Class: Bacillariophyceae				
1. *Achnanthes*	0	0	1	0.7

2. *Bacillaria*	0	0	1	0.7
3. *Bacteriastrum*	0	0	3	2
4. *Chaetoceros*	0	0	16	10.7
5. *Climacodium*	0	0	1	0.7
6. *Cocconies*	2	4.2	1	0.7
7. *Corethron*	0	0	1	0.7
8. *Coscinodiscus*	0	0	1	0.7
9. *Diatoma*	0	0	2	1.3
10. *Doctyliosolen*	0	0	1	0.7
11. *Eucampia*	0	0	1	0.7
12. *Fragilaria*	1	2.1	2	1.3
13. *Gomphonema*	0	0	2	1.3
14. *Guinardia*	0	0	1	0.7
15. *Gyrosigma*	3	6.3	2	1.3
16. *Hemialus*	0	0	2	1.3
17. *Lyptocylindrus*	0	0	2	1.3
18. *Melosira*	0	0	1	0.7
19. *Navicula*	3	6.3	3	2
20. *Odontella*	0	0	3	2
21. *Planktoniella*	0	0	1	0.7
22. *Pleurosigma*	0	0	1	0.7
23. *Probostcia*	0	0	1	0.7
24. *Pseudo-nitzschia*	0	0	2	1.3
25. *Rhaphonies*	0	0	1	0.7
26. *Rhizosolenia*	0	0	6	4
27. *Schroderella*	0	0	1	0.7
28. *Skeletonema*	0	0	1	0.7
29. *Synedra*	3	6.3	3	1.3
30. *Thalassionema*	0	0	2	1.3
Phylum: Xanthophyta				
Class: Xanthophyceae				
Order: Mischococcales				
Family: Chlorobotrydaceae				
1. Ophiocytium	0	0	1	0.7
Phylum: Euglenophyta				
Class: Euglenophyceae				
Order: Euglenales				
Family: Euglenaceae				
1. Euglena	2	4.2	2	1.3
2. Phacus	2	4.2	2	1.3
Kingdom: PROTOCTISTA				
Phylum: Chlorophyta				
Class: Siphonocladophyceae				
Order: Cladophorales				
Family: Cladophoraceae				
1. Cladophora	1	2.1	1	0.7
Class: Zygnemophyceae	0	0	0	0
Order: Oedogoniales	0	0	0	0
Family: Oedogoniaceae	0	0	0	0
1. Oedogonium	0	0	1	0.7
Order: Zygnematales	0	0	0	0
Family: Zygnemataceae	0	0	0	0
1. *Spirogyra*	1	2.1	1	0.7
Phylum: Charophyta				
Class: Charophyceae				
Order: Charales				
Family: Characeae				
1. *Chara*	3	6.3	2	1.3

A total of 10 species and a variety of taxa from genus *Microcystis* Kuetzing ex Lemmermann were recorded from Keenjhar Lake. These taxa are considered as toxic and capable of producing poisonous enzymes and organic odor in the water, and are responsible for the several intestinal illnesses by ingestion of

contaminated water (Davidson 1959, Gorham 1960, Schwimmer and Schwimmer 1968). An abundant ratio of the genus *Microcystis* was observed in the lake. Reports of human illnesses resulting from accidental ingestion of toxic cyanophyta during water sports were obtained in army trainees undertaking a canoeing exercise in the United Kingdom, in this case both gastro-intestinal and pulmonary illnesses were reported. Turner et al. (1990) stated that this genus is highly toxic and dangerous for life of aquatic animals, human causes so many diseases like diarrhea, vomiting, stomach pain, fever, headache, weakness pain in muscles and joints such ratio of microcystis species may cause lethal effect and may cause many gastro intestinal illness in the inhabitant human population as well as livestock. Much attention is needed and more research work is required on the control of Microcystis species and other poisonous algae to make the clean and fresh water for native human consumption.

The presence of blue green algal species indicate a high ratio of total hardness in the lake water, secondly resistance towards the temperature, third to protect for the growth of flora from sunlight, generally these species are included in third category of flood for fish and fauna. The blue green algae genus *Aphanocapsa, Aphanothece, Microcystis* is included in the toxic group. They create toxicity dangerous for aquatic life as well as human beings. A total number of 45 species of the blue green algae belong to 13 genera of phyla Cyanophyta in which 10 species of genus *Microcystis,* 7 species of genus *Oscillatoria,* 5 species of each genera *Aphanocapsa, Merismopedia* and a minimum number of one species of *Aphanothece, Eucapsis, Pseudoholopedia,* 2 species of *Gloeocapsa, Phormidium, Spirulina* and 3 species of *Chroococcus, Gomphosphaeria* and *Lyngbya* were recorded. *Phormidium* this genus has much more resistance power, even recorded temperature of up to 73^{o}C e.g. hot water spring Kotli (Kashmir), Chitral, Tata Pani near Nanga Parbat but in advance countries recorded up to 84^{o}C of water. *Aphanocapsa, Chroococcus, Eucapsis, Gloeocapsa, Gomphosphaeria, Merismopedia, Microcystis, Oscillatoria, Spirulina* are included in epilimnion flora and found as phyto, tycho and Euplankton. *Spirulina are indicative* of high temperature of water but its good habitat in high temperature of water along with high ratio of salinity and especially after monsoon season. The algal blooms observed in such a habitat are included in medicinal the group. In technologically advanced countries it has great importance and a high market value; it is also used as a vitamin.

A total of 58 species belonging to 13 genera of phyla Volvocophyta in which the largest number are from the genus *Cosmarium* (14 species), 10 species of genus *Scenedesmus,* 9 species of the genus *Pediastrum* and 1 species of genus *Arthrodesmus, Desmidium,* 2 species of the genus *Ankistrodesmus, Tetraedron, Spondylosium,* 3 species of genus *Coelastrum,* were recorded. Seven genera of family Desmidiaceae like *Arthrodesmus, Closterium, Cosmarium, Desmidium, Euastrum, Spondylosium, and Staurastrum* are included in hypolimnion flora of Desmid groups. All the species of these genera were collected from 1 cm above the soil in the lake water. The collection of these species proved to be difficult as care must be taken so as not to mix the sample with the soil along with nematodes and fungus. Fungal spore easily attack algal species. Fungus is more dangerous from toxic species for aquatic life, fishes, fauna etc. In these circumstances it is very difficult to save such flora or phytoplankton crops from contamination. At the time of culture or further growth, all the species of these genera indicate increased calcium hardness, as free floating flora produce a thick layer. Species of genera of order Chlorococcales like *Ankistrodesmus, Tetraedron, Coelastrum, Crucigenia, Scenedesmus, Pediastrum* are included in

epilimnion flora, these species food for fish and fauna species of the genus *Scenedesmus, Pediastrum* the presence of which indicate for chloride hardness.

Golden brown algae were also found during the survey with a total number of 38 species collected belonging to 17 genera of phyla Bacillariophyta. The species of class Bacillariophyceae are a source of primary food for aquatic fauna including fish, but they cannot be digested easily due to their slica wall and striae, therefore it is easy to record from gut contents of the fish. However, some species of genus *Gyrosigma, Nitzschia, Epithemia* indicate for pollution/polluted water.

The species of genus *Cladophora, Coleochaete*, *Oedogonium, spirogyra, Zygnema and Ulothrix* are food producers for aquatic fauna and fish. The species of *Spirogyra* are used as fodder for cattle. These genera are easily identified with the naked eye. *Cladophora* are included in multi-cellular algae. The species of *Chara* are excellent food producers for aquatic life and is a good indicator for alkaline water. When the pH is higher than 7.2, the genus *Chara*, once reaching maturity releases an odor which kills mosquitoes. The presence of *Chara* indicates 100% chances of fish availability; this genus absorbs calcium carbonate. At the time of collection a layer / small particles found layer/small particles attached with *Chara. Chara* produce crops still more than 17 species were recorded from different places through out the country. It is also multi-cellular algae/taxa and easily identified with eyes.

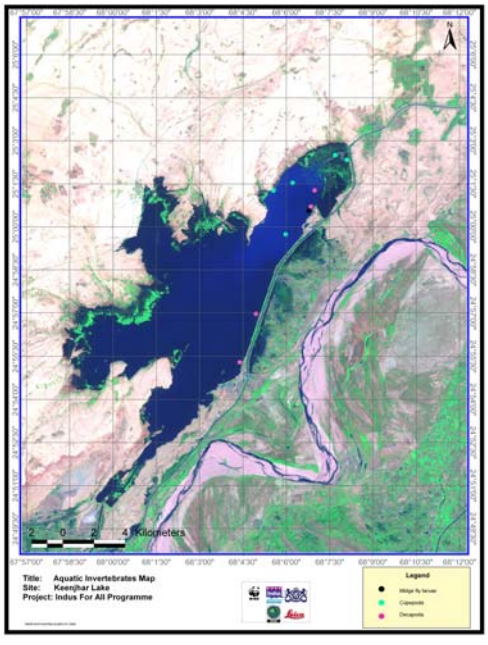
3.6.4 Threat and recomendatios

No threats or recomndations were given for this study exept for that the need for the community to be educated about the importance of phytoplankton as an integral part of the food chain. Care must be taken during fishing season to maintain the flora and fauna of the sea.

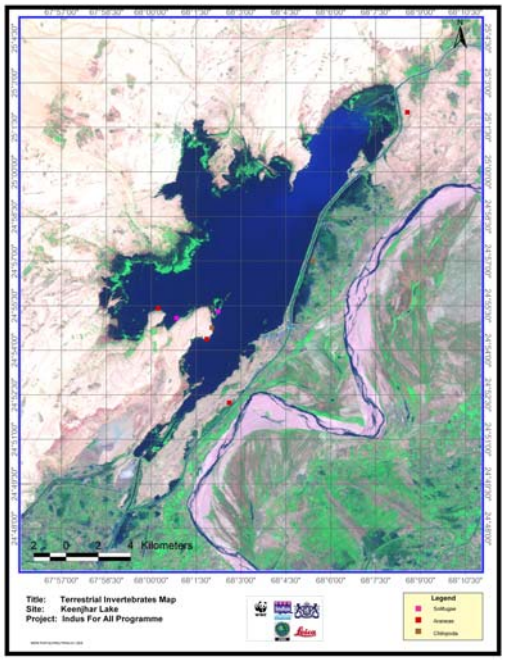
3.7 Zooplankton

3.7.1 Sampling locations

Maps 8 and **9** show the sampling points for aquatic and terrestrial invertebrates from Keenjhar Lake.



Map 8 – sampling points for aquatic



Map 9 – sampling points for

invertebrates **terrestrial invertebrates**

3.7.2 Species account

During the summer survey of 2007 the Lake and its adjoining areas were explored for the micro-invertebrate sampling at various sampling sites. Some of the same as well as many more sites were visited during the winter same year and adequate sampling was done and observations recorded regarding the terrestrial and aquatic invertebrate fauna of the reservoir and its adjoining areas. **Table 21** and **22** gives detailed of the aquatic invertebrates collected from Keenjhar Lake.

Table 21 - Data of aquatic invertebrates collected from Keenjhar Lake

S. No.	Invertebrate groups - Aquatic	Locality (Coordinates)	Date
1	*Decapoda*	N 24 55' 297'', E0 68 04' 390'' N 24 56' 961'', E 068 04' 949'' N 25 00' 706'', E 068 06 855'' N 25 01' 266'', E 068 06' 983''	16-06-07 19-06-07 14-10-07 16-10-07
2	*Copepoda*	N 24 59' 734', E 068 05' 980'' N 25 02' 497'', E 068 07' 694'' N 25 02' 335'', E068 08' 103'' N 25 01' 258'', E 068 05' 557'' N 25 01' 526'', E 068 06' 221''	17-06-07 14-10-07 15-10-07 16-10-07 16-10-07
3	*Midge fly larvae*	N 25 00' 721'', E 068 06 815''	18-6-07 16-10-07

Table 22 – Data of terrestrial invertebrates collected from Keenjhar Lake

S. No.	Invertebrate groups - terrestrial	Locality (Coordinates)	Date
1	Araneae	Khapri area N 25 01' 439'' E 68º 08′ 362″ N 25 01' 444'' E 68º 08′ 356″ N 24º 55′ 404″, E 68º 00′ 239″ Hanif Shah area N 24º 54′ 375″, E 68º 01′ 898 N 24º 52′ 154″, E 68º 02′ 645	 17-6-07 19-6-07 14-10-07 15-10-07 16-10-07
2	*Solifugae*	N 24º 55′ 303″, E 68º 02′ 234″ Daulatpur N 24º 55′ 085, E 68º 00′ 844''	18-6-07 15-10-07
3	*Chilopoda*	N 24º 55' 173″, E 68º 59′ 848″ N 24º 54′ 347″, E 68º 01′ 809	17-6-07 16-10-07

3.7.3 Aquatic macro-invertebrates found in Keenjhar

- Macrobrachium malcolmsonii

Order : Decapoda
Suborder : Natantia
Infraorder : Caridea
Superfamily : Palaemonoidea
Family : Palaemonoidae
Subfamily : Palaemoninae
Genus : *Macrobrachium* **(De Man, 1879)**
Species : *malcolmsonii*
Athority : Milne Edwards, 1844

This is a freshwater species captured from Keenjhar Lake is a prawn of commercial importance. This giant prawn of river Indus grows up to 250 grams. This prawn breeds from March to October and its larvae grow in brackish water. The larvae after attaining post-larval stage in about 30-45 days migrate towards freshwater. Their upstream migration is recorded at Kotri Barrage, Jamshoro and can be collected for stocking in ponds and inland water.

- *Macrobrachium dayanum (Henderson, 1893)*

Order : Decapoda
Suborder : Natantia
Infraorder : Caridea
Superfamily : Palaemonoidea
Family : Palaemonoidae
Subfamily : Palaemoninae
Genus: ***Macrobrachium*** **(De Man, 1879)**
Species: ***dayanum*** **(Henderson, 1893)**

Image 8 – ***Macrobrachium dayanum***

The other prawn *Macrobrachium dayanum* found in the Keenjhar Lake is an effectively large and vigorous freshwater species. It is perhaps the most abundant prawn species of this lake and is caught in abundance by the fishermen though according to them its population has also reduced to a great extent recently. Its healthy size is indeed a significant factor that has made this prawn a marketable item and it is thus an allure for the fishermen of the area. The decrease in its production is also owing to the fact that the other prawn species has literally reduced to rarity and therefore the fishermen have swiftly shifted to the *dayanum* species.

3.7.4 Aquatic micro-invertebrates found in Keenjhar

- **Copepoda**
  Myriads of zooplankton captured during sampling from Keenjhar Lake during summer and winter surveys were investigated and found to belong to the subclass *Copepoda* of the class *Crustacea*. The *Copepod* population was found to decline tremendously during the winter. Copepods belonging to the genus *Mesocyclops* were also found to be abundant.

Phylum Arthropoda
Class Crustacea
Subclass Copepoda
Order Cyclopoida
Family Cyclopidae
Genus *Mesocyclops*
Species *Mesocyclops leuckarti*

Phylum Arthropoda
Class Crustacea
Subclass Copepoda
Order Cyclopoida
Family Cyclopidae
Genus *Tropocyclops*

Phylum Arthropoda
Class Crustacea
Subclass Copepoda
Order Cyclopoida
Family Cyclopidae
Genus *Macrocyclops*
Species *Macrocyclops ater*
Macrocyclops macreuus

- **Midge fly-larvae**
  Midge fly (family - *Chironomidae*, order - *Diptera*) larvae were also abundant in Keenjhar Lake and at various places in the reservoir ample sampling of these was done during the summer as well as the winter survey through the plankton net. A moderate population of midge fly larvae was observed and caught in Keenjhar Lake during the summer as well in winter, though the number of these larvae was much more plentiful during the winter. These flies are usually found in all but the most polluted aquatic conditions. Presence of Midge flies in large numbers indicates that there is an organic enrichment in the water-body that they dwell in. This also indicates that the effect of pollutants, human waste and other effluents getting added in to the reservoir has not yet turned drastic in terms of its damaging effect on the micro-invertebrate population of the reservoir.

3.7.5 Terrestrial invertebrates at Keenjhar

- **Order Araneae**
  A number of spiders captured from the adjoining areas of Keenjhar Lake were catalogued and identified at the genus level. Following is their taxonomic hierarchy. There is a very diverse and healthy population of spiders belonging to various families in the vicinity of both study areas.

Phylum Arthropoda
Class Arachnida
Order Araneae
Suborder Neocribellatae
Family Thomisidae
Genus *Thomisus*

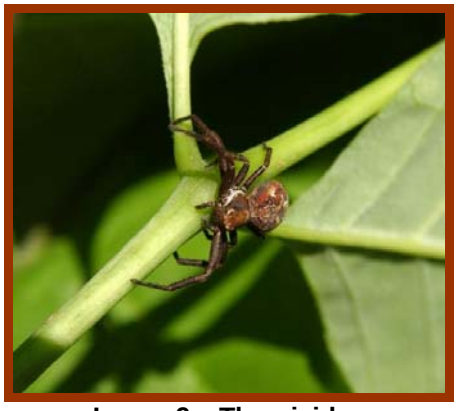


Image 9 – Thomisidae

- **Genus** *Thomisus*
  Seven specimens of Genus *Thomisus* were captured from the suburb of the Keenjhar Lake.

- **Family Araneidae:** this is a large family with more than 2500 species worldwide. All these spiders make orb webs that are big in relation to the spider. The webs are denser in the center. The genera *Cyclosa* and *Argiope* construct some sort of stabilizer in the center of the web. Members of this family are very docile, non-aggressive spiders that usually flee at the first sign of a threat. They are not dangerous to people and are actually quite beneficial because they catch and eat the pest-type insects. These are most noticeable in late summer in fall, when webs and adults reach their largest.

Image 10 – Araneidae

- **Genus** *Cyclosa*
  These are relatively rare spiders. Their small abdomen has a distinctive tubercle. Also the large webs are distinctive. It contains an irregular band of silk often full with debris. This camouflages the spider perfectly. The eggs are added later to this string.

Phylum Arthropoda
Class Arachnida
Order Araneae
Suborder Neocribellatae
Family Araneidae
Genus *Cyclosa*

- **Order Solifugae**
  A few solifugids specimens belonging to the following taxonomic hierarchy were captured from the adjoining areas of the Lake.

  - **Family: Galeodidae Sundevall 1833**
    Members of the Galeoidae family were found and captured from the vicinity of the lake. Galeodids are distinguished from other members of the order Solifugae by the presence of fine microsetae on the tarsal claws of legs II through IV. This vestiture of microsetae does not occur on any other group of solifuges. Most of the species are relatively long-legged, and include some of the largest members of the order. Members of the family are widely distributed in Europe, Africa, Southeastern Asia, Asia Minor, Arabia, Iran, Afghanistan, India and Pakistan.

Image 11 – Galeodidae

3.7.6 Discussion

It has been suggested that the zooplankton abundance allows for the enhanced survival and growth for fish larvae. The zooplankton biomass supports high ichthyoplankton concentrations. Many zooplanktons including the copepods are known to be the important component of the larval fish diets. Predaceous invertebrates preferably prey upon the smaller zooplanktons. If the nutrient supply is not continued, the elevated predation by fish larvae also creates food limitation. The predation pressure therefore not only controls the abundance of the zooplankton but can also change the composition and size spectrum of zooplankton community.
Zooplankton density and the gill infection of fish are inversely proportional to each other. At a low zooplankton density the fish fingerlings change their feeding behaviour and due to the insufficient zooplankton, they ingest a larger number of fish parasites from the detritus. It is possible that the lower intensity of gill

infection at a high zooplankton density could also be explained by the more intensive fish parasite consumption by the copepods.

The freshwater zooplankton comprise of three major groups of invertebrate animals: the rotifers, copepods, and cladocerans. The rotifers constitute a phylum found almost exclusively in freshwater and are not included in the photos of this web site. The copepods and cladocerans are both groups of the large subphylum Crustacea. Copepods constitute a class, which is widespread in both freshwater and marine environments. Cladocerans constitute a group of four orders living primarily in freshwater environments. All three of these major groups have species adapted to pelagic (open water), or littoral (vegetated), and benthic (bottom) environments. The reader can find detailed descriptions of the biology of cladocerans and copepods in Dodson and Frey (1991) and Williamson (1991), respectively. These sources also provide information on sampling, culturing, identification techniques, and include a good review of literature on these vital groups.

Dodson and Frey (1991) and Williamson (1991) also include keys to identification. The keys for the copepods and cladocerans go only as far as the genus level. Since taxonomy is a dynamic science, names of some groups have changed with time; thus professionals also use a widely scattered primary literature. In Pakistan, however, no profound work has been done regarding the identification and key-making of the zooplankton and there is dearth of literature which adds to the complications related to the identification of the rich and diverse zooplankton fauna of Pakistan up to the species and, in many cases, even up to the genus level.

Zooplanktons are common in the pelagic and littoral regions of ponds, lakes, large rivers, and oceans. In freshwater, these assemblages are dominated by the rotifers and two groups of micro crustaceans plus the four orders of cladocerans and the class Copepoda. The copepods are also dominant in marine environments. The littoral and benthic regions of freshwater and marine environments characteristically hold large numbers of the diverse and ancient micro crustacean class Ostracoda. Most species of these four groups make their living grazing algae from the water column or off surfaces and are, in turn, a vital link for passing energy up the food chain to fish.

The majority of freshwater zooplanktons have a strong potential for dispersal. Most species so far investigated are capable of forming resting eggs, which are resistant to desiccation, freezing, and digestive enzymes. Furthermore, many species are parthenogenetic, which allows single females to reproduce. Nevertheless, the cosmopolitan distribution of many species has been questioned and newly discovered exotics are allowing detailed discovery of the dispersal process.

Zooplanktons occupy an important position in the trophic structure and play a major role in the energy transfer of an aquatic ecosystem. An inadequate knowledge of the zooplankton and their dynamics is a major handicap for better understanding of life processes of freshwater bodies. Such studies have extreme significance and ecological value since eutrophication is bound with the components and production of zooplankton.

Among zooplankton, the relative abundance of copepods was higher in the Keenjhar Lake. The abundance of crustaceans collected by the plankton net method was found healthier than their usual abundance in polluted rivers and streams.

3.7.7 Conclusion

The present study, like most of the invertebrate studies conducted elsewhere, was biased by the sampling program and the equipment. Another postulation is the inherent assumption of an even distribution of the sub sampled population, which is mostly rare, because of the patchy distribution of zooplankton. Comparing with the huge availability of both terrestrial and aquatic invertebrates in and around the lake, the temporal scale was also biased rather limited as the survey was carried on for five days. The samples collected were sufficient, however, to describe what was present at the times sampled. Temporal variations and seasonality in the abundance of zooplanktons have been observed all over the world. Some of these variations are possibly due *en route* for the year- to-year variability in environmental factors. The species diversity tends to be low in stressed and polluted ecosystems.

Detectable changes in the abundance or species composition of zooplankton may reflect fundamental changes in the aquatic environment affecting phytoplankton. In turn, because zooplankton are eaten by larger animals, some of which are of commercial importance, changes in zooplankton communities can provide early indications of forthcoming changes in the food conditions for fish, birds and mammals. As most of the zooplankton are relatively short-lived and have enormously high growth rates, they respond quickly to the environmental perturbations that influence diversity, such as any localized or broad-spectrum pollution, degradation and predation pressure. Crustacean zooplankton growth and development rates are well known to depend strongly on water temperature. The diversity in the stages of life history of the copepods may also be a sensitive early warning of temperature increases in the aquatic ecosystems in response to global atmospheric warming

Planktonic nutrient regeneration is a fundamental process that maintains most of the primary productivity in freshwater environments, and the phosphorus supply for stream plankton comes primarily from within the plankton community, rather than from external loading or from larger organisms such as fish.

A special role of larger zooplanktons in clearing fresh water can be explained by their combined direct (clearing lake water from algae at a rate higher than primary production) and indirect (suppression of rotifers and protists by predation, interference and resource competition) impact on internal cycle of nutrients. Small-bodied zooplanktons also play important role in clearing lake water, however large cladocerans are more efficient in controlling phytoplankton biomass.

Zooplankton make a major link in the pathway of energy from algae to higher trophic, they are a strong bridge between producers and higher consumers in aquatic ecosystems. They are extremely important as food for young fish and for certain forage fish. The zooplanktons graze on phytoplankton and are themselves the primary food source for many larval fish, some larger fish and most invertebrates found in the freshwaters (Darnell 1961). Planktivorous (plankton eating) fish regulate the abundance and size structure of zooplankton populations. Prey is targeted usually on an individual basis, although the gill rakers of certain fish collect some zooplankton as water passes through the mouth and across the gills. Planktivorous fish prefer larger zooplanktons and can eliminate many important crustacean groups from the water body. Planktonic animals, especially rotifers, cladocerans, and copepods of the order Cyclopoida are the most important

food items in freshwater aquaculture, and copepod nauplii are especially valuable for feeding fry.

During the winter survey the primary productivity of the Keenjhar Lake was high and the greenish colours owing to the abundance of algae and other phytoplankton persisted. The fisheries practice was less than the summer days and the mesh size of the nets deployed was usually two inches, which is considered reasonably acceptable as most of the small fish and other fry can easily escape this net and therefore survive till they achieve maturation.

The fisheries practices are reduced tremendously during winter as the most of the fishery is done through licensing which helps to reduce the exploitation of resources. There was however some large nets deployed at certain places that also were huge spawning place for fish. There is a visible decline in the prawn population due to the seasonal variation. In Keenjhar the prawn population reaches its maximum during June/ July periods and turn to their minimum during the Nov/Dec.

During the winter survey the sampling for invertebrates was done at every significant site of the lake. The most suitable time for zooplankton collection is during the sunset periods and against the direction of the wind, still the zooplankton population was found to be much less than the summer survey

In the adjoining areas of the Keenjhar Lake there is a healthy population of arachnids including spiders as well as the solifugids, which are supported by the lake water for their survival. The population of spiders is mostly isolated in pockets in the suburbs of the lake still their sufficient abundance states that the ecological linkages in the area are unbroken and are less affected by pollution or any other environmental factors. These populations also indicate the stable ecological balance of the area. During the winter the population of arachnid including the Araneae and Solifugids also declined tremendously.

3.7.8 Threats and recommendations

No threats or recommendations were submitted with the study report. However the author did note that there is an urgent need to make a detailed list of species before conservation measures are undertaken. Known species of invertebrates represent only a small proportion of the actual number likely to occur, particularly from freshwater, saline lakes, deserts and hot springs. Little data is available to demonstrate the decline in species populations. Systematic plankton investigations have not been made in most freshwaters of the country. The information on the distribution of planktonic organisms must be regarded as tentative. The distribution of most of the organisms described here must be expected to be wider than reported. Many of the invertebrates have life cycle phases or temperature restrictions (thermoclines), which limit their presence or abundance during times of the year.

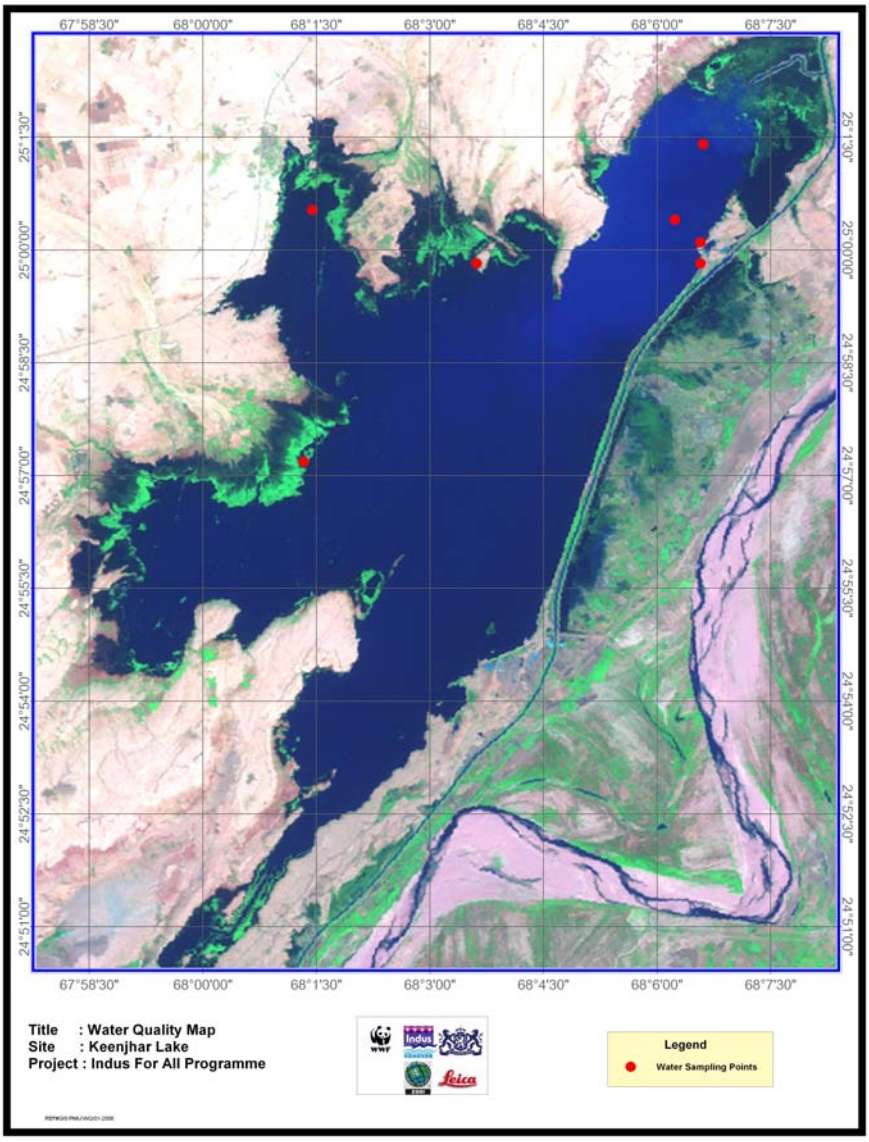
The author also pointed out that while studying the invertebrate fauna of an area, different sampling gear and different approaches of sampling have different biases. Absolute accuracy of the diversity and abundance is difficult to determine because the only baseline for comparison is often our own samples. The researcher should therefore be familiar with the bias inherent in the individual sampling gear and analyses. Sampling at each station with a wide variety of sizes of nets and meshes, for example, significantly increases precision in the study of invertebrates.

3.8 Physico-chemical properties of water

3.8.1 Sampling locations

Map 10 shows the sampling points for water quality at Keenjhar Lake

Map 10 – Sampling points for water quality testing at Keenjhar Lake



3.8.2 Field observations during water sampling

3.8.2.1 Population and human activities

There are about seven villages in the study area of Keenjhar Lake boundaries. The two largest villages are Jhampir and Sonari, having more than fifty homes in each. The main economic activities in the local areas are agriculture, livestock and fisheries. In Jhampir area there are coal, silica sand and other mines. The mining/crushing produce waste which may move/flow with storm water through Jhampir Lai into Keenjhar Lake. The waste water of Jhampir village also finds its way into Keenjhar Lake. The agriculture run off flows through the surface drains into Keenjhar Lake raising the turbidity and nutrient load. These nutrients are for algal growth/bloom, which were found at different locations of the lake. The livestock / buffaloes wallowing in Keenjhar Lake particularly in Sonari area is one of the reasons of biological waste. Also it is a regular feature that the women folk

of the neighboring area wash clothes and utensils with detergents at the banks of Keenjhar Lake. This may be the cause of phenols present in water. At the picnic point of Keenjhar Lake the washing of diesel vehicles is wide spread during weekends and on holidays. This is causing pollution (COD), increasing the solid waste and organic load in the lake.

3.8.2.2 Flow and levels

The Keenjhar Lake historical flows and levels have decreased due to scarcity of water, climate changes, siltation of reservoir and misuse of water resources. The level of water in Keenjhar Lake has always been critical. The variation in flow which is seasonal; particularly during dry period has caused serious loss to biodiversity. The fisherman and farmers face problems in meeting their targets of fish and agriculture production. Some time production is such low that it threatens their livelihood. Because of siltation the Keenjhar Lake capacity has decreased substantially. Now the government has recently started a project of increasing reservoir level by 1.22-1.52 m. The designed pond level of Keenjhar Lake is 16.16 m above sea level. This should be maintained to ensure its full natural resources production. These observations were also agreed by the field staff and local community.

Table 23 – Sample collection points for Keenjhar Lake

Sample No	Geographical location	Location /Significance
KL-B1	N2459.819 E6806.578	Soneri-1 (biological waste)- Buffalos entry point
KL-B2	N2500.399 E6806.240	Soneri-2 (algal growth)
KL-B3	N2509.819 E6804.578	Soneri-3 (Drinking Water pumping station)
KL-B4	N2501.406 E6806.611	Mid point of the Lake
KL-B5	N2459.819 E6803.618	1 km down from head regulator of Keenjhar lake. (KB Feeder is main source of water supply to Keenjhar Lake).
KL-B6	n/a	Downstream head regulator of Keenjhar lake
KL-B7	n/a	Upstream of Keenjhar lake head regulator
KL-B8	N2500.097 E6806.578	Ali Bux Manchhari village. (Observe human activities and drain entry into Keenjhar Lake).
KL-B9	N2500.528 E6801.450	Jhampir Nai. (See effect of industrial waste like coal, Dolomite mining, silica sand etc coming with rainwater into the Lake.)
KL-B10	N2457.180 E6801.335	Shoro village drain (This drain brings storm water into the Lake).
KL-B11	n/a	Picnic point. (Every weekend during summer huge number of people visit the lake as picnic place where solid waste is thrown into the lake and frequent washing of motor vehicles take place)
KL-B12	n/a	KB Feeder outlet(Karachi Water supply source)

Keenjhar Lake study area water samples were collected from different potential locations during pre and post monsoon. The water quality data obtained in the month of July 2007 (pre monsoon) and October/November 2007 (post monsoon) is shown in the annex document. The data assessed is presented in two parts as physical and chemical parameters.

For the sake of brevity the water quality results are given below for the purpose of its use as drinking, agriculture and fishing against the WHO and other important water quality guidelines/standards. Only important sample locations and water quality parameters, assessed in this study are elaborated in detail here.

Comparing all the samples with standards they have exhibited good water quality except one sample taken from KB feeder, upstream of head regulator which showed more turbidity than the standard as 5 NTU **(Table 24).**

Table 24 – Physical parameter of Keenjhar Lake - Pre monsoon

	Physical Parameters	Pre monsoon
1	Temperature	30-32^{o}C
2	Electrical Conductivity	490-587 µS/cm
3	TDS	314-376 ppm
4	pH	6.96-8.49
5	Turbidity	0.73-8.14
6	Total Hardness	120-155 ppm
7	Calcium	72-80 ppm
8	Magnesium	43-80 ppm
9	Sulphate	14-24 ppm
10	Chlorine	28.9-63.5 ppm
11	Alkalinity	91.5-109.8 ppm

Table 25 – Chemical parameter – Pre-monsoon

	Chemical Parameters	Pre monsoon
1	Alkalinity	
2	Phenols	1.7-3.57ppb
3	Cr	9.3-33.29 ppb
4	Pb	5.19-10.11 ppb
5	Cd	4.28-9.16 ppb
6	Ni	7.73-9.82 ppm
7	BOD	5.06-10.1 ppm
8	COD	12.64-16.43 ppm

The COD and BOD are both high. The lead value shows that these parameters are within the WHO guidelines. The Cd and Ni values are both higher than Pakistani and WHO drinking water quality guidelines. This may be due to the industrial and municipal waste entering from Kotri Industrial area through KB Feeder into Keenjhar Lake. The Phenols found in 50% samples were slightly above the WHO guidelines. This may be due to the municipal/biological waste coming from neighboring villages and wallowing of the buffalos.

Table 26 – Physical parameter – post-monsoon

	Physical Parameters	Pre-monsoon
1	Temperature	25-29^{o}C
2	Electrical Conductivity	529-674 µS/cm
3	TDS	356-432 ppm
4	pH	8.00-8.31
5	Turbidity	3.11-97.2
6	Total Hardness	60-127 ppm
7	Calcium	25-45 ppm
8	Magnesium	35-89 ppm
9	Sulphate	80-170 ppm
10	Chlorine	50-106 ppm
11	Alkalinity	30-40 ppm

Table 27 – Chemical parameter – Post-monsoon

	Chemical Parameters	Post monsoon
1	**DO**	DO varied from 1.2-2.7 ppm
2	**Phenols**	3.4-15.3
3	**Cr**	6.4-20.8 ppb
4	**Pb**	10.93-20.63 ppb
5	**Cd**	0.61-4.74 ppb
6	**Ni**	0.93-1.73 ppm
7	**BOD**	1.00-6.07 ppm
8	**COD**	5.05-12.13 ppm

The value of Ni is higher than Pakistani and WHO Drinking water quality guidelines (0.02 ppm or mg/l).

3.8.3 Drinking water

The total dissolved solid, TDS (or conductivity) is a very important parameter along side pH in determining the water quality. The values of both in all samples fall within WHO acceptable range. The TDS below 500mg/l shows that the dissolved solids are on good side considering all of its uses.

The turbidity (or TSS) is also within WHO standard of 5 NTU except at locations KL-A6 and A7 (Pre monsoon). These location points are near to K.B feeder. The K.B feeder receives water from Indus River at Kotri Barrage which contains high turbidity. The relatively higher levels were also noted at these locations during 1st sampling (before monsoon) period.

The dissolved oxygen is low (Less than 3.0mg/l); good quality of surface water normally has 9 mg/l of Dissolved Oxygen (depending upon pH and temperature). The depletion of dissolved oxygen is an indicator of organic pollution causing BOD and COD. This was found more so when the water level and flow were low before monsoon period.

The Indus water is generally contaminated carrying organic and inorganic pollution load from upstream human activities. The Sindh Environmental Protection Agency (SEPA 2002) reported that the Indus River BOD is over 6.5 mg/l, which according to Global Environmental Monitoring System (GEMS) classification puts this river as “highly polluted”. K.B feeder also carries the municipal effluents of Jamshoro and industrial effluents of Kotri site. The high levels of BOD and COD indicates that sufficient pollution is exerted in before monsoon period through K.B feeder water.

The Phenol levels were very high due to use of washing and other Phenol substances by the people. The total hardness, sulphates, chlorides, calcium and magnesium were found in the acceptable range of WHO/other national and international guidelines.

Toxic elements detected in the water consisted of chromium which is within the WHO guidelines, Lead levels were found violating WHO standard, but this is not true in before monsoon period. The Nickel levels were also found exceeding the WHO limit. The Cadmium levels, however were high at location Keenjhar Lake A6 and A7, having high turbidity of water entering from K.B Feeder.

3.8.4 Agriculture and livestock

The water quality of Keenjhar Lake is very good, considering the TDS (<500 mg/l, and pH (6.5-8.50). The hardness, calcium, magnesium, chlorides and sulphates are as good as required for drinking water quality. From this, it appears that None Degree of Restriction of Use is required for agriculture according to FAO Standards for agriculture crops.

The water salinity (TDS) is well below 1000 mg/l, which is excellent as useable for all livestock and poultry as per FAO guidelines.

3.8.5 Fisheries

Keenjhar Lake water quality is not well suited for aquaculture as reported by Pescode 1977 and WHO. Although the TDS and pH are within acceptable range, the Lead and Phenol were found in very high quantity. The two main sources of dissolved oxygen in stream or canal water are the atmosphere and aquatic plants. Aquatic plants introduce oxygen into stream water as a byproduct of photosynthesis. The amount of oxygen that can dissolve in water is limited by physical conditions such as temperature and atmosphere pressure.

Fish growth and activity usually require 5-6 mg/l or ppm of dissolved oxygen. In this study, the Dissolved Oxygen (DO) has been found below or near 2.0 mg/l (ppm) which does not support fish at all. Other pollutants such as sewage, industrial effluents or agricultural runoff result in the build up of organic matter and the consumption of dissolved oxygen by microbial decomposers as they break down the organic matter. **Tables 28** to **30** give the details of water quality parameters taken from Keenjhar Lake

Table 28 – Keenjhar water quality assessment – pre-monsoon (samples KLB3 – KLB7)

	Parameter	Permissible WHO Standards	KLB3 Soneri3	KLB4 Mid Point	KLB6 KBF d/s (RD2.4)	KLB7 KBF u/s	Remarks
1	TDS (mg/l	1000	329	337	376	375	Normal
2	pH	6.5-8.5	8.35	8.03	7.75	7.62	Within range
3	Turbidity (NUT)	5	1.77	1.45	4.52	8.14	Permissible except KLB7
4	Total Hardness (mg/l)	500	125±0.15	132±0.12	140±0.2	144±0.2	Normal
5	SO_4 (mg/l)	250	20±0.15	15±0.25	18±0.15	24±0.25	Normal
6	Cl (mg/l)	250	54.8±0.25	59.4±0.23	63.5±0.25	58.7±0.35	Permissible
7	Magnesium (mg/l)	150	45±0.23	57±0.15	60±0.22	64±0.25	Permissible
8	Calcium (mg/l)	75	80±0.23	75±0.15	80±0.22	80±0.25	Permissible-though it is slightly high
9	COD				15.16	16.43	High (References show max value for fresh water from 3-5 mg/l

10	BOD (mg/l)		10.1		9.3	8.3	High (Literature show max value for fresh water less than 2-3 mg/l
11	Phenol (µg/l)	0.002 (mg/l)	1.7	3.4	2.89	2.2	Slightly high at some locations
12	Cr (µg/l)	0.05(mg/l)			14.63	9.3	Normal
13	Cd (µg/l)	0.003(mg/l)			9.16	4.28	Slightly high
14	Pb (µg/l)	0.01(mg/l)			8.43	5.19	Normal
15	Ni (mg/l)	0.02(mg/l)			8.11	7.73	Very high

The ± values show the standard deviation

Table 29 – Keenjhar water quality assessment pre-monsoon (samples KLB8 – KLB12)

S.no	**Parameter**	**Permissible WHO Standards**	**KLB8**	**KLB9**	**KLB10**	**KLB11**	**KLB12**	**Remarks**
1	TDS (mg/l	1000	340	330	332	314	323	Normal
2	pH	6.5-8.5	8.08	8.2	7.89	8.18	8.00	Within range
3	Turbidity (NUT)	5	0.73	1.65	0.9	3.03	1.63	Permissible
4	Total Hardness (mg/l)	500	124±0.15	132±0.20	124±0.2	120±0.2	130±0.3	Normal
5	SO_4 (mg/l)	250	20±0.25	14±0.35	18±0.25	20±0.22	18±0.32	Normal
6	Cl (mg/l)	250	44.7±0.35	55.8±0.2	55.2±0.22	53.1±0.24	52.9±0.24	Permissible
7	Magnesium (mg/l)	150	44±0.25	60±0.15	46±0.15	43±0.15	50±0.22	Permissible
8	Calcium (mg/l)	75	80±0.25	72±0.15	78±0.15	77±0.15	80±0.22	Permissible-though it is 9slightly high
9	BOD(mg/l)		8.09				8.3	High (literature show max value for fresh water less than 2-3 mg/l
10	Phenol (µg/l)	0.002	3.57	3.4	2.2	2.3	2.8	Slightly high at some locations

The ± values show the standard deviation

Table 30 – Keenjhar water quality assessment (post-monsoon)

	Parameters	Permissible (WHO) Standard	Sample locations									
			KL-A3	KL-A4	KL-A6	KL-A7	KL-A8	KL-A9	KL-A10	KL-A11	KL-A12	Remarks
1	TDS (mg/L)	1000	364.0	374.0	432.0	432.0	377.0	368.0	356.0	338.0	348.0	Normal
2	pH	6.5-8.5	8.00	8.30	8.18	8.18	8.00	8.30	8.30	8.31	8.15	Normal
3	Turbidity (NTU)	5 NTU	4.73	13.3	83.3	97.2	5.46	3.86	5.12	4.71	3.11	Very high at KL-A6, KL-A7
4	DO (mg/L)	> 2.0 mg/l (*)	1.3	1.4	1.9	1.2	1.7	2.1	2.4	2.7	1.8	Low except KL-9,10,11
5	Total Hardness (mg/L)	500	126 ±0.32	115 ±0.35	127 ±0.33	124 ±0.25	125 ±0.20	112 ±0.35	80 ±0.22	70 ±0.15	60 ±0.15	Normal
6	SO_4^- (mg/ L)	250	80 ±0.15	135 ±0.12	155 ±0.15	145 ±0.15	115 ±0.20	133 ±0.25	170 ±0.25	155 ±0.32	165 ±0.33	Normal
7	Cl^- (mg/ L)	250	100 ±0.25	80 ±0.22	105 ±0.23	106 ±0.25	80 ±0.30	78 ±0.30	60 ±0.15	50 ±0.15	70 ±0.15	Normal
8	Magnesium (mg/ L)	150	86 ±0.15	75 ±0.20	87 ±0.15	89 ±0.30	80 ±0.30	72 ±0.35	40 ±.033	40 ±0.40	35 ±0.42	Normal
9	Calcium (mg/ L)	75	40 ±0.25	40 ±0.20	40 ±0.15	35 ±0.30	45 ±0.30	40 ±0.35	40 ±0.33	30 ±0.40	25 ±0.42	Normal
10	COD (mg/L)		7.58	--	5.56	5.05	12.13	--	--	--	--	Relatively high at KL-A3 and A8
11	BOD (mg/L)		1.52	--	1.52	1.00	6.07	--	--	--	--	Relatively high at KL-A8
12	Cr (µg/L)	0.05 (mg/L)	6.4	10.5	20.8	10.2	8.00	14.3	18.8	14.0	12.0	Normal
13	Cd (µg/L)	0.003 (mg/L)	0.84	2.38	4.74	3.81	0.74	1.59	0.61	0.63	1.21	High at KL-A6,A7
14	Pb (µg/L)	0.01 (mg/L)	17.18	20.63	16.65	14.69	10.93	12.44	18.79	18.61	16.13	Not very high
15	Ni (mg/L)	0.02 (mg/L)	1.53	0.93	1.73	1.38	0.99	1.07	1.12	0.93	1.40	High
16	Phenol (µg/L)	0.002 (mg/L)	15.3	8.5	8.5	8.5	6.8	6.8	6.8	3.4	5.1	Very high

(*) Stream water quality standards (Pescode, 1977)
The ± values show the standard deviation

3.8.6 Threats and recommendations

The report did not highlight specific threats and recommendations in the report though the author did comment that the limited monitoring does not give a clear picture, It is therefore necessary that the continuous year round water quality monitoring program may be initiated to record the changes in water quality, preferably full range stream water quality parameters including biological ones. Any study which helps determine the assimilative capacity of river/ stream/reservoir will be a yard mark and corner stone in developing the criteria of total maximum daily loads (TMDLs) for public safety and other beneficial use of water. One recommendation was that the population growth (particularly in Ameer Pir) and human activities in point source location/villages need to be checked to control the pollution. For this public awareness program and training of NGOs/communities is vital to address & arrest the environmental degradation, especially in the picnic/tourist location area.

Chapter 4: Comparison of the four study sites

4.1 Mammals

4.1.1 Summary

There is no significant difference in results of the summer and winter surveys of the study areas. The same 20 species were recorded from the study areas during both the surveys. However, during the winter survey, the population of Hump-back dolphin was larger in different creeks at Keti Bunder. This is probably due to the availability of fish which they feed on. Moreover, most of the mammals particularly the nocturnal mammals were found more active during the summer survey and less active comparatively during the winter survey. The reasons seem to be the homoeothermy and the hibernation factors for less activeness of mammals during winter.

The existence of Indian otter was doubtful in Chotiari Reservoir prior to these studies. During the present surveys both in summer and winter, the existence of this animal was confirmed in Chotiari Reservoir and Keti Shah and its population was estimated at both the sites.

Estimated populations of mammals at different sites during two different surveys do not show any significant differences. For example, Hog deer population at Pai forest estimated during the summer survey was 18 animals whereas estimates during winter survey showed a population of 20 animals. During the summer survey 7 otters were estimated at Chotiari Reservoir but during winter survey about 12 animals were estimated. However, the locations where the otters were found during the summer survey were different from the locations during winter surveys. The locations along Nara canal where otters were found during summer survey showed no sign of otters during winter survey as the Nara canal was dry during winter survey. It shows that food availability, shelter and health of the habitat are the main factors.

Local people as well as most of the conservationists believed that there exists the Asiatic wild ass in north eastern side of Chotiari. The present studies revealed that the existing population is apparently the feral donkeys known as “Asses of Achhro Thar” and not the Asiatic wild ass. There is close resemblance of these animals with the Asiatic wild ass and their coexistence in the same habitat with the Asiatic Wild Ass for the last 7 decades. Investigation through genomic studies is trying to identify if these animals are wild asses, feral donkeys or some race of the Asiatic wild ass. In this regard a genomic analysis of all the three races will clearly suggest that either the Asses of Achhro Thar are feral donkeys or they are a separate race or subspecies. Concerns about wild animals among the local residents are not much severe.

Habitat loss and natural disasters affect wildlife species but the mammalian fauna of the area is facing serious threats from anthropogenic activities. The apparent low abundance of many large mammalian species is strong evidence that hunting and habitat degradation is having a considerable effect on their populations.

A few wildlife species also create problems for the local people and thus are considered as problem species. The major concerns about wild animals in different sites of *Indus for All Programme* are the damages to crops through agricultural pests like wild boar and porcupine and threats to human lives from mad / feral dogs and snake bites.

Some socio-economic issues like un-employment, less education, lack of awareness, less availability of basic needs etc. at different sites are also important factors in wildlife conservation and management in the study area.

4.1.2 Species identified

Over 40 days in the field (21 days during summer in June 2007 and 22 days during winter in January 2008) a total of 20 large and medium sized mammal species, belonging to five orders (Carnivora, Artiodactyla, Perissodactyla, Cetacea and Pholidota) were recorded from the five sites of Indus for All Programme. Eight species were recorded from Pai forest, 14 from Chotiari, 9 from Keenjhar, 14 from Keti Bunder and 8 from Keti Shah. **Table 31** lists all the species recorded over the survey period.

Table 31 – Species recorded from different sites

S.no	Common Name	Zoological Name	Local Name	Order
1	Asiatic jackal	*Canis aureus*	Geedar/Giddar	Carnivora
2	Caracal or Desert lynx	*Felis caracal*	Siva gush	Carnivora
3	Jungle cat	*Felis chaus*	Jang Billo	Carnivora
4	Fishing cat	*Prionailurus viverrinus*	Mash Billo	Carnivora
5	Indian desert cat	*Felis sylvestris ornata*	Sahrai Billi	Carnivora
6	Bengal fox	*Vulpes bengalensis*	Lumar	Carnivora
7	Desert fox or Red fox	*Vulpes vulpes pusilla*	Sahrai Lumar	Carnivora
8	Indian otter	*Lutrogale perspicillata*	Ludher	Carnivora
9	Small Indian mongoose	*Herpestes javanicus*	Neola	Carnivora
10	Grey mongoose	*Herpestes edwardsi*	Neola	Carnivora
11	Small Indian civet	*Viverricula indica*	Kasturi Billa	Carnivora
12	Hog deer	*Axis porcinus*	Para	Artiodactyla
13	Indian wild boar	*Sus scrofa*	Suar	Artiodactyla
14	Chinkara	*Gazella bennettii*	Chitka Hiran	Artiodactyla
15	Feral donkey	*Equus sp.*	Jangli Gadha	Perissodactyla
16	Indus dolphin	*Platanista minor*	Bhulan	Cetacea
17	Bottle-nosed dolphin	*Tursiops truncatus*	Malhar	Cetacea
18	Hump-backed dolphin	*Sousa chinensis*	Humma	Cetacea
19	Finless porpoise	*Neophocaena hocaenoides*	Tabi	Cetacea
20	Indian pangolin	*Manis crassicaudata*	Bagra, Silu	Pholidota

4.1.3 Observation records

Out of the total 20 recorded species, 15 species were observed directly while the remaining five species were recorded on the basis of indirect evidences such as the presence of fecal materials, foot prints and interviews of local residents and wildlife watchers. The observation records of different mammals found in all the five sites are given in the **Table 32**.

Table 32 – Observation records of different mammals at sites

Sr. No.	Species	Direct Observations					Indirect observations through tracks, faeces and interviews from locals Residents				
		KB	K	P	C	KS	KB	K	P	C	KS
1	Asiatic jackal	✓	✓	✓	✓	-	-	-	-	-	✓
2	Caracal	-	-	-	-	-	-	-	-	✓	-
3	Jungle cat	-	-	-	✓	-	✓	✓	✓	✓	✓
4	Fishing cat	-	-	-	-	-	✓	✓	-	✓	-
5	Indian desert cat	-	-	-	-	-	✓	-	-	✓	-
6	Bengal fox	✓	-	-	✓	-	✓	✓	✓	✓	-
7	Desert fox	-	-	-	✓	-	✓	✓	-	✓	-
8	Indian otter	-	-	-	-	-	-	-	-	✓	-
9	Small mongoose	✓	✓	✓	✓	-	-	-	-	-	✓
10	Grey mongoose	-	-	✓	✓	-	-	-	-	-	✓
11	Small Indian civet	✓	-	✓	-	-	-	-	-	-	✓
12	Hog deer	-	-	✓	-	-	-	-	✓	✓	✓
13	Indian wild boar	-	✓	-	-	-	✓	✓	✓	✓	✓
14	Chinkara	-	-	-	✓	-	-	-	-	✓	-
15	Feral donkey	-	-	-	✓	-	-	-	-	✓	-
16	Indus dolphin	-	-	-	-	✓	-	-	-	-	-
17	Bottle-nosed dolphin	✓	-	-	-	-	-	-	-	-	-
18	Hump-backed dolphin	✓	-	-	-	-	-	-	-	-	-
19	Finless porpoise	✓	-	-	-	-	-	-	-	-	-
20	Indian pangolin	-	-	-	-	-	✓	✓	-	-	-
Legend: KB = Keti Bunder, K=Keenjhar, P=Pai Forest, C=Chotiari, KS=Keti Shah											

4.1.4 Conservation status of mammal species

According to the IUCN International Red List 2006, Jungle cat, Small Indian mongoose and Small Indian civet are categorized as Least Concern (LC), Fishing cat as Vulnerable (VU) and Finless porpoise as Data Deficient (DD).

According to the Pakistan IUCN Red List of Mammals 2005, one species is Critically Endangered (CE), one Endangered (E), three Vulnerable (VU), six Near Threatened (NT), four Least Concern (LC) and four Data Deficient (DD).

Ten species are protected in Sindh under Sindh Wildlife Protection Ordinance 1972. Three species are enlisted in Appendix II while six species in Appendix I of the CITES category 2007. The conservation status of different mammals found at Indus for All Programme sites is given in **Table 33** below.

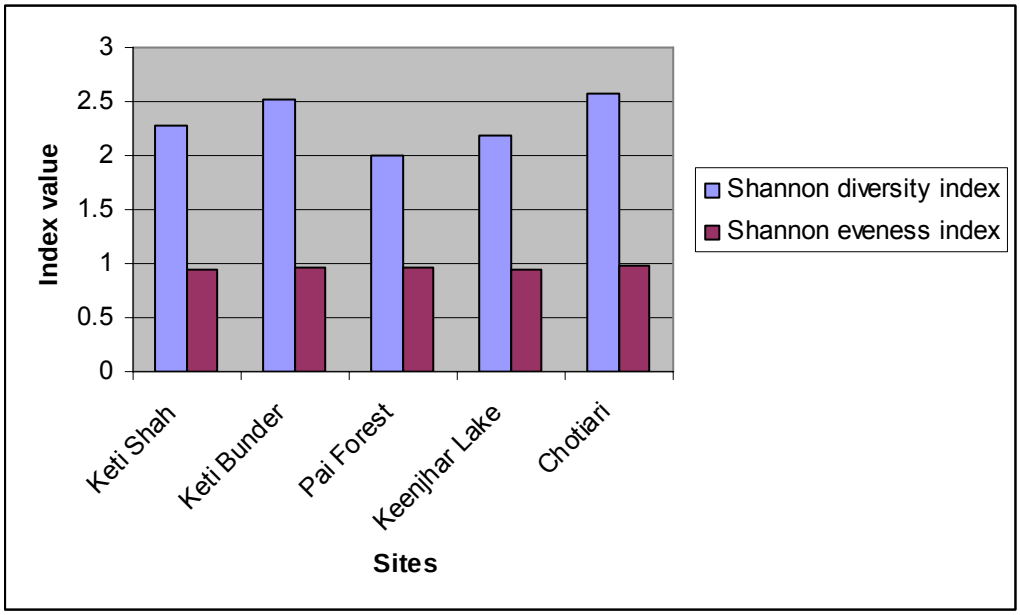
Table 33 – Conservation status of mammals found at Indus for All Programme sites

Sr. No.	Mammalian Species Recorded	IUCN International Red List 2006	IUCN Pakistan Red List 2005	Sindh Wildlife Protection Ordinance 1972	CITES Category 2007
1	Asiatic jackal	-	NT	-	-
2	Caracal or Desert lynx	-	CE	P	Appendix I
3	Jungle cat	LC	LC	P	Appendix II
4	Fishing cat	VU	NT	P	Appendix II
5	Indian desert cat	-	DD	P	Appendix II
6	Bengal fox	-	NT	-	-
7	Desert fox / Red fox	-	NT	-	-
8	Indian otter	-	NT	P	-
9	Small Indian mongoose	LC	LC	-	-
10	Grey mongoose	-	LC	-	-
11	Small Indian civet	LC	NT	P	-
12	Hog deer	-	VU	P	Appendix I
13	Indian wild boar	-	LC	-	-
14	Chinkara	-	VU	P	-
15	Feral donkey	-	-	-	-
16	Indus dolphin	-	E	P	Appendix I
17	Bottle-nosed dolphin	-	DD	-	Appendix I
18	Hump-backed dolphin	-	DD	-	Appendix I
19	Finless porpoise	DD	DD	-	Appendix I
20	Indian pangolin	-	VU	P	-
Legend: CE=Critically Endangered, E=Endangered VU=Vulnerable, NT=Near Threatened, LC=Least Concern, DD=Data Deficient, P=Protected					

4.1.5 Species diversity

Looking at the diversity index over the four sites (shown in **Figure 18**) Chotiari Reservoir holds the highest level of diversity of mammals followed by Keti Bunder. Given the variety of habitats at Chotiari Reservoir (desert, wetland and forest) it is not surprising that this site holds the highest index. Similarly, Keti Bunder comprises of both terrestrial and marine habitats which results in a high diversity index despite apparent environmental degradation both inland and in the creeks. Even with some variance in diversity, the evenness of diversity across the sites is quite regular, except for Chotiari Reservoir. These indexes do not take into account the diversity across seasons, something that is discussed further on in this chapter.

Figure 18 – Shannon diversity and evenness index over the programme sites



4.1.6 Comparison of species observed during summer and winter

Number of animals recorded during summer and winter surveys are merely rough estimates and not the actual populations (shown in **Table 34 to 38**). The last column in the following tables showing total animals is not reflecting the total population of different species at different sites. Rather it is just the sum of observed animals during summer and winter and the animals observed during summer might be the same counted or observed during in winter. However, some populations of all the existing species at the four sites were estimated scientifically and are discussed later on in the chapter.

Table 34 – Mammals recorded from Keti Shah during summer and winter surveys

Sr. No.	Common Name	Summer survey	Winter survey	Total Animals
1	Asiatic jackal	12	4	16
2	Jungle cat	2	-	2
3	Bengal fox	1	-	1
4	Desert fox	1	-	1
5	Indian otter	-	11	11
6	Small Indian mongoose	7	1	8
7	Grey mongoose	3	-	3
8	Small Indian civet	1	-	1
9	Hog deer	2	3	5
10	Indian wild boar	4	14	18
11	Indus dolphin	3	13	16

Table 35 – Mammals recorded from Chotiari during summer and winter surveys

Sr. No.	Common Name	Summer survey	Winter survey	Total animals
1	Asiatic jackal	25	12	37
2	Caracal	3	-	3
3	Jungle cat	3	2	5
4	Fishing cat	2	1	3
5	Indian desert cat	2	-	2
6	Bengal fox	3	1	4
7	Desert fox	2	-	2

8	Indian otter	7	12	19
9	Small Indian mongoose	7	5	12
10	Grey mongoose	5	2	7
11	Hog deer	7	7	14
12	Indian wild boar	7	2	9
13	Chinkara	3	-	6
14	Feral donkey	90	-	90

Table 36 – Mammals recorded from Pai Forest during summer and winter surveys

Sr. No.	Common Name	Summer survey	Winter survey	Total population
1	Asiatic jackal	25	15	40
2	Jungle cat	2	1	3
3	Bengal fox	3	2	5
4	Small Indian mongoose	5	1	6
5	Grey mongoose	2	-	2
6	Small Indian civet	6	-	6
7	Hog deer	18	20	19
8	Indian wild boar	85	-	85

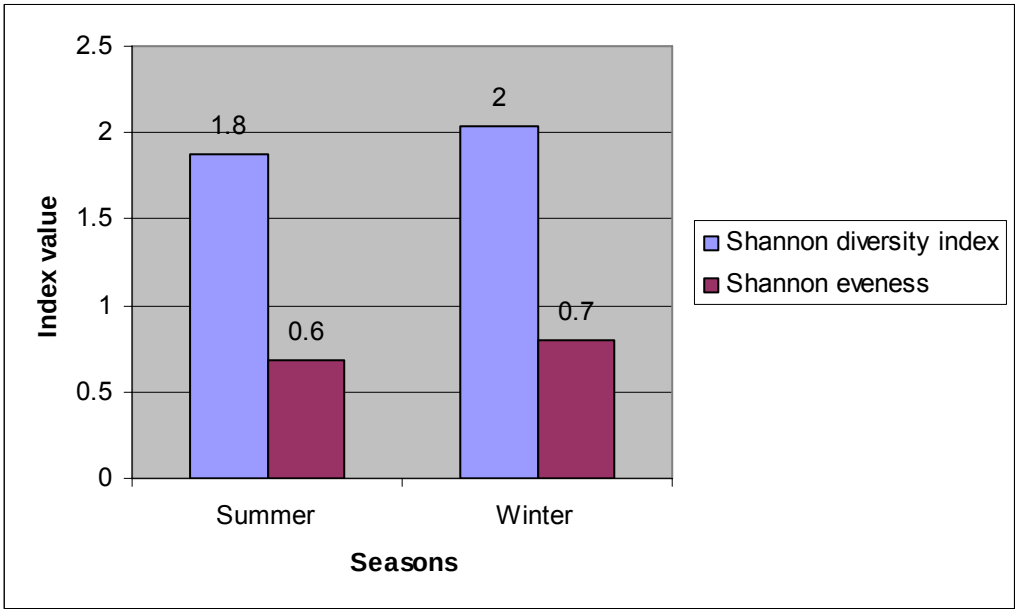
Table 37 - Mammals recorded from Keenjhar Lake during summer and winter surveys

Sr. No.	Common Name	Summer survey	Winter survey	Total Animals
1	Asiatic jackal	46	14	60
2	Jungle cat	2	4	6
3	Fishing cat	1	3	4
4	Bengal fox	1	-	1
5	Desert fox	1	-	1
6	Small Indian mongoose	4	2	6
7	Grey mongoose	2	-	2
8	Indian wild boar	15	-	15
9	Indian pangolin	1	1	2

Table 38 – Mammals recorded from Keti Bunder during summer and winter surveys

Sr. No.	Common Name	Summer survey	Winter survey	Total Animals
1	Asiatic jackal	13	4	17
2	Jungle cat	2	-	2
3	Fishing cat	1	-	1
4	Indian desert cat	1	-	1
5	Bengal fox	2	1	3
6	Desert fox	1	-	1
7	Small Indian mongoose	12	2	14
8	Grey mongoose	5	3	8
9	Small Indian civet	2	-	2
10	Indian wild boar	4	7	11
11	Bottle-nosed dolphin	-	2	2
12	Hump-backed dolphin	-	62	62
13	Finless porpoise	2	-	2
14	Indian pangolin	2	-	2

Figure 19 – Shannon diversity and Evenness index over all sites for summer and winter



There was more diversity of medium and large mammals in winter than summer across the four sites. There may be several reasons for this such as mammals were more active in winter foraging for food or were more detectable due to less vegetation on the ground.

4.1.7 Population Estimations

Populations of 14 different large mammals were estimated that included eight from Pai forest, four from Chotiari, three from Keenjhar one from Keti Bunder and two from Keti Shah. Estimated populations are given in the **Table 39 and 40**.

Table 39 – Estimated population of species found at the five sites

	Hog Deer	Indian Wild Boar	Indus dolphin	Small Indian civet	Desert fox	Asiatic jackal	Jungle cat
Keti Bunder	n/a	0	n/a	n/a	n/a	0	n/a
Keenjhar Lake	n/a	15	n/a	n/a	5	46	n/a
Chotiari Reservoir	7	n/a	n/a	n/a	6	n/a	n/a
Pai Forest	19	85	n/a	6	n/a	40	3
Keti Shah	n/a	n/a	13	n/a	n/a	n/a	n/a

Table 40 – Estimated population of species found at the five sites

	Bengal Fox	Small Indian Mongoose	Grey mongoose	Indian Otter	Chinkara	Hump-backed Dolphin
Keti Bunder	n/a	n/a	n/a	n/a	n/a	62
Keenjhar Lake	n/a	n/a	n/a	n/a	n/a	n/a
Chotiari Reservoir	n/a	n/a	n/a	12	5	n/a
Pai Forest	5	40	27	n/a	n/a	n/a
Keti Shah	n/a	n/a	n/a	11	n/a	n/a

4.1.8 Assessment of level of threats to mammals at different study sites

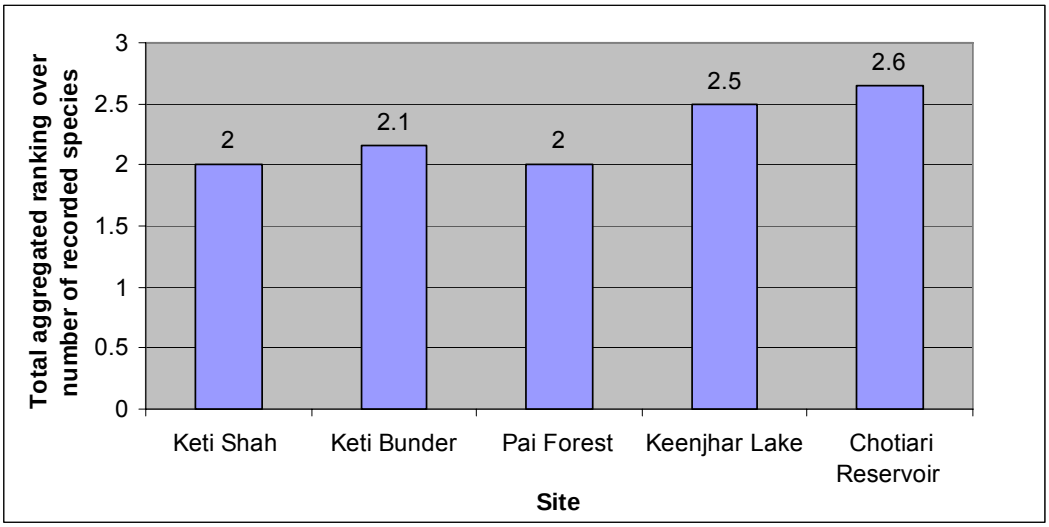
Various threats to different mammals were identified at five different study sites that include; habitat destruction, illegal hunting, poaching, live trapping, food competition, lack of awareness, law and order situation, weak enforcement of wildlife laws etc. Based on indirect and direct observations in the field and after interviewing different people from local communities and wildlife watchers and forest guards an assessment was made to indicate the level of threats to every mammal species in Indus for All programme sites.

1 = no threats, 2 = minor threats, 3 = moderate threats, 4 = highly threatened, 5 = critically threatened

Table 41 – Assessment of level of threats to mammals at different study sites

Sr. No.	Common Name	Keti Shah	Keti Bunder	Pai Forest	Keenjhar Lake	Chotiari Reservoir
1	Asiatic jackal	2	2	2	2	2
2	Caracal or Desert lynx		-	-	-	4
3	Jungle cat	2	2	2	4	3
4	Fishing cat	-	3	-	4	3
5	Indian desert cat	-	3	-	-	2
6	Bengal fox	2	3	2	2	3
7	Desert fox or Red fox	2	3	-	2	3
8	Indian otter	4	-	-	5	4
9	Small Indian mongoose	1	1	1	1	1
10	Grey mongoose	1	1	1	1	1
11	Small Indian civet	2	3	2	-	-
12	Hog deer	4	-	4	-	3
13	Indian wild boar	1	1	2	2	2
14	Chinkara	-	-	-	-	2
15	Feral donkey	-	-	-	-	4
16	Indus dolphin	1	-	-	-	-
17	Bottle-nosed dolphin	-	1	-	-	-
18	Hump-backed dolphin	-	1	-	-	-
19	Finless porpoise	-	1	-	-	-
20	Indian pangolin	-	3	-	2	-

Figure 20 – Aggregated threat ranking adjusted against number of species recorded from each site

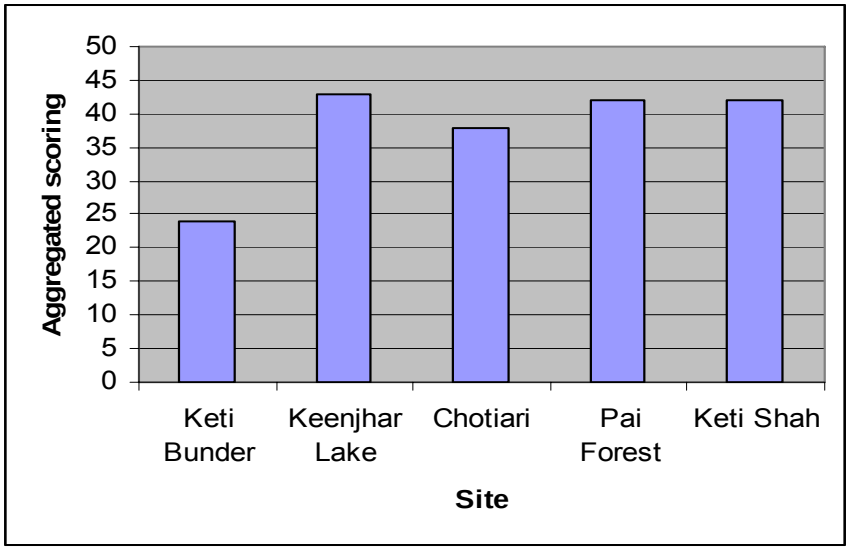


Chotiari Reservoir and Keenjhar Lake had the highest averaged disturbance factor against the species that were recorded there. Though this is an arbitrary scoring it does give an indication over the overall threat to large mammals at each site. Looking at general issues over the sites, Table 41 lists all the potential threats and attributes scores to them (ranging from 1 to 5, see legend below **Table 42**) across the sites. **Figure 21** gives the aggregated score for all sites.

Table 42 – Threats ranking for large mammals at sites

S. No.	Nature of Threats	Keti Bunder	Keenjhar Lake	Chotiari	Pai Forest	Keti Shah
1	Food competition with livestock	1	1	1	4	1
2	Disease transmission from livestock	1	1	2	2	1
3	Habitat removal / degradation	1	3	2	4	3
4	Wood cutting	2	1	1	4	4
5	Lack of awareness	3	3	3	3	3
6	Killing of problem species / pests	2	4	2	2	2
7	Poisoning of animals	1	1	2	1	1
8	Hunting Pressure	1	5	5	3	3
9	Hunting with dogs	0	2	1	4	1
10	Use of fire arms	0	5	4	4	3
11	Live trapping	1	3	3	3	4
12	Dominance of feral dogs	5	4	3	3	2
13	Water pollution	1	1	1	0	0
14	Presence of fish farms	0	4	3	0	0
15	Entanglement of cetaceans in fishing gears	1	0	0	0	0
16	Weak enforcement of wildlife laws	3	5	5	5	5
17	Law and order situation	0	0	0	0	5
18	Natural threats	1	0	0	0	4
	Total score	24	43	38	42	42
1= low, 2 = medium, 3 = average, 4= significant, 5 = high						

Figure 21 – Aggregated score for disturbance factors across sites



Most of the sites have similar ranking with Keenjhar Lake on top followed by Pai Forest, Keti Shah and Chotiari Reservoir. Surprisingly Keti Bunder has significantly less disturbance than other sites, perhaps due to relatively less human population.

4.2 Small mammals

4.2.1 Species recorded

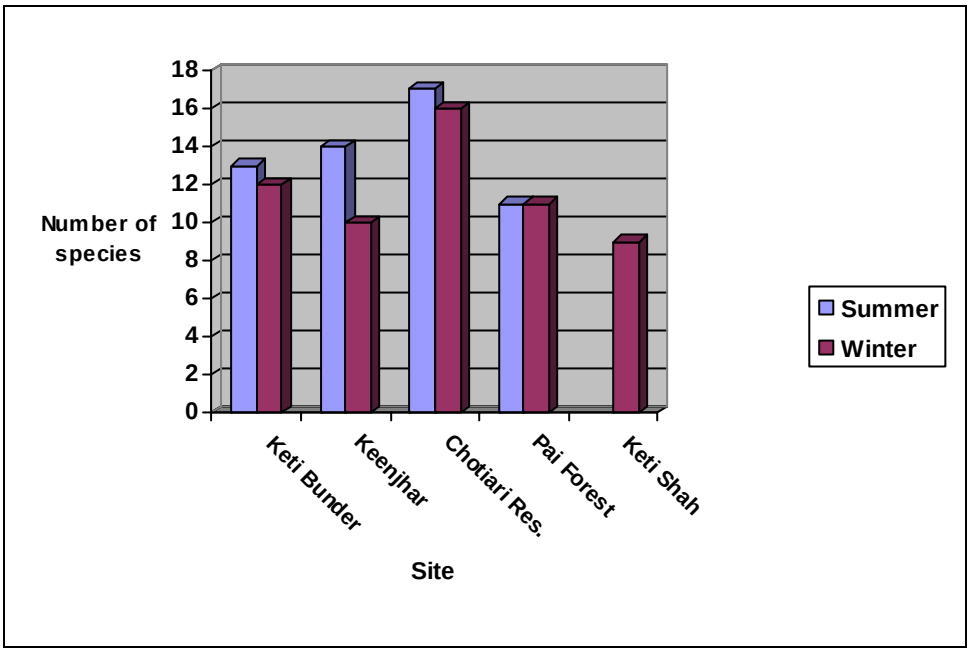
A total of 23 small mammal species were observed or collected from the five sites of the Indus for All Programme, 15 from Keti Bunder, 17 from Keenjhar, 19 from Chotiari, 14 from Pai forest and 9 from Keti Shah riverine forest. Most of these species were recorded in summer. The table below gives an account of species found at each site.

Table 43 – Total species recorded at five sites over summer and winter

	English Name	Scientific Name	Keti Bunder		Keenjhar		Chotiari		Pai		Keti Shah	
			S	W	S	W	S	W	S	W	S	W
1	Cairo spiny mouse	*Acomys cahirnus*	-	+	+	-	-	-	-	-	-	-
2	Leaf-nosed bat	*Asellia tridens*	-	-	+	-	-	+	-	-	-	-
3	Sindh Rice Rat	*Bandicota bengalensis*	+	+	+	+	+	+	+	+	-	+
4	Palm Squirrel	*Funambulus pennantii*	+	+	+	+	+	+	+	+	-	+
5	Baluchistan Gerbil	*Gerbilus nanus*	-	-	-	+	+	+	-	-	-	-
6	Indian bush rat	*Golunda ellioti*	+	+	-	-	-	-	+	-	-	-
7	Long-eared Hedgehog	*Hemiechinus collaris*	+	-	+	-	+	+	+	+	-	-
8	Indian crested porcupine	*Hystrix indica*	+	+	+	+	+	+	+	+	-	+
9	Desert hare	*Lepus nigricolis*	+	+	+	-	+	+	+	+	-	-
10	Indian Desert Jird	*Meriones hurrianae*	-	-	-	+	+	+	-	-	-	-
11	Sand coloured rat	*Millardia gleadwi*	-	+	-	-	+	-	-	+	-	-
12	Soft-furred field rat	*Millardia meltada*	-	-	-	-	+	+	-	+	-	-
13	Little Indian field-mouse	*Mus booduga*	-	-	-	-	+	+	-	-	-	-
14	House mouse	*Mus musculus*	+	-	+	-	+	+	+	+	-	+
15	Grey spiny mouse	*Mus saxicola*	-	-	+	+	-	-	-	-	-	-
16	Short-tailed rat	*Nesokia indica*	-	-	-	-	-	+	-	-	-	-
17	Indian Hedgehog	*Paraechinus micropus*	+	-	+	+	+	+	-	+	-	+
18	Kuhls' bat	*Pipistrellus kuhlii*	+	+	+	+	+	-	+	-	-	-
19	Common Rat	*Rattus rattus*	+	+	+	+	+	+	+	+	-	+
20	Large mouse tailed bat	*Rhinopoma microphyllum*	+	+	+	-		-	-	-	-	+
21	Common yellow-bellied bat	*Scotophilus heather*	-	-	-	-	+	-	+	-	-	-
22	House shrew	*Suncus murinus*	+	+	-	-	+	+	-		-	+
23	Indian Gerbil	*Tatera indica*	+	+	+	+	+	+	+	+	-	+

Figure 22 below shows the number of small mammal species recorded at each site over summer and winter. Chotiari Reservoir has the highest level of diversity followed by Keenjhar, Keti Bunder and then Pai Forest.

Figure 22 – Comparison of number of small mammal species over summer and winter



4.2.2 Similarity index over sites and seasons

Figures 23 and 24 shows the similarity over sites. There is similarity over Keti Bunder, Keenjhar Lake, Pai Forest and Keti Shah during winter and very little with Chotiari Reservoir. This phenomenon is common over most of the terrestrial studies indicating that Chotiari Reservoir has some inherent quality that makes it outstanding in terms of biodiversity.

Figure 23 – Similarity index over five programme site during summer

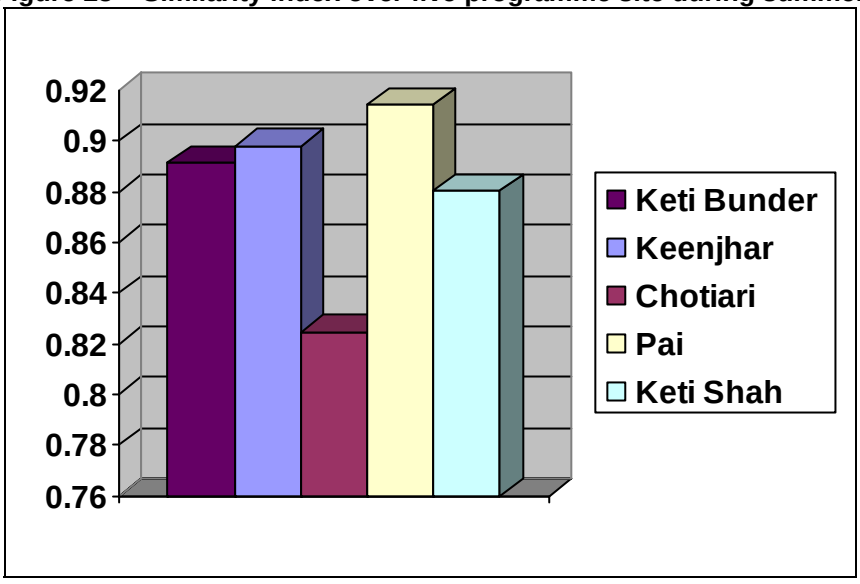
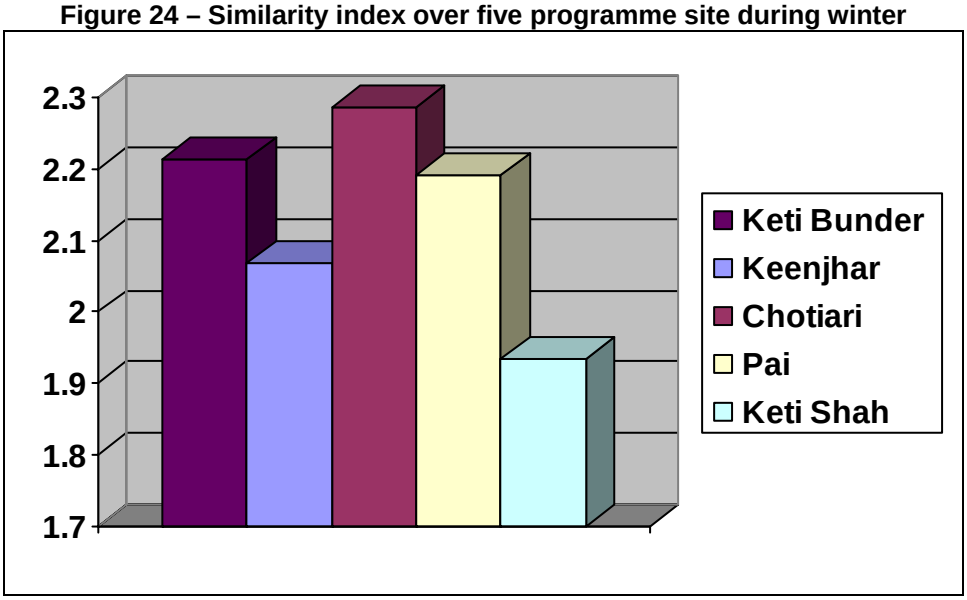


Figure 24 – Similarity index over five programme site during winter



4.2.3 Feeding habits

The feeding habits of small mammals varied over sites though with no particular trend over the sites. Given the diversity of habitats over sites this is to be expected. Over the season there was some variation of feeding habits, probably due to change in food availability since many small mammal species adapt to constantly changing situations. **Figures 25 and 26** give details of the percentage of species in each site against the main feeding habits.

Figure 25 – Percentage of species recorded for each site over feeding habit

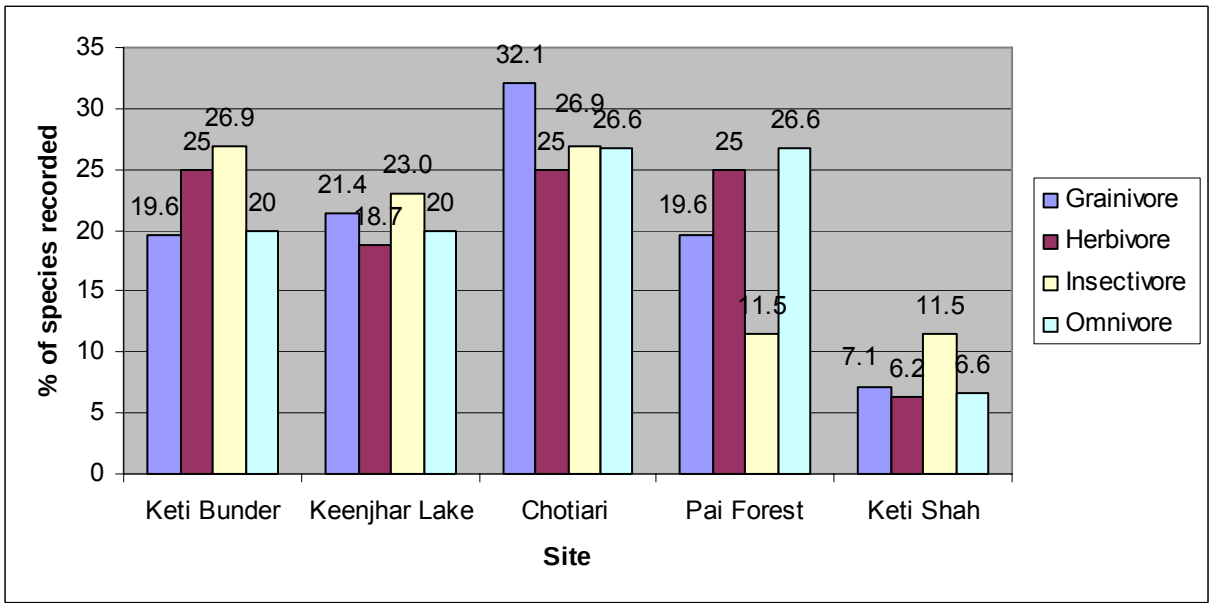
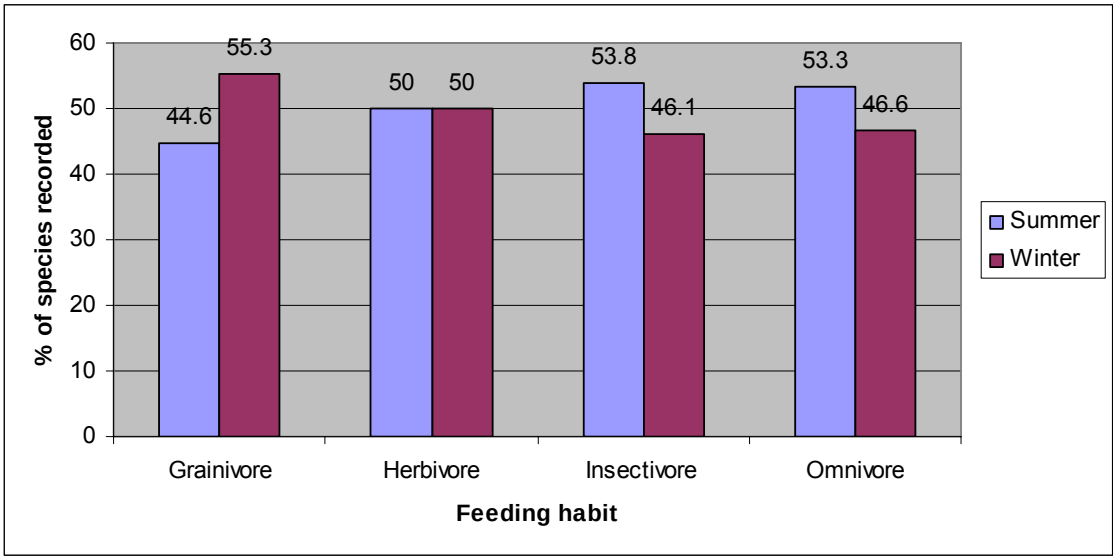


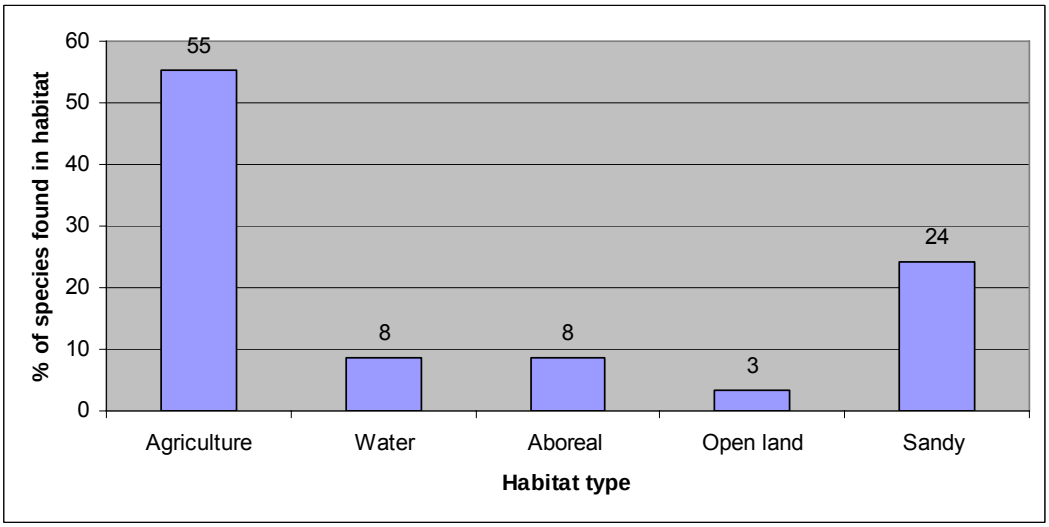
Figure 26 – Percentage of species recorded over season and against feeding habits



4.2.4 Habitat

Over the fives sites agriculture habitat supported the most species with more than 50% of all records being taken from agriculture habitats followed by sandy habitats (23%). The remaining water, tree and open habitats mad up the outstanding 27%. **Figure 27** shows the percentage of species found in each habitat. This result indicates that agriculture land plays an important role in maintaining the ecosystem, despite it being a man-made ecosystem. The fact that open land supported very few small mammal species also suggests that some minimum vegetative cover is required to support a diversity of small mammals.

Figure 27 – Number of species observed according the habitat



4.2.5 Status of small mammals across the survey sites

All the small mammals recorded during the survey were categorized as Common or of Least Concern. There are no rare, endangered or endemic species though many parts of the country are data deficient for several species so these categories are still quite speculative. There was no obvious trend or dominance of the two categories except in Keti Bunder where species if Less Concern were more dominant that Common species and vice versa in Keenjhar Lake where

Common species were more dominant. **Figure's 28 and 29** show the results over site and season.

Figure 28 – Percentage of species recorded across sites against status categories

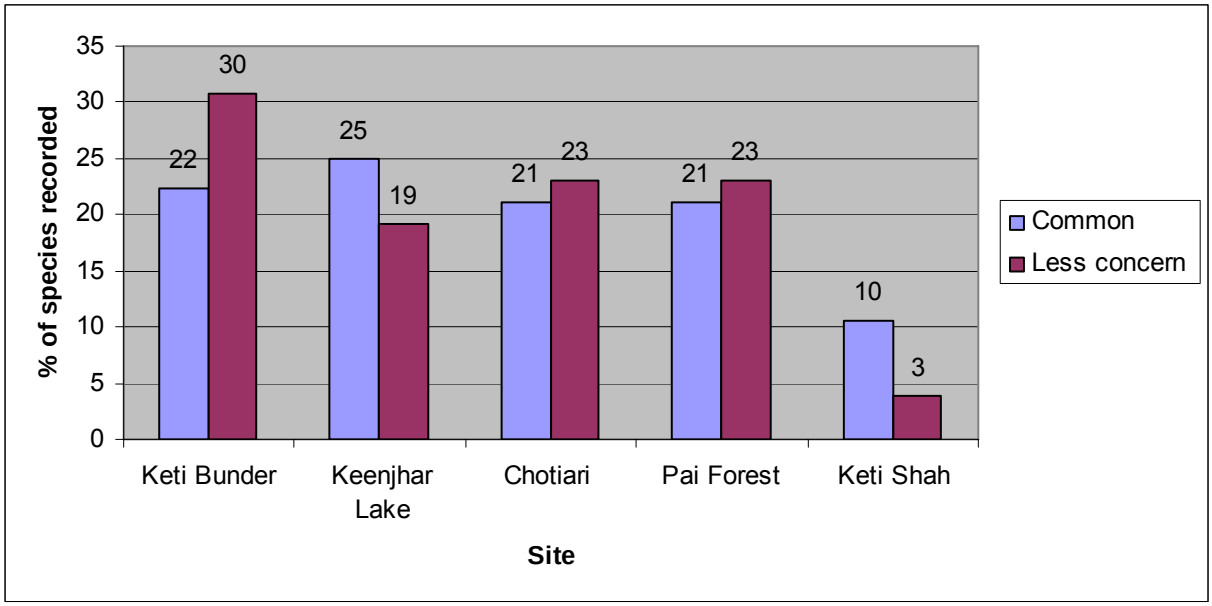
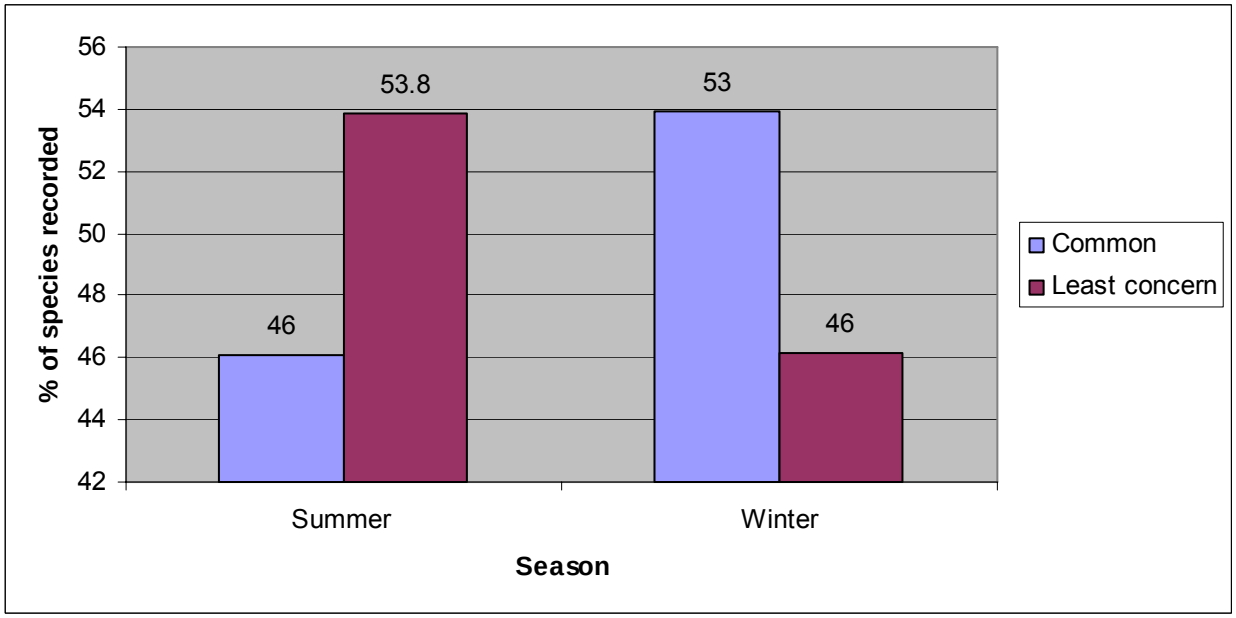


Figure 29 – Percentage of species recorded across season against status categories



4.3 Reptiles and amphibians

4.3.1 Summary

During summer and pre-winter surveys, 3251 amphibians and reptiles were either observed or collected. A total of 65 species are distributed among the entire IFAP sites of which 47 herpetiles were either observed or collected. The remaining 18 (represented by blue rows) species reported by the earlier workers or the local inhabitants could not be confirmed during the surveys. It does not imply that these species are not present in the study sites. There is likelihood that these species might be observed during future ecological assessment of herpetiles.

Out of all the programme sites, Chotiari reservoir is the most productive herpetofauna associated habitat with the highest richness (31) and Margalef diversity index of 4.1277, Keti Bunder representing the second highest richness (27) and diversity with Margalef index of 3.823, Keenjhar Lake being at third place with richness (23) and Margalef diversity index of 3.506. The Pai forest and Keti Shah are least diverse of all the five programme sites with Margalef diversity indices of 3.237 and 2.845 respectively. The herpetofauna of Keti Shah is less diverse as compared to other sites due to the consistent seasonal inundation, which renders very little favorable conditions for the support of herpeto-fauna. The Pai forest, on the other hand, is so severely depleted in terms of human disturbances and wood-cutting that the herpetiles are unable to support their lives in an imbalanced ecosystem.

Some systematic records of amphibians and reptiles have been reported from the Indus for All Programme sites by Minton (1966), Mertens (1969) and Muhammad Shareef Khan (2003, 2005). Comprehensive biological assessment with reference to amphibians and reptiles has however never been conducted. The preliminary baseline studies made by Hafeez-ur-Rehman (2007) report 23 species of amphibians and reptiles from Keti Bunder, 31 from Keenjhar Lake, 35 from Chotiari Reservoir and 23 species from Pai Forest. These were reported, based on collection, observation or as a result of interviews with local people or reported by the earlier authors. The detailed assessment studies conducted in June 2007 enlist and document 27 species of amphibians and reptiles from Keti Bunder, 23 species from Keenjhar Lake, 31 species from Chotiari Reservoir, 18 species from Pai forest and 16 species from Keti Shah. The number of species collected and observed during the fieldwork carried out in June and November, 2007 in programme sites, is lower than the total number expected in the area but was not unexpected for the following reasons: Being excellent biological indicators, the amphibians and reptiles respond quickly to weather or climate changes and take refuge into burrows in case of danger and unfavorable conditions. The amphibians and reptiles are mostly nocturnal species and require night surveys. Some of the sites were difficult to approach at night and the nocturnal survey was only possible in limited areas. Amphibian and reptilian activity is also restricted to a specific time of the day and specific season of the year. If the presence of the team in the area did not correspond with the appropriate activity time and specific habitat of the species the possibility of sighting the species became minimal despite the other environmental conditions being suitable, and the species being present. There is always a need of consistent monitoring of amphibian and reptilian species during their activity period, over the months for several years, to comprehensively record the potential herpeto-fauna. This was indeed the limiting factor in such short duration surveys. All these factors indicate the practical difficulties in the documentation of these species. There is a great need to carry out more work in order to add to the

existing lists. The baseline studies need much more time to effectively prepare herpeto-faunal inventory of the area.

4.3.2 Species recorded

During the present studies, the author has been able to document and enlist 27 species of amphibians and reptiles from Keti Bunder, 23 species from Keenjhar Lake, 31 species from Chotiari Reservoir, 18 species from Pai forest and 16 species from Keti Shah. The quantitative assessment and comparison of species diversity and evenness through Shannon-weaver diversity index of these sites in terms of amphibians and reptilian diversity is given in the **Table 44.**

Table 44 – Amphibian and reptilian diversity among sites (Figures are number of individuals observed/collected)

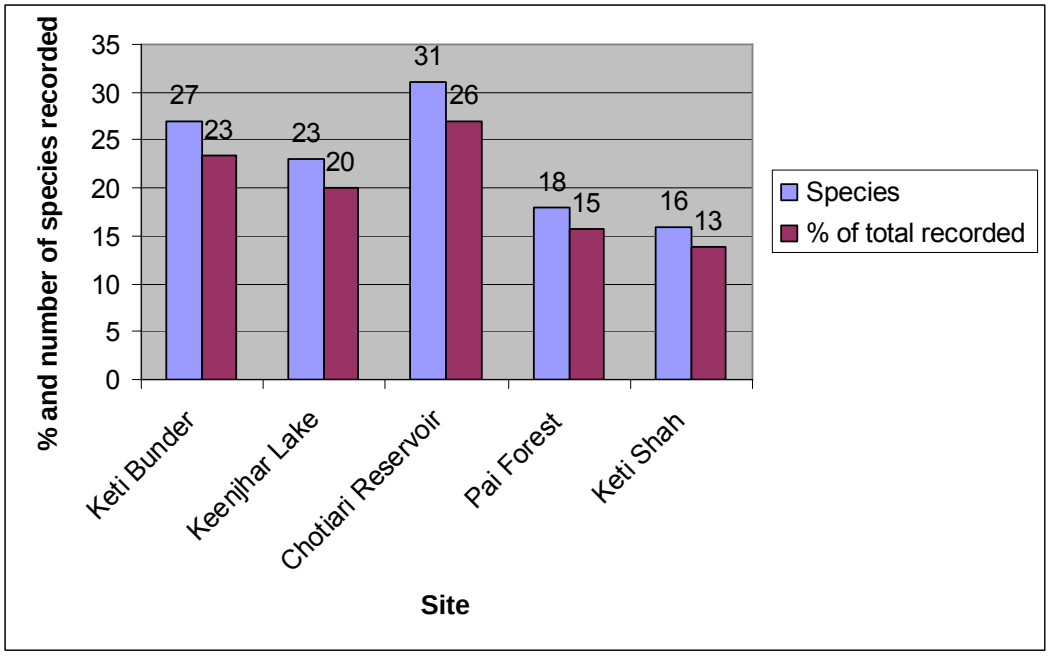
S. No.	Species Name	Total	Keti Bunder	Keenjhar Lake	Chotiari Reservoir	Pai Forest	Keti Shah
1	*Bufo stomaticus*	387	117	74	139	42	15
2	*Euphlyctis c. cyanophlyctis*	138	39	32	47	20	0
3	*Hoplobatrachus tigerinus*	126	31	50	33	08	04
4	*Kachuga smithi*	128	0	0	66	0	62
5	*Kachuga tecta*	33	0	0	14	0	19
6	*Geoclemys hamiltonii*	30	0	0	30	0	0
7	*Hardella thurjii*	03	0	0	0	0	03
8	*Aspideretes gangeticus*	15	0	02	08	0	05
9	*Aspideretes hurum*	0	0	0	0	0	0
10	*Chitra indica*	0	0	0	0	0	0
11	*Lissemys punctata andersoni*	28	14	04	04	06	0
12	*Geochelone elagans*	0	0	0	0	0	0
13	*Crocodylus palustris*	100	0	0	100	0	0
14	*Calotes v. versicolor*	220	170	28	12	05	05
15	*Trapelus agilis pakistanensis*	58	0	49	09	0	0
16	*Trapelus megalonyx*	19	0	12	07	0	0
17	*Trapelus rubrigularis*	08	0	08	0	0	0
18	*Eublepharis macularius*	30	0	13	13	04	0
19	*Crossobamon orientalis*	141	0	0	141	0	0
20	*Cyrtopodion scaber*	66	25	25	12	04	0
21	*Hemidactylus brookii*	28	14	0	0	06	08
22	*Hemidactylus flaviviridis*	338	158	70	42	26	42
23	*Hemidactylus leschenaultii*	07	0	0	0	07	0
24	*Cyrtopodion k. kachhense*	07	0	07	0	0	0

S. No.	Species Name	Total	Keti Bunder	Keenjhar Lake	Chotiari Reservoir	Pai Forest	Keti Shah
25	*Acanthodactylus cantoris*	260	06	24	230	0	0
26	*Eremias cholistanica*	15	0	0	15	0	0
27	*Mesalina watsonana*	04	0	0	04	0	0
28	*Ophisops jerdonii*	17	04	04	0	09	0
29	*Novoeumeces blythianus*	0	0	0	0	0	0
30	*Eutropis macularia*	0	0	0	0	0	0
31	*Eutropis dissimilis*	53	41	0	0	06	06
32	*Ophiomorus tridactylus*	271	0	0	271	0	0
33	*Ophiomorus raithmai*	0	0	0	0	0	0
34	*Eurylepis t. taeniolatus*	03	0	0	0	03	0
35	*Uromastyx hardwickii*	58	18	22	11	07	0
36	*Varanus bengalensis*	223	73	48	65	24	13
37	*Varanus griseus konieczнyi*	0	0	0	0	0	0
38	*Leptotyphlops macrorhynchus*	0	0	0	0	0	0
39	*Ramphotyphlops braminus*	0	0	0	0	0	0
40	*Eryx johnii*	24	08	08	08	0	0
41	*Eryx conicus*	11	0	01	04	03	03
42	*Python molurus*	0	0	0	0	0	0
43	*Amphiesma stolatum*	0	0	0	0	0	0
44	*Boiga trigonata*	0	0	0	0	0	0
45	*Lycodon s. striatus*	03	03	0	0	0	0
46	*Lycodon travancoricus*	0	0	0	0	0	0
47	*Lytorhynchus paradoxus*	0	0	0	0	0	0
48	*Oligodon a. arnensis*	01	01	0	0	0	0
49	*Platyceps r. rhodorachis*	0	0	0	0	0	0
50	*Platyceps v. indusai*	04	0	0	04	0	0
51	*Platyceps v. ventromaculatus*	12	10	0	0	02	0
52	*Psammophis c. condanarus*	0	0	0	0	0	0
53	*Psamophis l. leithii*	03	03	0	0	0	0
54	*Psamophis s. schokari*	0	0	0	0	0	0
55	*Ptyas m. mucosus*	34	09	13	09	0	03
56	*Spalerosophis arenarius*	0	0	0	0	0	0
57	*Spalerosophis atriceps*	08	04	04	0	0	0

S. No.	Species Name	Total	Keti Bunder	Keenjhar Lake	Chotiari Reservoir	Pai Forest	Keti Shah
58	*Xenochrophis p. piscator*	21	06	11	0	0	04
59	*Xenochrophis c. cerasogaster*	02	0	0	02	0	0
60	*Naja n. naja*	23	16	0	06	0	01
61	*Bungarus c. caeruleus*	06	01	0	03	0	02
62	*Daboia r. russelii*	11	07	0	04	0	0
63	*Echis carinatus sochureki*	269	116	22	122	09	0
64	*Hydrophis caerulescens*	03	03	0	0	0	0
65	*Praescutata viperina*	02	02	0	0	0	0
	Total Number (number of individuals collected)	3251	899	531	1435	191	195

Rows shaded in light-blue and species reported in literature/ or reported by local inhabitants

Figure 30 – Percentage of species and total species number recorded from each site



4.3.3 Species diversity

The following tables and figures examine the diversity of each site plus the evenness across the sites. This analysis incorporates both summer and winter season data.

The results in **Table 45** show that Chotiari Reservoir has the highest species account, flowed by Keti Bunder, Keenjhar Lake, Pai Forest and then Keti Shah. However the evenness analysis shows that Chotiari Reservoir has the lowest evenness value, suggesting that the area is undergoing complex ecological

changes that may be natural or may be manmade e.g. flooding of habitats. Migration and hibernation can also affect reptile and amphibian species.

Table 45 – Species richness and diversity index for reptile and amphibian species recorded from Keenjhar Lake

S.no	Type of index	Keti Bunder	Keenjhar Lake	Chotiari Reservoir	Pai Forest	Keti Shah
1	Richness (number of species)	27	23	31	18	16
2	Evenness	0.4526	0.6787	0.4563	0.6948	0.5376
3	Shannon Index	2.503	2.748	2.649	2.526	2.152
4	Margalef Index	3.823	3.506	4.127	3.237	2.845

Figure 31 – Evenness of reptile and amphibian species across sites

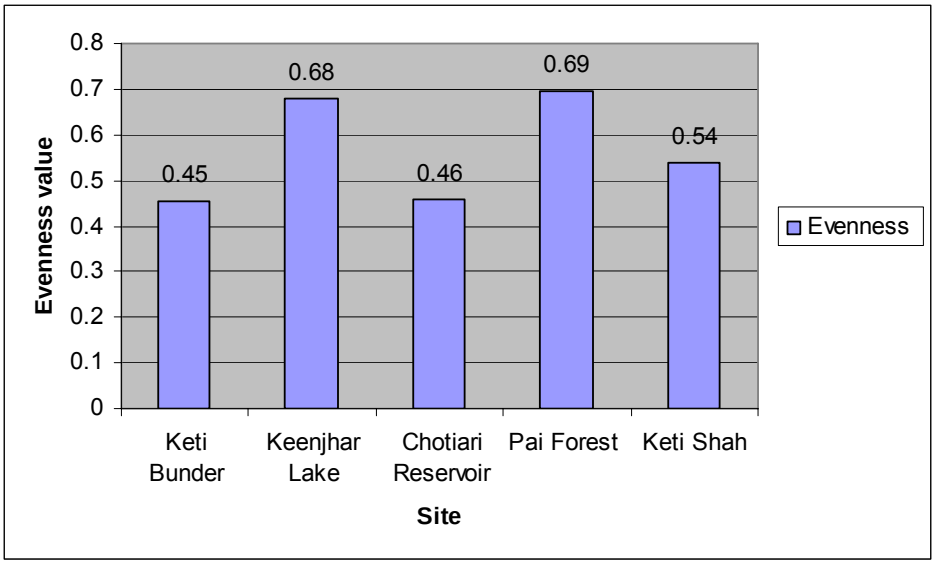
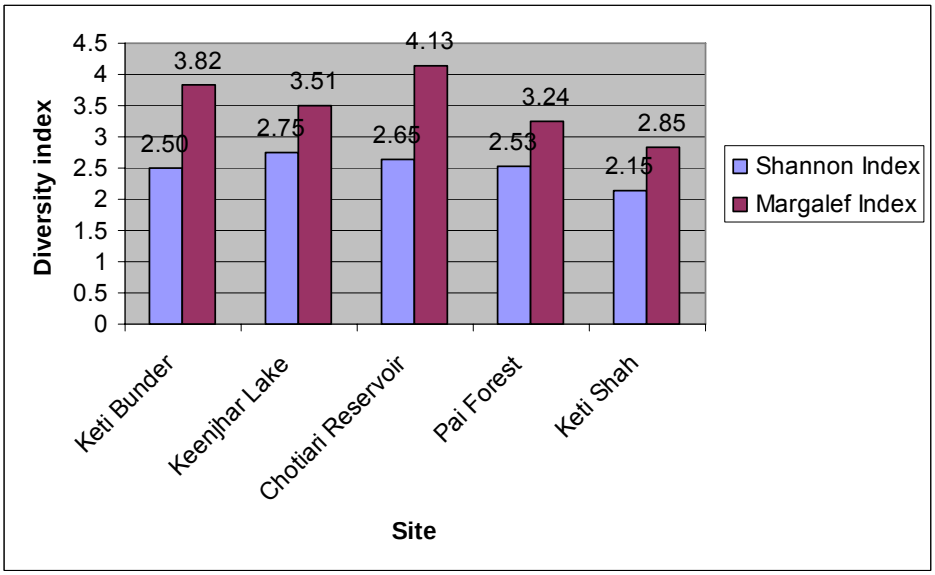


Figure 32 – Shannon and Margalef index for reptile and amphibian species for all sites



In the Margalef index Chotiari Reservoir shows the highest level of diversity whereas the Shanno index gives Keenjhar Lake as the highest. The former does not take into evenness so may be biased by the difference in animal counts. Overall Keti Shah has the lowest diversity in both analysis followed by Pai Forest. Reasons for the difference can be complex and need investigation to establish what is driving the diversity at each site.

4.4 Avi-fauna

4.4.1 Summary

4.4.1.1 Keti Bunder

The main habitats in Keti Bunder are coastal areas, creeks, agriculture and fruit farms, and riverine and estuarine area (Karo Chhan). A total of 68 species of birds were recorded during the summer surveys. Out of these 68 species recorded 22 were water birds, 6 birds of prey, and 25 passerines along with pigeons, doves, mynas, kingfishers, parakeets, cuckoos, bee-eaters and woodpeckers. Blue rock-pigeon, Common myna and Common-babbler were quite common Grey and Black Partridges and Rain quails are they key species at this site.

Along with the above mentioned birds 3 species were over summering bird's viz. Curlew Eurasian Redshank and Osprey along with the summer breeding visitor, Pied Crested Cuckoo. The majority of the birds were found to in forest areas, cultivated land and orchards. The main creek area comprises of Hajamro, Chann, Khobar and Bhoori creeks.

A total of 91 species of birds were recorded in the winter surveys 50 species were resident, 32 winter visitors, 7 were irregular year-round visitors and 2 passage migrants. 2 species were rare and 6 species were scarce. The important species recorded were; Painted Stork, Black-headed Ibis, Common quail, Black-bellied tern, Rufous-fronted Prinia, Paradise flycatcher and Rosy pastor.

4.4.1.2 Keenjhar Lake

The main habitats for birds in Keenjhar Lake are marshes, agriculture areas, fallow land, stony areas and desert habitat. There are agriculture fields in the north, east and western sides with an embankment on the southern side. Between the bund and the National Highway, there are marshy areas with villages around the lake. In the north is the town of Jhimpeer. There is a stony area and desert habitat the astern and western Side.

A total of 57 species of birds were recorded in summer out of which 20 were water birds, three raptors, twenty five passerines and twelve other including Pigeons, Doves, Cuckoos, Bee-eaters etc. Two early migrants' viz. barn swallow and green sandpiper were recorded. The most common Bird species of Keenjhar Lake were Little grebe, Little cormorant, Pond heron, Little egret, Pond heron, Red-wattled lapwing, Blue rock-pigeon, Collared dove, Little brown-dove Little Green Bee-eater, Bank myna and Streaked-weaver. Grey partridge, Purple heron and Chestnut-bellied sandgrouse are the key species.

During the winter surveys, the main lake associated marshes, agricultural fields, vicinity of villages, fish farm areas, grass field, bunds of the lake and another wetland viz Jhol Dhand were surveyed. A total of 98 species of birds were recorded. Out of which 51 were resident, 42 winter visitors 03 were irregular year-round visitors and two passage migrants. Most of the birds were found on or near the wetland habitats. A pair of Pallas's Fishing Eagle was found nesting on

Eucalyptus near Jakhro fish form. Among the threatened species, the Black-bellied tern which is a near threatened species was recorded. On the nearby wetland called Jhol Dhand, some important species such as greater flamingo, Pallid Harrier, Common Kestrel, Imperial Eagle, Steppe Eagle and Chestnut bellied Sandgrouse were recorded.

4.4.1.3 Chotiari Reservoir

Chotiari Reservoir is located in Sanghar District, it occupies an area of about 18,000 ha and the reservoir exhibits of terrestrial and aquatic ecosystems. The aquatic features of the reservoir area comprise diversity of small and large size (1-200 ha) fresh and brackish water lakes. These lakes are a source of subsistence and commercial fisheries for the local people and habitat for crocodiles, otters, fresh water turtles and feeding and nesting grounds for variety of resident and migratory birds. It has diverse habitat for birds, which include lakes, swamps/marshes/reed beds having somewhat dense vegetation cover, irrigations canals, riverine forest, cultivates land and desert area. The area provides suitable habitat for a wide variety of birds. As many as 109 species of birds have been recorded from the area (Ghalib et al 1999). There are certain species of birds of particular importance viz. Marbled Teal, Jerdon's/Sind Babbler, Pallas's Fishing Eagle, White-backed Vulture, Saker Falcon, Watercock, Wood Sandpiper, Knot, Ruff, Painted Snipe and Cliff Swallow.

The main area of the Chotiari reservoir is the wetland where there are marshes beside the embankment. There are agricultural fields in the northern and western side. The southern and the eastern sides consist of desert habitat. A total of 80 birds were recorded in the summer survey. Four summer breeding visitors viz. Water cock, Red Turtle Dove, Blue-cheeked, Bee-eater and Pied Crested Cuckoo were recorded. Two over summering birds viz. White-tailed Plover, Greenshank were also recorded. A total of thirty passerines, twenty-five water birds, four raptors and eleven others including pigeons, doves, cuckoos owls, nightjars, kingfishers, bee-eaters and rollers were observed. Plain Sand Martin and Barn Swallow were also quite common at the time. Grey and Black Partridge, Watercock, Chestnut-bellied Sandgrouse, Lesser Golden backed Woodpecker are also key species found at the site.

The main habitats in the area are wetland and associated marshes, desert habitat and agriculture areas. During the winter surveys, the nearby dhands were also surveyed such as Dogriyoon, Naughno, Panihal, Sanghriaro, Rarr and Kharor dhands. A total of seventy-two species of birds were recorded. Out of which 34 were resident, 34 were winter visitors, three passage migrants and one rare vagrant Purple Heron (two) and Red-crested Pochard (one) and Greater White fronted Goose (one) were recorded. Nesting of Pallas's Fishing Eagle was also recorded.

4.4.1.4 Pai Forest

Pai forest has forest and agriculture areas as which are home to various habitats of birds. The total number of bird species recorded was 56. Out of these, 6 were water birds, 3 raptors, 29 passerines, and 18 others including pigeons, doves, parakeets, kingfishers, cuckoos, rollers, owlets, nightjars, bee-eater etc. the most common species were: Little Brown Dove, Little Green Bee-eater and Bank Myna Two over summering birds viz. Baillon's Crake and Green Sandpiper and two summer breeding visitors viz. Pied Crested Cuckoo and Red Turtle Dove were recorded. Grey Partridge, Common Green Pigeon, Crested Honey Buzzard,

Shikra, Sind Pied Woodpecker and Lesser Golden Woodpecker are the key species.

Keti Shah is a riverine forest areas. 54 Species of Birds were recorded in the summer surveys, water birds, 3 raptors, 25 passerines and 14 other having partridges, Pigeons, Doves, Parakeets, Cuckoos, Kingfishers, Bee-eaters and Rollers etc. The common species were, Pond Heron, Black kite, Red-wattled lapwing, House swift, Little Green bee-eater, Plain sand-martin and Blue rock-pigeon. The key species are Grey and Black partridge. A summer breeding visitor viz. Small Indian pratincole, and one early migrant viz. Common swallow and one passage migrant viz. Rosy starling were recorded. A total of 92 species of birds was recorded in the winter surveys, out of which 58 species were resident 30 species were winter visitors, 1 species was year round visitor, 2 species were year round visitors.

4.4.2 Species recorded

The total number of bird species recorded on each site (inclusive of summer and winter season) is shown below in **Table 46.**

Table 46 – Total number of bird species recorded at each site

S. No.	Total No. of Species recorded on Each Site	No. of Species
1.	Chotiari Wetland Complex	113
2.	Keenjhar Lake	111
3.	Keti Bunder	108
4.	Pai Forest	81
5.	Keti Shah	79

The total number of birds recorded from all the 5 sites is 181 species. A total of 117 species of birds were recorded in summer and 158 species in winter.

Table 47 – List of bird species recorded from each site

	Common Name	Keenjhar Lake		Keti Bunder		Chotiari Reservoir		Pai forest		Keti Shah	
		S	W	S	W	S	W	S	W	S	W
1	Ashy crowned finch-lark	+	-	-	-	+	+	+	-	-	-
2	Asian Paradise flycatcher	-	-	-	+	-	-	-	-	-	-
3	Ballion's crake	-	-	-	-	-	-	+	-	-	-
4	Bank Myna	+	+	+	+	+	+	-	+	-	+
5	Barn owl	-	-	-	-	+	-	-	-	-	-
6	Baya weaver	-	-	-	-	-	-	-	-	-	+
7	Bay-Backed Shrike	+	+	-	-	+	+	+	-	-	+
8	Black bellied Tern	-	+	-	-	-	-	-	-	-	
9	Black Bittern	+	-	+	-	+	-	-	-	-	+
10	Black Drongo	+	+	+	-	+	+	+	+	-	+
11	black headed ibis	-	-	-	+	-	-	-		-	-
12	Black Kite	-	+	+	+	-	-	-	+	+	+
13	Black Partridge	-	-	+	+	+	-	-	-	+	+
14	Black Redstart	-	-	-	-	-	+	-	+	-	-
15	Black Shouldered Kite	+	+	+	-	+	+	-	+	-	-
16	Black winged Stilt	+	+	+	+	+	+	-	+	-	+

17	Black-bellied Tern	+	-	-	-	-	-	-	-	-	+
18	Black-billed tern	-	-	-	+	-	-	-	-	-	-
19	Black-breasted Quail	-	-	+	-	-	-	-	-	-	-
20	Black-Crowned Night Heron	-	+	-	-	+	+	-	-	+	-
21	Black-headed Gull	-	+	-	+	-	+	-	-	-	-
22	Blue Rock Pigeon	+	+	+	+	+	-	+	+	-	+
23	Blue-cheeked Beeater	-	-	-	-	+	-	-		-	-
24	Blue-throat	-	+	-	+	-	+	-	+	-	-
25	Brahminy Kite	+	+	+	+	-	-	+	+	-	+
26	Brown-headed Gull	-	-		+	-	-	-	-	-	-
27	Caspian tern	-	-	+	-	-	-	-	-	+	-
28	Caspian tern	-	-	-	+	-	-	-	-	-	-
29	Cattle Egret	+	+	+	+	+	-	+	+	+	+
30	Cettis Warbler	-	+	-	-	-	+	-	-	-	-
31	Chestnut-bellied Sand grouse	+	-	-	-	+	-	-	-	-	-
32	Cinnamon bittern	-	-	-	-	+	-	-	-	-	-
33	Clamorous Reed Warbler	-	+	-	-	-	-	-	-	-	-
34	Collared Dove	+	-	+	-	+	+	+	-	-	+
35	Common Babbler	+	+	+	+	+	+	+	+	-	+
36	Common buzzard	-	-	-	-	-	+	-	-	+	-
37	Common Crow Pheasant	+	+	+	+	+	+	+	+	+	+
38	Common green-pigeon	-	-	-	-	-	-	+	-	-	-
39	Common Kestrel	-	+	-	-	-	-	-	-	-	-
40	Common Kingfisher	-	+	+	+	+	-	-	-	+	-
41	Common Koel	+	-	+	+	+	-	+	-	-	+
42	Common Moorhen	-	+	-	-	+	+	-	-	-	-
43	Common Myna	+	+	+	+	+	+	+	+	-	+
44	Common or Black Coot	-	+	-	+	-	+	-	-	-	-
45	Common pochard	-	-	-	-	-	+	-	-	-	-
46	Common quail	-	-	-	+	-	-	-	-	-	-
47	Common Redshank	-	-	+	+	-	+	-	+	+	-
48	Common sandpiper	-	-	-	-	-	-	-	+	+	-
49	Common Snipe	-	+	-	-	-	-	-	-	-	-
50	Common Starling	-	+	-	-	+	-	+	-	-	-
51	Common Teal	-	+	-	+	-	+	-	-	+	-
52	Common wood-shrike	-	-	+	-	-		-	+	-	-
53	Common/Barn Swallow	+	+	+	-	+	+	-	+	-	+
54	Crested honey buzzard	-	-	-	+	-	-	+	+	+	+
55	Crested Lark	+	+	+	+	+	+	+	+	-	+
56	Desert Lark	+	+	-	-	-	-	-	-	-	-
57	Desert Wheatear	-	+	-	-	-	+	-	-	-	-
58	Eastern Pied Wheatear	-	+	-	-	-	-	-	+	-	-
59	Egyptian vulture	-	-	-	-	-	-	-	-	+	-
60	Eurasian Chiffchaff	-	+	-	+	-	+	-	-	-	-

61	Eurasian Curlew	-	-	+	+	-	-	-	-	-	-
62	Eurasian Griffon Vulture	-	+	-	-	-	-	-	-	-	-
63	Eurasian oystercatcher	-	-	-	+	-	-	-	-	-	-
64	Eurasian sparrowhawk	-	-	-	-	-	-	-	+	-	-
65	Eurasian Widgeon	-	-	-	+	-	-	-	-	+	-
66	Gadwall	-	+	-	-	-	+	-	-	+	-
67	Glossy ibis	-	-	-	-	+	+	-	-	-	-
68	Graceful Prinia	-	-	+	-	+	-	+	-	-	-
69	Great Black Headed Gull	-	+	-	+	-	+	-	-	-	-
70	Great Cormorant	-	-	-	+	-	+	-	-	-	-
71	Great Grey Shrike	+	+	-		+	-	-	-	-	-
72	Great stone-curlew	-	-	-	+	-	-	-	-	-	-
73	Great White Egret	-	+	-	+	-	+	-	-	+	-
74	Great-crested tern	-	-	-	+	-	-	-	-	-	-
75	Greater Flamingo	-	-	-	+	-	-	-	-	-	-
76	Greater sand plover	-	-	-	+	-	-	-	-	-	-
77	Greater Spotted Eagle	-	+	-	-	-	-	-	-	+	-
78	Greater white-fronted goose	-	-	-	-	-	+	-	-	-	-
79	Green sandpiper	+	+	-	-	-	-	+	-	+	-
80	Greenshank	-	+	-	+	+	-	-	+	+	-
81	Grey Heron	-		+	+	+	+	-	-	+	+
82	Gull-billed Tern	-	+	+	+	+		-	-	-	-
83	Herring Gull	-	+	-	+	-	+	-	-	-	-
84	Heuglins Gull	-	-	-	+	-		-	-	-	-
85	Hoopoe	-	+	-	-	-	+	-	-	-	-
86	House Bunting	-	+	-	-	-	-	-	-	-	-
87	Indian Collared Dove	-	+	-	+	-	-	-	+	-	-
88	Indian great-horned owl	-	-	-	-	-	-	-	+	-	-
89	Indian Grey Partridge	+	+	+	+	+	-	+	+	-	+
90	Indian Grey Partridge	+	+	+	+	+	+	+		-	-
91	Indian house crow	+	+	+	+	+	+	+	+	+	+
92	Indian House Sparrow	+	+	+	+	+	+	+	+	-	+
93	Indian Pond Heron	+	+	+	+	+	+	+	+	+	+
94	Indian River Tern	+	+	+	+	+	+		+	+	+
95	Indian Robin	+	+	-	-	+	-	+	+	-	+
96	Indian Roller	-	+	-	+	+	-	+	+	-	+
97	Indian sand-lark	-	-	-	-	-	-	-	+	-	-
98	Indian Tree-Pie	+	+	+	+	+	+	+	+	-	+
99	Intermediate Egret	-	+	-	-	+	+	-	-	-	-
100	Isabelline Shrike	-	+	-	-	-	-	-	+	-	-
101	Jungle Babbler	-	+	+	+	+	-	+	+	-	+
102	Kentish plover	-	-	+	+	-	-	-	-	-	-
103	Large-pied wagtail	-	-	-	-	-	+	-	-	-	-
104	Lesser crested tern	-	-	+	+	-	-	-	-	-	-
105	Lesser golden-backed woodpecker	-	-	+	+	+	-	+	+	-	-
106	Lesser sand plover	-	-	+	+	-	-	-		-	-
107	Lesser Whitethroat	-	+	-	+	-	+	-	+	-	-
108	Little Brown Dove	+	+	+	+	+	+	+	+	+	+
109	Little Cormorant	+	+	+	-	+	+	-		-	+

110	Little Egret	+	+	+	+	+	+	-	+	+	+
111	Little Grebe/Dabchick	+	+			+	+	-		-	-
112	Little Green Bee-eater	+	+	+	+	+	-	+	+	-	+
113	Little Green Heron	-	-	-	-	-	-	-	-	-	-
114	Little Ringed Plover	-	+	-		-	-	-	-	-	-
115	Little Stint	-	+	-	+	-	+	-	+	-	-
116	Little Tern	+	+	+	+	+	-	-	-	-	-
117	Little/House Swift	+	-	-	-	-	-	-	-	+	+
118	Long-legged buzzard	-	-	-	+	-	+	-	-	-	-
119	Long-tailed shrike	-	-	-	-	+	-	+	+	-	-
120	Mallard	-	-	-	-	-	+	-	-	+	-
121	Marsh Harrier	-	+	-	+	-	+	-	-	+	-
122	Marsh Sandpiper	-	+	-	-	-	-	-	-	-	-
123	Northern Pintail	-	+	-	+	-	+	-	-	-	-
125	Oriental white-eye	-	-	-	+	-	-	-	-	-	-
126	Osprey	+	+	+	+	-	+	-	-	+	-
127	Paddy-field Pipit	+	+	+	-	+		+	+	-	-
128	Paddy-field Warbler	-	+	-	-	-	-	-	-	-	-
129	Painted stork	-	-	-	+	-	-	-	-	-	-
130	Pallas's Fishing Eagle	-	+	-	-	+	+	-	+	+	-
131	Pheasant-tailed Jacana	+	+	+	-	+		-		-	-
132	Pied Bush Chat	+	+	+	+	+	+	+	+	-	-
133	Pied Kingfisher	+	+	+	+	+	+	-	+	+	+
134	Pied-crested cuckoo	-	-	+	-	+	-	+	-	-	+
135	Plain leaf Warbler	-	+	-	-	-	-	-	-	-	-
136	Plain prinia	+	+	+	-	+	+	+	+	-	+
137	Plain Sand Martin	-	+	-	-	+	+		+	-	+
138	Purple gallinule	-	-	-	-	+	+	-	-	-	-
139	Purple Heron	+	+	-	-	+	+	-	-	+	-
140	Purple Sun Bird	+	+	+	+	+	+	+	+	-	+
141	Red turtle-dove	-	-	-	-	+	-	+		+	-
142	Red-crested pochard	-	-	-	-	-	+	-	-	-	-
143	Red-vented Bulbul	+	-	+	+	+	-	+	+	-	+
144	Red-wattled Lapwing	+	+	+	+	+	+	+	+	+	+
145	Rose-ringed Parakeet	-	+	+	+	+	-	+	+	-	+
146	Rosy pastor	-	-	-	+		-	-	-	-	+
147	Rufous-fronted Prinia	-	-	+	+	+	-	+	-	-	+
148	Shikra	-	-	+	+	+	-	+	+	+	-
149	Short-eared owl	-	-	-	+	-	-	-	-	-	-
150	Shoveller	-	+	-	-	-	+	-	-	+	-
151	Sind pied woodpecker	-	-	-	-	-	-	+	+	-	-
152	Sind sparrow	-	-	-	-	+	-	-	-	-	+
153	Singing bush-lark	-	-	+	-	-	-	-	-	-	-
154	Slender billed gull	-	-	-	+	-	-	-	-	-	-
155	Small Indian pratincole	-	-	-	-	-	-	-	-	+	+
156	Small minivet	-	-	-	-	-	-	+	-	-	-
157	Small skylark	+	-	+	+	+	-	+	-	-	-
158	Spotted Owlet	-	-	-	-	+	-	+	+	+	-
159	Spotted redshank	-	-	-	-	-	-	-	-	+	-
160	Steppe Eagle	-	+	-	-	-	-	-	-	-	-
161	Streaked Weaver	+	-	+	-	-	-	-	-	-	+
162	Striated Babbler	+	+	+	-	-	+	+	+	-	+

163	Syke's Nightjar	-	+	-	+	+	-	+		-	-
164	Tailor bird	-		+	+	-	-	+	+	-	-
165	Tufted Duck	-	+	-	-	-	+	-	-	+	-
166	Watercock	-	-	-	-	+	-	-	-	-	-
167	Western reef heron	-	-	+	+	-	-	-	-	-	-
168	Whimbrel	-	-	-	+	-	-	-	-	-	-
169	Whiskered Tern	+	+	+	+	-	+	-	-	-	-
170	White cheeked tern	-	-	+	-	-	-	-	-	-	-
171	White spoonbill	-	-	-	+	-	-	-	-	+	-
172	White Wagtail	-	+	-	+	-	-	-	+	-	-
173	White-breasted Kingfisher	+	-	-	-	+	-	-	-	-	+
174	White-breasted Water hen	+	+	-	+	+	+	+	-	-	-
175	White-browed Fantail flycatcher	-	+	-	+	-	-	+	-	-	-
176	White-browed wagtail	-	-	-	-	+	-	-	-	-	+
177	White-cheeked Bulbul	+	+	+	+	+	+	+	+	-	+
178	White-eyed buzzard	-	-	+	+	+	-	-	-	+	-
179	White-tailed Lapwing	-	+	-	-	+	+	-	-	+	+
180	White-throated Kingfisher	-	+	-	+	-	+	+	-	+	-
181	White-throated Munia	-	+	+	-	-	-	+	-	-	-
182	Wire-tailed Swallow	+	-	+	-	+	-	-	-	-	-
183	Wood Sandpiper	-	+	-	-	-	+	-	-	-	-
184	Yellow- bellied Prinia	+	-	-	-	-	-	-	+	-	-
185	Yellow Bittern	+	-	-	-	+	-	-	-	-	-
186	Yellow Wagtail	-	+	+	+	-	+	-	-	-	-
187	Yellow-fronted woodpecker	-	-	-	-	-	-	+	-	-	-
188	Yellow-throated Sparrow	+	-	-	-	+	-	+	+	-	-

4.4.3 Analysis of avifauna recorded

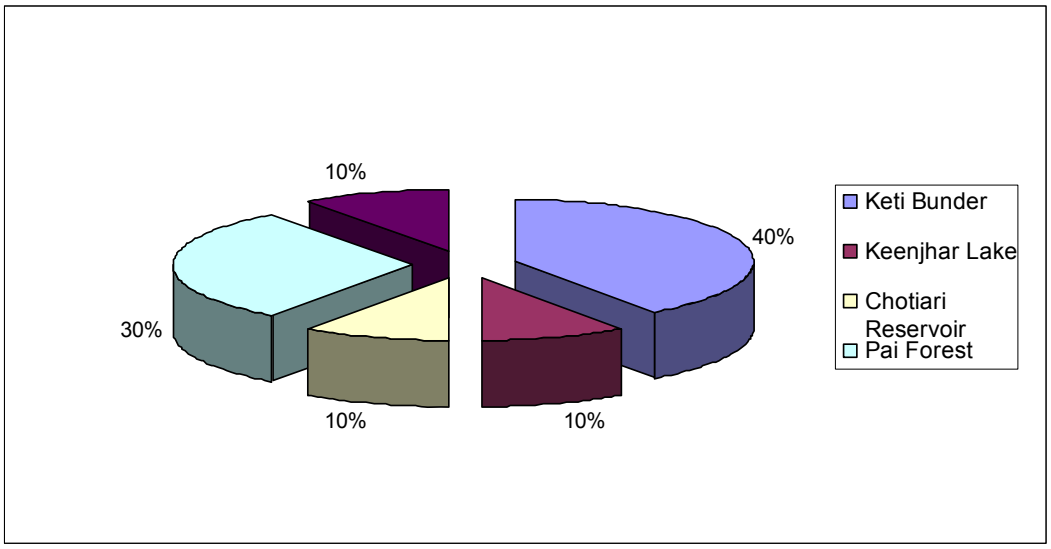
4.4.3.1 Summer survey

The following table **(Table 48)** shows the biodiversity index for each. This is also graphically shown in **Figure 34** as a pie-graph

Table 48 – Biodiversity index for sites surveyed during summer

	Site	Biodiversity index
1	Keti Bunder	0.04
2	Keenjhar Lake	0.01
3	Pai Forest	0.03
4	Chotiari Reservoir	0.01
5	Keti Shah	0.01

Figure 33 – Biodiversity Index of bird species during summer across all sites



It can be inferred the biodiversity runs (highest first) from Keti Bunder >Pai Forest >Keenjhar Lake> Chotiari Reservoir>Shah Belo.

Interestingly Chotiari Reservoir comes second to last whereas it would be expected to be on top like it does for mammals, reptiles and amphibians. Keti Bunder and Keenjhar Lake certainly have the potential to support a diverse variety of avifauna even though they are subjected to a high level of environmental degradation.

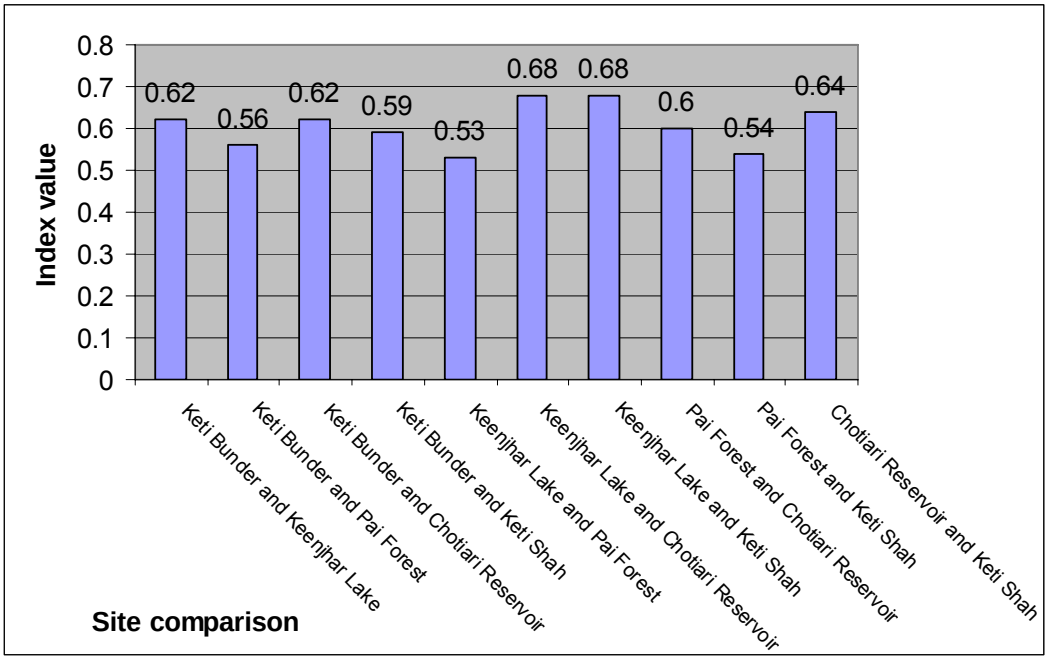
Looking at similarity index it can be inferred that the index value (highest first) runs as: Keenjhar lake: Chotiari Reservoir = Keenjhar Lake: Keti Shah>Chotiari Reservoir: Shah Belo>Keti Bunder: Chotiari Reservoir=Keti Bunder: Keenjhar lake>Pai Forest: Chotiari Reservoir>Keti Bunder: Keti Shah>Keti Bunder: Pai Forest>Keenjhar Lake: Pai Forest

Note: Species Similarity decreases from Keenjhar Lake: Chotiari Reservoir = Keenjhar lake: Shah Belo to Keenjhar Lake: Pai Forest

The list below gives the comparison index for each comparison. **Figure 34** gives a graphical outlay of the index.

- **Similarity Index**
  - Similarity Index Keti Bunder and Keenjhar Lake =0.62
  - Similarity Index Keti Bunder and Pai Forest =0.56
  - Similarity Index Keti Bunder and Chotiari Reservoir =0.62
  - Similarity Index Keti Bunder and Shah Belo =0.59
  - Similarity Index Keenjhar Lake and Pai Forest =0.53
  - Similarity Index Keenjhar Lake and Chotiari Reservoir =0.68
  - Similarity Index Keenjhar Lake and Shah Belo =0.68
  - Similarity Index Pai Forest and Chotiari Reservoir =0.60
  - Similarity Index Pai Forest and Shah Belo =0.54
  - Similarity Index Chotiari Reservoir and Shah Belo =0.64

Figure 34 – Similarity Index for birds recorded during summer across all sites

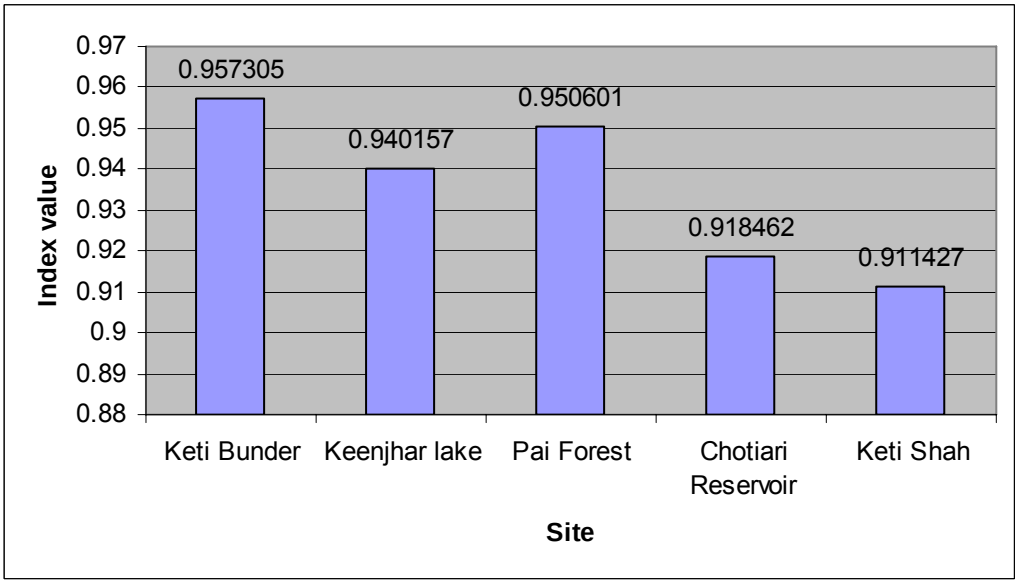


Finally coming to the biodiversity index, **Table 49** shows the indexes for each site and **Figure 35** gives a graphical portrayal of the same figures.

Table 49 - Simpson's Index from Keenjhar Lake in summer

S.no	Site name	Index
1	Keti Bunder	0.957305
2	Keenjhar lake	0.940157
3	Pai Forest	0.950601
4	Chotiari Reservoir	0.918462
5	Keti Shah	0.911427

Figure 35 – Simpson's diversity index for winter over all sites



It can be concluded that the index runs (highest firsts) as Keti Bunder >Pai Forest>Keenjhar lake >Chotiari Reservoir>Keti Shah. It is important to note that species similarity and species diversity increases from Keti Bunder to Keti Shah

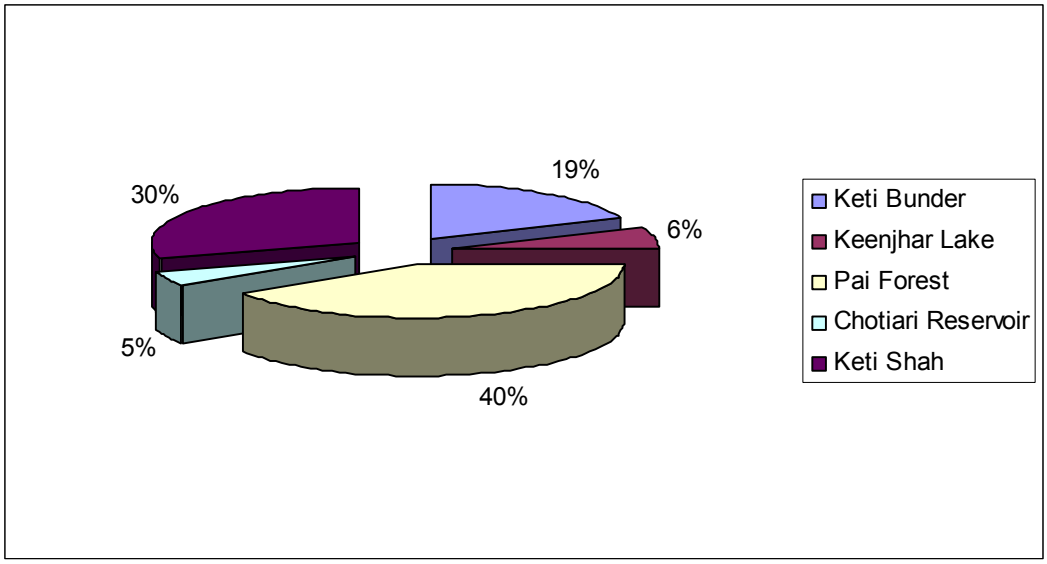
4.4.3.2 Winter surveys

Table 50 and **Figure 36** show the biodiversity index for winter results at Keenjhar Lake.

Table 50 – Biodiversity index for sites surveyed during winter

S.no	Site	Biodiversity index
1	Keti Bunder	0.02
2	Keenjhar Lake	0.007
3	Pai Forest	0.044
4	Chotiari Reservoir	0.005
5	Keti Shah	0.032

Figure 36 – Biodiversity Index of bird species during winter across all sites



It is evident from the lower values of biodiversity index in the above table and graph that the avifauna is not diverse. However, the sites can be arranged on a scale of species diversity in descending order as:

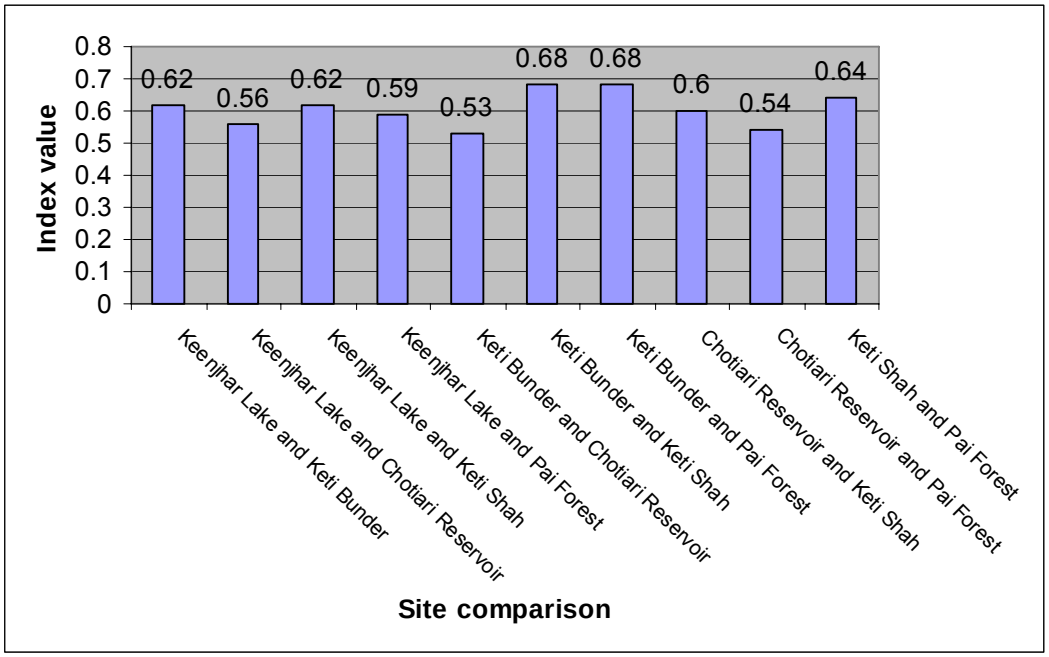
Pai Forest > Keti Shah > Keti Bunder> Keenjhar lake > Chotiari Reservoir

Again Pai Forest has the highest index followed by Keti Shah and then Keti Bunder. This is quite unusual since all of these sites are subjected to environmental degradation, especially Pai Forest. It would have been expected that the three wetlands, Chotiari Reservoir, Keti Bunder and Keenjhar Lake would have been on top, especially for avifauna.

Coming to the similarity index, the following list and Figure X gives the similarity values across all sites

- **Similarity Index**
  - Similarity Index Keenjhar Lake and Keti Bunder = 0.51
  - Similarity Index Keenjhar Lake and Chotiari Reservoir = 0.62
  - Similarity Index Keenjhar Lake and Keti Shah = 0.5
  - Similarity Index Keenjhar Lake and Pai Forest = 0.62
  - Similarity Index Keti Bunder and Chotiari Reservoir = 0.43
  - Similarity Index Keti Bunder and Keti Shah = 0.45
  - Similarity Index Keti Bunder and Pai Forest = 0.48
  - Similarity Index Chotiari Reservoir and Keti Shah = 0.52
  - Similarity Index Chotiari Reservoir and Pai Forest = 0.43
  - Similarity Index Keti Shah and Pai Forest = 0.58

Figure 37 – Similarity Index for birds recorded during winter across all sites



From above table and graph, higher values of similarity index show that Keenjhar lake-Chotiari Reservoir and Keenjhar-Pai Forest have much common species composition as compared to other pairs of sites. Pairs of sites can be arranged on a scale of similar species composition in descending order as:

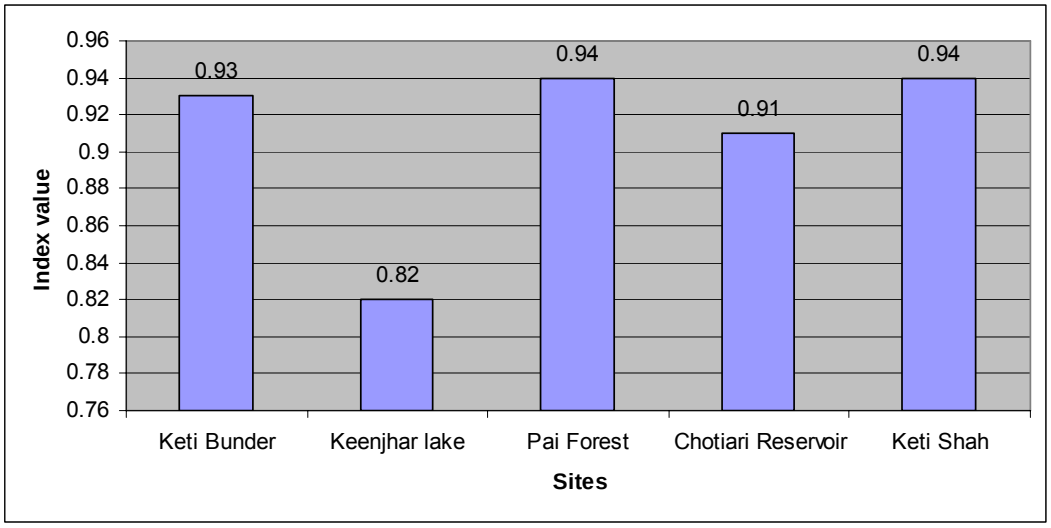
Keenjhar lake -Chotiari Wetlands Complex and Keenjhar- Pai Forest **>** Shah Belo-Pai Forest **>** Chotiari Wetlands Complex- Shah Belo > Keenjhar lake- Keti Bunder> Keenjhar lake- Shah Belo**>** Keti Bunder- Pai Forest> Keti Bunder- Shah Belo > Keti Bunder- Chotiari Wetlands Complex > Chotiari Wetlands Complex- Pai Forest

Finally coming to the diversity index for the sites, **Table 51** and **Figure 38** show the Simpson's index for all the sites during winter.

Table 51 – Simpson's Index of all sites in winter

S.no	Site name	Index
1	Keti Bunder	0.93
2	Keenjhar lake	0.82
3	Pai Forest	0.94
4	Chotiari Reservoir	0.91
5	Keti Shah	0.94

Figure 38 – Simpson's index for all sites



The higher value of Simpson's index in above table and graph clearly spell out that bird species are evenly distributed at Keti Shah, Pai Forest and Keti Bunder. However, Keenjhar Lake's comparatively lower value implies dominance of fewer bird species at that lake. The sites can be arranged on a scale of species evenness in descending order as:

Shah Belo and Pai Forest > Keti Bunder > Chotiari Wetlands Complex > Keenjhar lake

4.4.3.3 Summer and winter

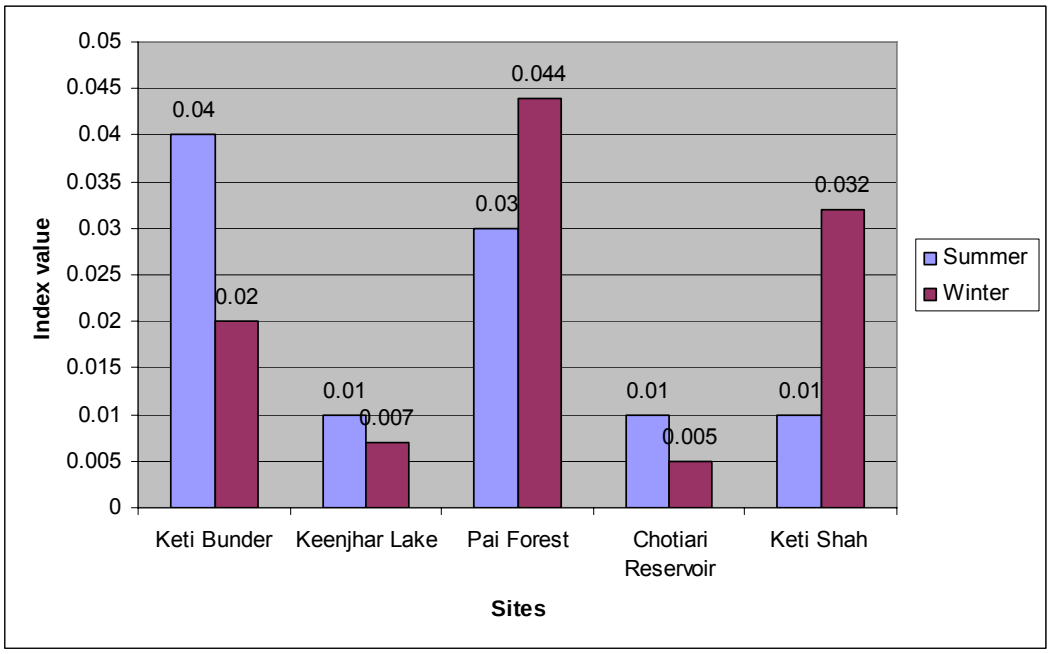
The following table and figures compare the biodiversity index, similarity and Simpson's index over the sites and over the season.

Table 52 and **Figure 39** show the biodiversity index over site and season

Table 52 – Biodiversity index over sites and over season

S.No	Site	Summer	Winter
1	Keti Bunder	0.04	0.02
2	Keenjhar Lake	0.01	0.007
3	Pai Forest	0.03	0.044
4	Chotiari Reservoir	0.01	0.005
5	Keti Shah	0.01	0.032

Figure 39 – Biodiversity indexes for all sites over summer and winter



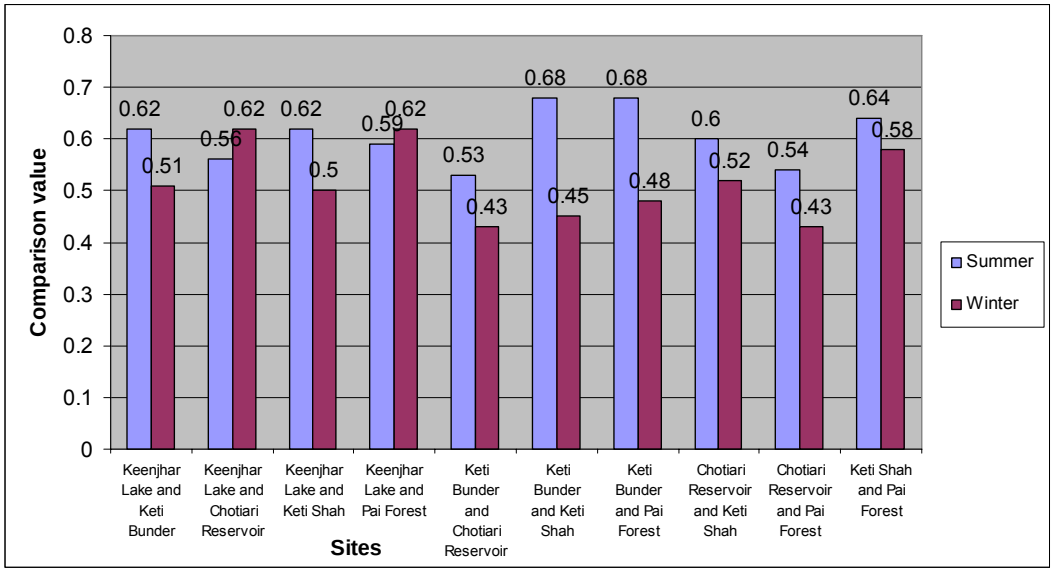
As can be seen in **Figure 39**, diversity is quite changeable over time and space. Pai Forest has the highest diversity in winter whereas Keti Bunder had the highest diversity in summer. Chotiari Reservoir is thought to be the most diverse site under the Indus for All Programme. However it is on par with Keenjhar Lake for both summer and winter. It is inferred that migration and anthropogenic factors such as hunting, trapping and habitat removal may be causing birds to avoid certain areas that may include our site areas.

Figure 40 shows the similarity between the sites.

	Summer	Winter
Similarity Index Keenjhar Lake and Keti Bunder	0.62	0.51
Similarity Index Keenjhar Lake and Chotiari Reservoir	0.56	0.62
Similarity Index Keenjhar Lake and Keti Shah	0.62	0.5
Similarity Index Keenjhar Lake and Pai Forest	0.59	0.62
Similarity Index Keti Bunder and Chotiari Reservoir	0.53	0.43
Similarity Index Keti Bunder and Keti Shah	0.68	0.45
Similarity Index Keti Bunder and Pai Forest	0.68	0.48
Similarity Index Chotiari Reservoir and Keti Shah	0.6	0.52
Similarity Index Chotiari Reservoir and Pai Forest	0.54	0.43
Similarity Index Keti Shah and Pai Forest	0.64	0.58

As with the diversity index, there is significant variation over winter and summer seasons. In summer there is more similarity with Keti Bunder – Keti Shah and Keti Bunder – Pai Forest whereas is winter the similarity lies in Keenjhar Lake – Pai Forest and Keenjhar Lake – Chotiari Reservoir. Again this indicates that the arrival (or departure) of migratory birds and/or differing levels of disturbance over the seasons is affecting the presence and absence of birds across the sites.

Figure 40 – Similarity index between sites and over season

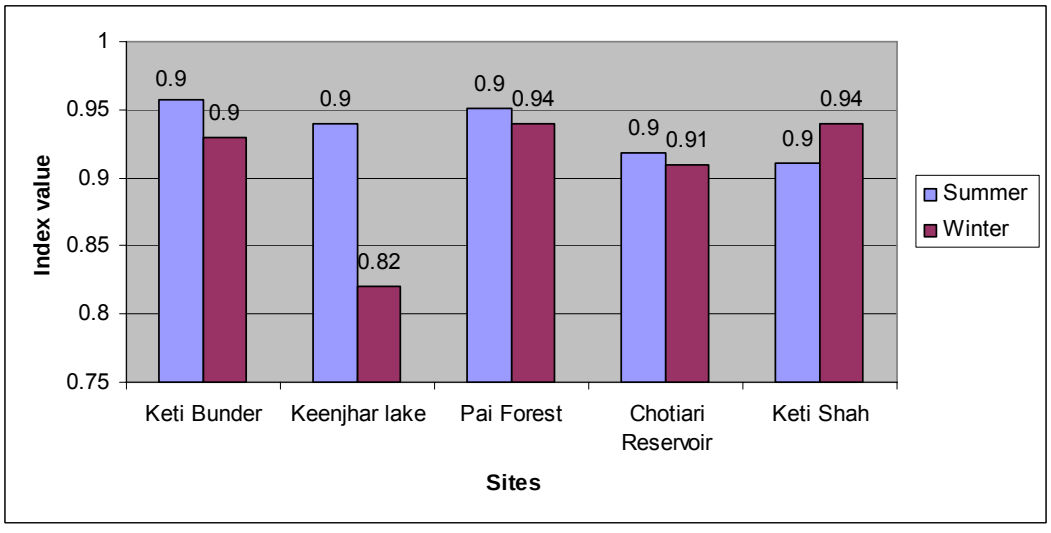


The following **Table 53** and **Figure 41** show the Simpson's index over sites and season.

Table 53 – Simpson's index over site and season

S.no	Site	Summer	Winter
1	Keti Bunder	0.95	0.93
2	Keenjhar lake	0.94	0.82
3	Pai Forest	0.95	0.94
4	Chotiari Reservoir	0.91	0.91
5	Keti Shah	0.91	0.94

Figure 41 – Simpson's index over sites and seasons



Apart from Keenjhar Lake, there is not much difference in the Simpson's index apart from slightly lower levels in winter. This does not necessary mean less species but since less evenness across the population of species.

Image 12 – Oriental reed-warbler at Keenjhar Lake

Image 13 – White wagtail at Keenjhar Lake

Image 14 – Indian Robin at Keti Shah

Image 15 – Striated babbler at Keti Shah

4.5 Phytoplankton

4.5.1 Summary

4.5.1.1 Keti Bunder

In Keti Bunder a total of 76 samples were collected and during the summer 26 algal/phytoplankton samples were collected out of which 39 algal species belonged to 30 genera of 6 phyla (Cyanophyta, Volvocophyta, Bacillariophyta, Xanthophyta, Dinophyta, Euglenophyta and Chlorophyta). During the winter surveys a total of 50 algal samples were collected in Keti Bunder; out of which 150 algal/phytoplankton species belonged to 65 genera of 8 phyla namely Cyanophyta, Volvocophyta, Dinophyta, Bacillariophyta, Xanthophyta, Euglenophyta, Chlorophyta and Charophyta. The phyla Charophyta was not found in the summer survey.

4.5.1.2 Keenjhar Lake

In Keenjhar Lake a total of 65 algal/phytoplankton samples were collected during this period out of which 155 algal species belonging to 53 genera of 7 phyla (Cyanophyta, Volvocophyta, Bacillariophyta, Chrysophyta, Dinophyta, Chlorophyta, and Charophyta in the summer. In Chotiari a total of 85 algal/phytoplankton samples were collected during the summer months out of which 248 algal species belonging to 96 genera of 9 phyla (Cyanophyta, Volvocophyta, Bacillariophyta, Chrysophyta, Xanthophyta, Dinophyta, Euglenophyta, Chlorophyta, and Charophyta.

More than 60 algal samples were collected from Keenjhar Lake, out of which 167 species belonging to 60 genera of 8 phyla namely Cyanophyta, Volvocophyta,

Bacillariophyta, Dinophyta, Euglenophyta, Chrysophyta, Chlorophyta, and Charophyta were observed. The phyla Euglenophyta was not found in the summer survey.

4.5.1.3 Pai Forest

In Pai Forest a total of 67 Algal species were collected in the summer survey which belonged to 32 genera of 6 phyla Cyanophyta, Volvocophyta, Bacillariophyta, Xanthophyta, Euglenophyta and Chlorophyta. A total of 33 (49.2%) species from 16 genera of phyla Cyanophyta, 10 (15%) species belongs to 7 genera of phyla Volvocophyta, 14 (20.8%) species belongs to 8 genera of phyla Bacillariophyta, 2 (3%) species belongs to 1 genus of phyla Xanthophyta, 4 (6%) species belongs to 2 genera of phyla Euglenophyta, 4 (6%) species belongs to 2 genera of phyla Chlorophyta.

4.5.1.4 Chotiari Reservoir

More than 100 samples were collected from Chotiari reservoir dam, out of these a total of 359 algal species belonging to 116 genera of 9 phyla Cyanophyta, Volvocophyta, Bacillariophyta, Chrysophyta, Xanthophyta, Dinophyta, Euglenophyta, Chlorophyta and Charophyta, 80 aquatic plants and 32 fishes along with some physico-chemical parameters were recorded. The phyla Xanthophyta was not found in the summer survey. Twenty five algal samples were collected during the winter survey. Out of the 71 species belonging to 34 genera of 7 phyla e.g. Cyanophyta, Volvocophyta, Bacillariophyta, Xanthophyta, Euglenophyta, Chlorophyta and Charophyta along with seventeen aquatic plants and some physico-chemical parameter were recorded, water is rich in primary productivity and plant production. The phyla Charophyta was not found in the summer survey.

4.5.2 Account of number of species recorded

All the samples from the four sites were of better quality during the winter surveys compared to the ones in summer (**see Figure 42 below**). This may be due to better water quality and lack of salinity which was observed in the summer months.

Figure 42 – summer and winter comparison of the number of species collected in the four sites

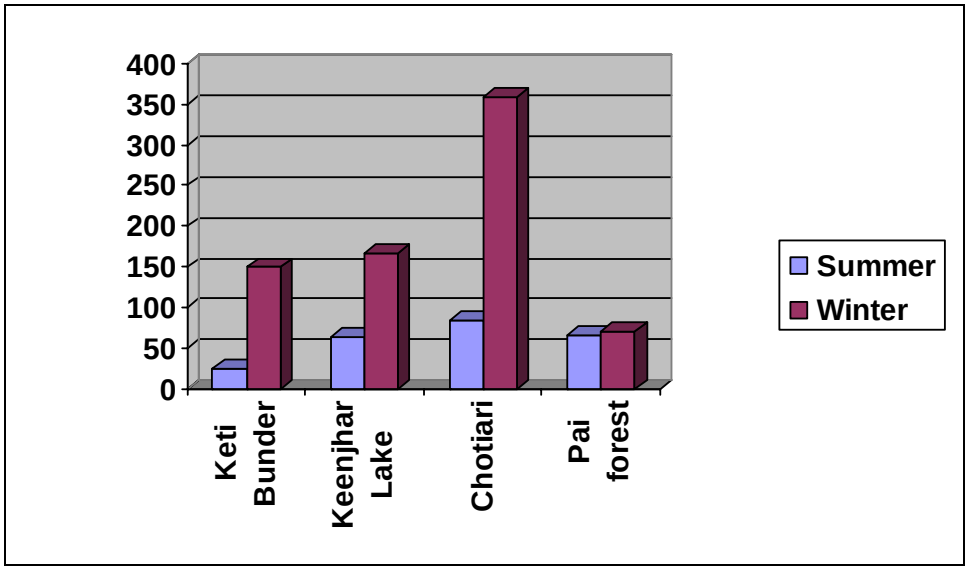


Table 54 – Comparison of phylum during the summer and winter survey in all four sites.

S.no	Class	Keti Bunder		Keenjhar Lake		Chotiari Reservoir		Pai Forest	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Phylum								
1	Cyanophyta	✓	✓	✓	✓	✓	✓	✓	✓
2	Volvocophyta	✓	✓	✓	✓	✓	✓	✓	✓
3	Bacillariophyta	✓	✓	✓	✓	✓	✓	✓	✓
4	Xanthophyta	✓	✓	×	×	×	✓	✓	✓
5	Dinophyta	✓	✓	✓	✓	✓	✓	×	×
6	Euglenophyta	✓	✓	×	✓	✓	✓	✓	✓
7	Chlorophyta	✓	✓	✓	✓	✓	✓	✓	✓
8	Charophyta	×	✓	✓	✓	✓	✓	×	✓
9	Chrysophyta	×	×	✓	✓	✓	✓	×	×

4.6 Freshwater fisheries

4.6.1 Introductory note

Comparison of freshwater fisheries is only applicable to Keenjhar Lake and Chotiari Reservoir and therefore only appears in these reports. There is a separate report for Keti Bunder under marine fisheries.

4.6.2 Species account

A total of 55 species of fish were recorded from Keenjhar Lake and a total of 47 from Chotiari Reservoir. Both water bodies are freshwater and are fed by the River Indus, therefore similar if not exact species are expected from each site. **Table 55** below gives an account of the species present at each water body.

Table 55 – Freshwater fish species recorded from Keenjhar Lake and Chotiari Reservoir

S.no	Species	Keenjhar	Chotiari
1	*Ailia coila*	+	+
2	*Amblypharyngodon mola*	+	+
3	*Aspidoparia morar*	+	+
4	*Bagarius bagarius*	+	+
5	*Barilius vagra*	+	+
6	*Chanda nama*	+	+
7	*Channa marulia*	+	+
8	*Channa punctata*	+	+
9	*Chela cachius*	+	+
10	*Chitala chitala*	+	+
11	*Cirrhinus mrigala*	+	+
12	*Cirrhinus reba*	+	+
13	*Clupisoma garua*	+	+
14	*Clupisoma naziri*	+	-
15	*Colisa fasciata*	+	+
16	*Colisa lalia*	+	-
17	*Ctenopharyngodon idella*	+	-
18	*Cyprinus carpio*	+	+
19	*Esomus danricus*	+	+
20	*Gagata cenia*	-	+
21	*Eutropiichthys vacha*	+	-
22	*Gagata cenia*	+	-

23	*Gibelion catla*	+	+
24	*Glossogobius giuris*	+	+
25	*Gudusia chapra*	+	+
26	*Heteropneustes fossilis*	+	+
27	*Labeo calbasu*	+	+
28	*Labeo dero*	+	+
29	*Labeo dyocheilus pakistanicus*	+	+
30	*Labeo gonius*	+	+
31	*Labeo rohita*	+	+
32	*Hypophthalmichthys molitrix*	+	-
33	*Hypophthalmichthys nobilis*	+	-
34	*Mastacembelus armatus*	+	+
35	*Mystus bleekri*	+	+
36	*Mystus cavasius*	+	+
37	*Mystus vittatus*	+	-
38	*Nangra nangra*	+	-
39	*Notopterus notopterus*	+	+
40	*Ompok bimaculatus*	+	+
41	*Oreochromis mossambicus*	+	+
42	*Osteobrama cotio*	+	+
43	*Parambasis baculis*	+	+
44	*Parambasis ranga*	+	+
45	*Puntius chola*	+	+
46	*Puntius sophore*	+	+
47	*Puntius ticto*	+	+
48	*Rasbora daniconius*	+	+
49	*Rita rita*	+	+
50	*Salmophasia bacaila*	+	+
51	*Securicula gora*	+	+
52	*Sicamugil cascasia*	+	+
53	*Sperata sarwari*	+	+
54	*Systomus sarana*	+	+
55	*Wallago attu*	+	+
56	*Xenentodon cancila*	+	+

4.6.3 Status of species at each site

The status of each fish species was assessed both locally and nationally. **Figure 42** shows the number of species recorded in each category over both the sites. Since both sites had a similar number of species (Chotiari Reservoir has seven less species) the numbers are quite comparable. As can be seen, most species fall under the common or less common category with only a few species being very common or rare. Of course it would be unusual to find many species belonging to the rare or very common category.

Figure 43 - Number of species recorded across each local status category

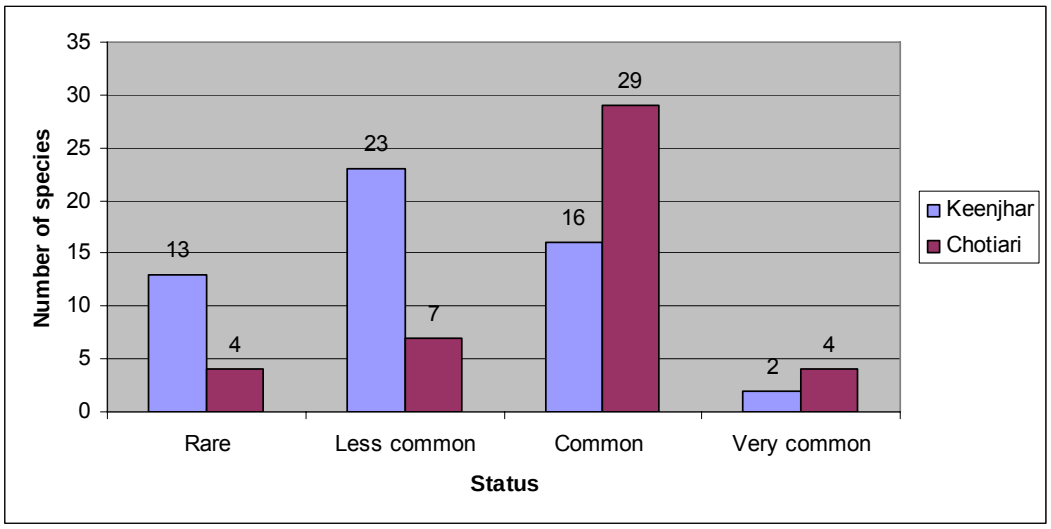


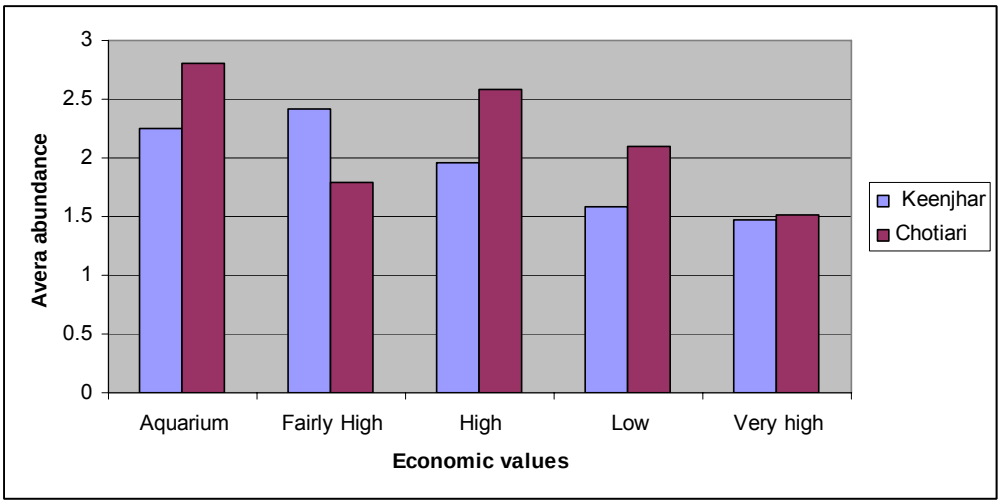
Figure 44 shows the status of fish species at national or country level. Most species fall into the category of common or less common and it is pertinent to note that no species were categorized as very common, indicating that either no fish species in the country has been classified under this category or that there are very few species that are very common, non of which are found in Keenjhar Lake or Chotiari Reservoir.

Figure 44 – Number of species recorded across each national or country status category

4.6.4 Economic values

The economic value for each species was identified and plotted against the average density (number of each fish species caught from 100). **Figure 45** shows the number of species in each category from the two freshwater sites. There was quite and even spread of species over the economic categories though most species had high or aquarium values. Species having very high value were the least common which may reflect that they are being targeted for extraction.

Figure 45 – Average abundance from each category over the two freshwater sites (Keenjhar Lake and Chotiari Reservoir)



4.7 Zooplankton

Note: there is no comparative study between the sites on zooplankton primarily because the results are so different between areas there is very little comparative data to use. Therefore the report on zooplankton has been kept to findings and discussion only

4.8 Physico-chemical properties of water

4.8.1 Summary of water quality

4.8.1.1 Drinking water

- **Keti Bunder**

  Two samples were collected from the Keti Bunder Town area. Sample KB- B1/A1is representing the surface drainage discharging in to Hajamro Creek near to Keti Bunder Town and sample KB-B2/A2 is representing the Keti Bunder Town waste water discharging in to Hajamro creek near Keti Bunder Town (Table 2). Since these two effluents are falling into sea, therefore the National Environmental Quality Standards (NEQs) of Pakistan (*for the effluents disposal into sea)* are referred for comparison.

  It is worth mentioning that the time of sample collection (KB-B1) the water level in Hajamro creek at Keti Bunder Town and in the surface drain was high due to high tide which therefore flooded the surface drain. It is because of this the TDS and other related parameters such as EC, hardness, chlorides, sulphates were found higher than the sample collected from the same location after monsoon (KB-A1). This time the Hajamro Creek near to Keti Bunder Town and surface drain level were very low.

  The Waste water coming from Keti Bunder Town contains washing water (originally KB water /saline water) used for different purposes excluding the drinking water). The drinking water is an expensive commodity and comes in tankers. Since more water is used in non drinking house-hold activities, the waste water generated has high

salinity/TDS and Ni content which is above the NEQs. The other parameters given in Table 2 were within NEQs limits.

Keti Bunder Creeks Area: The values of Keti Bunder water quality in creek areas were compared with the Coastal Water Quality Standards. The marine water quality values are those specified values which are considered safe for the marine life, fish, and mangrove growth. The results show that except for the phenol and nickel, the values of all parameters are well suited for all type of fish, prawn, and Palla fish grown in marine water (Table 3). The cause of high nickel and phenol contamination could be attributed to the increasing level of pollution (municipal and industry waste) entering in to sea from Karachi.

In Bhoori creek area people are using hand pump for drinking water, hence the sample was collected to find the drinking water quality parameters. The results of the tube well water show that the water quality is not very good, as it has the influence of the sea. The TDS and the salt concentration (calcium, magnesium chlorides and) were found exceeding the WHO drinking water quality standards. The nickel and phenol levels were also violating the WHO guidelines. Other parameters as reflected in Table 4 are within WHO safe limits.

- **Keenjhar Lake**

  The total dissolved solid, TDS (or conductivity) is very important parameter along with pH in determining the water quality. The values of both in all samples fall within WHO acceptable range. The TDS below 500mg/l shows that the dissolved solids are on good side considering all of its uses.

  The turbidity (or TSS) is also within WHO standard of 5 NTU except at locations KL-A6 and A7 (Pre monsoon). These location points are near to K.B feeder. The K.B feeder receives water from Indus River at Kotri Barrage which contains high turbidity. The relatively higher levels were also noted at these locations during 1st sampling (before monsoon) period.

  The dissolved oxygen is found low (Less than 3.0mg/l) as the good quality surface water normally has dissolved oxygen as high as 9 mg/l (depending upon pH and temperature). The depletion of dissolved oxygen is an indicator of organic pollution causing BOD and COD. This was found more so when the water level and flow were low before monsoon period.

  The Indus water is generally contaminated carrying organic and inorganic pollution load from upstream human activities. The Sindh Environmental Protection Agency (SEPA 2002) reported that the Indus River BOD is over 6.5 mg/l, which according to Global Environmental Monitoring System (GEMS) classification puts this river as “highly polluted”. K.B feeder also carries the municipal effluents of Jamshoro and industrial effluents of Kotri site. The high levels of BOD and COD indicates that sufficient pollution is exerted in before monsoon period through K.B feeder water.

The Phenol levels were very high due to use of washing and other Phenol substances by the people. The total hardness, sulphates, chlorides, calcium and magnesium were found in the acceptable range of WHO / other national and international guidelines.

Toxic elements detected in the water consisted of chromium which is within the WHO guidelines, Id levels were found violating WHO standard, but this is not true before monsoon period. The Nickel levels were also found exceeding the WHO limit. The Cadmium levels, however were high at location Keenjhar Lake A6 and A7, having high turbidity of water entering from K.B Feeder.

- **Chotiari Reservoir**

  The drinking water quality is judged by comparing the results with the WHO drinking water quality Standards. The main reservoir data show that the water quality is fit for drinking according to the WHO standards. However, some parameters such as Cr, Ni and Phenol were a little excessive than the recommended guideline values. It seems that the Indus River water coming from upstream contains these contaminants because no other pollutant sources are seen. The TDS, pH and DO are within WHO guidelines. The COD and BOD values are slightly higher indicating some organic pollution coming from the upstream of the Indus River water. The CR-B8 is showing high value of TDS, pH, Cl, and Mg which is attributed to seepage water.

  The groundwater samples collected from the surrounding area of the reservoir have shown that the quality is very poor. All the assessed parameters are violating the WHO drinking water guidelines. The Arsenic has been particularly observed in the groundwater which shows higher value than the recommended WHO guidelines. It is noteworthy to mention that no significant change is observed in two data sets particularly for groundwater quality (Pre and post monsoon).

  The lakes which are in the study area and are affected by the reservoir have no access of Indus River and that all are getting seepage water from the reservoir and rain water. The water quality confirms that it is not suitable for drinking and contains high TDS and salts of magnesium and calcium chlorides/sulphates. These lakes receive less rain water hence no major change is observed in water quality data sets of both before and after monsoon periods.

- **Pai Forest**

  The ground water of Pai Forest as sampled from two locations indicates that the water quality in most of the parameters is well within the WHO Drinking Water Quality Guidelines except the phenol and Arsenic. The Arsenic contamination in ground water has been an important issue; here it was also determined and found as high as 0.07 mg/l. The WHO Drinking Water guideline permits Arsenic up to 0.01 mg/l. Studies in other countries have shown that drinking water containing elevated levels of arsenic can cause the thickening and discoloration of the skin. Sometimes these changes can lead to skin cancer, which may be curable if discovered early. Numbness in the

hands and feet and digestive problems such as stomach pain, nausea, vomiting, and diarrhea can also occur due to the elevated levels of arsenic.

There is no industry or any other source which can be blamed for arsenic contamination. Previous studies suggest the geological formation of some area contain arsenic which gets drifted into the ground water.

- **Keti Shah**

  The ground water of Keti Shah as sampled from two locations indicates that the water quality in almost all parameters is well within the WHO Drinking Water quality guidelines. The two fresh water samples were also equally good with some little fluctuations. The Keti shah forest project area water was therefore good for all applications.

4.8.1.2 Agriculture

- **Keti Bunder**

  Most focus was in the creek areas which are devoid of agriculture land

- **Keenjhar Lake**

  The water quality of Keenjhar Lame is very good, considering the TDS (<500 mg/l, and pH(6.5-8.50) . The hardness, calcium, magnesium, chlorides and sulphates are as good as required for drinking water quality. From this, it appears that None Degree of Restriction of Use is required for agriculture according to FAO Standards for agriculture crops. The water salinity (TDS) is well below 1000 mg/l, which is excellent as useable for all livestock and poultry as per FAO guidelines.

- **Chotiari Reservoir**

  The water quality of the reservoir is very good, considering the TDS (<500 mg/l, and pH (6.5-8.50). According to FAO Standards for agriculture crops, it appears that None Degree of Restriction of Use is applicable for agriculture crops, as it receives regular fresh water from the Nara Canal through Raunto Canal. The water salinity (TDS) of the reservoir is well below 1000 mg/l, which is excellent for all livestock and poultry as per FAO guidelines. The Bakar lake water is satisfactory for the use of livestock and poultry, however, the other two lakes: Dongrion and Patherio water is unfit for livestock and poultry. The groundwater is also unfit for agriculture and poultry but can be used for livestock. It is also noticed that there is no significant change in most of the parameters before and after monsoon period.

- **Pai Forest**

  The TDS of Pai Forest groundwater is slightly higher than the recommended value of FAO (450 mg/l) for the crops. The forest trees normally have more tolerance level then the crops. Therefore, this water quality can be considered as an acceptable standard for the forest. The pH value is also in the acceptable range (6.5-8.5). The water can be considered for Non Degree of Restriction of Use. The ground water salinity (TDS) is well below 1000 mg/l, which is excellent as useable for all livestock and poultry as per FAO guidelines.

- **Keti Shah**

  The TDS of Keti Shah Forest groundwater and surface water is excellent and lower than the recommended value of FAO (<450 mg/l) for the crops. The forest trees normally have more tolerance level than the crops. Therefore, this water quality can be considered good for the forest. The pH value is also in the FAO acceptable range (6.5-8.5). From this, it appears that this water can be considered for Non Degree of Restriction of Use. The ground water and surface water salinity (TDS) is well below 1000 mg/l, which is excellent as useable for all livestock and poultry as per FAO guidelines.

4.8.1.3 Fisheries

- **Keti Bunder**

  Water quality parameters were only taken for freshwater water bodies and not marine

- **Keenjhar Lake**

  The Keenjhar Lake water quality is not well suited for aquaculture as reported by Pescode 1977 and WHO. Although the TDS and pH are within acceptable range, the Lead and Phenol have found very high quantity. The two main sources of dissolved oxygen in stream or canal water are the atmosphere and aquatic plants. Aquatic plants introduce oxygen into stream water as a byproduct of photosynthesis. The amount of oxygen that can dissolve in water is limited by physical conditions such as temperature and atmosphere pressure.

  Fish growth and activity usually require 5-6 mg/l or ppm of dissolved oxygen. In this study, the Dissolved Oxygen (DO) has been found below or near 2.0 mg/l (ppm) which does not support fish at all. Other pollutants such as sewage, industrial effluents or agricultural runoff result in the build up of organic matter and the consumption of dissolved oxygen by microbial decomposers as they break down the organic matter.

- **Chotiari Reservoir**

  The minimum Dissolved Oxygen (DO) level that Fish can safely tolerate depends upon temperature and to some extent the specie types. As a rule of thumb, Dissolved Oxygen (DO) should be maintained above 3.0 mg/l for warm water fish and 5.0 mg/l for cold water fish. Prolonged exposure to low, non -lethal levels of DO constitute a chronic stress and will cause fish to stop feeding, reduce their ability to convert ingested food in to fish flesh, and make them more susceptible to disease.

  The good quality surface water normally have dissolved oxygen as high as 9 mg/l (depending upon pH and temperature).The dissolved oxygen is found above 3.0 mg/l, Phenol within acceptable limit of 0.02 mg/l. Lead level is also less than 0.1 mg/l All these parameters along with TDS (less than 1000 mg/l) are sufficiently supporting to fish culture. It is also observed that the phenols have decreased to some extent after rain fall.

  The water quality of Bakar Lake in terms of TDS, Phenol and Lead is suitable for fish development. However, the DO is at the marginal level

and fluctuates around 2.0 mg/l. The water quality of Dongrion and Patherio Lakes is hazardous for fishery in light of above parameters.

- **Pai Forest**

  The Samano Rahoo Lake is an artificial lake in the project area which, support the livestock, wild life and fisheries in Pai Forest. This lake receives fresh water intermittently from the canal supplies. The samples taken from the lake prior to monsoon indicate acceptable quality, (in terms of TDS, Phenol and Lead) for fisheries, as reported by Pescode (1977) and livestock as per FAO guidelines.

  In June 2007, before monsoon Samano Rahoo Lake was full, while after monsoon, surprisingly the lake had less water, there was no flow from the watercourse. This also indicates that there is no significant role of rain water. The water which was available in the lake after the monsoon period is in fact the seepage water coming from the adjacent agricultural lands. Because of the seepage in the lake, the magnesium and calcium salts level (of sulphates, chlorides) has increased after monsoon (sample PF-A3). The turbidity, phenol and other metals, except the Chromium, also were found high in the lake. The lake is only surface water available to livestock and wild life of Pai Forest. The frequent entry of livestock into the lake for drinking and resting resulted in erosion of lake banks, causing high turbidity. The plant tree leaves and washing materials (detergents, etc) used by women along the lake may be the cause of phenol based substances. There is no industry or visible source of metallic pollution. The inherent Indus River pollution due to the upstream human activities may be one cause of lake contamination Conclusion

- **Keti Shah**

  The Shah Belo Lake is connected with the Indus River upstream of Sukkur Barrage and moves through the forest, having high quality of water for fish, wild life and livestock. This and river Indus samples show the dissolve oxygen is between 1-2.6 mg/l, which is low , as normally more than 4 mg/l DO is required for the sustenance of the fisheries. The values of TDS, Phenol and Lead are within the acceptable range, as proposed by Pescode (19

Table 56 – water quality parameters over site and season

	Keti Bunder		Keenjhar Lake		Chotiari		Pai Forest		Keti Shah	
Parameters	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
Temperature	25-29oC	30-32oC	30-32oC	25-29oC	30-32oC	25-29oC.	30-32oC.	25-29oC.	n/a	25-29oC.
Electrical Conductivity	1502-48400 µS/cm.	47200-52700 µS/cm	490-587 µS/cm	529-674 µS/cm,	553-39500 µS/cm	571-15400 µS/cm.	772-810 µS/cm.	760-3430 µS/cm	n/a	287-427µS/cm.
TDS	962-36608 ppm	30208-33728 ppm	314-376 ppm	356-432 ppm	354-25280 ppm	366-9856 ppm	490-519 ppm.	495-2196 ppm	n/a	184-274 ppm
pH	7.16-8.00	7.93-8.81	6.96-8.49	8.00-8.31	7.3-8.9	7.20-8.36	7.62-8.47	7.43-7.94	n/a	7.50-7.80
Turbidity	12.7-94.0	13.2-471	0.73-8.14	3.11-97.2	0.83-17.5 NTU	2.00-40.0	4.04-188 NTU	3.10-833 NTU	n/a	1.50-400 NTU
Total Hardness	300-5000 ppm	5504-5804 ppm	120-155 ppm	60-127 ppm	100-3450 ppm	105-3000 ppm	190-250 ppm	150-444 ppm	n/a	60-120 ppm
Calcium	100-1000 ppm	900-1100 ppm	72-80 ppm	25-45 ppm	50-1600 ppm.	40-310 ppm.	110-170 ppm	75-144 ppm	n/a	30-80 ppm
Magnesium	200-4200 ppm	4604-4704 ppm	43-80 ppm	35-89 ppm	40-3400 ppm	65-2690 ppm	140 ppm.	75-300 ppm	n/a	30-47 ppm
Sulphate	100-13380 ppm	1650-1780 ppm	14-24 ppm	80-170 ppm	75-3450 ppm.	62-1125 ppm	75-175 ppm.	100-1150 ppm	n/a	10-55 ppm.
Chlorine	350-20000 ppm	18000-20000 ppm	28.9-63.5 ppm	50-106 ppm	150 -14000 ppm.	100-2250 ppm	29.8-97.3 ppm	55-350 ppm	n/a	24-54 ppm
Alkalinity	120.0-898.0 ppm.	113-113 ppm.	91.5-109.8 ppm	30-40 ppm	30-330 ppm	80-460 ppm.	40-110 ppm.	73-123 ppm.	n/a	35-70 ppm
Phenols	34-340ppb	34 ppb	1.7-3.57ppb	3.4-15.3	6.8-510ppb	5.1-74.8ppb	8.5-17ppb	8.5-51.0 ppb	n/a	8.5-8.5ppb
Cr	3.53-12.64 ppm	10.44-41.32 ppb	9.3-33.29 ppb	6.4-20.8 ppb	n/a	30-72.6 ppb	53.92-56.02 ppb	23.3-53.9 ppb	n/a	8.99-15.9 ppb
Pb	8.08-75.84 ppm	16.20-17.20 ppb	5.19-10.11 ppb	10.93-20.63 ppb	n/a	6.82-14.6 ppb	23.70-27.50 ppb.	9.65-13.06 ppb.	n/a	21.31-33.85 ppb.
Cd	11.2-64.0 ppb	2.20-2.92 ppb.	4.28-9.16 ppb	0.61-4.74 ppb	n/a	0.66-2.45 ppb.	20.05-21.77 ppb.	0.28-0.98 ppb.	n/a	1.95-5.75 ppb
Ni	12.2-35.21 ppb	6.5-7.8 ppm	7.73-9.82 ppm	0.93-1.73 ppm	n/a	2.32-9.59 ppm	17.05-19.75 ppm	3.48-27.9 ppm	n/a	0.82-1.73 ppm
BOD	0.53-12.4 ppb	3.05-8.75 ppm	5.06-10.1 ppm	1.00-6.07 ppm	n/a	1.76-4.58 ppm	n/a	n/a	n/a	1.26-1.52 ppm
COD	1.9-25.9 ppm	9.2-51.5 ppm	12.64-16.43 ppm	5.05-12.13 ppm	n/a	5.16-11.15 ppm	n/a	n/a	n/a	8.85-19.10 ppm
Arsenic	n/a	n/a	n/a	n/a	n/a	25-50 ppb	30-77 ppb	25-75 ppb	n/a	
DO	n/a	n/a	n/a	n/a	0.18 to 4.92 mg/l	1.5 to 3.2 mg/l	n/a	n/a	n/a	1.4 -2.3 ppm
Nitrates	n/a	n/a	n/a	n/a	n/a	0.182 and 0.345 mg/l.	n/a	n/a	n/a	n/a
Phosphate	n/a	n/a	n/a	n/a	n/a	0.42 and 0.52 mg/l.	n/a	n/a	n/a	n/a

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