Study of Impact of Some Aspects of Environmental Changes at Keoladeo National Park (KNP), Wetland Bharatpur

A THESIS

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Dedicated

to

My Beloved Mother and Father

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Date:
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ABSTRACT

The present work is the study of influence of predominant environmental parameters such as water sources, water distribution and its quality and human associated activities on Keoladeo National Park, Bharatpur (KNP) wetland. The ecology of the park is compatible with the migratory and resident birds for which KNP is having its reputation on the world map. The water supply from the natural sources to KNP wetlands has changed in the last two decades. As additional sources, water is now being supplied from the Chambal pipe line project which is basically a drinking water project scheme for Bharatpur area and Goverdhan drain. This change in water sources has affected the ecology of the park and is inappropriate for the KNP habitat.

The changes in the human related activities in the vicinity of the park, during the last decade, have also been affecting the ecology of the park. The main human activities include the National highway passing along the periphery of the park (NH-11), increasing urbanization and restricting the entry of villager's livestock. These activities have an adverse effect on the park ecology resulting in increased noise levels and unwanted growth of wild flora. Increased noise level and unwanted growth of wild flora adversely affect the breeding and staging of the birds. The increased noise level affects the behavioural aspect of birds including their communication system and hearing ability. As a result of increasing sound level, the birds are moving to the inner and core areas of KNP and in the nearby satellite wetlands.

Changes in environmental factors and their impact on birds and eco-tourism have also been studied. Due to these changes, the number of migratory birds in the park is decreasing thereby deteriorating the park's glory as a world heritage. According to a recent survey, a downfall has been observed in the number of migrating birds and also in the number of foreign tourists. The hotels and local community which depend on the visits of these tourists (mainly foreigners) are also struggling for their survival. Hoteliers are providing the hotel premises for various social ceremonies and functions. These changes in hotel activities have also further increased the noise pollution and human intervention around the KNP.

The study suggests that water in KNP should be supplied from its natural source Ajan Dam rather than Chambal drinking water project. There should be control on the human activities in order to decrease noise level around KNP. The highway should be shifted from the present alignment so as to reduce noise level. Further public functions in the vicinity of KNP need to be restricted to ensure a suitable environment for the birds.

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ABBREVIATIONS

BAS	-	Bellanwila-Attidiya Sanctuary
BOD	-	Biochemical Oxygen Demand (mg/l)
C	-	Centigrade
CAF	-	Central Asian Flyway
CPCB	-	Central Pollution Control Board
DB	-	Decibel Rating
DO	-	Dissolved Oxygen (mg/l)
EC	-	Electrical Conductivity
Ha	-	Hectare
IBA	-	Important Bird Area
IPCC	-	Intergovernmental Panel on Climate Change
IUCN	-	International Union for the Conservation of Nature
Km	-	Kilomètre
L	-	Litre
LCV	-	Light Commercial Vehicle
Leq	-	Equivalent Noise Level
Lmax	-	Maximum Noise Level
Lmin	-	Minimum Noise Level
LMV	-	Light Motor Vehicle
Lnp	-	Noise Pollution Level
Mm^3	-	Million Cubic Metre
M	-	Metre
Mg	-	Milligram
Mg/l	-	Milligram per Litre
Mm	-	Millimetre
MOEF	-	Ministry of Environment and Forests
MOIB	-	Ministry of Information and Broadcasting
NC	-	Noise Climate
NH	-	National Highway
NTU	-	Nepholometric Turbidity Unit
OBS	-	Okhla Bird Sanctuary
PCU	-	Passenger Car unit

SD	-	Standard Deviation
SLM	-	Sound Level Meter
SWMA	-	Stillwater Wildlife Management Area
T	-	Temperature
TDS	-	Total Dissolved Solid
UNESCO	-	United Nations Economic Social and Cultural Organization
WHO	-	World Health Organisation
WWF	-	World Wildlife Federation

CHAPTER 1
INTRODUCTION

The impacts of steadily changing climate, such as rising global average temperature and severity of extreme events, droughts and floods are affecting human well-being and biodiversity (IPCC 2007). The impact of a steadily changing environmental factors affected ecosystems, economies and our global society (MOEF, 2007).

Various environmental factors such as regional climate, geomorphology, hydrology and physicochemical parameters of water facilitate the existence of wetlands in the landscape. Existence of a particular wetland at a given location is reliant on the occurrence of a relatively narrow range of environmental variables (Mitsch and Gosselink, 2000).

1.1. Introduction of wetlands

India is among the first signatory to the Ramsar Convention held in Iran in 1971 to protect and conserve on Wetlands. The convention's mission is "the conservation and wise use of all wetlands through national action and international cooperation, as a contributor towards achieving sustainable development throughout the world". World wetland day is celebrated every year on 22nd February for awareness of their conservation.

The Ramsar convention on wetlands defines wetlands very broadly as areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.

There are presently 169 Contracting Parties to the Ramsar Convention, with 2241 wetland sites, designated for inclusion in the Ramsar List of Wetlands of International Importance. The Ramsar sites cover over 215,240,661 hectares of wetland (https://rsis.ramsar.org /www.ramsar.org).

Wetlands are important feeding and breeding areas for wildlife. It also provides a staging place for migratory birds and refuge for waterfowls. Wetlands are important in supporting diversity of the species and have a complex of wetland values. Wetlands perform numerous valuable functions such as recycle nutrients, purify water, attenuate floods, maintain stream flow, recharge ground water, and also serve in providing drinking water, fish, fodder, fuel, wildlife habitat. (Prasad et al, 2002).

1.2 Distribution of wetlands in India

Wetlands in India occupy 58.2 million hectares of area, including the areas under wet paddy cultivation (Bassi et al, 2014). The majority of the inland wetlands are directly or indirectly depended on the major rivers like Ganga, Brahmaputra, Narmada, Godavari, Krishna, Kaveri and Tapti. They occur in the hot arid regions of Gujarat and Rajasthan, the deltaic regions of the east and west coasts, highlands of central India, wet humid zones of south peninsular India and the Andaman and Nicobar and Lakshadweep Islands (MOEF, 1993).

Table 1.1: Distribution of area of wetlands of India

Type of Wetland	**Area (million ha)**
Area under paddy cultivation	40.9
Area suitable for fish culture	3.6
Area under capture fisheries (brackish and freshwater)	2.9
Mangroves	0.4
Estuaries	3.9
Backwater	3.5
Man-made impoundments	3.0
Rivers, including main tributaries	(28,000 km, length)
Canals and irrigation channels	(113,000 km, length)
Total Area of Wetlands(Excluding Rivers and Canals)	**58.2**

(Reference: Scot, 1989)

India presently has 26 Ramsar wetland sites of International Importance and 68 wetlands have been identified for protection under the National Wetland Conservation Projects. Wetland provides numerous uses, keeping the water table high and stable during drought by releasing water. They perform flood mitigation agents to reduce flood level and trap nutrients. The Keoladeo National Park (KNP) was designated as a Ramsar Site in1981 and World Heritage Site in 1985 which has given it the international recognition.

It occupies 29.05 km^2 areas enclosed by masonry wall, 11.6 km^2 areas of which comprises of water (Appendix-1). It is divided into 15 blocks (A to O, figure 3.1). The main aquatic blocks are used for nesting, breeding and staging of water-birds. Blocks K, L, D, and E are key area of the study. A variety of Migratory and resident birds such as Siberian Crane and Black Francolin, Painted Stork, Saras Crane, Darter, Ibis etc. has been main attraction for the tourist in these blocks of KNP. Some of the birds are shown in Figure 1.1.

Figure1.1: Faunal variety in KNP showing bird's richness (a) Black Francolin (b) Saras Crane (c) Painted Stork (d) Common Kingfisher

1.3 Problem arising in KNP

Many natural habitats in the study area are undergoing changes as a result of hydrological abstraction and human activities. Under this regime, numbers of various species (popular Siberian Crane) is swiftly deteriorating (Figure1.2). Birds constitutes most noticeable component among the diverse biotic community. They are also considered as the indicators of the dangers which lay ahead for an ecosystem of a wetland.

Figure 1.2: Siberian Crane is now endangered species in KNP

Keoladeo National Park has witnessed history of floods in 20th century due to heavy precipitation in catchment area of rivers Banganga and Gambhiri. In the 1980's, due to the upstream diversions and deforestation, the water supply from the Banganga River decreased. In 2003, Panchana Dam was built on the river Gambhiri at Panchana, 90 km south in Karauli District to supply water to the upstream villages. Recent droughts in 2004, 2006 and 2007 dried out the impoundments, enabling an invasion of weed trees and species in KNP leading to changes in its ecology structure (Singh et al, 2010).

It can be observed that the population of Siberian Crane in KNP has reduced sharply in last 30 years (Figure 1.3). They were 100 in 1970, was only five in 1993,

two in 2002 and not seen from 2004 onwards. Now Siberian Crane is critically endangered species in KNP and as well as on Central Asian Flyway routes.

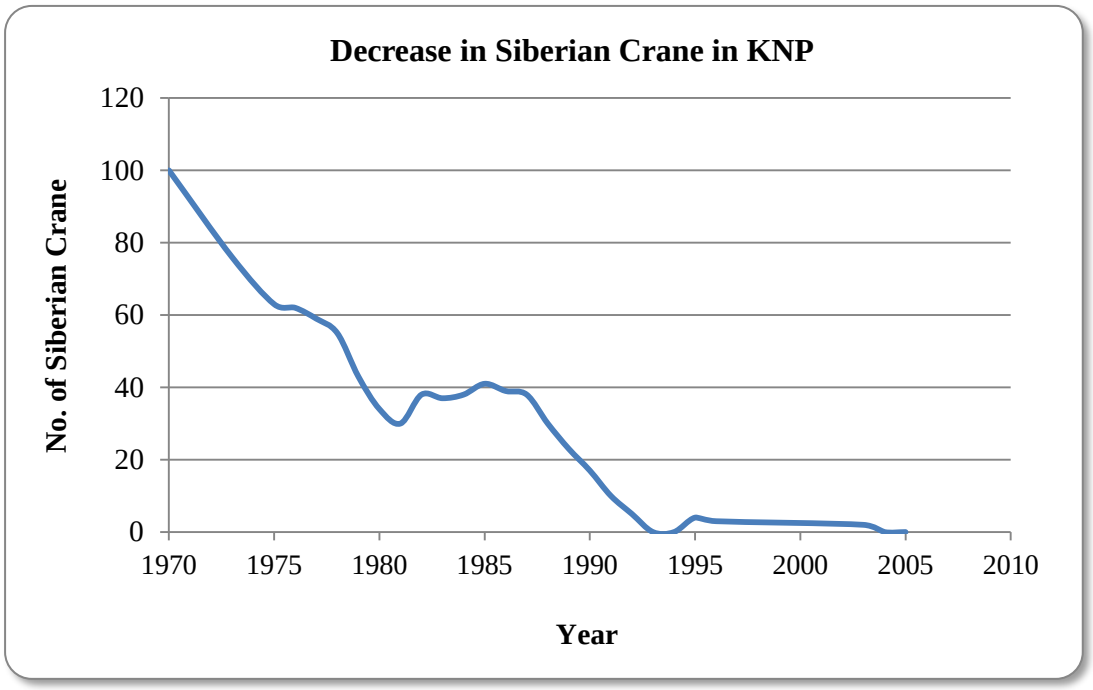


Figure 1.3: Siberian Crane swiftly decreased in KNP (Source- KNP Bharatpur)

Due to acute water scarcity the ecosystem of the Park has been affected. This has resulted in reduction in the number of arrival of migratory birds in the National Park. In 2004, when drought conditions prevailed in Bharatpur, less than thousand birds arrived in the KNP whereas more than thousands of the birds were observed at one of satellite wetlands in Nonera which is located just about 70 km from KNP (Bhadouria et al, 2012). It shows that ecology of wetlands play a key role in attracting the population of many aquatic birds. Due to low rainfall, less number of aquatic birds and inadequate water supply in KNP during 2004 to 2006, its world heritage tag was in danger in 2007 (UNESCO team visit).

1.4 Motivation and scope for the research work

Many research works have been done on birds (Siberian crane and other migratory birds), fish, mammals and invertebrates as well as on predominant flora including grassland and angiosperm of KNP wetland. However, no such study has been carried out in KNP to determine the key changing environmental factors and their impacts on inter-related parameters of KNP.

Scope of research work includes study of change in water sources and noise pollution due to human activities and their impact on birds and ecotourism. It will help to devise a better action plan to mitigate various problems in KNP.

1.5 Research objectives

On the basis of issues stated above, the objectives of the study were planned as follows:

- To study predominant environmental parameters such as hydrological changes (changes in water source and their quality) and increasing human activities in vicinity of Keoladeo National Park wetland.
- Analysis of current environmental changes such as changes in water source, increased traffic on NH-11 and noise pollution on KNP.
- To study the impact on birds, ecotourism and dependent local community (hotels, guide rickshaw pullers and villagers, struggling for their survival).
- Determine suitable measures for conservation of ecology of KNP, Bharatpur wetland.

1.6 Orientation of chapters in the Thesis

The thesis is divided into six chapters. A brief introduction of each chapter has been given as below.

- In Chapter 1 the background, statement of the problem, outline, rationale, and objectives of the present research in KNP is described.
- Chapter 2 presents the review of literature on critical environmental factors which affect the wetland. The chapter deals with the published literature on the observed environmental changes, their impacts on water-birds.
- Chapter 3 describes the KNP wetland system. It includes inflow of water to KNP wetland, meteorological variation, human intervention around KNP, birds and ecotourism in KNP.
- Chapter 4 presents the study sites and methodology used in this work. This includes survey and experimental work carried out in the research.

- Chapter 5 deals with results and discussion of the current environmental changes in KNP. This chapter also examines the changes in water and its quality, noise variability and its effect on KNP wetland. It also includes study of corresponding impacts on birds, ecotourism and dependent local community.
- Chapter 6 presents the conclusions of the study. The chapter also includes some suggestions for further research.

CHAPTER 2

LITERATURE REVIEW

An important feature of Earth's climate is that it has been changing every time (Sekercioglu et al. 2012). It has been observed that in the past climate changes particularly warming were of lesser magnitude and at slower rate than the recent past. Therefore, there have not been major disturbances in the planet ecosystem and dependent organism (Huntley et al., 2006).Biodiversity is essential for the survival and well being of humans. It regulates climate and maintains ecosystem resilience. Wetlands are one of the most productive ecosystems of the world among all of our natural resources. Many wetlands in eastern Asia and northern Australia have deteriorated. Their condition is worsening due to increasing pressure of the introduction of alien species, water pollution, urban encroachment, reclamation and infilling, and hydrological disruption (Revenga et al. 2000; Storrs and Finlayson, 1997; Finlayson and D'Cruz, 2005; Dudgeon et al. 2006).

In general, the wetlands serve the following purposes (Galbraith et al, 2005)

- Habitat for aquatic birds, other animals and plants
- Biodiversity
- Food production
- Water storage, including mitigating the effects of floods and droughts
- Groundwater recharge
- Water purification
- Nutrient cycling
- Recreation and tourism
- Climate change mitigation

This chapter deals with relevant literature on wetlands and the effect of some environmental changes on wetlands.

2.1 Importance of wetlands for their biota

Wetlands play an important role in maintaining biodiversity as they support large genetic diversity both endemic as well as migratory species. In the UK alone, 3500 species of invertebrates, 150 species of aquatic plants, 22 species of ducks and 33 species of wading birds have been identified as living in wetlands (Merritt, 1994). Flood plains and their biodiversity purely depend on free surface water flow.

Substantial researches have increased the understanding of wetland's influence on the number of water birds that breed and on their breeding success. However, the relation between wetlands and the population and propagation of various waterfowl species is not well understood. This relation depends mainly on the species of birds, local climate, number of wetlands in the area, the wetland's area and the depth of water (Dahl and Watmough 2007). Bird abundance can be predicted by water level fluctuation and wetland area, as bigger wetlands have more microhabitats attracting more number of species such as in Kolleru lake, India (Ringelman and Longcore, 1982; Paszkowski and Tonn, 2000; Froneman et al., 2001, Gajardo, et al. 2009, Lakshmi and Rao,2015). The wetland's features were significantly correlated with bird abundance.

Shanbhag and Borges (2007) studied the natural wetlands such as Curtorim Lake and Maina Lake in Goa. They investigated that vegetation and 45-60% open spaces attract higher number of ducks and water birds in winter. The maximum depth of 3.5 m was observed in winter season. Increase in water depth, more than 90% open space and low vegetation is not conducive environment for water birds. As increase in water level and depth has negative effect on wading birds (Maheswaren and Rahamani, 2001) and divers (Wanless et al, 1993). Gajardo, et al. (2009) studied eight wetlands to the North of Bio Bio River in Chile. Twenty six bird's species of ducks and geese were observed and strong relationship between species richness and wetland area was found. Bigger wetlands supported a higher number of bird species as depicted in Figure 2.1.

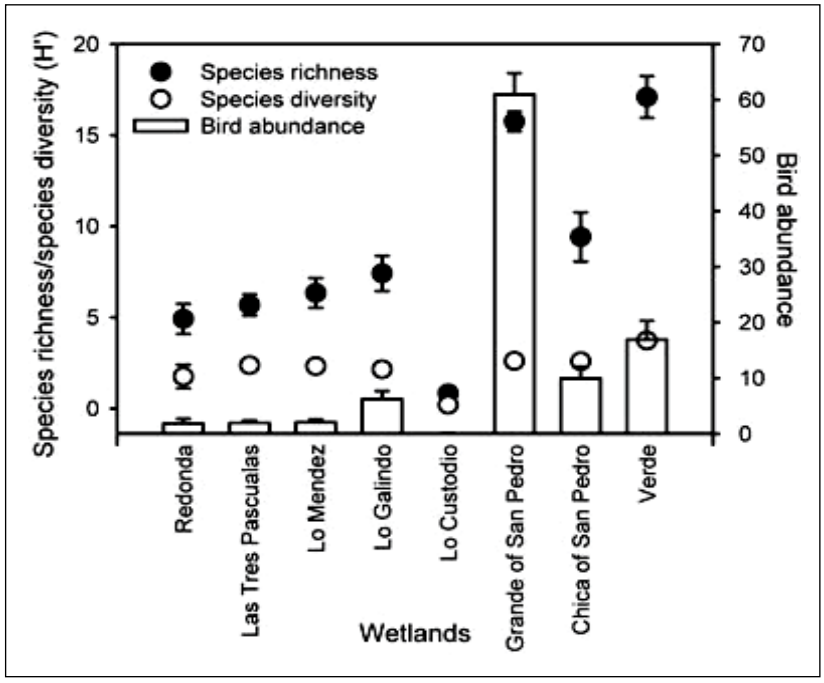


Figure 2.1: Species richness diversity and water bird abundance by wetland with averages and S.D.[s] in the wetlands of the concepcion-Tacahuano-San Pedro metropolitan area during 2000/2001 (Reference: Gajardo, et al., 2009).

Wetlands also make breeding habitats available for many species, including recreational and commercially important fish, by providing nutrient-rich feeding areas and refuge from predators and environmental variations (Welcomme, 1979: Maitland and Morgan, 1997).Abundance of fish in wetland serves main food for water birds. It has been shown that wetland habitat with controlled flooding increases fish abundance, species richness and abundance of birds (Jurajda et al., 2004; Cowx, 2001).

Previous studies suggested that the water level fluctuation is the wetland characteristic that best predicts bird abundance. It was also been observed that the habitat and bird assemblages did not remain unchanged throughout the year. The birds responded differently to one or another habitat characteristic depending on the season. Wetlands also indirectly improve biological productivity in other freshwater systems by the physical, mental and societal well-being associated with wetlands (Fuller et al., 2007). It also provides cultural heritage and aesthetic value, export of food, in the form of primary and secondary production (Henning et al., 2007). Fresh water wetlands Kolleru, the most important and large fresh water ecosystem situated

between the rivers Krishna and Godavari, supports high bird diversity and abundance in winter season and well known as bird's heaven. It attracted 232 species of birds belonging to 138 Genera. Out of 232 species, 6 are globally threatened, 20 are near threatened and 100 are migratory (Lakshmi and Rao, 2015).

In view of above, it is clear that the wetlands are very important for attracting the birds, providing them compatible environments and food. The biota of any wetland is dependent on the wetland characteristics and is susceptible to any kind of changes which affect the wetland.

2.2 Critical environmental aspects

The wetlands characteristics include size of aquatic area, water depth in aquatic area and vegetation in the aquatic parts. These characteristics of wetlands significantly depend on the environmental factors such as hydrology, meteorology and the human related activities which directly or indirectly have effects on the wetland, as depicted in Figure 2.2. These relevant factors need to be identified and controlled for a particular wetland habitat in order to achieve the desired ecosystem. These environmental factors are discussed in following paragraphs.

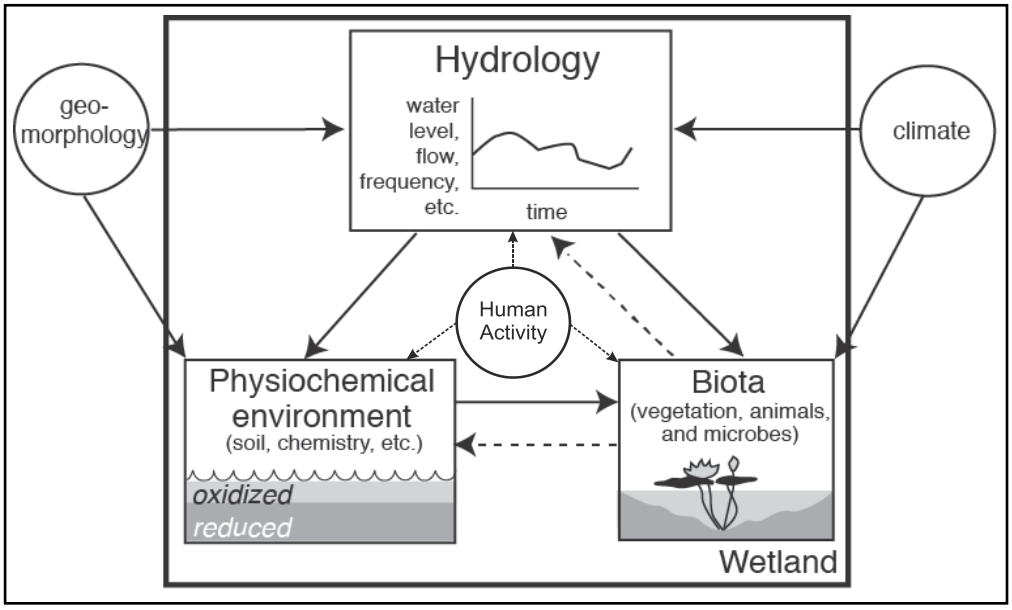


Figure 2.2: Presentation of inter-relationship between three main components of wetland as hydrology, physiochemical environment and biota (Reference: Mitsch and Gosselink, 2015)

2.2.1 Hydrological aspect

The key environmental forcing factor in wetlands is hydrology. Most of the wetlands in the tropics are subjected to considerable water-level fluctuations according to the dry and rainy season and it belongs to the flood plain category (Junk et al, 1989). The hydrological regime influences composition of plant and animal communities and it activates the biological processes in aquatic and terrestrial areas (Junk et al. 1989). Wetlands in tropical places are hot spots for the development and maintenance of biodiversity (Gopal, B., 2001).

It has been investigated that hydrologic cycle establishes proper balances in surface-water flow, precipitation, evapotranspiration and ground-water flow in a region for their growth. Wetland has outflows and inflows of water and it is the equilibrium that affects the wetland characteristics (Day et al., 2005; Kath, 2012). It was observed that wetlands act as basins for particular nutrients and sediments. These are the sources of bacteria affecting the water chemistry (Bailey, 2006; Koch et al. 2007). Organisms, living in these wetlands, not only sustain but also require these water level fluctuations for the long-term survival (Adis and Junk 2002). Inconsistency of water in wetlands is attributed to changes in hydrological outputs/ inputs and is linked to hydraulic controls (McLaughlin and Cohen, 2013). Change in water level is significant factor for many aquatic fauna and flora (Bullock and Acreman, 2003; Gouriveau, 2009).

The most abundant and spectacular winter migrants to the Indian subcontinent are the ducks and geese which constitute about 85% of migrant winter bird populations of approximately 3 million birds, wading, shorebirds and cranes (Alfred et al, 2001). However the recent studies have shown that the population of the wetland birds is declining and many wetlands are in danger (Zhang et al., 2015). This phenomenon is an indication of many environmental changes and possibly the degradation of the wetlands, as the birds are among the first indicators of dangers ahead for an individual wetland.

2.2.1.1 Water availability and their observed impact on wetland

Water is a major component of wetlands and also a medium of transporting nutrients. Its effect on wetland habitat variability due to fluctuations is recognized as having an impact on wetland hydrology. A change in timing of supply of water inputs causes changes in water parameters such as depth, solute concentration and also affects food availability, sizes, fauna and flora species (Gouriveau, 2009; McLaughlin and Cohen, 2013). This directly or indirectly influences bird congregation.

Around 70% area of the Earth surface is covered by water, but a small portion (3%) of this is fresh water (Figure 2.3). Therefore, non-marine living beings rely on less than 1% of the planet's total freshwater for their survival (Courtland, R., 2008). There is huge competition for this available fresh water. It is necessary not only to maintain biodiversity, but also to produce food, fuel, generate power, provide water for domestic and industrial uses and maintain the carbon content of ecosystems. Groundwater fulfils some of these needs but the pressure on surface water is huge. As far as the freshwater wetlands are concerned, adequate and timely availability of fresh water is necessary for the sustainable biological values including amount of fish, proper growth of vegetation and biodiversity (Yimer, 2009; Ramamurthy and Raj Kumar, 2014).

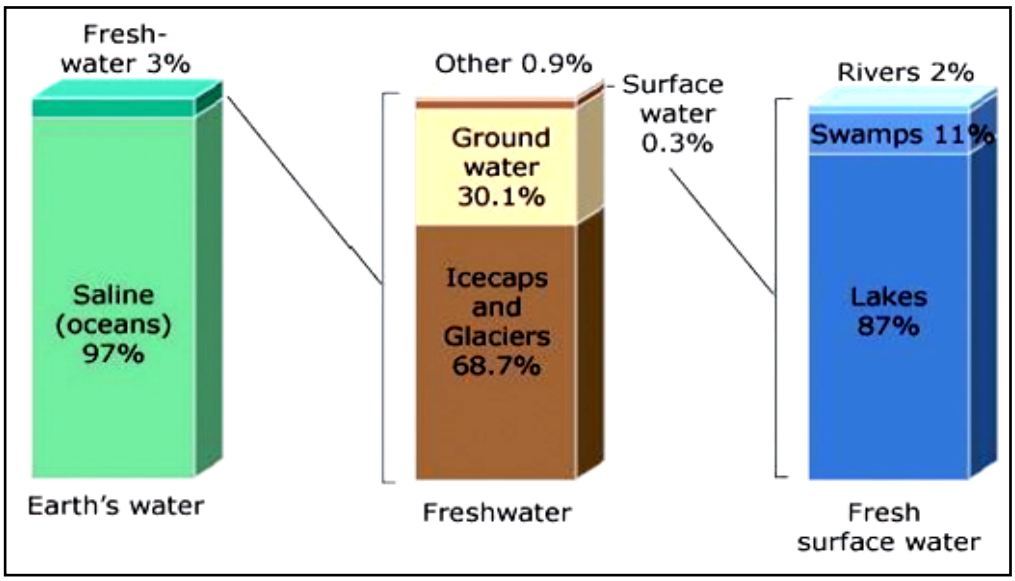


Figure 2.3: Distribution of Earth's water, survival of Planet living is depending upon fresh water (around 1%) (Reference: Courtland, R. 2008)

Less wealthy countries like Africa and Asia as compared to America are unable to make the massive investments required for fresh water security and hence remain vulnerable to drought, floods and water pollution as illustrated in Figure 2.4. Recent estimates suggest that there are 1.2 million square kilometres of wetland in the world. More than 50% of wetlands were lost during the twentieth century, mostly situated in parts of North America, Europe, Australia, and New Zealand. Globally habitats associated with 65% of continental freshwater discharge are threatened (Vorosmarty et al. 2010).

Freshwater species are being lost much more rapidly than other species as given in Table 2.1 (Vorormarty et al, 2010). There are several reasons for this. However, one major factor is the vulnerability of species that depend on relatively small areas of habitat that are under pressure due to the increasing human demand for water resources.

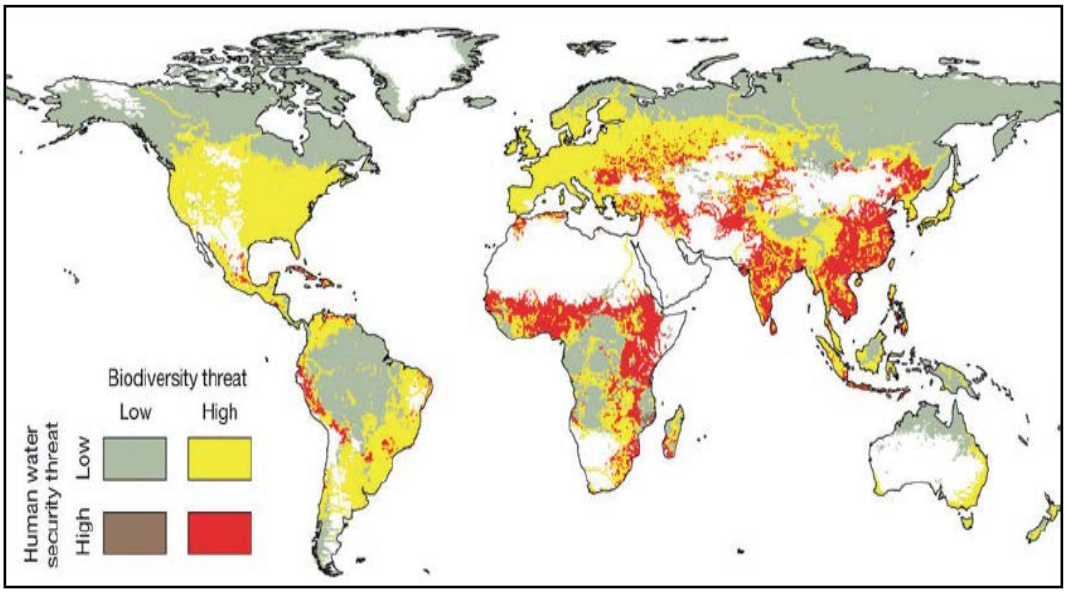


Figure 2.4: Threat to human water security and biodiversity
(Reference: Vorormarty et al, 2010)

Xing et al, (2011) analysed on the basis of spatial distribution of ecological instability at Sanjiang wetland (3 wetlands area Tongfu, Enargi and Wokenhe) in China. They included parameters as average annual rainfall, vegetation area, wetland area, runoff and flood. They found that ecosystem in Tongfu area was stable

as vegetation condition was good whereas Enargi area and Wokenhe area ecosystem were unstable as wetland area and surface runoff were very less compared to others.

Table 2.1: Status of freshwater biodiversity

Species	Status (IUCN Red-List) 4
Freshwater mammalian species (145)	38% threatened with extinction
Freshwater amphibian species (4242)	Over 25% threatened with extinction
Freshwater fish in Africa	Nearly 25% threatened with extinction
Freshwater fish in Mediterranean Basin	Over 55% threatened with extinction
Freshwater species in Africa (5,167 assessed)*	Over 20% threatened with extinction
Extinct birds (136)	Over 10% freshwater dependent birds

*(*Freshwater fish, crabs, molluscs, dragon flies and some plants.)*
(Reference: Vorosmarty et al. 2010)

Behera et al. (2012) studied the changes in the land use in Samaspur wetland in Raibareli U. P. with satellite remote sensing. Between the years 1975-1990, the water spread area had increased whereas it decreased in the years 1990-2006. The increase was due to flow of water from Sharda canal and the decrease later on was due to dams constructed across river, and increased urbanization. They concluded that the policy driven measure impacted on land use and natural wetland ecosystem in this area. They also reported considerable reduction in the wetland area. Maximum occurred in *Rai Bareli* and minimum in *Berauch*. The wetland is facing water scarcity and human interference which is adversely affecting the resident and migratory birds including threatened species such as Saras Crane and Painted Stork.

Changes in the amount of water and its depth in a wetland affected the incoming of nutrients and sediment in to wetland and are responsible for decline of many wetland bird species (Naiman et al., 1992; Behera et al., 2012). Less vegetation due to drought was the main reason of duck nest failure in Stillwater wildlife management area (SWMA) in Carson City, Nevada (Hallock and Hallock, 1993, Jobin and Picman, 1997). Lowering of water tables reduces the number and the variety of wetlands and their vegetation communities. Drought also reduced the

richness, and breeding success of birds in many individual wetlands (Higgins et al., 1992).

In last decade (2000-2010), India has lost more than 38% of its wetland and rate of degradation has been reviewed as high as 88% in some area (Vijayan, V.S., 2004; Varghese et al., 2008). Main causes of degradation of this wetland were hydrological alteration, pollution by various sources and habitat destruction by land filling. In most delta regions of India, China, Pakistan, and Bangladesh there has been drying of wetlands and deterioration of ecosystems due to precipitation decline and droughts. For instance, construction of upstream reservoirs, improper use of groundwater and droughts from 1999 to 2001 have led to drying of the Momoge wetland, situated in the Songnen Plain, China (IPCC,2007).

2.2.1.2 Water quality and their observed impact on wetland

The quality of water is characterised by the physiochemical parameters (pH, DO, BOD, turbidity, nitrates, etc.). Feng et al. (2010) studied water quality in urban wetland and found that open water plant coverage and catchment style affects the ecosystem. Water quality in high level plant coverage is better than low level plant coverage. Mahanta et al. (2011) studied in the Brahmaputra-Barak basin of North East India. Water quality of the studied rivers in urban areas showed significant stress due to poor water quality caused by increased urbanization and industrialisation. Collected water quality data did not meet the Indian national guidelines for several rivers of the Brahmaputra Barak basin. This study recommended the control of river water pollution of this region so that sustainability of the river ecosystems of the basin could be maintained. Some of the salient features of the river water quality of the region are given in Table 2.2.

Moundiotiya et al. (2004) analysed Jamua-Ramgarh wetland in Jaipur for ecological changes. They suggested chemical property was suitable to maintain but other human activity and agriculture practices around lake should be restricted which reduces flow of water in this wetland. Total hardness and chloride in water were (120.8 and 82.07 mg/l) quite high which puts this wetland into hard and polluted category.

Table 2.2: Salient features of the river water quality

Parameters	Mean	St. Deviation	Range
pH	7.5	0.6	4.2-9.6
TDS (mg/l)	87.7	66.1	10-430
EC (µS/cm)	106.0	93.0	16-656
DO (mg/l)	7.0	1.5	3.1-9.5
BOD (mg/l)	1.7	2.6	0.1-20.0
Turbidity (NTU)	95.7	165.1	2-914
Hardness (in mg/l as $CaCO_3$)	51.6	38.6	4-218

(Source- Mahanta et al., 2011)

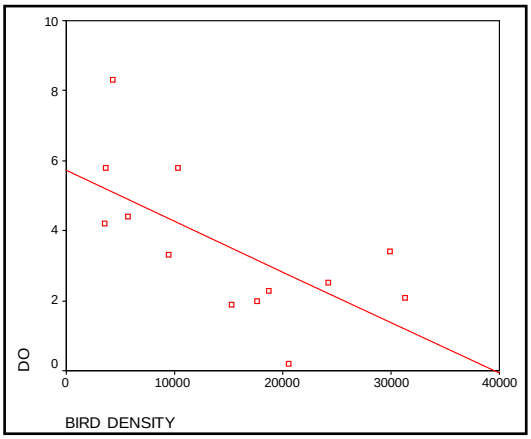
DO is main parameter of water to indicate good quality and is positively related to the distribution and abundance of various algae used as food for birds. DO was ranged from 4.88-13.4 mg/l. Water temperature influences the solubility of oxygen and with a probable increase in water temperature together with a large biological oxygen demand (in floodplains), the concentration of oxygen further reduces (Ficke et al., 2007).

Ramamurthy and Rajkumar, (2014) correlated the water quality and the bird density, diversity and richness and reported various effects of different physico-chemical parameters such as pH, water depth, DO, salinity and turbidity. All the studied water quality factors were found to significantly influence one or more water bird population characteristics. Yimer (2009) studied at Jimmy wetland in Ethiopia and found that physiochemical parameter of water sample in three wetlands were important for biotic integrity with relation to vegetation nutrient. Omotoriogun et al (2011) studied the wetland of Yankari Game Reserve, Bauchi Nigeria on water quality and reported the changes in water chemistry affect density and diversity of water and terrestrial birds in ten wetlands. Diversity was negatively correlated to the size of wetland.

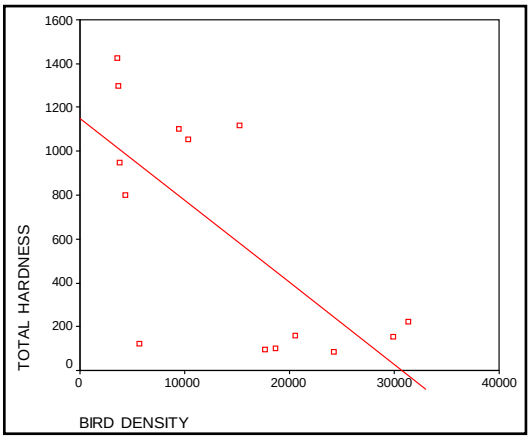
Deshkar et al., (2010) studied in village pond of Gujarat for abiotic factor and bird diversity. They revealed that temperature and bird density were positively correlated but negative correlated with DO. They also found that bird density was

positively correlated with bicarbonate alkalinity. This study investigated that the wetland is occupied by the resident birds (65-95%) during major part of the year. In winter it was equally populated with the resident and migratory birds (50%). The DO, total hardness and water cover were measured and it showed significant differences across the four seasons. DO was maximum during monsoon (6.0 $\pm$ 0.3 mg/l) and low during summer (3.7 $\pm$ 0.31 mg/l).

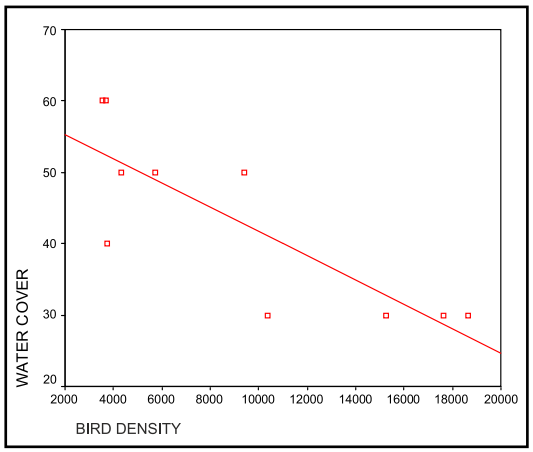
a) Bird Density and Dissolved Oxygen



b) Bird Density and Total Hardness



c) Bird Density and Water cover



d) Bird density and Total hardness

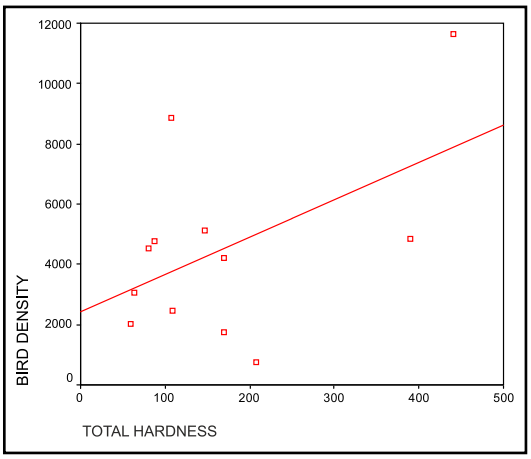


Figure 2.5: Seasonal correlation of various parameters (a) DO and bird density (b) Total hardness and bird density (c) Water cover and bird density in summer (d) Total hardness and bird density in winter at MVP Gujrat. (Reference: Deshkar et al, 2010)

The Total hardness was lower during monsoon (186.80±26.05 mg $CaCO_3$/l), as well as post monsoon (163.80±20.69 mg $CaCO_3$/l) but increased rapidly in winter and summer to 514.7±59.31 mg $CaCO_3$/l and 608.80±75.5 mg $CaCO_3$/l respectively. Highest water cover 87.5±2.1% was noted during post monsoon and lowest 47.8±3.5% during summer. Physicochemical parameters and the bird density correlation were studied. A significant negative correlation was established between the bird density and DO, bird density and total hardness, bird density and water cover, during summer, whereas positive correlation was observed between bird density and total hardness in winter (Figure 2.5). This study concluded that various abiotic parameters such as water temperature, water cover and water depth significantly influence the density as well as diversity of the water birds rather than any single factor alone.

Manral and Khudsar, (2013) assessed water quality and avian diversity in Okhla Bird Sanctuary (OBS), a wetland of river Yamuna. They studied the physiochemical and nutrient content of the river. They observed low DO and high BOD and COD which is indicative of high pollution. Urgent need to control the water quality and to restore the originality of the bird sanctuary was suggested. As reported (Raina et al., 1984), an excess nitrate concentration can result in algal bloom. Manral and Khusdar, (2013) reported a higher concentration of nitrate resulted in algal bloom in the water body as shown in Figure 2.6. Algal bloom kills fish which is the main food for birds. It also blocks light which reduces the growth of submerged plants.

Adamus et al. (2001) reported that frogs are a significant prey item for some wetland birds but excessive nitrates have been the cause of deaths of some frogs. Major nutrients such as phosphates, nitrates, and ammonium, can be transported into aquatic systems. They affect the functions performed by wetlands. Moderate nutrient levels spur the growth of submerged plants that provide food for ducks, as well as support more aquatic insects that serve as food for ducklings and for aerial foragers like swallows.

Figure 2.6: Algal bloom and sub-merged vegetation community in Okhla Bird Sanctuary (Reference: Manral and Khudsar, 2013)

As discussed above, the water quality is very important environmental factor which determines the wetland characteristics. The DO, BOD, salinity, pH and total hardness etc. are among the physiochemical parameters which govern the water quality in the wetland and consequently the wetland dependent birds are affected.

2.2.2 Meteorological aspect

Meteorological factors such as rainfall trend and temperature variation are also important parameters which affect the wetland and their dependents. Rainfall can directly affect the water availability in the wetland. However a temporal change in the monsoon in tropical areas may alter the vegetation availability for the wetland dependents. Extensive work has been done to study the effect of meteorological parameters on different wetlands.

Lloréns (2008) reported that regional precipitation and runoff regimes determine the seasonal dynamics of the water volume of a certain wetland. By the middle of the 21th century, annual average runoff and water availability are expected to increase by 10-40% at high latitudes and in some wet tropical areas, and decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics, with an increase in heavy precipitation events (IPCC, 2007). Some climate change models

predict possible increase in the intensity of rainfall on fewer rain days resulting in enhanced flooding events (IPCC, 2007). High magnitude floods cause channel widening, which is exacerbated by sparse riparian vegetation typical of drought periods. An increase in floods would probably result in more silt, pollutants and organic matter entering streams and rivers with the corresponding degradation in water quality that could lead to a loss of sensitive stream species.

Due to the reduced rainfall, increasing temperature and other climate changes (e.g. greenhouse gas emission) the earth's surface average temperature is expected to increase continuously. It is expected to increase very fast in 21st century as shown in the Figure 2.7 (McMichael et al., 2003). Increased temperature increases the evaporation rate, dries the wetlands, increases the water requirements and in turn affects the biota of the wetland.

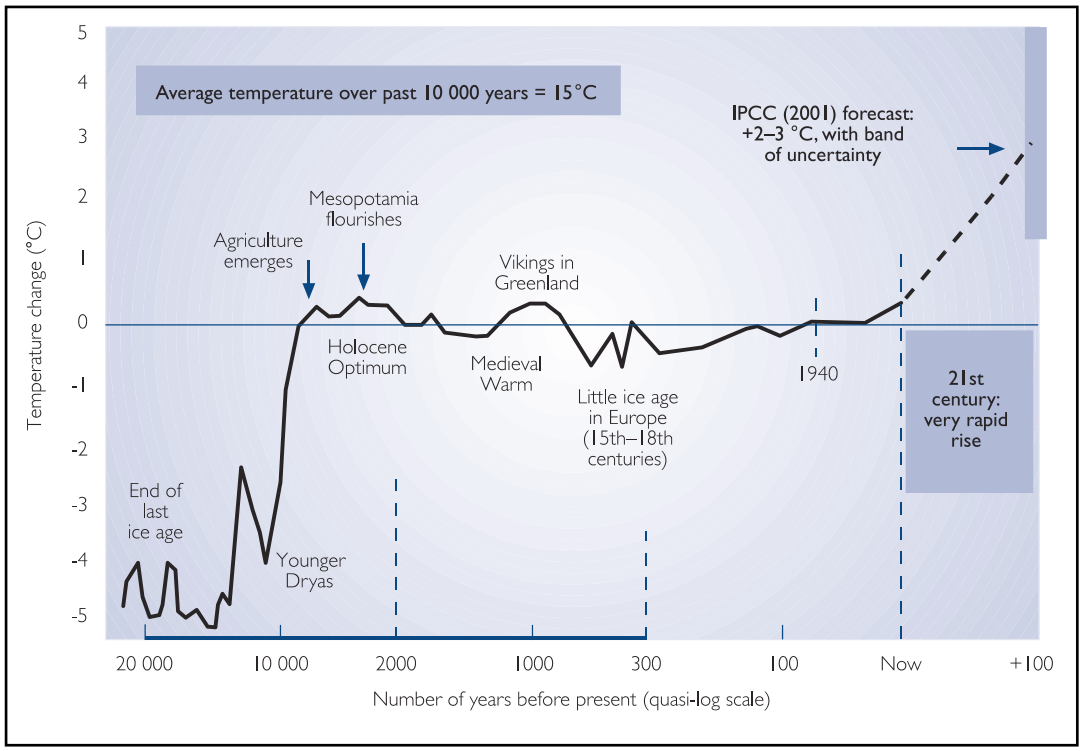


Figure 2.7: Earth's average surface temperature, over the past 20 000 years (Reference: McMichael et al., 2003)

Ganguly (2015) also correlated the migratory water-birds count and meteorological aspects. The correlation of bird count and rainfall/minimum temperature was quite complex. Barros and Albernaz (2014) studied the possible

impact of climate change on wetlands and its biota in the Brazilian Amazon. A summary of the possible effects of climate change on the floodplain environment and its biota is shown in Figure 2.8. They reported that the reduction in rainfall led to longer periods of low water levels in rivers and prolonged drought in the Amazon flood plain (Marengo and Nobre, 2001). These conditions associated with increased evapotranspiration, might reduce the extent of flooded areas or convert them into dry-lands (Burkett and Kusler, 2000). On the other hand the reported effect of increased rainfall was an increase in the velocity of water flow which result in the large movement of sediments that might cause the displacement and death of many fish (Pujolar et al., 2011)

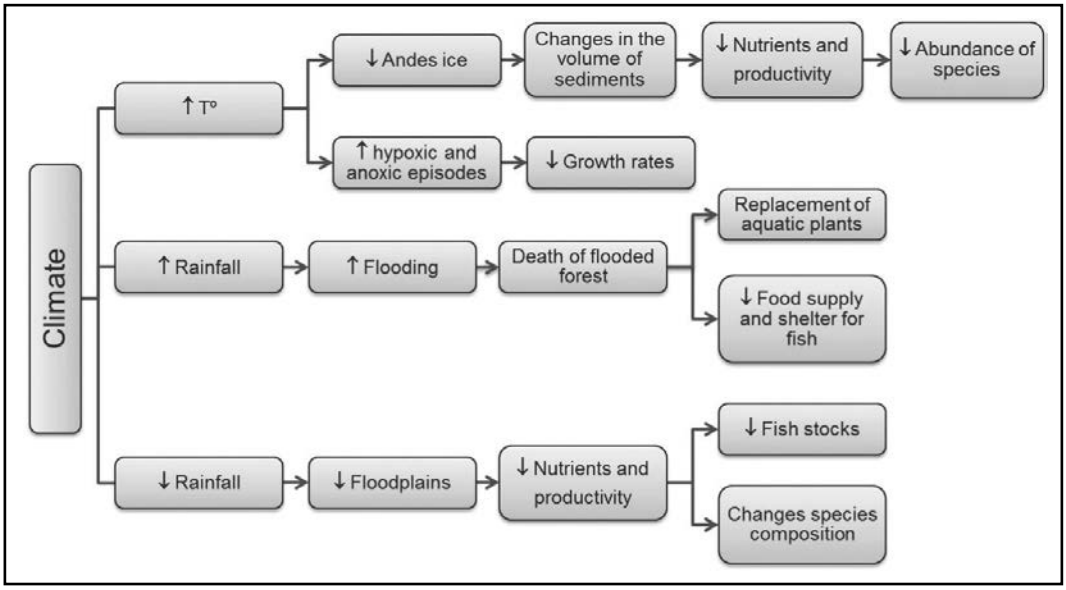


Figure 2.8: A schematic graphical presentation of the possible impact of climate change on the floodplains environment and its biota (Reference: Barros and Albernaz, 2014)

Paul et al. (2006) reported that climate change affects hydrology of wetland ecosystems through changes in temperature and precipitation. At higher elevations, the habitat loss is caused by climate change due to increase in temperature. On the other hand in lowlands, the precipitation changes are the main cause for habitat loss. The predicted changes in temperature and CO_2 concentration may alter growth, reproduction and host-pathogen relationships in both plants and animals (Enquist, 2002; Li et al., 2009). According to the latest evaluations, the average temperature at the surface of the earth has increased by 0.74 (0.56-0.92) °C during the twentieth

century. Temperature changes have direct effects on evapotranspiration and NPP (Net Primary Productivity). Its vital effect was seen on vegetation change in the tropics (Delire et al., 2008). Temperature increases are likely to have greater impact tropical endemics than on changes in precipitation. It was expected that the planet's average temperature will increase by 1.1 -6.4 °C (IPCC, 2007). Currently the rate of increase is extremely fast than in the past (average global temperature increased by about 5°C over 5000-7000 years as reported by Huntley et al. 2006). IPCC 2007 also reported that surface warming is playing a crucial role in bird's extinction (Figure 2.9). Increase in temperature by 1.8 °C would cause extinction of almost 230 land birds in 2100 which is double than that if temperature rises by 1.1°C. This ratio increases exponentially with change in temperature.

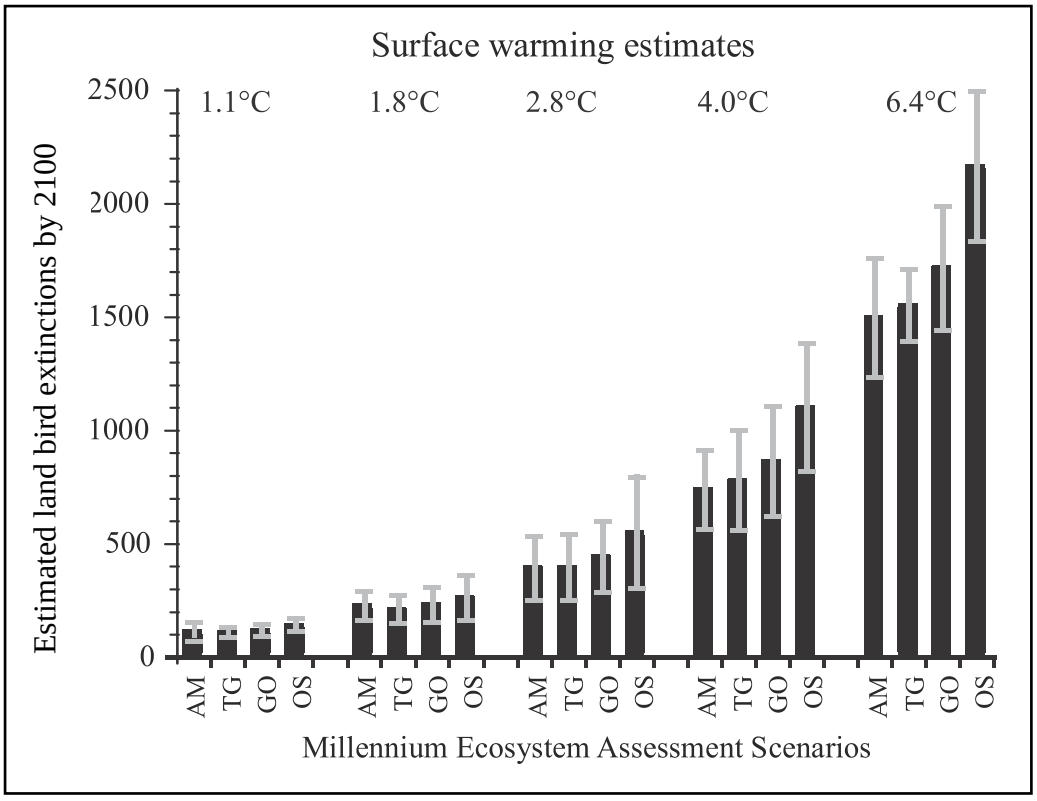


Figure 2.9: Numbers of world land bird species projected to commited to extinction upto 2100 by various surface warming estimates (Reference: IPCC2007)

The final result analysed was the increase in temperature and decrease in precipitation, which had the most dramatic effect on wetland ecosystems. The vegetation was also affected by these changes in precipitation and temperature. The degree to which wetland vegetation will be affected is determined by the current

characteristics of the wetland as well as the climate scenario. It has been observed that major changes in precipitation patterns also bring changes in birds' species (Tyrberg, 2010). Changes in the monsoon regime may prove to be more significant than temperature changes. According to Studds and Marra, (2007) migratory birds experienced increasingly severe food shortages on their wintering grounds due to reduced rainfall. This could affect non-breeding performance and influence their time of departure for their breeding grounds. As revealed by the literature, the precipitation and temperature affect the wetlands and their biota considerably.

2.2.3 Human associated activity aspect

There are many human activities that have affected wetlands world wide, such as alteration of the hydrological regime and the native flora and fauna. Their effect was also witnessed on the tourism activity in the particular wetland tourist area. By the year 2025, forthcoming changes in human population and economic development are expected to affect wetlands to a much larger degree than expected future changes in climate (Vörösmarty et al., 2000). Increasing human activities on the land represent a fundamental source of change in the global environment (Dale et al. 2000). Hence, it is clear that the some of human activities are disturbing the important wetland areas.

The most common human associated acts that affect the wetland are

- Irrigation
- Urbanization
- Constructions in the water shed areas
- Increasing noise level due to highway

2.2.3.1 Effect of irrigation on wetland

Galbraith et al. (2005) pointed out that agriculture activities can result in direct loss of wetland by converting them into agricultural lands, water withdrawal from rivers and damming for water storage may change water application, its quantity and nutrients in that particular wetland. Other effects of agricultural activities are salinization, sediment deposition, erosion and eutrophication. The chemicals used in agriculture activities may lead to the soil pollution. Several

authors have identified agriculture across the country as one of the primary causes of non-point-source pollution in aquatic systems (Brenner, 1995; Reinelt and Horner, 1995). Agricultural chemicals are used to control noxious weeds, insect pests, and damaging fungi and bacteria but may prove to be a major pollutant for KNP ecology if not controlled (Bhadoria et al., 2012). Lei and Jin 2002 studied at Jianghan Lake in China found that human activity as agriculture, lake reclamation have negative effect on number of birds and on function of wetland. Sustainable management and practices rehabilitates the flood regulation function of this wetland.

2.2.3.2 Effect of urbanization on wetland

Urbanization affects the wetland's functions at the scale of the watershed and within individual wetlands. These disturbances caused by urbanization impose a variety of changes that affect the watershed processes and therefore the down gradient drainage system and the wetlands found there. Changes include filling wetlands, clearing of vegetation, compaction of soil, modifications in water conveyance, alterations to riparian corridors, human intrusions, introduction of chemical contaminants, and increased areas of impervious surface. Approximately 13% of the wetland losses in the United States can be attributed to urbanization, road building, and other types of conversion (Tiner, 1984).

2.2.3.3 Effect of construction on wetland

Dass et al. 2013 studied Ramgarh Dam in Jaipur for reduced flow of water. Ramgarh Dam served as the main source of water supply to Jaipur and it irrigated upstream area up to 1961. Thereafter its water was reserved to meet water demand of Jaipur city and served water to Jaipur city till mid of year 2006. 415 water retaining structures as reservoirs, anicuts and earthen dams reduced flow of water to this dam. Many human activities as illegal mining activities, road constructions and urbanization reduced flow of water in it. Similarly 7 major, 12 medium and 134 minor irrigation projects functioning in the Chambal River basin, have greatly reduced river flow (Hussain and Badola, 2001). Dams obstruct the dispersal and migration of organisms. These and other effects have been directly linked to loss of populations of entire species of freshwater fish (Nilsson et al., 2005). Jain et al. (2008) revealed that wetland area has reduced 30% from 1919 to 2003 in Harike

wetland in India. This decline of wetland area has negative impact on water flow in it. They also observed runoff from upstream catchment was reducing due to various man made construction.

2.2.3.4 Impact of noise level on the birds

Another consequence of urbanization is the increase in the number and length of highways. The nearby highways may affect the wetlands ecology mainly by generating noise and air pollution. It was validated that certain effects of noise and air can extend to a distance of more than 1 km from a roadway (Houlahan et al., 2006; Findlay and Bourdages, 2000; Forman and Deblinger, 2000). Houlahan et al. (2006) reported that adjacent land use can affect wetland plant diversity up to 250-300 m away from highway; Forman and Deblinger (2000) stated that the road-effect zone spreads on averages of approximately 600 m in width. Findlay and Bourdages (2000), based on their findings stated that road densities significantly affect wetland reptile, amphibian, bird, and vascular plant species richness up to distances of at least 2 km from the roadway. As reported (Dooling and Popper, 2007; Kaseloo 2004; Warren et al. 2006) essentially three types of potential effects of highway traffic noise have been identified (1) behavioural and/or physiological effects, (2) damage to hearing from acoustic over-exposure, and (3) masking of communication signals and other biologically relevant sounds. The study revealed that the behavioural and physiological effects are dominant where the distance of birds from the traffic is less. In comparison to humans and other animals, the birds are more resistant to both temporary and permanent hearing loss from acoustic overexposure however the studies suggest that the traffic noise may cause hearing loss in the birds.

Increased urbanization and its associated activities such as residential and highway construction in last decades have also increased traffic volume and thereby noise level. In addition to the traffic volume on highway there are many other activities (construction and other activities) which increase the noise level (Phukan and Kalita, 2013). Currently noise pollution is third most hazardous environmental problem (Agarwal, S., 2011). Evaluation of noise pollution in three urban parks in the city of Trabzon, located in the north-eastern part of Turkey has observed 15 dB(A) above standard due to heavy traffic and population growth around it. Noise

pollution in urban parks can reduce by using various plants (Ozdemir et al, 2014). 77.1 % of the locations in residential areas are observing noise level higher than the standard level in Quetta (Pakistan) due to traffic alone (Khan et al, 2014). It adversely affects health and creates interference in communication (Zanin, 2006, Prabhat, 2007). The impact of road traffic noise can cause physiological changes in human and can indirectly affect bird behaviour (Quis, 2001, Foreman et al. 2002, Kumar and Dhankhar, 2015). Stone (2000) evaluated bird populations over a wide range of land use types. This study suggests that there was a marked decrease in bird population in noisy areas. Warren et al. (2006) evaluated that highway noise affect bird. Effects of low, medium, and high traffic volumes on bird population of 20 passerine bird species in pasture woodland environment near several roads in western central Spain was studied. They marked a difference between the number of birds and the extent of breeding population in each of the three areas (Peris and Pescador, 2004).

2.3 KNP wetland and its current status

KNP is facing various problems as studied by many researchers. One of the most common causes of degrading of wetland ecology in KNP is lack of water, inadequate food, invasion of undesirable plants and animal species as depicted below.

KNP had faced drought in the years 2004, 2006 and 2007 when the monsoon failed. These years adversely affected the flora and fauna at the KNP and it took a lot of time for the park to recover (Pundir and Mamgain, 2014). Whereas Vijayan (1991) studied the water balance in KNP and observed average surface inflows of water during 1966 to 1990 (12 out of 24 years) were 14.0 Mm^3. In 1983, the highest input from rainfall was 7.37 Mm^3 and the highest water storage was 21.94 Mm^3. However water in Ajan Dam from Gambhiri River (Construction of Panchana Dam) is continuously decreasing during 1981 to 2010.

Quality of water also plays a major role in attracting migratory birds in KNP wetland such as Gambhiri River water. Dissolved oxygen is most important parameter for the aquatic life of such park (KNP) including the organisms that break

down man-made pollutants (Sunder and Khatri, 2015). Its high concentration around 5.8 positively affects the park's life. The DO level varies with water depth and the organic matter present in the water. Water depth increases in rainy season and reaches to its maximum level in October due to the influx of rain and water from Ajan Dam. Arrival, departure and wetland utilization by migratory waterfowl was studied by Bhupathy et al (1998) in Keoladeo National park (KNP), Bharatpur from August through May between 1987 and 1989. Direct observation method was used for data collection. Waterfowl started arriving in the KNP in the first fortnight of August and were seen till May. They extended their stay in KNP during the year of normal rainfall.

The wetlands in the Keoladeo National Park, receive water from the Ajan Dam that in turn receives water from the Banganga and Gambhiri rivers. A total of 58 species of fish have been recorded in KNP which were main food for birds. Of these, seven species are new and reported after 1995. Of the new arrivals, African catfish is one of the most dangerous invasive aquatic species of the KNP. The highest number of fish species was found in open water with sparse vegetation having high DO and the lowest in (*Paspalum distichum*) dominated areas of wetland of KNP due to low DO (Kumar et al,1995).

Scarcity of water in KNP and drought impacted the natural habitat in KNP. Population of famous birds the threatened Sarus Crane has declined 125 pair in 1985 to drastically with 8 pairs in2003, because of mortality or shifting due to continuous droughts and shrinkage in water spread area. The critically endangered Siberian was only five in 1993 and nil 2004 onwards. The critically endangered raptors recorded were the Long-billed Vulture and White-backed Vulture, very rare due to lack of secondary food (Vijayan et al, 2009). Among all ornithological studies, the most important one was bird ringing in KNP. Between 1965 and 1974, 10, 958 common teals *(Anascrecca)* were trapped and ringed at Keoladeo National Park. Most ringed birds were recovered in the former USSR (485 recoveries), while 85 birds were recovered from the Indian subcontinent. Ringing numbers suggest that males arrive first from their breeding grounds in September, before female arrive. It shows

migration patterns, their time of arrival and departure of migratory birds in KNP (Ambedkar and Daniel, 1990).

Yadav, et al. (2014) investigated the temporal changes of different land cover in KNP. They observed major changes in KNP and in its catchment area in their study during last two decades (1999-2011). They found that agricultural area in vicinity in KNP has decreased by 13% in 2009 and 16% in 2011 as compared to 1999 and built up area has also increased by 7% and 9% in the same period showing increase in human pressure and urbanisation around KNP. It also indicates that people (involved in agriculture) have substituted from primary sector of income to secondary or tertiary sector (agriculture to job/business) of income. They also studied that dense forests decreased from 2.9% in 1999 to 2% in 2011 in KNP. Moreover, water area decreased by 7% during 1999 to 2009 but increased by 2% during 2009 to 2011. They concluded that during 1999 to 2009 water spread in KNP consistently decreased and thereby affected flora and fauna in KNP.

Each species of wetland-dependent bird has a unique composite set of needs. Survival of migratory water birds mainly depends on valued source of food in aquatic vegetation(Ali and Vijayan, 1987).It was found that growth rate of several species, such as floating vegetation (*Nymphoides indicum, Nymphoides cristatum, Nymphaea nouchali* and *Nymphaeastellata),* fish, waterbirds and the corresponding carrying capacity of the wetland decreased with the increase in biomass density of wild grasses (Singh et al., 2010).

Singh et al. (2010) studied in KNP Bharatpur and found that this wetland supports a variety of flora and fauna due to nutrient availability in water. This study was done on dominant plants *Acacia Nilotica, Prospis juliflora* and *Parvi flora* to evaluate their survival. They found that Na, K and N contents are high in the soil of the park indicating good health of wetland as these plant are salt tolerant. These are main weed plants in KNP adversely affecting growth of other plants. Their presence in KNP has been deteriorating bird abundance for the last decade. It has been experienced that changing environmental conditions and competitive adaptations in KNP has facilitated the invasion of weeds as *Paspalum distichum, Acacia nilotica,*

Eleocharisplantagenia and *Typhaangustata* into KNP wetland (Reddy et al 2010). The positions of 27 and 34 satellite areas within 100 km (smaller circle) and (bigger circle) around KNP are prominent to attract various migratory birds (Bhadouria et al, 2012). The areas falling under smaller circle (100 km radius) are most dominant for various migratory birds found in these wetlands however the presence of birds has also been recorded in the areas falling under second circle when environmental changes occurs such low rainfall, adequate food and security.

Bhadouria et al. (2012) studied nearby satellite wetland of KNP and recorded a total of 75 species of birds. These birds were also found in KNP. Maximum 44 species were recorded in single wetland namely *Radiabund* in Alwar. They also observed that wetland of larger size attract more number of species. It means that size of wetland is directly correlated to number of species but it cannot be applied to KNP which is much lesser but attracts a significant number of breeder and staging water birds. Detailed study of bird's usage in these wetlands is not available and species richness and distance relation from KNP has not been investigated.

2.4 Impact of environmental changes on the birds

Huntley (2006) studied that birds may adapt to the environment change condition without shifting location or may adjust their geographical distribution. The ranges of many species are shifted up to 1000 km. Environment changes have a larger impact on migrant species. These changes alter their breeding and wintering area. The avian species richness is likely to decline in Europe and Africa.

Karunarathna et al. (2010) revealed decline in biodiversity mainly due to water pollution and habitat destruction in Bellanwila-Attidiya Sanctuary (BAS), Sri Lanka. This may result in extinction of many birds and reptiles species (5 are nationally threatened). BAS in Sri Lanka an important bird area (IBA) in Bolgoda river basin recorded 78 species of birds comprising 15.8% of Srilanka avifauna (Karunarathna et al, 2010). Their number in BAS declined as 153 species of birds were recorded in BAS in 1990 (Gunawardana, 1991).

Sekercioglu 2012 reported combined effect of climate change, habitat loss with surface warming. It could increase bird extinctions at faster pace than individual factor. It could result in extinction of 100-500 species due to increase in surface warming 1.8 °C. 600-900 species became extinct due to warming beyond 3.5 °C as expected by Tollefson, 2011. Out of them 89% of birds extinction occurred in tropical area. Loarie et al., (2009) revealed that in a century 92% of currently protected areas are likely to become climatically unsuitable in savannah, deserts and grasslands. Barbet-Massin et al. (2009) predicted that by 2100, the environment change could cause the range of 37 of 64 trans-Saharan migrants (e.g. Collared flycatcher, albicollis and thrush nightingale, luscinia) to shrink and shift by an average 500 km. This could result in major decrease in the richness of bird communities in Africa.

In the prairie pothole region, in the late 1970's, as the number of wetlands area increased the population of dabbling ducks increased but at a ratio of less than 1:1. In the past 40 years, the duck-pothole ratio has decreased possibly due to the decrease in upland cover and increase in predation. Large decreases in suitable habitat (46%) predicted for survival of 31 water-bird species in PPR region mainly due to land cover and climatic variation by the 2040's (Steen et al, 2014). Bellrose (1977) also found waterfowl densities and propagation to be related to the number of wetlands per square mile. Generally, water birds densities and propagation increased as the number of wetlands increased. However, he found that mallard production decreased when the number of wetlands exceeded 12 per square mile. Bellard, C. (2012) also estimated that bio diversity losses due to climate changes were significantly important than other factors in coming future (Figure 2.10).

Climatic change will also have an effect on the biodiversity of all ecosystems. In Britain the population of *Whinchats* is estimated to have declined by 57% between 1995 and 2008 and the species is now largely confined to upland and marginal upland areas (Baillie et al. 2010). Many fish species may also be unable to travel to other systems if the waterways connecting wetlands are lost due to warming and a decrease in precipitation. Flyways for migratory birds will also be altered. Over 80% of migratory birds use wetlands as a stopping ground in their travels (Mitsch and Gosselink, 2007).

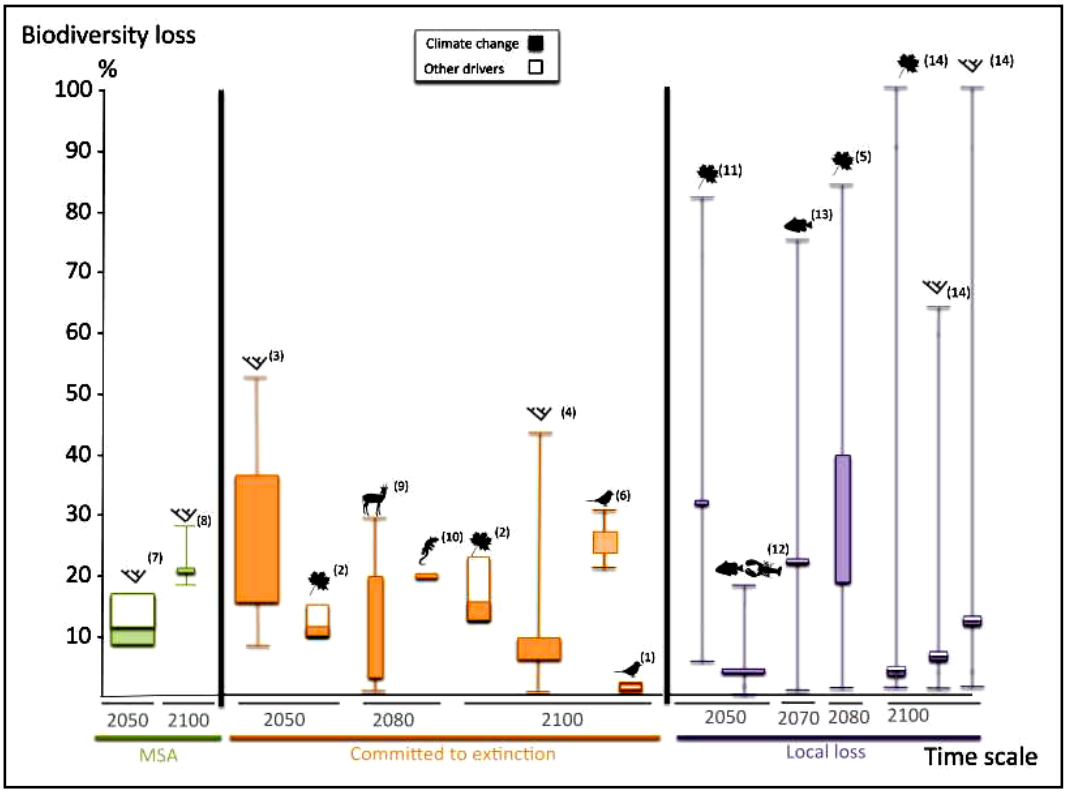


Figure 2.10: Loss of biodiversity due to climate change, for different taxonomic, temporal and spatial scales, the width of the box illustrates three levels of generality, global scale and several taxonomic groups (Reference: Bellard, C., 2012)

The literature review showed that environmental changes (hydrological, meteorological and human associated activities) affect wetland and their biota. Currently it is also found that most of the wetlands are deteriorating. The world heritage site 'Keoladeo National Park, Bharatpur' is also facing problems. Hence, this research is undertaken to study the impact of some environmental factors on the park.

CHAPTER 3

KEOLADEO NATIONAL PARK (KNP) WETLAND, BHARATPUR SYSTEM

This chapter deals with the main features of KNP wetland system. It includes its historic development, inflow of water from main rivers, meteorological variation, birds and ecotourism in KNP.

3.1 Study area Keoladeo National Park

Keoladeo National Park (27º7'6"N – 27º 12'2"N and 77º 29'5" E – 77º 33'9"E) is located on Agra-Jaipur National Highway NH-11 in Bharatpur. It is popularly known as Bharatpur Ghana Bird Sanctuary. Earlier it was a purely temporary rain fed fresh water area flooded by different streams of river Banganga and Gambhiri. Excess water was drained to river Yamuna through Ghana canal. Wetland ecosystem of KNP had natural shallow depression 1.5 to 2.0 m deep. Ajan earthen dam was constructed in 1726-1763 to fill the wet Moat around Bharatpur Fort. Later it was used to regulate water in KNP. From1850 to 1899 dykes and canal structures were made for proper and controlled supply of water to KNP. These were used to maintain water level during non rainy season in KNP. Feature of KNP comprising canals, wetland area and trails along with NH-11 passing around KNP is shown in Figure 3.1.

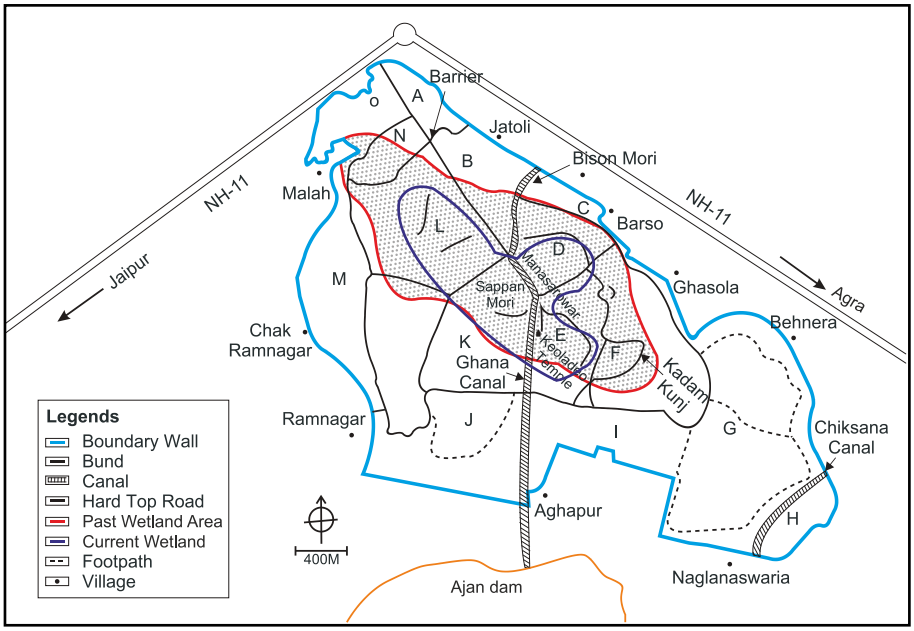


Figure 3.1: Features of KNP comprising canals, wetland area and trails

3.1.1 Development of Keoladeo National Park (KNP) wetland, Bharatpur

For a long time, the major wintering area of KNP was used as an important duck shooting area by the Maharaja of Bharatpur due to availability of large number of aquatic birds. Present status of Keoladeo National Park (KNP) wetland has covered a long journey and has been presented in Table 3.1.

Table 3.1: Milestones of Keoladeo National Park wetland, Bharatpur

YEAR	MILESTONE
1850+	Established as the private duck shooting preserve of the Maharaja of Bharatpur
1901	First deliberately flooded to create a hunting reserve
1956	Designated as Keoladeo Ghana (Bharatpur) Bird Sanctuary by the Forestry Department
1964	Last big shoot held but the Maharajah retained shooting rights until 1972
1967	Designated a Protected Forest
1972	Wildlife (Protection) Act prohibited shooting
1981	Designated as a Ramsar site
1982	Established as Keoladeo National Park.
1985	Listed as World Heritage site by UNESCO
1990	Entered on the Montreux Record of wetland sites under stress
2004	Siberian crane was not seen from 2004 onwards
2007	World Heritage Site was in danger (UNESCO)

3.1.2 Historical value of KNP wetland

In last 125 year this wetland has observed a unique combination of varieties of flora and fauna who maintained their existence due to aquatic and terrestrial energy balance. Keoladeo National Park's flora has seen of over 375 species of angiosperms of which 90 species are wetland species (Ali and Vijayan, 1987). The fauna has more than 350 species of birds (migratory and resident) which include 42 species of raptors and 9 species of owls, 27 species of mammals, 13 species of reptiles, 7 species of amphibians (Mathur et al, 2009). KNP also has 58 species of fishes, 71 species of butterflies, 30 species of dragonflies and 30 species of spiders.

3.1.3 Importance of Keoladeo National Park

Wetlands have very dynamic systems. They exhibit rapid temporal instabilities in the structure and function of the ecosystem of particular zone with variation in some parameters. This is in contrast to the terrestrial ecosystems, where the changes in space and time are relatively less remarkable. KNP wetland is distributed in 15 blocks and K, L, D and E are aquatic blocks as shown in the Figure 3.2.

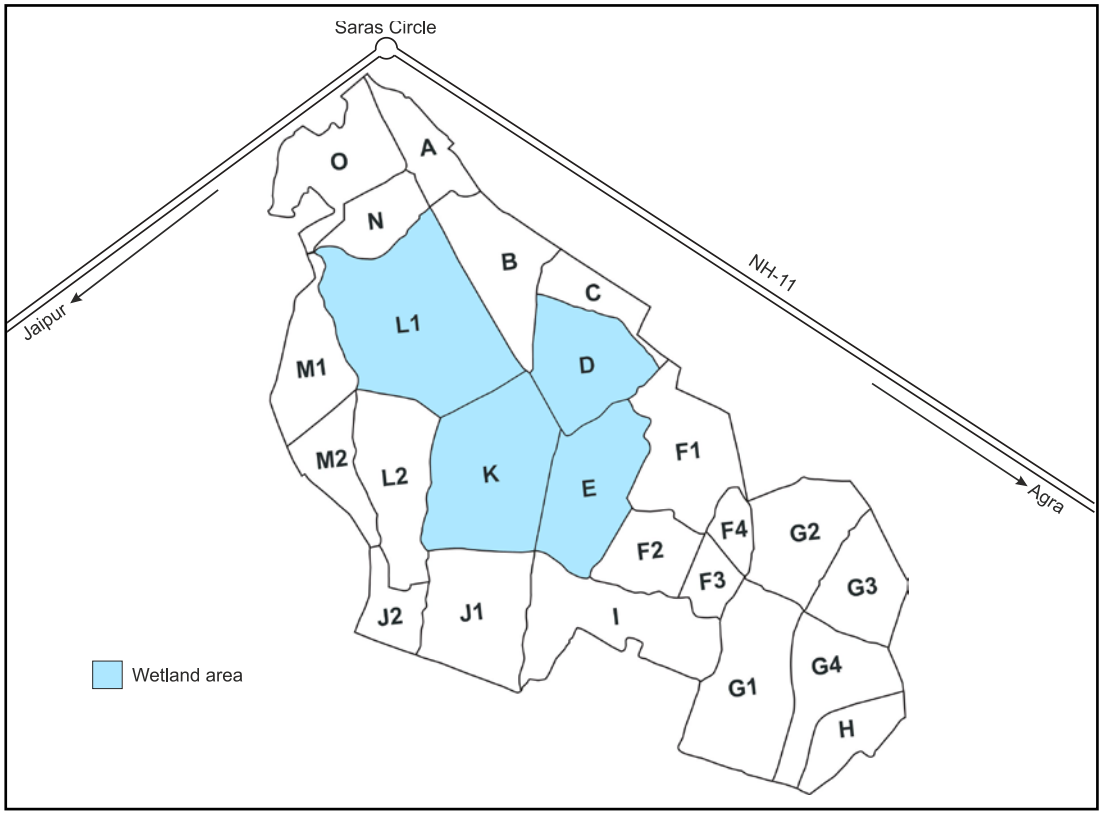


Figure 3.2: Block wise distribution of Keoladeo National Park, Bharatpur

KNP Wetland is useful to maintain wintering ground for waterbirds, tourism and providing livelihood to local people. KNP was the only known wintering ground famous globally for the central population of the Siberian Cranes. Other renowned Migratory aquatic birds that arrived in KNP in large numbers are Graylag Goose, Bar-headed Goose, Comb Duck, Ruddy Shelduck (Anatidae) and Purple Swamphen, Eurasian Moorhen (Rallidae) etc.

Owing to the abundance of the birds, Keoladeo National Park is often referred as ***'Birders Paradise'***. There are three main routes of the Asia Pacific Global Migratory Flyway. KNP lies on the Central Asian Flyway (CAF) so large

number of migratory waterfowls that breed in the Pale arctic region reaches every year in winter for staging through it (Figure 3.3).

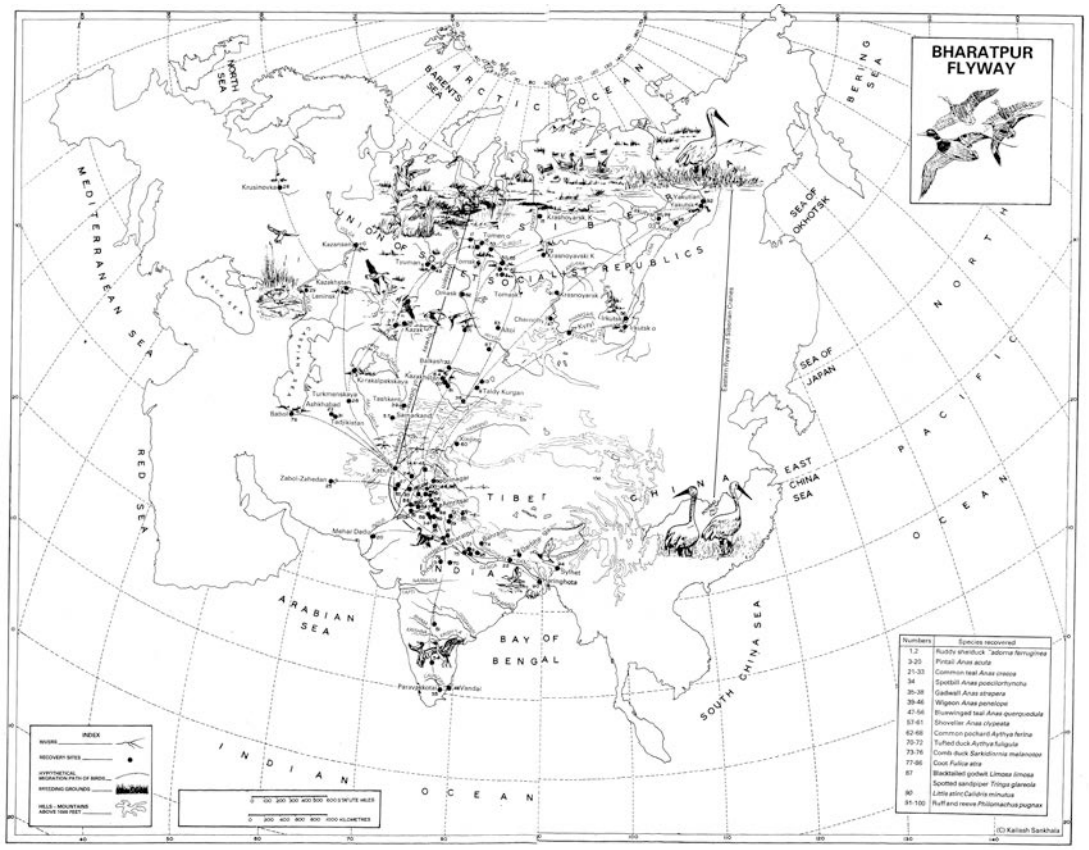


Figure 3.3: Main routes of the Asia Pacific Global Migratory Flyway through birds arrived in KNP (Source- Sankhala, 1990)

The Park has one of the world's most spectacular heronry, which harbour a large number of resident birds (up to 15 species) on the same tree. It was recognised as one of the 10 top heronry in India and also studied that more than 5000 nests have been observed in KNP (Subramanya, 2003).

3.2 Water storage around KNP

The city of Bharatpur is situated under low lying pocket in saucer shaped topography at the confluence of Banganga, Gambhiri and Ruparail rivers. Bharatpur flood plains were regularly flooded by waters from Banganga and Gambhiri and intermittently from Ruparail (Figure 3.4).

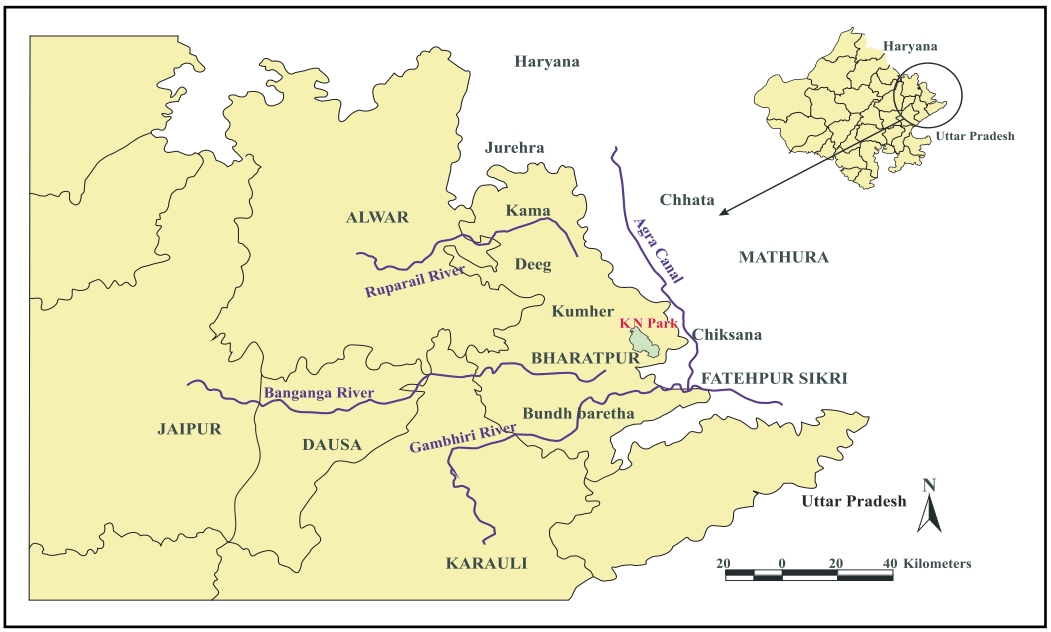


Figure 3.4: Various water sources to KNP Bharatpur

3.2.1 Historical background of inflow of water to KNP

The Banganga, Ruparail and Gambhiri rivers used to get flooded annually. They overflowed their low banks and inundated floodplain marshes and forests of Bharatpur. KNP wetland is now a part of these floodplain and forest. These rivers provide ample water to KNP.Two dams were specially made to prevent flooding and to provide relief in times of famine (Singh, 2007).First one called Moti Jheel is used to accommodate runoff from northern Bharatpur and also flood water of the Ruparail River. The second Ajan earthen Dam (Bund) specially made by Maharaja Suraj Mal, was used to contain the runoff as well as flood from the Banganga.

3.2.2 Watershed and drainage of area

KNP ecology depends on two main rivers Banganga and Gambhiri. They flow only during rainy season. These rivers were dammed at various places to retain water during flood as shown in Figure 3.5 and also to increase water holding capacity. These dams were used for irrigating agriculture field and to provide drinking water (Table 3.2).

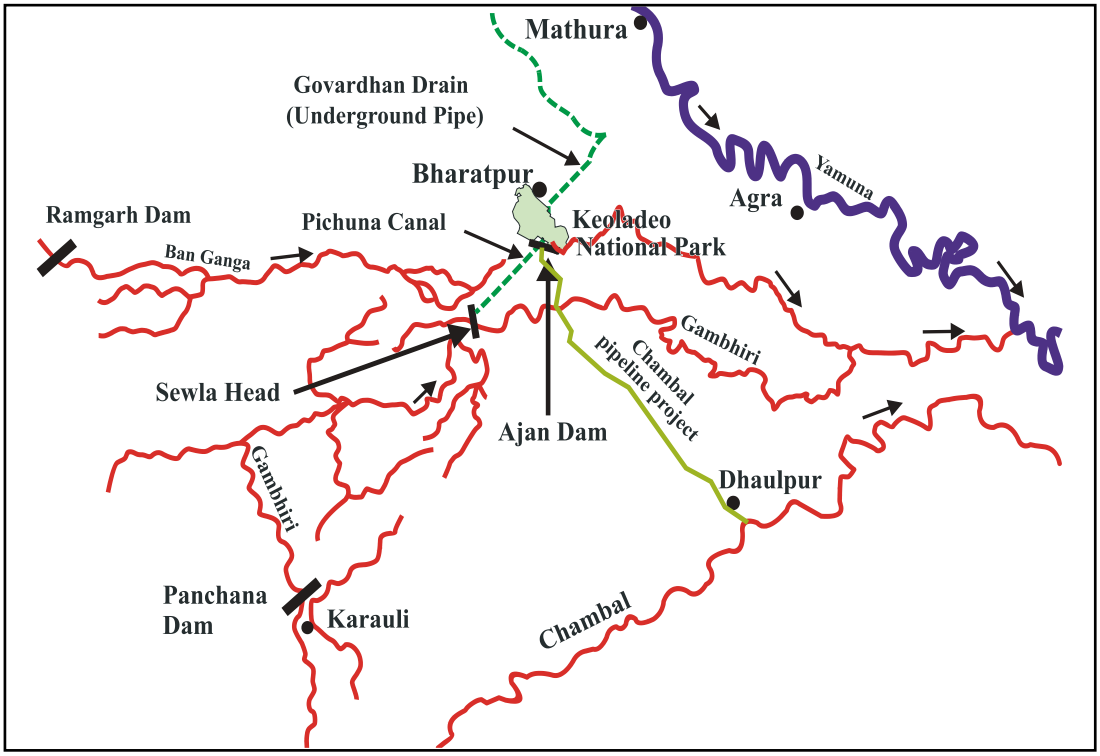


Figure 3.5: Different stream of rivers and dams near KNP

Table 3.2: Various dams, uses and water holding capacity on different rivers near KNP

Stream flow to KNP	Construction of dams	Capacity to hold water (Mm^3)	Area Irrigated (hectares)	Uses	Present use for KNP
Gambhiri River	Panchana Dam	52.6	10000	Save Bharatpur from flash floods and agriculture	Excess water through Ajan Dam convey to KNP
Gambhiri River	Ajan Dam	8.5	30000	Feed water to KNP	Drain water KNP
Banganga River	Ramgarh Dam	69.5	12500	Drinking and irrigation	No water reach to KNP
Banganga River	Nekpur head	15.4	12000	Drinking and irrigation of command area	No water reach to KNP
Ruparail River	Sikri Dam	7.8	18000	Supply water to Kumher town	No water reach to KNP
Kakund River	Bund Baretha Dam	50.7	8000	Satellite wetland to support water birds	Drinking water supply to Bharatpur

(Source-Irrigation Department Bharatpur)

Banganga River originates in the Aravali hills near Bairath in Jaipur district. The total length of the river is 200 km. The total catchment area of basin is 8878 km^2. It has an easterly flow towards Bharatpur. It contains irrigation dam at Ramgarh near Jaipur which used to meets drinking water requirement of Jaipur district. Water flow in Banganga River had ceased due to construction of various minor dams and bunds in the basin area (Dass et al, 2013). It has 10 medium and 177 minor irrigation projects in Banganga basin with water storage capacity of 106.6 Mm^3 (Singh, 2007). River Gambhiri originates in Karauli and after flowing 80 km it enters in the southern part of Bharatpur. Gambhiri River is also a non perennial river. Total catchment area of the river in Rajasthan is 3887 km^2. It has 50 dams and irrigation projects. Various main dams Panchana, Juggar and Baretha built on major tributaries Bhadrawati, Juggar and Kakund to Gambhiri River respectively. Table 3.3 shows catchment area and water holding capacity of main dams in Gambhiri basin reduced natural water flow toward KNP flood plains.

Table 3.3: Main Irrigation Projects (Dams) constructed in Gambhiri Basin

Name of Dam	**Capacity (Mm^3)**	**Catchment area (km^2)**
Panchana Dam	52.6	246
Juggar Dam	24.6	227.9
Kyarda	6.6	50
Bund-Baretha Dam	50.7	223
Ajan Dam	8.5	206

(Source-Irrigation Department Bharatpur)

The other two rivers Kakund and Ruparail have been dammed as laid down and not providing water to KNP now. The Kakund River was the chief stream of the Gambhiri River and Bund Baretha Dam was constructed on it in the period 1866 to 1897. Now it is popularly known as satellite wetland Bund Baretha and provides drinking water to Bharatpur and a staging site for various migratory birds. River Ruparail originates from the Thana-gaji hills in Alwar district enters Bharatpur district near Gopalgarh and flows into the northern part at the eastern edge of Banganga basin. In 1840, its water was stored by Sikri Dam in Deeg. In the last decade water

from Gambhiri river was also decreased due to construction of many dams (Singh, 2007).

3.3 Meteorological variation around KNP Bharatpur

Temperature and rainfall are two factors which play a major role in maintaining water cover in KNP wetland. These are fluctuating and changing rapidly.

3.3.1 Rainfall trends in Bharatpur

During early twentieth century Bharatpur area received heavy rainfall. Past 110 year of annual average rainfall and its pattern has been depicted in Figure 3.6. Its trend line shows that rainfall in this part of area was declining. Earlier average annual rainfall in this area was 690 mm and now due to less rainfall it decreased to 555 mm.

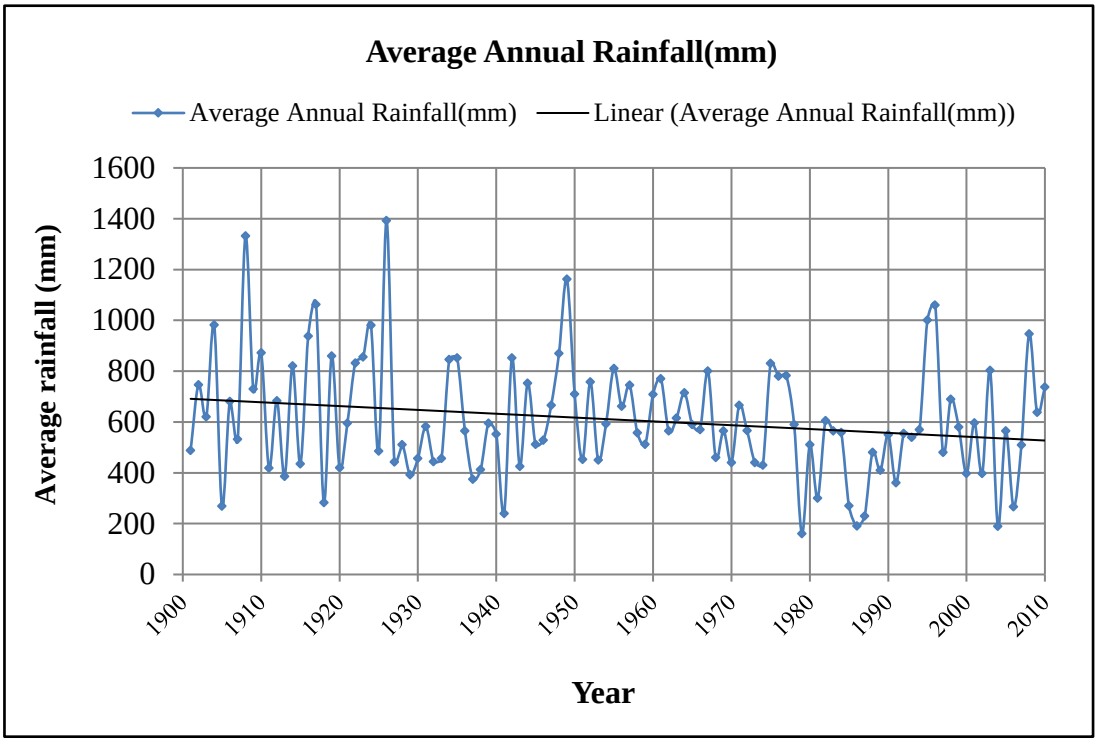


Figure 3.6: Average annual rainfall trends in Bharatpur from 1901-2010. (Source-Irrigation Department Bharatpur)

Table 3.4: Monthly rainfall and rainy days in Bharatpur during 2004-2010

Month	2004		2005		2006		2007		2008		2009		2010	
	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days
January	-	-	12	1	-	-	-	-	-	-	0	0	10	1
February	-	-	6	2	-	-	43	5	-	-	1.8	1	3.5	2
March	-	-	7.6	5	-	-	37	4	-	-	2.4	2	0	0
April	17	1	-	-	27	1	-	-	4.2	2	5.9	2	1	1
May	-	-	9	4	-	-	49	7	66.9	6	38.1	7	2	2
June	-	-	1.1	4	22	3	129	7	342	14	56.1	5	8.6	5
July	-	-	442	15	16	5	64	12	174	17	203.4	14	231.2	14
August	127	8	30.2	7	121	14	123	9	178	22	209.3	12	140.4	18
September	8.3	5	56.4	8	8.7	3	64	5	182	10	83.1	5	306.1	15
October	37	3	-	-	71	2	-	-	1.5	2	6.1	6	0	0
November	-	-	-	-	-	-	-	-	-	-	29.1	4	32.7	6
December	-	-	-	-	-	-	-	-	-	-	3	1	1.8	1
Total	**189**	**17**	**564**	**46**	**266**	**28**	**509**	**49**	**947**	**73**	**638.3**	**59**	**737.3**	**65**

(Source- Directorate of Mustard and Rap seed Centre, Bharatpur)

Distribution of rainfall during the last decade in Bharatpur and Ajan Dam catchment area was erratic. Monthly rainfall and number of rainy days in Bharatpur for the period 2004-2010 is given in Table 3.4. 90% of rainfall occurs during four monsoon months from June to September. There were significant variations in the rainfall in monsoon season in different years. KNP received heavy rainfall in the year 2008 only.

3.3.2 Flood and drought in Bharatpur

Bharatpur region received heavy rainfall in the period 1977- 1998. Average annual rainfall and water supplied to KNP wetland from Ajan Dam during flood years in the period of 1977-2010 has been given in Table 3.5. KNP Bharatpur received heavy rainfall was ranging 600-923 mm and total water supplied to KNP was ranging 15.9 to 22.0 Mm^3 during these years. These amounts of water were quite high for KNP. Milne (1997) conducted a study and assessed that 65 million-tonnes fish are carried by floods and fed into KNP through Ajan Dam every year. Arrival of large number of water-birds as storks, herons, cormorants in KNP was

mainly dependent on this base food (fish and frogs). Total requirement of water in KNP was 15 Mm^3 for maintaining its ecology which were supplied through Ajan Dam.

Table 3.5: Average annual rainfall and water supplied to KNP wetland from Ajan Dam during flood years in the period 1977-2010

Year	Water supplied (Ajan Dam) to KNP (Mm^3)	Contribution by rainfall in KNP (Mm^3)	Total water application in KNP (Mm^3)	Average annual rainfall (mm)
1977	10.4	6.4	16.8	752
1978	13.3	6.8	20.1	600
1983	14.6	7.4	22.0	897
1995	14.6	7.0	21.6	923
1996	12.2	7.0	19.2	906
1998	7.9	8.0	15.9	916
2005	8.2	5.9	14.1	631
2008	16.0	4.1	20.1	763

(Reference: Singh, 2007; Source- Irrigation Department, Bharatpur)

However water in Ajan Dam from Gambhiri River (Construction of Panchana Dam) is continuously decreasing during 1981 to 2010 as shown in Figure 3.7. During the last decade 2000-2010 Bharatpur also witnessed frequent drought and water supplied to KNP was negligible from Ajan Dam as given in Table 3.6.

Table 3.6: Annual rainfall and water supplied to KNP wetland from Ajan Dam during drought years in the period 2000-2010.

Year	Annual rainfall near KNP(mm)	Water supplied to KNP from Ajan Dam (Mm^3)
2000	397	4.0
2002	398	0.0
2004	189	0.5
2006	266	0.02
2007	509	0.0
2009	638	0.1

(Source- Irrigation Department, Bharatpur)

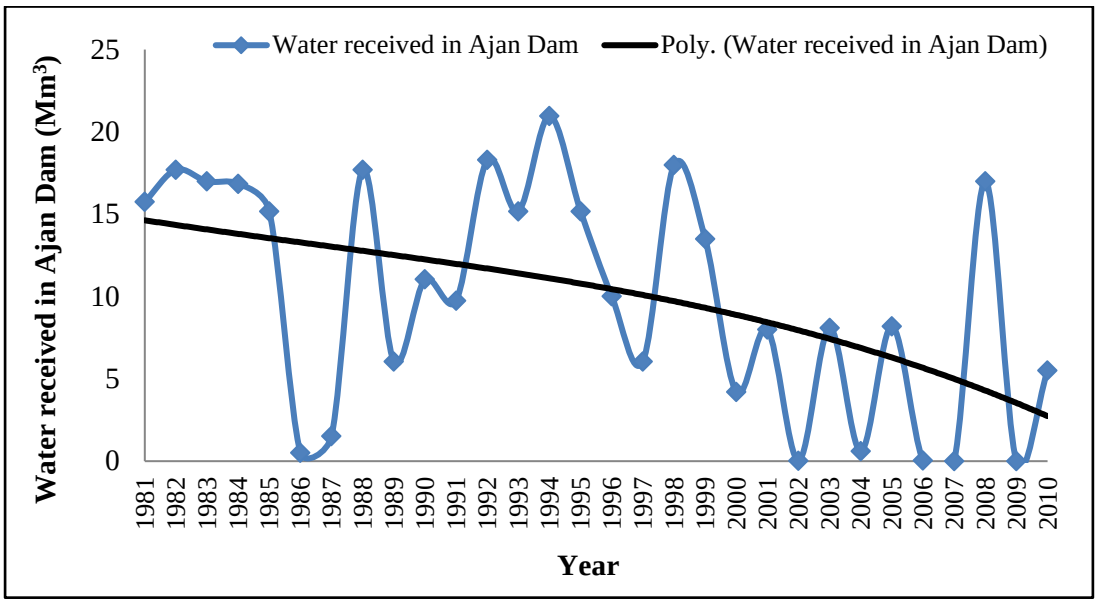


Figure 3.7: Variation of water received in Ajan Dam, during 1981-2010 and trend line

Scarcity of water in 2006 and 2007 drought impacted the natural habitat in KNP in such a way that most of the migratory birds did not arrive as given in Table 3.7.

Table 3.7: Number of main migratory birds arrived in KNP during 1998-2010

Species	**1998-99**	**1999-00**	**2000-01**	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**2009-10**
Black-Ibis	-	-	-	-	-	-	-	1205	90	67	10	0
Eurasian Spoonbill	-	-	-	-	-	-	-	-	-	-	144	3
Greylag Goose	4296	3038	1152	977	-	955	1169	691	11	-	842	2
Bar-Headed Goose	631	288	347	563	-	543	377	-	-	-	435	143
Lwseer Whistling-Duck	1880	181	38	87	-	122	-	125	25	14	1218	0
Ruddy Shelduck	4	0	0	8	-	6	14	-	-	-	69	28
Red Crested Pochard	714	7	4	1	-	145	-	95	4	-	-	0
White Eyed Pochard	521	110	78	1	-	23	-	-	-	-	-	0
Cotton Pygmy Goose	-	-	-	-	-	-	-	-	-	-	24	0
Gadwall	1880	814	1118	557	-	1677	195	1363	2	-	1638	2
Eurasian Wigeon	590	168	12	115	-	332	-	79	6	-	510	0
Mallard	-	-	-	-	-	-	-	-	-	-	2	0
Garganey	232	9	12	4	-	30	-	13	8	-	132	1
Northern Pintail	3479	1634	3445	953	-	3347	597	3708	10	-	4154	428

(Source-KNP, Bharatpur)

3.3.3 Temperature variation

Climate of KNP wetland is extremely hot in summers and freezing in winters. Average monthly maximum and minimum temperature variation in Bharatpur during 2004 to 2010 has been given in Table 3.8. The mean maximum temperatures ranged from 15.1 to 23.2°C in January during peak cold whereas 42.0 to 45.7°C in May when heat wave conditions prevailed. It was also seen that the mean minimum temperature varied from 3.4 to 8.2°C in December and 24.9 to 28.3°C in June. Winter period is suitable for water birds in KNP.

Table 3.8: Average monthly maximum and minimum temperature during 2004 - 2010 in Bharatpur

Year	**2004**		**2005**		**2006**		**2007**		**2008**		**2009**		**2010**	
Month	Temp (°C)		Temp (°C)		Temp (°C)		Temp (°C)		Temp (°C)		Temp (°C)		Temp (°C)	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	19.6	4.9	23.2	5.4	15.1	3.5	14.4	2.6	18.3	4.5	21.7	7.0	18.5	6.4
February	29.8	6.8	27.6	9.2	24.1	7.1	22.5	6.8	23.5	8.8	27.1	8.2	26.0	9.4
March	41.8	14.6	34.2	13.2	31.6	16.2	32.5	17.1	32.6	13.8	33.1	13.5	35.8	15.1
April	42.2	22.1	40	14.8	38.9	19.8	39.2	22.4	36.9	18.8	38.9	19.8	42.3	23.7
May	43.8	25.6	44,6	25.1	44.8	24.2	45.7	24.2	42.3	26.6	42.0	25.3	43.9	28.5
June	42.3	25.2	44.3	25.5	44.1	25.1	44.1	24.9	38.3	26.6	42.9	27.9	42.7	28.3
July	40.1	28.4	40.7	27.1	41.4	25.6	41.6	25.6	33.5	26.2	35.4	26.8	35.9	26.7
August	33.8	26.4	34.8	26.1	35.2	23.6	36.1.	24.6	34.2	26.5	34.9	26.3	34.2	26.1
September	34.7	24.5	34.6	22.8	34.8	20.1	34.5	22.8	33.5	24.7	35.1	24.3	32.4	24.2
October	35.2	17.2	34.9	17.1	35.2	15.2	37.2	15.6	35.6	18.4	34.3	18.2	34.2	19.7
November	28.2	12.4	29.5	11.8	32.2	9.8	32.8	10.1	30.6	13.4	27.7	13.1	27.1	15.1
December	24.4	8.2	23.6	7.5	22.4	3.4	23.5	7.2	22.8	6.1	23.3	8.0	22.1	6.4

(Source- Directorate of Mustard and Rap seed Centre, Bharatpur)

3.4 Human growth and its associated activities around KNP

Bharatpur is situated at the eastern most part of Rajasthan and very well connected to Uttar Pradesh and Madhya Pradesh through National Highway. After construction of NH-11 from Jaipur to Agra in 2008, it is one of the vastly developed areas in this part of Rajasthan. Urbanization in Bharatpur and in this part of Rajasthan is increasing at a faster rate. Population and Population density of Bharatpur for the period of 1941 to 2011 is shown in Figure 3.8. The decrease in population of Bharatpur in 1991 is due to creation of new district of Karauli. Most of the growth and sub urban development in Bharatpur has been seen along Highway. Built-up area around KNP catchment area increased from 7% in 1989 to 17 % in 2011 due to mass construction (Yadav et al, 2014).

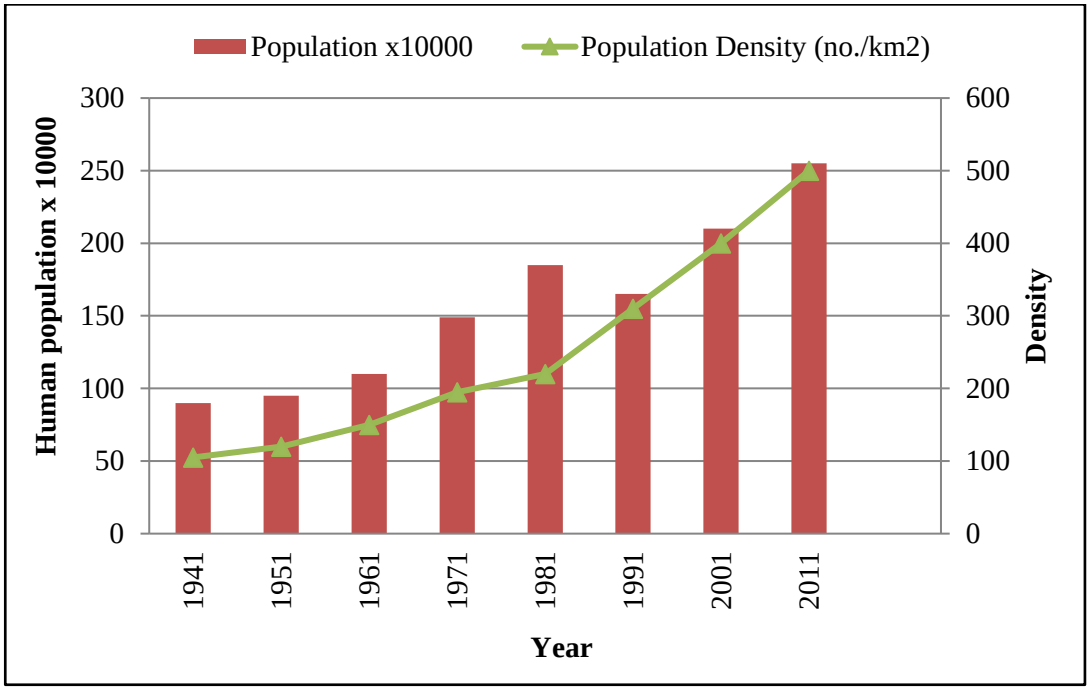


Figure 3.8: Variation of population and its density in Bharatpur during 1941-2011(Source- Census, 2011)

3.4.1 Intrusion around vicinity of KNP

High rate of population growth in Bharatpur in the last 20 years is one of the environmental factors governing the various changes in resources as water, agriculture and livestock near KNP.

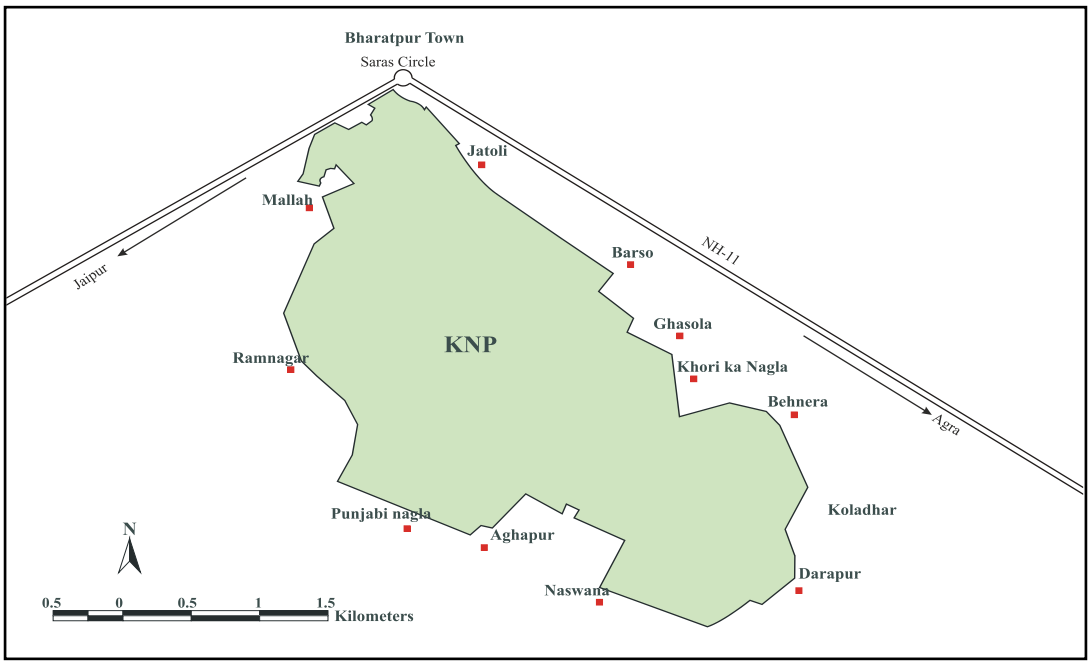


Figure 3.9: Villages situated around KNP boundary. Their inhabitants are dependent on KNP

NH-11 passes along the periphery (a stretch of 5 km) of KNP; on eastern side villages Behnera, Barso and Jatoli around 400 m away and on Northern side outside KNP gate (Figure 3.9). Their inhabitants were purely dependent on KNP in matters of cutting wood, fodder and wages. The forests of KNP provided fodder, wood and earnings. Cutting wood and fodder is banned as Wild Life Act 1972 has been enforced. It has impacted on livestock and survival of villagers of the surrounding areas and also on KNP ecosystem. The earning pattern of villagers has been changing. It was also observed that there were different categories of hotels and guest houses constructed around KNP for tourists. They were situated within 1/2 kilometer from KNP. Presently 34 hotels and guest houses are located just outside KNP gate on National Highway 11. It was found that tourist preferred to stay in nearby hotels.

3.4.2 Transient of National Highway-11 around KNP

Bharatpur is situated on important tourists' triangle connecting Delhi-Agra-Jaipur. These historic places are visited by large number of domestic and foreigner tourists through out the year.

Figure 3.10: Golden Triangle Delhi-Agra-Jaipur National Highway connecting Bharatpur and KNP

In the last decade, this route Delhi to Agra, Agra to Jaipur and Jaipur to Delhi was well connected by newly constructed 4-6 lane National highway including Yamuna Express Highway, NH-11 and NH-8 respectively (Figure 3.10). Road transport is a major source of noise generation. On Highway continuous traffic and speed of vehicles induced noise level. This noise may be go up to 100 dB(A) (Agarwal, 2011). Noise from road transport vehicle is mainly generated by the engine propulsion system and other accessories (Hillquist and Scott, 1975; Priede, 1982). Other factors contributing to noise are excessive load, traffic flow rate, horn and change in engine power. CPCB, 1998 have recommended Ambient Noise Level (L_{eq}) 55 dB(A) for urban residential area and 50 dB(A) for silence area and Eco sensitive zone. These limits are reduced by 10 dB(A) in Night hours (10 pm to 6 am).

Increased vehicle movement and noise level on NH-11 outside KNP may affect bird activity. Past observation reveals annual average daily traffic flow on the

Agra-Jaipur NH-11 in 2010-11 were 635 LMV, 125 LCV, 196 Trucks, 403 heavy trucks and 137 multi axle vehicle, total of 1496 (Source- toll plaza, Bharatpur).

3.5 Vegetation in KNP

The KNP comprises of three eco-systems namely wetland, grassland and woodland. Wetland and grassland are the most sensitive ecosystems to provide staging site for migratory and breeding resident birds in KNP. Ecology of KNP wetland consists a woodland dominated by '*Kadam' (Mitragyna parviflora),* Jamun (*Syzygium cuminii),* Desi Babul (*Acacia nilotica*) Karel *(Capparisaphylla),* Fards *(Tamarix),* Handi *(Prospis cinraria)* trees in F and G blocks, wetland having open fresh water lakes and marshy area dominated by plants such as floating vegetation (*Nymphoides indicum, Nymphoides cristatum, Nymphaea nouchali* and *Nymphaeastellata),* (K, L, D and E blocks) and grasslands mainly consists *Paspalum distichum*, a perennial amphibious grass and *Prosopis juliflora* (I, J, L_2 and M blocks). *Prosopis juliflora* was planted in small patches in the 1970. Gradually it got spread over the entire park *Prosopis juliflora* is in IUCN's new list of 100 world's worst invasive alien species. *Prosopis juliflora* is an evergreen fast-growing, drought resistant, natural fuel wood and highly tolerant to water stress, soil salinity. Trees and shrubs usually found in savanna are *Prosopis cineraria*, *Acacia nilotica*, *A. leucophloea*, *Zizyphus maurutiana* and *Salvadora persica*. Certain wetland areas are also bordered with this kind of vegetation. Low grasslands, mainly of *Sporobolus helvolus* and *Cynodon dactylon*, occur in some parts of the KNP with a few scattered trees and shrubs such as *Acacia nilotica, Prosopis cineraria, Salvadora persica* and *Krignelia reticulata*.

The wetland of Keoladeo National Park has more than 90 species of flowering plants. These are classified as follows: (a) Free floating *(Spirodella polyrhiza, Lemna perpusilla, Eichorniacrassipes*), (b) Rooted with floating leaves *(Nymphaeapubescens, N.nouchali, Nymphoides cristatum*), (c) Un-anchored submerged *(Ceratophyllum demersum, Utricularian aurea, U.stellaris*), (d) Rooted submerged *(Hydrilla verticilata, Najas minor, Potamogeton crispus)* (Mathur et al, 2009).

3.6 Birds in KNP

Source of food for survival of migratory water birds is aquatic vegetation in wetland. They survive on nutritious seeds, roots and tubers available in wetland. Migration is essential for survival of migratory species for better availability of suitable habitats, both on migratory routes as serving areas and further on the final

destination as wintering sites (Verma and Mathur, 2009). It is critical for survival and thereafter for breeding at native site for these migratory water birds. KNP contains shallow water spread limited to1.30 meter depth in aquatic blocks K, L, D, and E. This water depth is important factor for attracting a large number of winter migrants for staging and breeding for resident water bird in KNP. The aquatic vegetation supports mainly the species of *Herons, Painted Storks, Cattle Egrets, Indian Cormorant and Asian Spoonbill.* Terrestrial area contains mainly shrubs, dense forest and wood land which are ideal foraging place for mammals in KNP. Excessive growth of wild grasses such as *Paspalum distichum* affected the existence of various species in the KNP.

3.6.1 Breeding resident birds in KNP

These birds arrive in KNP as monsoon rains start during May-June.

Table 3.9: Various common resident birds in KNP

Species of birds	Arrival Month	Departure Month	Average duration of stay (days)
Asian Openbill	May	April	312
Eurasian Spoonbill	May	April	289
Open billed Stork	June	April	168
Little Cormorant	June	April	173
Great Cormorant	June	April	176
Darter	June	March	185
Black-headed Ibis	June	March	189
Black-crowned Night Heron	June	March	198
Great Egret	June	April	267
Intermediate Egret	June	April	213
Cattle Egret	June	April	224
Little Egret	June	April	228
Grey Heron	July	March	165
Purple Heron	July	March	143
Painted Stork	July	February	153
Indian Cormorant	September	March	195

(Source- KNP, Bharatpur)

These birds are mostly found in pairs for breeding. Nest building in KNP starts when various aquatic blocks K, L, D and E are filled with sufficient water. Open Billed Storks start building their nest first. On the same tree Heron, Egrets Cormorant, Darters also build their nests form a mixed colony of birds called heronry. Data in Table 3.9 shows majority of common resident birds often seen in KNP after monsoon rain, arrival and departure month, their average stay depends upon the availability of suitable feeding sites.

3.6.2 Migratory birds in KNP

Natural habitat of KNP having mosaic of wetland and grassland attracts around 85 species of migratory birds from various parts of world (Afghanistan, Turkmenistan, Siberia, Himalayan and Ladakh region in CAF). Important of them have been taken up in this work. As winter starts, KNP scenario changes to staging winter birds mainly Duck, Geese and Crane. These birds begin to arrive in KNP from mid August. Main migratory birds, their expected arrival and departure month are given in the Table 3.10.

Table 3.10: Various common migratory birds in KNP

Species	Arrival Month	Departure Month	Duration of stay as recorded (days)
Gadwall	September	February	156
Shoveller	September	February	164
Common teal	Mid August	March	186
Blue winged teal	Mid August	March	192
Coot	September	February	143
Commmon Pochard	September	March	168
Redcrested Pochard	September	March	178
Pintail	September	March	162
Greyleg goose	October	March	134
Brahminy Duck	October	March	138

(Source- KNP, Bharatpur)

Their status on arrival in KNP has been perceived as: *Gagrany or Blue winged Teal, Common Teal* arrived very first then *Pintail, Common Pochard and Grey-leg Goose* in the last. Some migratory wader birds have a common feature. They stop over at Bharatpur KNP on their journey to South, in transit on their migratory route (Mathur et al, 2009). They stay in Bharatpur for one or two weeks and then disperse to other places towards South. Even on return journey these birds assemble at Bharatpur in mid March before leaving for their breeding places in the temperate region. Many of winter birds are only transient for KNP. In particular time the counting of bird's population gets reduced as they fly away to other wetlands.

3.7 Ecotourism in KNP

Impact of visitor pattern may be more severe at a local level as they are important in maintaining economy of local community (Cole 1981). KNP is one of the important destinations to visit for foreign tourist due to migratory birds. Bharatpur economy mainly depends upon tourism in KNP as large number of domestic and foreign tourists visit in different seasons.

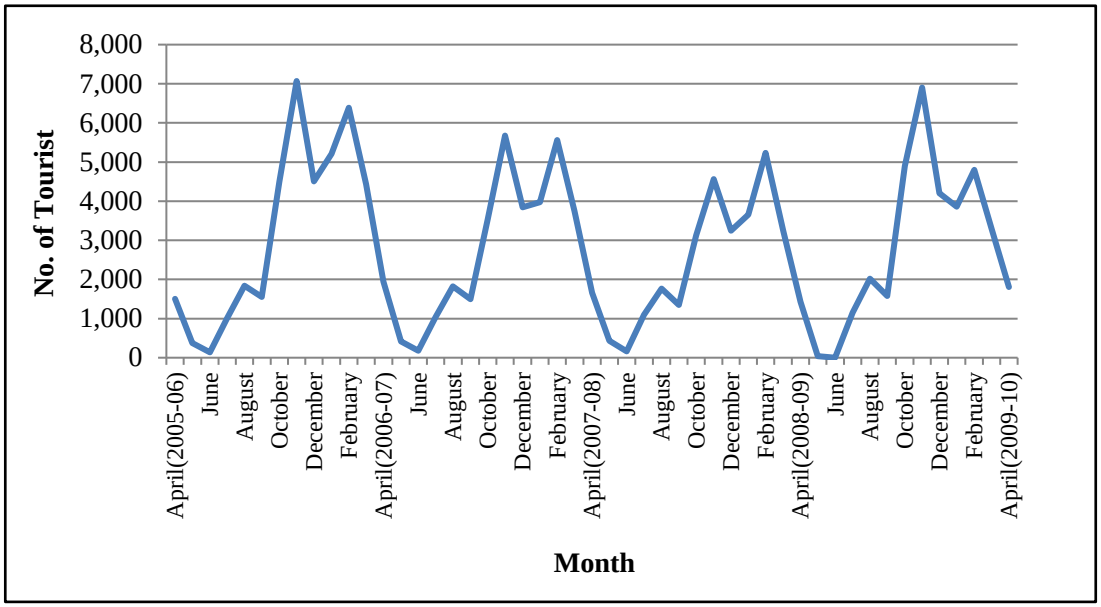


Figure 3.11: Monthly movements of tourists in KNP during 2005-2010, shown their seasonality and fluctuation in different months

Domestic tourists including students visit this site preferably in holidays and weekends whereas foreign tourists visit during their journey on golden triangle

Delhi-Agra and Jaipur. Monthly inflow of tourists in KNP during 2005 to 2010 has been presented in Figure 3.11.Visiting of tourists in winter are increasing abruptly from September onwards as variety of birds arrived in KNP and minimum in summer months are idle period for dependents income. Tourists and local dependent community based on KNP biodiversity. It provides the rickshaw pullers, guide and other workers (local villagers) with substantial economic opportunities. However, due to the seasonality of tourism at the park the rickshaw pullers and guides are unable to rely solely on tourism to maintain their livelihood. Minimum 3 hours are required to make trip from KNP gate to E block and sightseeing of activities of birds in KNP and return back. Rickshaw-pullers and guides are hired on hourly basis in KNP and their current charges are 100 and 150 ₹/hour respectively.

CHAPTER 4
MATERIALS AND METHODS

This chapter discusses the study sites and methodology which has been undertaken for carrying out the present research work. It includes KNP wetland and surrounding area. A detailed study and site visit of the study area had been conducted to mark prominent locations for experimental work. The methods used for experimental work and various survey have been dealt with thereafter.

4.1 Study Sites

The area of this study was Keoladeo National Park Wetland in Bharatpur and surrounding area including watershed of Gambhiri River (also reported as Gambhir), Ajan Dam and National Highway -11 along KNP which affect its ecosystem. Birds activities as nesting breeding of resident birds and staging of migratory birds are concentrated in its K, L, D and E blocks which are aquatic area in KNP wetland. They constitute 33% of the total area of the park (Table 4.1).

Table 4.1: Aquatic blocks and their area in KNP

Aquatic Block	Area (km^2)	Perimeter (in km)	Containing Average depth of water (m)	% of total area of KNP
D	1.39	4.8	1.20	4.7
E	1.56	5.4	1.35	5.3
K	2.28	5.9	1.15	7.7
L1	3.06	7.6	1.20	10.35
L2	1.45	5.9	1.25	4.9

Surrounding study sites include Ajan Dam about 500 m away from KNP, conventional water sources Gambhiri rivers and alternative water projects Chambal pipe line project and Goverdhan drain for observing water parameters. It also include Bund Baretha Dam as satellite wetland where migratory birds activity was observed.

Other surrounding study sites comprise of National Highway-11 around KNP and hotels, guest houses, nearby villages which are major sources of noise pollution.

Graphical presentation of research planning included in this study has been shown in Figure 4.1.

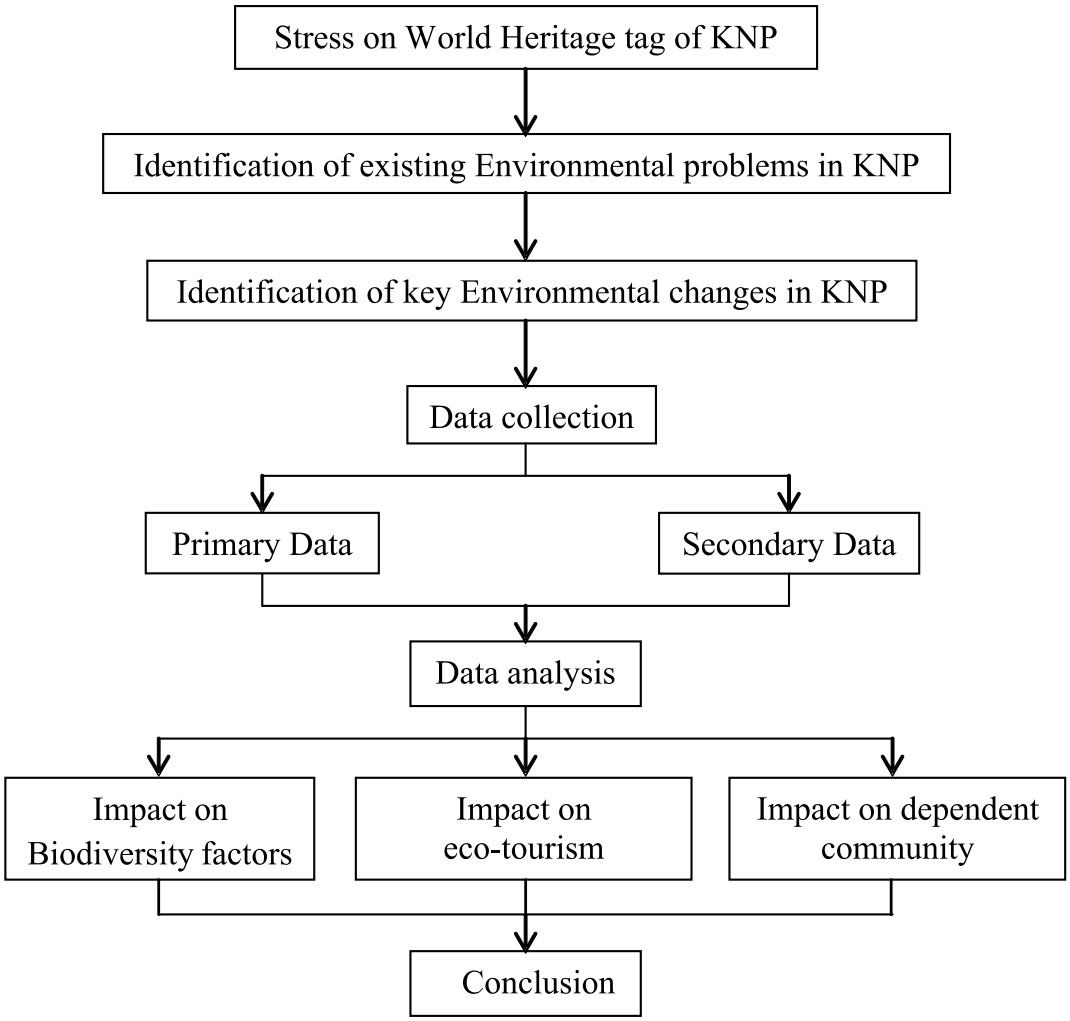


Figure 4.1: Flow diagram of Research planning

4.2 Collection of water samples and their testing

Field visits were done in KNP to select the appropriate location for collecting water samples and for measuring depth in each aquatic block K, L, D and E. Water samples from different aquatic blocks (4 samples) were collected from selected points during the period 2011 to 2014 (up to December) in morning at 9.00AM as

marked in KNP map (Figure 4.2). Water samples from Ajan Dam and other alternatives sources Chambal pipe line project and Goverdhan drain were also taken to examine the quality of water. Water quality analysis was done using standard methods (APHA, 1998). Water samples were tested for physiochemical parameters like pH, dissolved oxygen, BOD, Salinity, TDS and hardness. The tests were conducted in laboratory of Public Health Engineering Department and Polytechnic College Bharatpur.

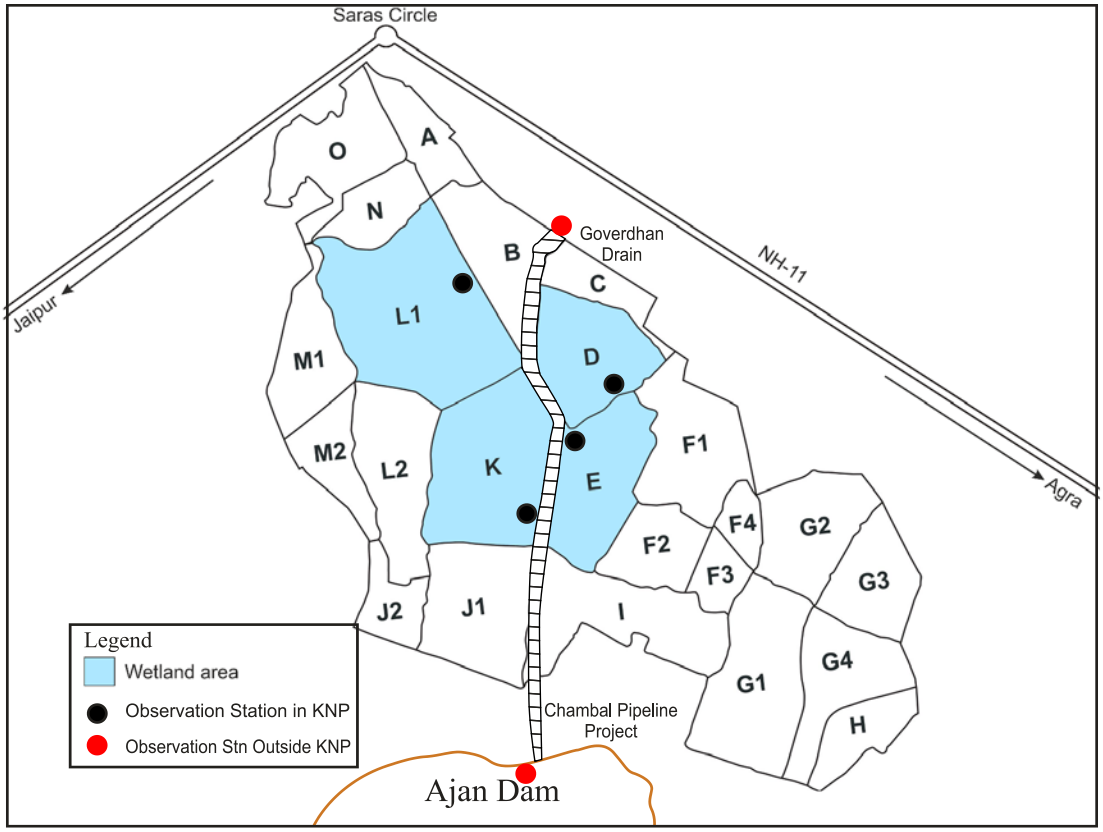


Figure 4.2: Water collection observation points inside and outside KNP.

4.3 Data collection of rainfall and water supplied to KNP

Water supply and rainfall are important factors for water budget in KNP. The data of water supply to KNP from Ajan Dam from 1981 to 2010 have been collected from Irrigation Department Bharatpur. Water supply during study period was frequently changing due to water crisis in KNP. The record of water supply from Chambal pipe project and Goverdhan drain to KNP was obtained from Water Resources Department Bharatpur. Average annual rainfall data in Bharatpur from 1901 to 2010 has been collected from Irrigation Department Bharatpur and monthly rainfall and rainy days data near KNP from 2004 to 2014 collected from Directorate

of Mustard and Rap seed Centre, Bharatpur. Data of rainfall at various rain gauge stations in the catchment area of KNP and Ajan Dam were collected from Irrigation department, Bharatpur.

4.4 Measurement and monitoring of traffic flow and noise level on NH-11

Average traffic volume on NH-11 has been collected from Toll- Plaza Bharatpur. Traffic flow on NH-11 at Saras Circle was observed and two directional traffic volumes were recorded manually on 23rd November, 2012 and hourly traffic volume from morning to night was calculated. Traffic composition in the study area included cars, jeeps, LCV, buses, trucks and multi axle vehicles.

The ambient traffic noise levels were recorded using Sound level Meter (SLM) Quest Technologies Model-1900. The QT-1900 is a type-1 integrating sound level meter that complies with IEC 651-1979. It covers a frequency range from 12.5Hz to 20 kHz with type-1, octave filters. The sound level due to traffic was measured during 2012 to 2014 monthly (September to December) at 4 identified locations at Saras Circle (L1), KNP gate (L2), Polytechnic College (L3), Siddhesh Resort, Agra road (L4) on NH-11 around KNP (Figure 4.3). It was measured in morning, afternoon, evening and night as traffic volume varies at different hours of the day. Speed breakers constructed at Saras Circle and outside KNP gate increases noise level. Noise levels were also measured during marriage functions around KNP hotels.

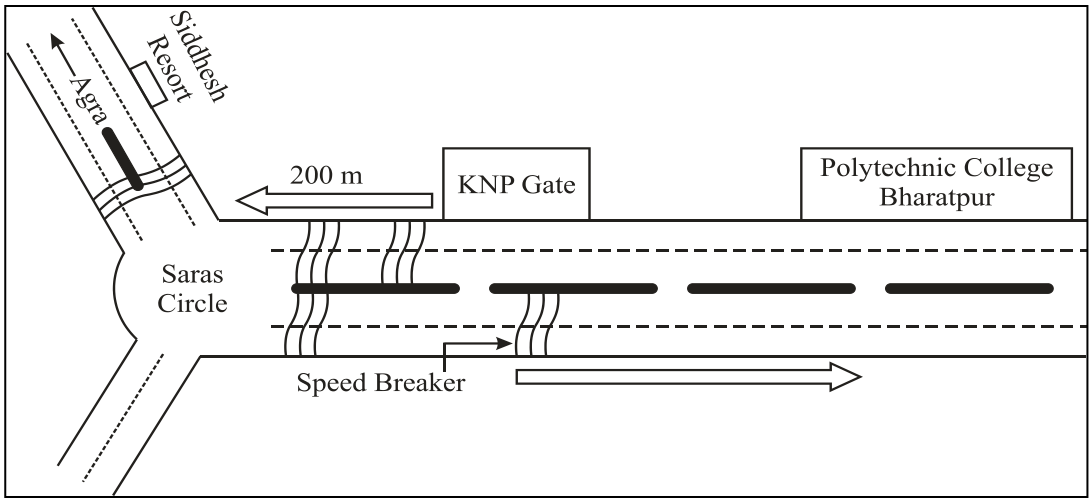


Figure 4.3: Schematic diagram on NH-11 around KNP showing location Saras Circle (L1), KNP gate (L2), Polytechnic College (L3), and Siddhesh Resort (Agra road (L4)) and distribution of rumbles and diversion

The effect of the noise on the bird count has been studied by a pilot study. Total 7 point selected 3 points in KNP along highway 200 m away from highway and 3 points situated 1000m away from highway and 1 point in middle of them. These study points made a Z- shape pattern. All these locations are selected on the basis of noise produced due to traffic near national highway (NH-11) and human activities in village (Mallah), hotels, rest-houses and residential colonies. The sound level was also recorded at these points using SLM. Four sound scale are used (1) level 1-High sound >75dBA, (2) level 2- Medium Sound - 50 to 75dBA, (3) level 3-Low sound- 35 to 49dBA and (4) level 4- No sound <34dBA.Birds count has been done in morning, noon and in evening at these locations.

4.5 Study of water birds and survey of tourists and local community

This study was conducted during the period 2011 to 2014. Regular field trips were made and field data of water-birds in park was obtained by park management. Observation of the birds was done during the field visit and their identifications were carried out by using 7 X 35 prismatic field binoculars, tally counter, camera and pictorial guides such as *A Pictorial Guide to the Birds of the Indian Subcontinent* (Salim Ali, 1983) and *Water birds of Northern India* (Alfred et al., 2001).Bird counts were done by two different methods. Actual head counts were done for bird species that were small in number. Birds were present in large flocks. A section of the flock was counted and used to estimate the total number in the flock. Bird's population, various breeding resident and migratory species in different seasons was also gathered with the help of photographs and support of local staff including foresters, guards and local biological experts in KNP.

Opinion of tourists, guides and rickshaw pullers regarding the current changes in ecology of KNP were recorded and studied. Foreign and domestic visitors' data was collected from KNP administration. A comprehensive questionnaire was prepared and feedback from the tourists (sample survey) on the current environmental changes in KNP was collected (Appendix-5). Total 1000 tourists have been taken on the basis of domestic and foreign visitors (600-400). Further, the tourist were selected on the basis age (20 years and above age group), qualification (Secondary and above), and purpose of visit (Orthinologist and photographers those are having knowledge about

the birds). The changes in livelihood of local dependents like guides and rickshaw pullers (sample survey) have also been surveyed. Locations of hotels around the study area was marked by field visit and shown in Figure 5.16. Survey of these hotels and guest houses was also done to assess visitors' stay and expenditure pattern. Feed back on current changes in KNP and its conservation was also taken from local public representatives including MLA, Mayor, Sarpanchs, and Ward Members.

CHAPTER 5
RESULTS AND DISCUSSION

KNP is facing problems due to inadequate supply of water and human associated activities. These factors have been affecting the number and variety of the migratory birds in the KNP. The results and discussion of the study with respect to water sources and human intervention in KNP are presented in this chapter. The studies were carried out by investigating seasonal changes in water quality, water area and the influence of human associated activities, passing of National Highway along KNP and increasing noise level around KNP.

5.1 Hydrological aspect in KNP

The migratory birds arrive in KNP due to the availability of suitable environment and food. The KNP needs adequate amount and good quality of water in the aquatic blocks for proper vegetation growth and primary food chain. It has been observed that the water supply to KNP from conventional sources has been reducing for last two decades.

5.1.1 Conventional water sources to KNP and their present status

The main sources of water supply in KNP Bharatpur are the rivers and rainfall. KNP had faced drought in the years 2004, 2006 and 2007 when the monsoon failed. These years adversely affected the flora and fauna at the KNP and it took a lot of time for the park to recover (Pundir and Mamgain, 2014). Conventional water sources for KNP were the Gambhiri and Banganga Rivers. The water from these rivers was full of biological values (such as fish and planktons). Water supply to KNP from these sources gradually decreased due to the construction of many dams and bunds in river basins. The observed reasons for decrease flow to KNP were construction of Panchana Dam on Gambhiri River in Karauli, to mitigate floods and fulfill irrigation requirements of the upstream area (Appendix-2). It was revealed that from 2002 to 2010 water supply through Panchana Dam via Ajan Dam to KNP has decreased significantly (Figure5.30). Various dams and other projects constructed in the watershed areas of Banganga River are given in the Table 5.1.

Table 5.1: Dams and head works in the watershed areas reducing water flow to KNP

River	Main Dam	Construction Year	Other dams /Head works	Reason of construction	Consequence
Gambhiri River	Panchana Dam in Karauli	1979-2003	Jugger Dam, Senthal, Arvari and Sevla head, Ajan Dam	Reservoir for irrigation, drinking and supply to KNP	35 villages on upstream getting water for irrigation whereas 425 villages on downstream witnessed water crisis and GW table lowered

(Reference: Dass et al., 2013)

Construction of these structures greatly affected the water availability in the KNP aquatic blocks. Due to consistent problem of water scarcity in KNP, UNESCO also threatened to take back its world heritage tag in the year 2007, if the ecological value were not maintained continuously.

5.1.2 Alternative water sources to KNP

During the period 2005-2009 negligible amount of water was supplied to KNP through Ajan Dam overflow of water from Panchana Dam (Gambhiri river) except in the year 2008. With this serious concern, the Government of Rajasthan and Central water commission have taken emergent action to fulfill water requirement to KNP. Consequently the water supply was started through Chambal pipe line project (which is mainly drinking water project for Bharatpur area) and the water has been supplying from 2011 onwards. Another alternative source of water to KNP was Goverdhan drain project (from Goverdhan canal) through which the water has been supplying to KNP from 2013 onwards. However, according to the plan, the water from Goverdhan drain would be supplied during drought/emergency (A total 9.9 Mm^3 per year can be supplied) to the KNP.

Supply of water to KNP has been frequently changing from these projects for the period during 2011-2014. Sources of water supply to KNP and their biological value are presented in Table 5.2. The distribution of water supply to KNP for the period during 2011-2014through these sources is given in Table 5.3.

Table 5.2: Sources of water supply to KNP and their biological value

Other viable Options	Completion Year of Construction	Plus/ Minus points
Panchana to Ajan Dam Revival of River (overflow water)	Started in 1979 and completed in the year 2003	(+)Containing fish & high biological quality (BQ)
79.6 km Chambal Pipeline project	Completed in the year 2010	Water for drinking (-) less BQ
17.1 km Closed Pipe line from Goverdhan drain	Completed in the year 2012	Waste water supply(-) less BQ

(+) advantage (-) disadvantage with respect to KNP ecology

Table 5.3: Water supplemented from different sources to KNP

Year	Water release to Keoladeo National Park, in Mm^3 (% of total supplied water)				Total water to KNP (Mm^3)
	Panchana Dam to Ajan Dam	Chambal pipe line project		Goverdhan drain	
		Volume (%)	Time of supply		
2010-11	5.5(100%)	Nil (0%)	-	Nil (0%)	5.5
2011-12	Nil (0%)	8.4 (100%)	10 Oct 11-Feb 12	Nil (0%)	8.4
2012-13	6.6 (41%)	9.5(59%)	16 Jun 12-31 Mar 13	Nil (0%)	16.1
2013-14	3.6 (32%)	2.3(20%)	26 June-20 Sep 13	5.3(48%)	11.1
2014-15	Nil (0%)	5.7(76%)	22 Jul 14-5 Dec 14	1.8(24%)	7.5

Timely supply of water from June onwards is important for proper growth of vegetation, adequate food chain and sufficient water level for attracting water birds. The supply of Chambal water to KNP was delayed in the year 2011-12 and 2014-15 and was provided in October and July respectively. Due to the delay in water supply the food chain was affected adversely. Total water supplied to KNP during study period was not meeting the water requirement (15.0 Mm^3) for this site except in the period 2012-13(16.1Mm^3). In addition to adequate and timely supply of water the physiochemical parameters of water also affects the biota. As the water has been supplemented through alternate sources the physiochemical parameters of water in KNP aquatic block might have changed.

5.1.3 Physicochemical parameters of water

Physiochemical parameters (such as temperature, pH, TDS, DO etc.) of water (aquatic blocks) in KNP for the period of 2011-2014 (bimonthly), have been tested and tabulated in the Table 5.4. These parameters were also studied for Ajan Dam and both the alternative sources namely Chambal pipe line and Goverdhan drain. The water quality of KNP prior to use of alternative sources was very near to Ajan Dam water quality as given in Table 5.5

Table 5.4: Physicochemical parameters of water of KNP Bharatpur, taken during August to April (2011-2014)

Aquatic area	Block-K			Block -L			Block-D			Block-E		
Parameters	**Range**	**Mean**	**S.D.**	**Range**	**Mean**	**S.D.**	**Range**	**Mean**	**S.D.**	**Range**	**Mean**	**S.D.**
Temperature °C	19.8-24.6	22.2	2.09	20 -25.9	23.7	3.26	20.4-24.5	22.8	3.03	20.7-26.4	24.2	3.07
pH	7.0-7.4	7.1	0.44	7.0 - 7.9	7.3	0.11	7.2-7.6	7.4	0.16	7.1-7.7	7.4	0.12
TDS (mg/l)	242-654	343	131.10	342 -980	489.3	141.75	224-655	430	395.21	287-765	470	22.33
DO (mg/l)	3.2-4.8	3.9	0.53	3.4 - 5.8	4.4	0.41	3.8-6.2	4.6	0.39	3.6-5.2	4.3	0.35
BOD (mg/l)	2.6-4.2	3.6	0.08	2.1 -3.5	2.7	0.22	2.8-3.4	3.1	0.18	2.4-4.4	3.3	0.15
Hardness (mg/l)	87-242	132	112.72	92 - 301	147	111.26	104-345	156	281.83	98-302	135	21.88
Cl (mg/l)	34-176	78	30.95	52 -214	94.3	92.94	38-178	74	181.93	48-188	65	20.71
Salinity (mg/l)	21-65	49	108.76	30 - 96	61.6	214.08	36-86	56	335.23	28-68	43	46.43
Ca (mg/l)	26-98	43	37.31	30 -132	45.6	37.28	27-94	47	136.89	34-78	48	14.22
Mg (mg/l)	32-134	49	49.99	41 -162	58.3	69.78	29-135	42	142.34	26-143	44	14.32

Table 5.5: Comparison of physicochemical parameters of water from various sources to KNP, Bharatpur

Parameters	Water sample from Ajan Dam			Water sample from Chambal pipe line			Water sample from Goverdhan drain		
	Range	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.
Temperature (°C)	20.2-25.9	23.6	2.45	19.5-21.9	20.6	0.65	19.2-22.9	20.5	1.72
pH	7.2-7.6	7.3	0.21	8.0-8.3	8.1	0.12	7.5-8.1	7.9	0.26
TDS (mg/l)	673-987	746	149.72	349-449	394	34.61	1971-2127	2178	71.02
DO (mg/l)	3.6-6.2	3.8	1.39	3.2-6.5	4.2	1.03	2.9-4.6	3.6	0.71
BOD (mg/l)	1.9- 4.5	3.1	0.80	0.6-1.2	1.1	0.18	3.1-4.5	3.9	0.71
Hardness (mg/l)	132-301	174	83.84	60-165	95	29.80	510-640	590	57.15
Cl (mg/l)	357-581	461	107.38	10.0-20.0	15	7.07	540-670	605	72.22
Salinity (mg/l)	31-89	59	8.40	55-95	75	16.27	270-340	280	33.66

The pH values in Table 5.4 show that the water in all aquatic blocks in KNP is slightly alkaline. The average TDS value varies from 343 to 490 mg/l. The average DO concentration varies from 3.9 to 4.6 mg/l. The BOD ranges from 2.7 to 4.4 mg/l. Hardness is ranged from 132 to 156 mg/l in blocks. Comparative study of the water parameters indicates that water from Chambal pipe project is more alkaline than that of Ajan Dam. Changes in water depth and DO concentration in different aquatic blocks are shown in the Figure 5.1 and Figure 5.2 respectively. The DO level varies with water depth and the organic matter present in the water. Water depth increases in rainy season and reaches to its maximum level in October due to the influx of rain and water from all sources. In winters the water depth and DO remain almost constant. In summer season the water depth and DO considerably decrease as temperature rises from March onwards.

The physiochemical parameters of the water from the Chambal pipe line project and Goverdhan drain are different from the Ajan Dam's water. The possible effect on the KNP wetland due to the changed water sources have been discussed subsequently.

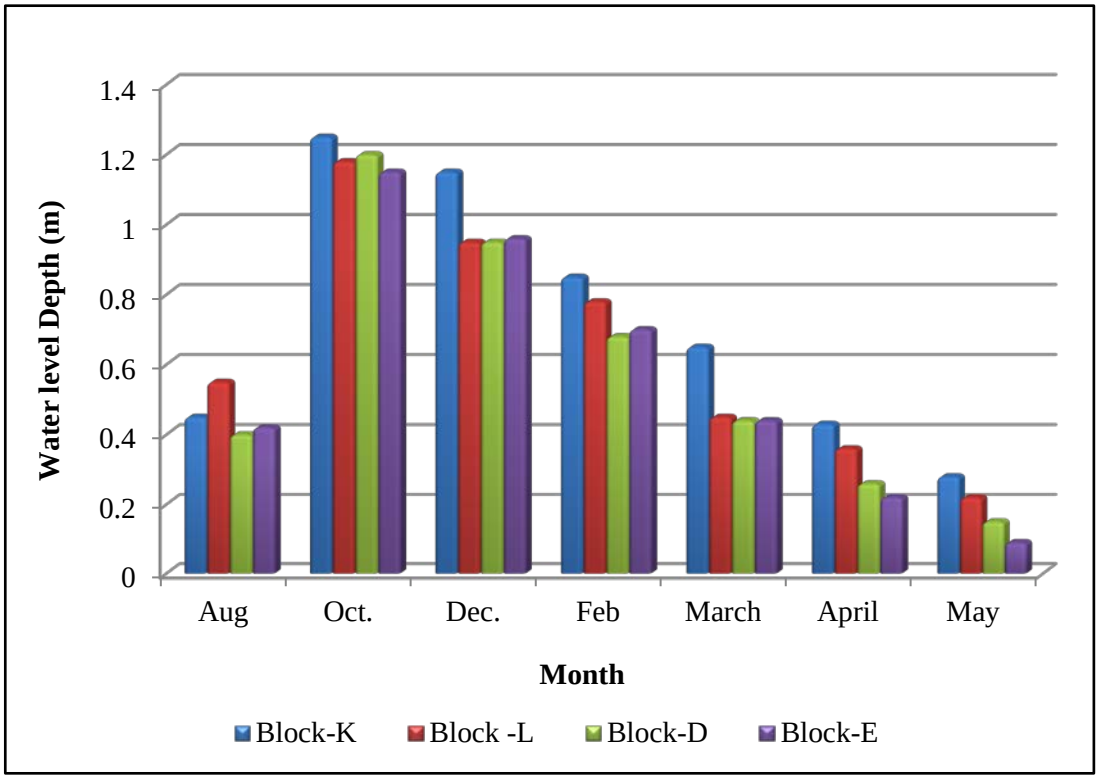


Figure 5.1: Variation of water depth in different aquatic blocks of KNP, during 2013-14

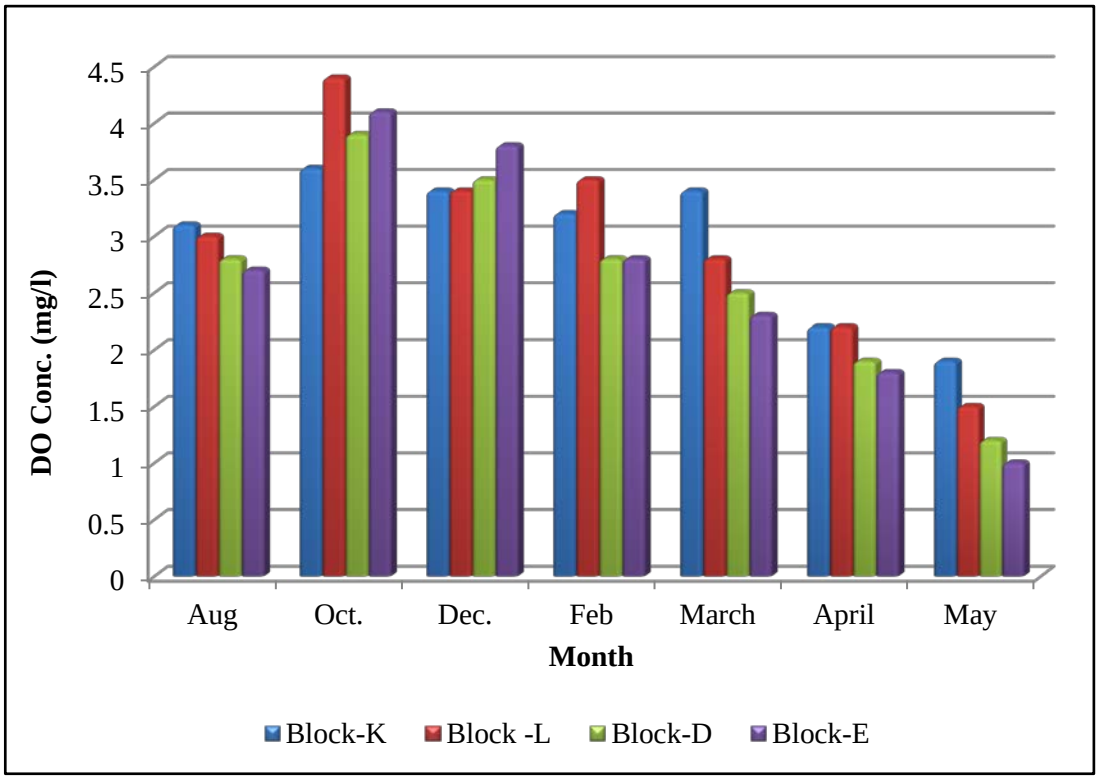


Figure 5.2: Variation of DO concentration in different aquatic blocks of KNP during 2013-14

The recommended pH range for aquaculture is 6.5 to 9.0 (William and Robert, 1992). The average pH value in KNP ranges from 7.1 to 7.4. The water from Chambal pipe line possess high pH value (8.0-8.3) than that from Ajan Dam (7.2-7.6). With respect to pH, the water from Ajan Dam is safer for fish growth. Recommended value of DO is more than 4 mg/l for survival of fish. Dissolved oxygen is most important parameter for the aquatic life of such park including the organisms that break down man-made pollutants (Sunder and Khatri, 2015). Its high concentration positively affects the park's life. The DO level was in the range of 3.6-6.2, 3.2-6.5 and 2.9-4.6 mg/l in the Ajan Dam, Chambal pipe line and Goverdhan drain water, respectively. The data suggests that Goverdhan drain has less DO level than other two sources and hence Goverdhan drain water is less suitable for aquatic life in KNP.

In the KNP, during study period, the BOD was found to vary in the range of 1.9-4.5, 0.6-1.2 and 3.1-4.5 mg/l in Ajan Dam, Chambal pipe line and Goverdhan drain water respectively. High BOD value depletes oxygen by microbial metabolism thereby; the fish and insects may die due to the lack of oxygen (Goldman et al, 1983). Goverdhan drain water has high BOD value resulting in lower DO. The concentration of TDS influences the organism in the aquatic regions. Total dissolved solids are considered one of the best indices of nutrient availability for the aquatic plants being grown. The effect of high TDS on different kind of fish was also observed. It was found that high TDS adversely affect at fertilization stage (Phyllis et al., 2007). Some species might be more sensitive to TDS toxicity at certain life stages and others during fertilization. Average TDS concentration varies from 343 to 490 mg/l in different aquatic blocks in KNP. The water from Ajan Dam is having TDS in the range of 673-987 mg/l. whereas the water of Chambal pipe line and Goverdhan drain water is having TDS in the range of 247-490 and 1971-2127 mg/l respectively. High value of TDS in L block was observed (980 mg/l) as water was supplied from Goverdhan drain in 2013.The high value of TDS (more than 1000mg/l) was not suitable for bird's activity. Water from Goverdhan drain is having very high value of TDS and does not seem to be suitable for the park.

The hardness of water can be understood by the amount of divalent salts; however, the calcium and magnesium are the most common ions responsible for water hardness. Calcium and magnesium are reported as the essential part of biological processes of fishes (bone and scale formation, blood clotting and other metabolic reactions) (Phyllis et al., 2007). Fish can absorb calcium and magnesium directly from the water or from food. A recommended range for free calcium in culture water is 25 to 100 mg/l (63 to 250 mg/l $CaCO_3$ hardness). In present study, the Ajan Dam, Chambal pipe line and Goverdhan drain water hardness (as $CaCO_3$) was observed in the range of 132-301, 60-165 and 510-640 mg/l, respectively. The Goverdhan drain water is having hardness in higher range which is not suitable for KNP. A total alkalinity of 20 mg/l or more is necessary for good pond productivity (William and Robert, 1992). All the three water sources are having salinity value higher than 20. As revealed from the Table 5.4, the D block is having low BOD as more water was supplied from Chambal project. The block L and E are having high TDS values (average values of 490 and 470 mg/l respectively) which was due to the supply of water from Goverdhan drain (in the year 2013 and 2014) having high TDS (1971-2127 mg/l).

Figures 5.3-5.6 are showing the variation in average temperature, BOD, pH and hardness respectively in different aquatic blocks of KNP. It is obvious that the temperature decreases August onward and minimum in December-February. Water is being supplied in these blocks generally during the period August to October and hence the BOD is higher in these months. The BOD was observed minimum in December and thereafter its value increases due to reduced water depth. The value of pH is higher in monsoon months as water is supplied to KNP. Hardness was observed maximum in L block as the Goverdhan drain water has been supplied. In fresh supplied water the concentration of calcium and magnesium generally remains high and decreases with time probably due to consumption by the fish.

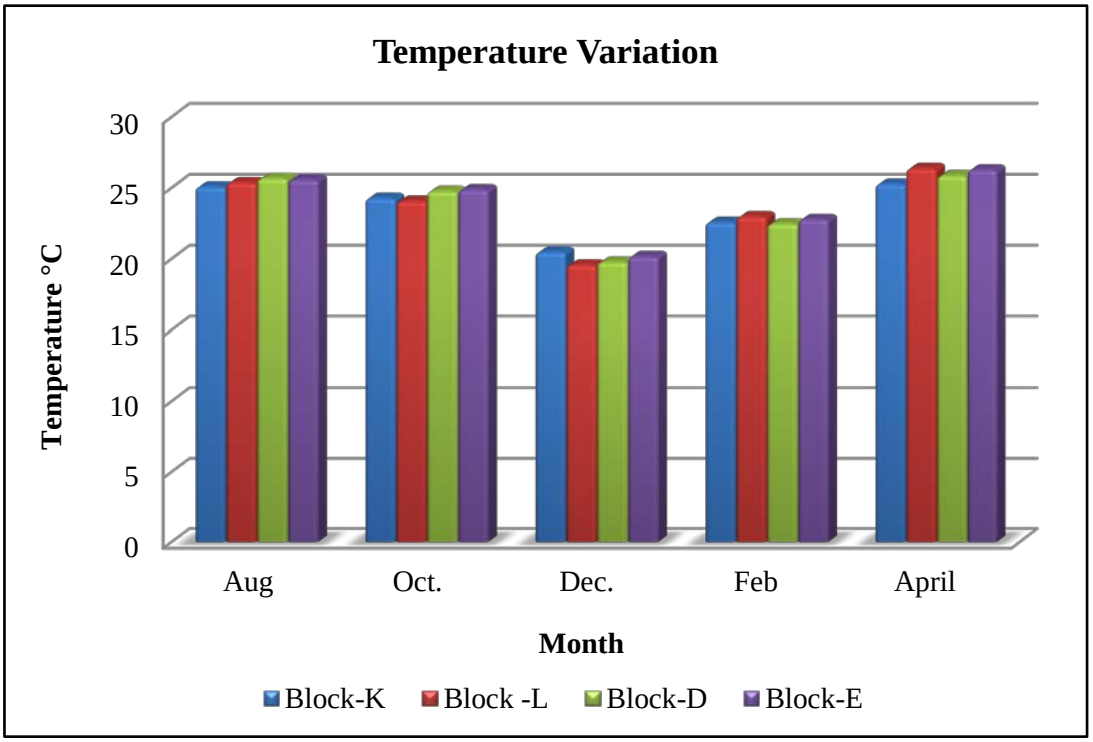


Figure 5.3: Variation of Temperature in different aquatic blocks of KNP during 2013-14

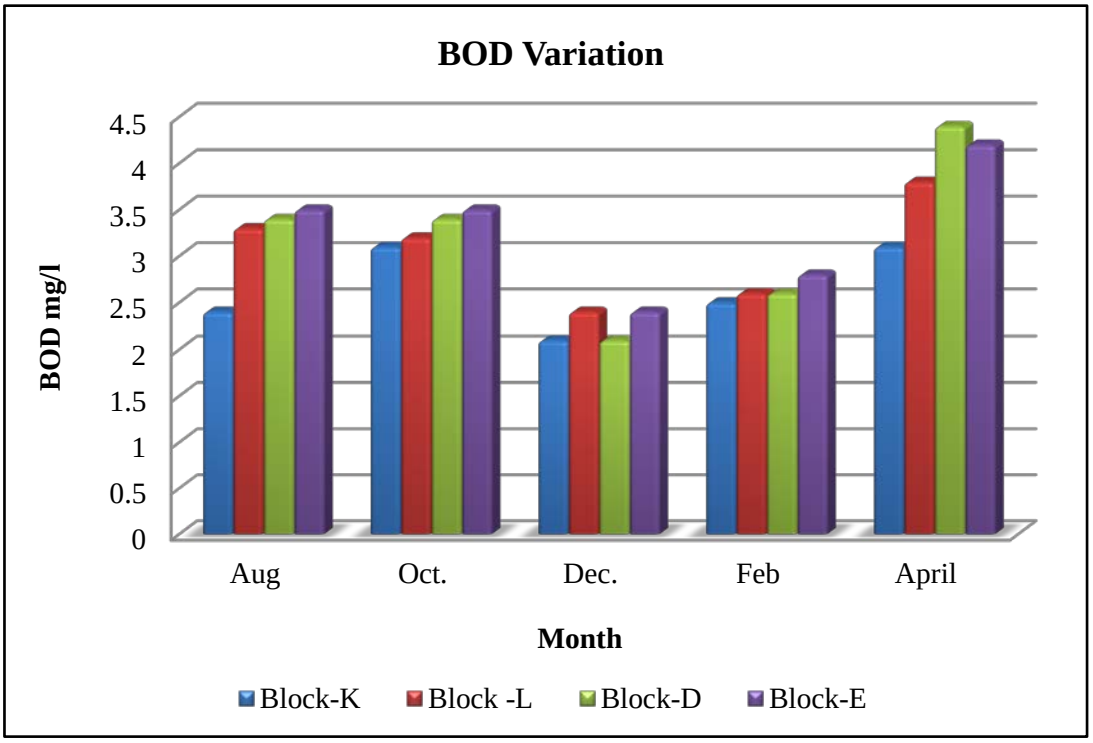


Figure 5.4: Variation of BOD in different aquatic blocks of KNP, during 2013-14

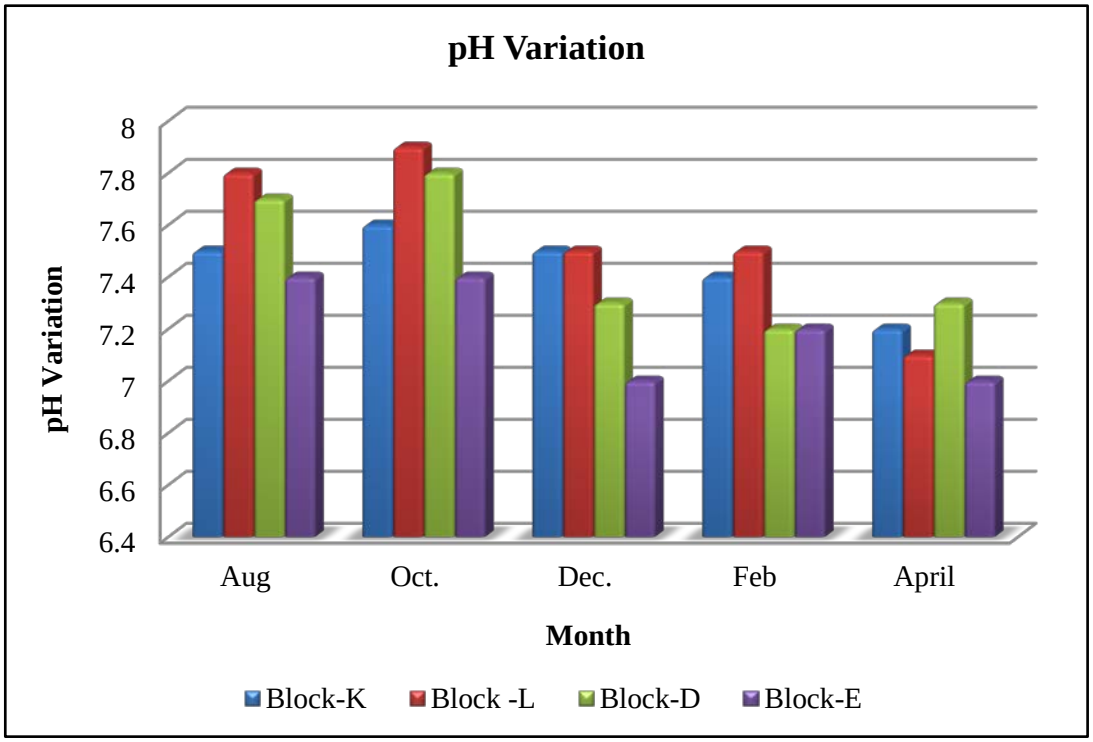


Figure 5.5: Variation of pH in different aquatic blocks of KNP during 2013-14

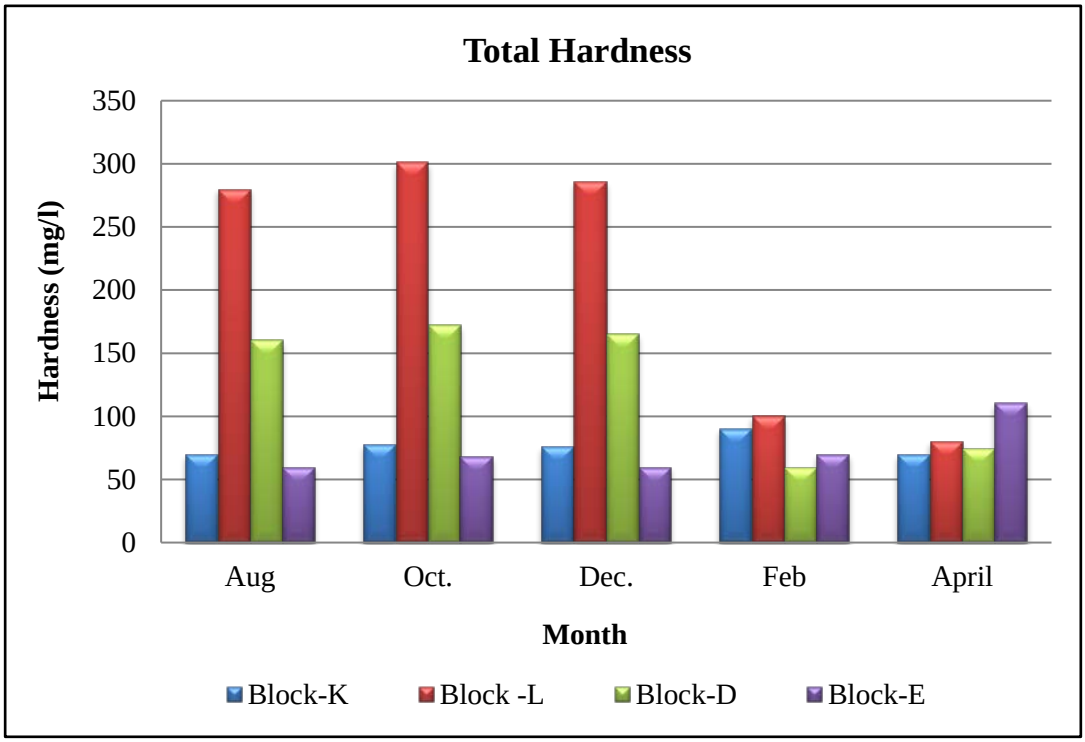


Figure 5.6: Variation of Hardness in different aquatic blocks of KNP, during 2013-14

In addition to the discussed physiochemical parameters, the biological values of the water sources affect the ecology of KNP. The Figure 5.7 is depicting the difference in the biological values of the water from two different sources.

Figure 5.7: Biological value of water sources to KNP (a) Ajan Dam water having plenty of fish quantity (b) The water from Chambal project is supplied through pipe line (c) Chambal project water outlet to KNP; having negligible amount of fish.

As observed, the water from Ajan Dam is having very good amount of fish, insects, planktons etc. On the other hand the water from Chambal project (drinking water) and Goverdhan drain, waste water (conveying through pipe lines) are having very less biological values.

5.1.4 Rainfall around KNP

The data for monthly rainfall and rainy days near KNP and annual rainfall in the surrounding catchment areas near KNP, from 2011 to 2014, are given in Table 5.6 and Table 5.7 respectively.

Table 5.6: Monthly rainfall and rainy days in the period 2011-2014 near KNP

Year	2011		2012		2013		2014	
Month	Rainfall (mm)	Rainy Days	Rainfall (mm)	Rainy Days	Rainfall (mm)	Rainy Days	Rainfall (mm)	Rainy Days
January	0.0	0	24.3	1	0	0	55.7	4
February	26.9	3	0.0	0	29.7	2	10.4	3
March	0.0	0	0.0	0	0	0	13.8	2
April	16.3	3	21.7	1	7.2	3	2.9	1
May	18.4	2	0.0	0	10.2	4	6.1	1
June	118.1	9	0.5	1	22.5	7	91.7	8
July	265.3	9	144.1	11	186.1	11	183.3	13
August	65.9	7	425.2	20	311.1	9	131.7	9
September	176.8	7	177.3	8	72.7	8	60	7
October	0.0	0	0.0	0	30.8	0	2.4	1
November	0.0	0	0.0	0	6	0	0	0
December	0.0	0	0.0	0	13.3	0	0	0
Mean/Total	687.7	37	793.1	42	689.6	44	558	49

(Source- Directorate of Mustard and Rap seed Centre, Bharatpur)

Table 5.7: Annual rainfall in catchment areas (at rain gauge stations) near KNP

Rain gauge station	Year (in mm)			
	2011	2012	2013	2014
Sewar	567	734	454	368
Uchain	623	568	627	621
Ajan Dam	911	811	425	459
Bharatpur	671	803	555	435
Sewla head	557	664	566	443
Baretha	652	679	572	565

(Source-Irrigation Department, Bharatpur)

The annual rainfall has been fluctuating between 688 and 793 mm during the period 2011-2014 as shown in Table 5.7. Maximum rainfall was 793.1 mm in the year 2012 which decreased to 558 mm in the year 2014. In this period Bharatpur and KNP catchment area received more than average rainfall but not enough to carry surface runoff in wetlands.

5.2 Human associated activities

Wetland habitats in KNP have been presently rendered vulnerable due to numerous human associated factors (Dass et al. 2013; Yadav et al, 2014). The most common human related activities, due to which the KNP ecology is facing problem, are

- Construction of many minor dams/bunds in the river basin
- Agriculture and Irrigation in the river basin
- Constructions of Highway
- Increasing urbanization
- Hotel Activities in the vicinity of KNP

50 dams and bunds have been constructed in the basin area of the Gambhiri River. Total 202 Mm^3 water has been stored in major and minor irrigating projects. It has increased the irrigating area by 48000 ha in the surrounding catchment area of dams. Construction of dams and increased irrigation has reduced the water inflow to the Ajan Dam as shown in Figure 3.5.

5.2.1 NH-11 and urbanization along the periphery of KNP

Passing of highway, traffic volume on highway and increasing urbanization near the habitat area cause nuisance to the fauna in KNP. A national highway is passing along the periphery of KNP since 2008 due to which population and urbanization has extended up to the KNP. The approach of highway and urbanization are shown in Figure 5.8. The National highway is passing just outside the entrance of the park [Figure 5.8 (a)].

Figure 5.8: (a) Shows national highway passing 30 m away from KNP entrance and (b) Development of residential and commercial construction 200 m away from KNP

Along the highway, the hotel activities and other constructions are in constant progress could be seen from inside the park [Figure 5.8(b)]. During the study period, the average traffic volume per day on the NH-11 is given in Table 5.8. The data suggests that the traffic volume has increased 3.7 times during 2011-14 near KNP on National Highway. Hourly traffic flow has been recorded on 23 November, 2012 and is given in the Tables 5.9.

Table 5.8: Average daily traffic volume on NH-11 in the period 2011-2014

Vehicle Type	Year			
	2010-11	**2011-12**	**2012-13**	**2013-14**
Car-Jeep / LMV	635	1769	2442	2674
LCV	125	352	447	503
Bus/Truck	196	777	547	540
Heavy Truck	403	479	831	831
Multi Axle	137	698	926	990

(Source-Toll plaza, Ludhawai, Bharatpur)

Table 5.9: Hourly traffic volume passing around KNP on NH-11, as recorded on 23rd November, 2012

	Agra to Jaipur				**Jaipur to Agra**			
Time	**Cars /LCV**	**Buses**	**Trucks**	**Multi Axle**	**Cars/ LCV**	**Buses**	**Trucks**	**Multi Axle**
6-7 am	20	6	25	6	23	8	30	10
7-8 am	25	8	29	8	30	10	35	15
8-9 am	75	16	42	12	70	4	55	11
9-10 am	117	14	49	11	122	6	51	9
10-11 am	88	7	49	15	86	5	43	11
11-12 Noon	135	15	50	12	117	15	73	13
12-1 pm	150	17	44	12	152	23	67	23
1-2 pm	132	15	43	32	149	12	58	34
2-3 pm	79	9	42	12	110	10	37	15
3-4 pm	105	11	48	7	130	8	72	15
4-5 pm	146	14	75	11	181	21	70	24
5-6 pm	146	8	75	65	134	16	80	52
6-7 pm	167	13	67	87	154	12	75	65
7-8 pm	143	17	86	68	127	19	89	90
8-9 pm	74	15	73	55	65	18	60	80
9-10 pm	60	12	50	97	69	16	83	113
Total	**1662**	**197**	**847**	**510**	**1719**	**203**	**941**	**580**

It has been observed that the movement of light vehicles was prominent during daytime whereas during evening and night the movement of heavy vehicles and loaded trucks was more in number on the NH-11. Merging of the traffic from Bharatpur town side and the national highway side, at Saras Circle and KNP entrance, is also increasing vehicles volume. Heavy vehicles produce extensive sound due to their horn, braking and hauling. Urbanization and the passing of medium and heavy traffic, from Saras circle to Polytechnic College, are creating noise problems. 20 cm high speed breakers (rumbles) were constructed on Saras circle and in front of the KNP (Figure 5.9) on NH-11. Due to these speed breakers, the hauling of vehicles (particularly heavy vehicles) has generating additional sound.

Figure 5.9: Speed breakers (20 cm high) constructed on NH-11 outside KNP gate

5.2.2 Hotel activities in the periphery of KNP

The main earning of the adjacent hotels and associated workers is due to foreign visitors because they prefer to stay for a longer duration. On the contrary 76% domestic visitors usually visit KNP for one day and do not prefer staying in hotels and only 20% stay for two days at weekend. However, nowadays decline in the number of foreigner visitor in KNP (Figure 5.35) has adversely affected the income of hotels adjacent to KNP. Due to the lowering of income from the tourist

(Table 5.15), the medium budget hotels which are marked in red in Figure 5.10 are providing their premises for the social activities (marriages). These activities in hotels create excessively noise as a result of rush of the vehicles, live bands, loud speakers, bursting of fire crackers etc.

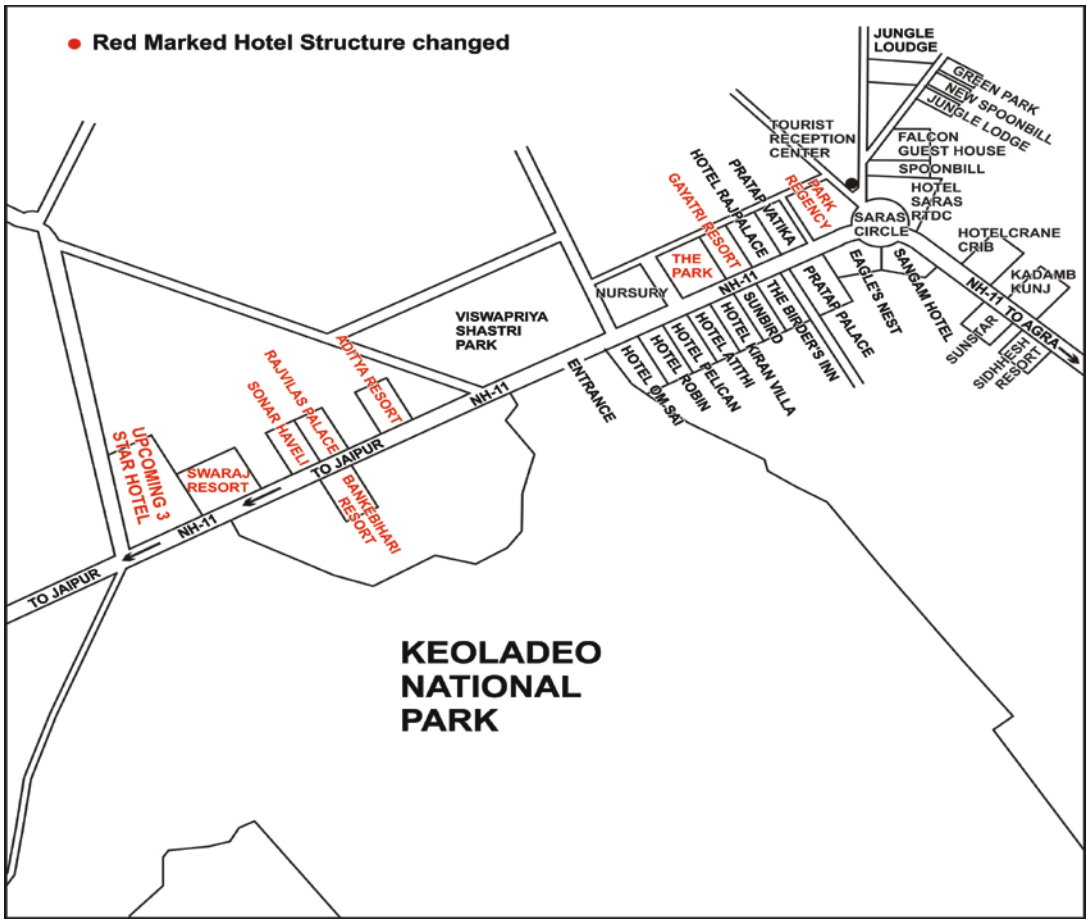


Figure 5.10: Hotels marked red around KNP available for marriages functions

5.2.3. Noise level around the periphery of the KNP

The National highway is just about 30 meters away from KNP entrance. This situation is very critical as it causes loud sound in the bird populated areas. Saras circle (road junction of NH-11, Bharatpur town side have mixed traffic) and the KNP main gate (road diversion NH-11, residential colony side have mixed traffic) are selected as main points to measure noise level due to traffic and speed breakers. Two other points have also been selected for the noise measurement as Polytechnic College and Siddhesh resort, Agra road on NH-11. The schematic diagram of National highway around KNP has been presented in the Figure 5.11.

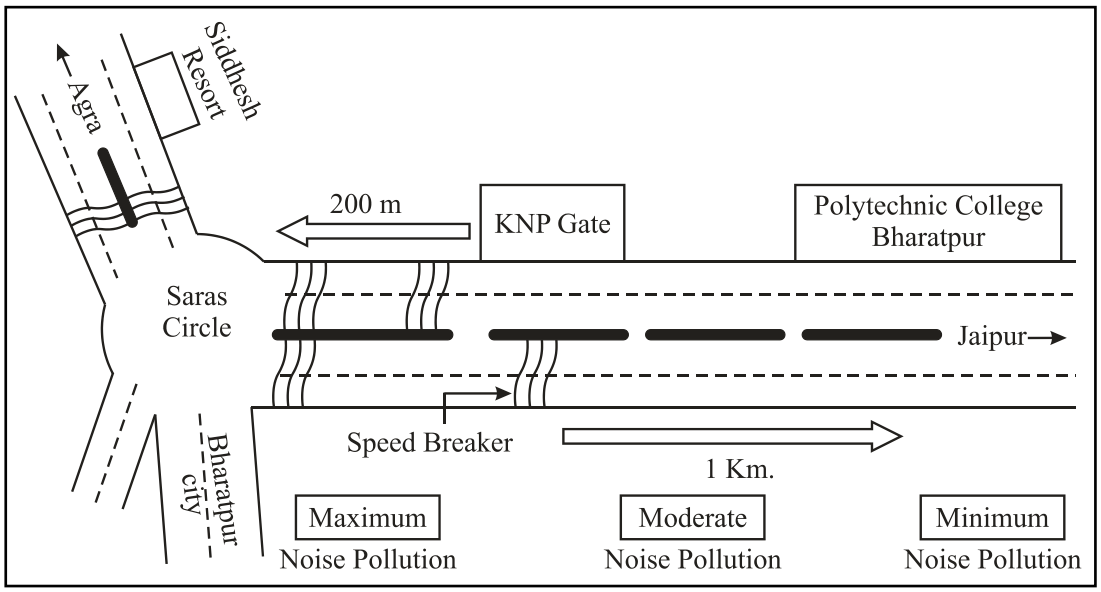


Figure 5.11: Schematic diagram of national highway around KNP showing distribution of rumbles, diversion and selected points to measure sound level

Different sampling sites for recording the sound level using SLM around KNP, the above mentioned four location are denoted as- Saras Circle (L1), KNP gate (L2), Polytechnic College (L3), Siddhesh Resort (Agra road (L4)) and given in Table 5.10.

Table 5.10. Location of various sites around KNP for sound measurement

Location on NH-11	**Site designation**	**Distance from KNP(m)**
KNP Gate, Site L1	L1	30
Saras Circle, Site L2	L2	200
Poly. College, Site L3	L3	1000
Siddhesh Resort (Agra road), Site L4	L4	500

Minimum (L_{min}), maximum (L_{max}), equivalent (L_{eq}) noise level has been recorded during September to December in 2012-14. The average Minimum (L_{min}), maximum (L_{max}), equivalent (L_{eq}) noise level, noise climate (NC) and noise pollution level (L_{np}), due to traffic have been presented in Figure 5.12-5.15.

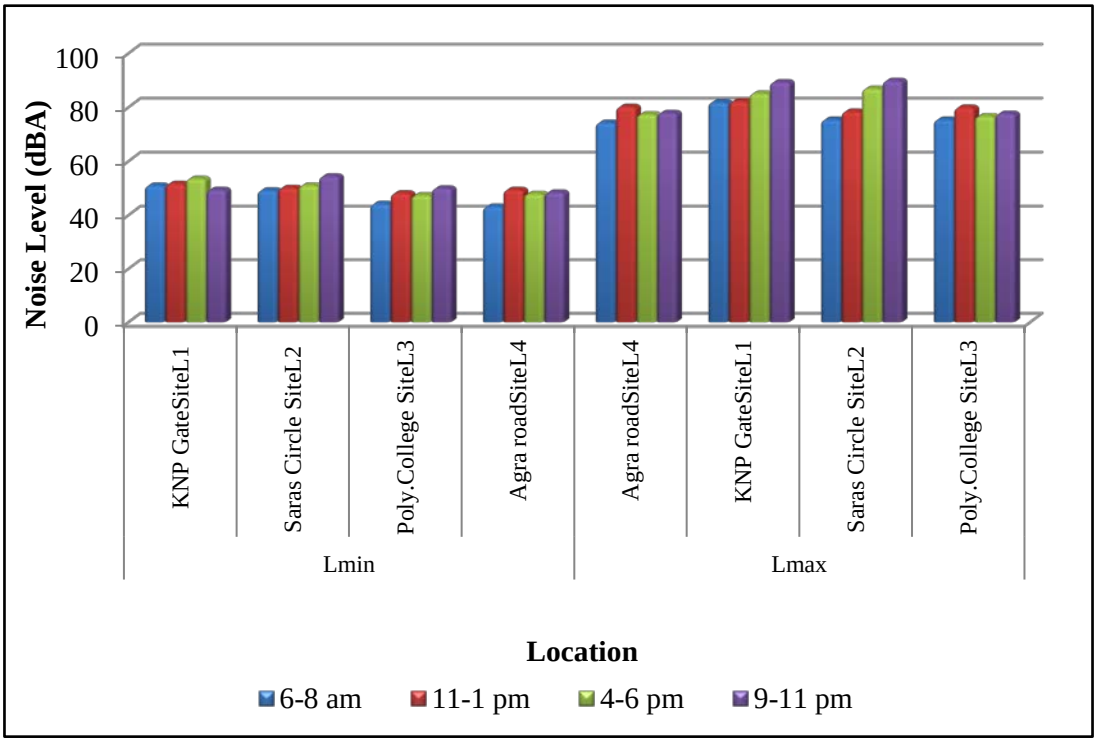


Figure 5.12: Average values of L_{min} and L_{max} due to traffic around KNP

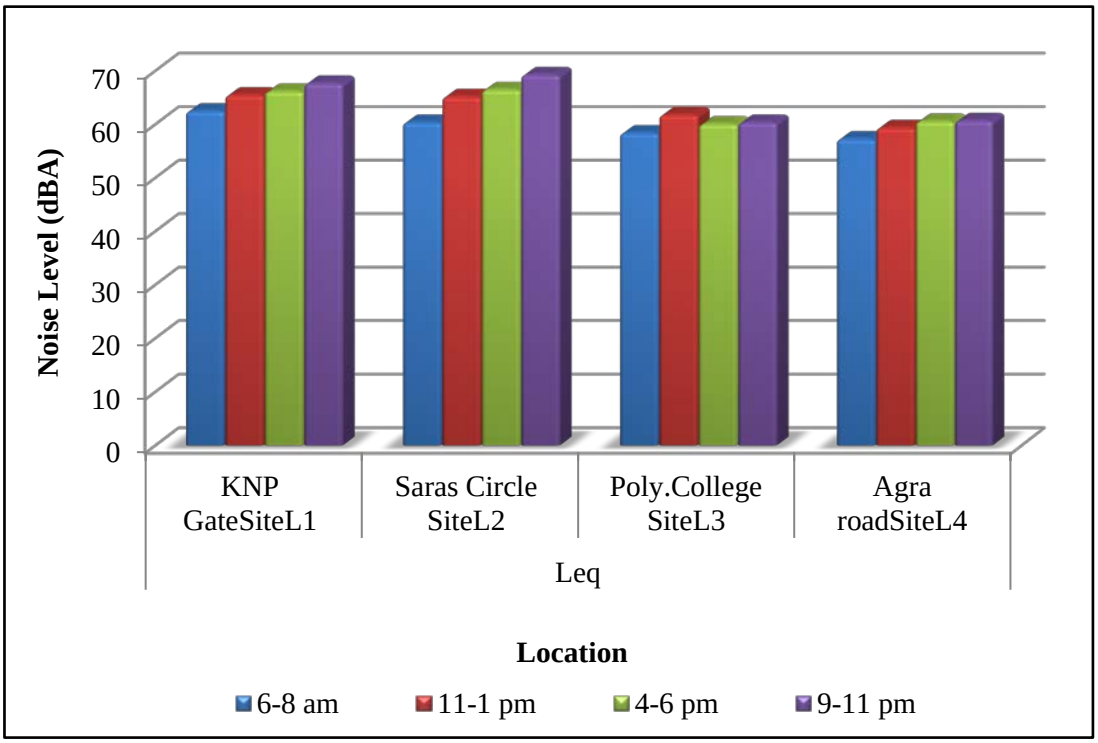


Figure 5.13: Average values of L_{eq} due to traffic around KNP

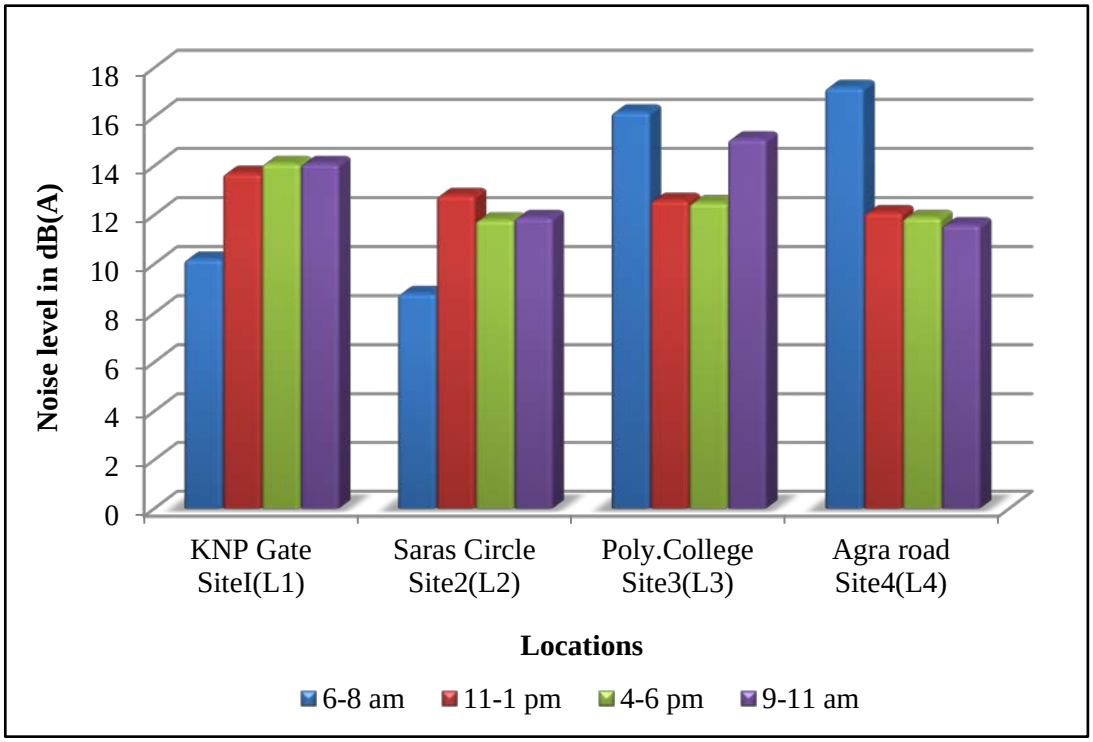


Figure 5.14: Average values of Noise Climate (NC) due to traffic around KNP

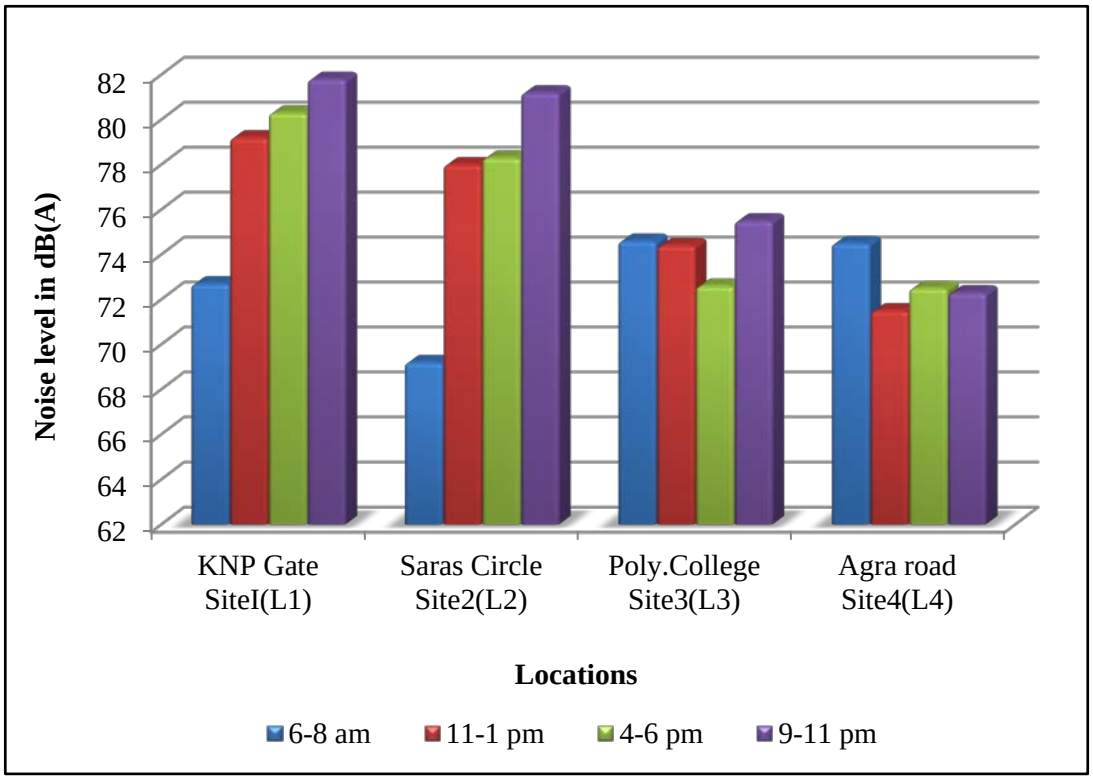


Figure 5.15: Average values of Noise pollution (L_{np}) due to traffic around KNP

The average noise level during marriage season around KNP (during 3-28 October, 2013, 6-18 December, 2014) has been recorded and presented in Figure 5.16-5.19.

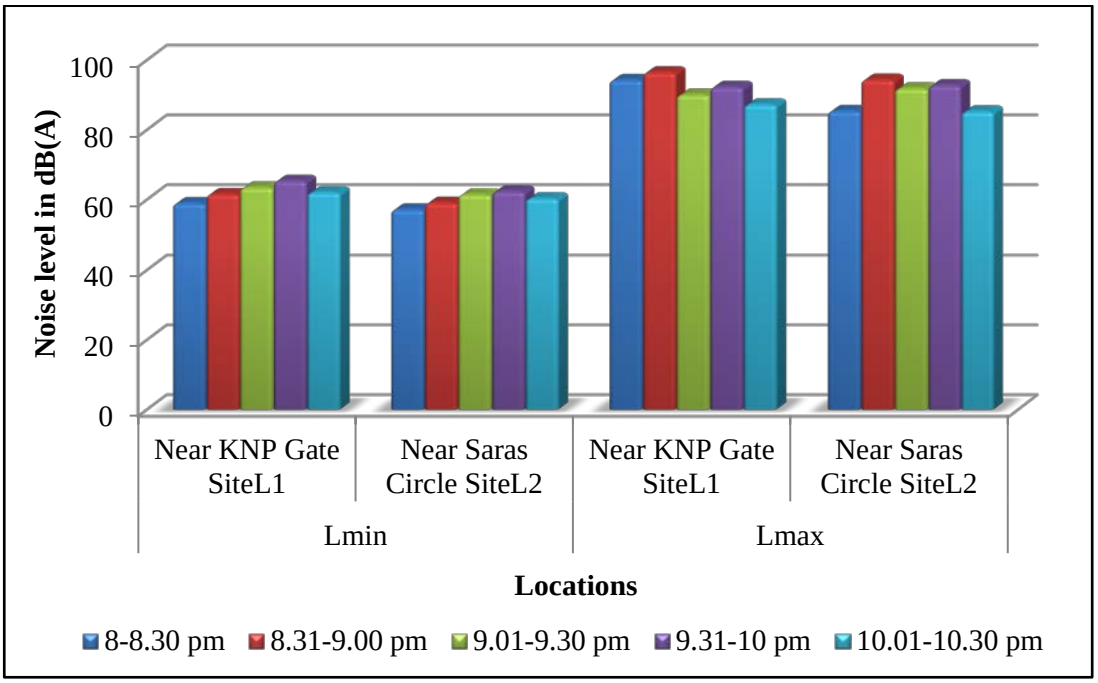


Figure 5.16: Average values of L_{min} and L_{max} during marriage function around KNP

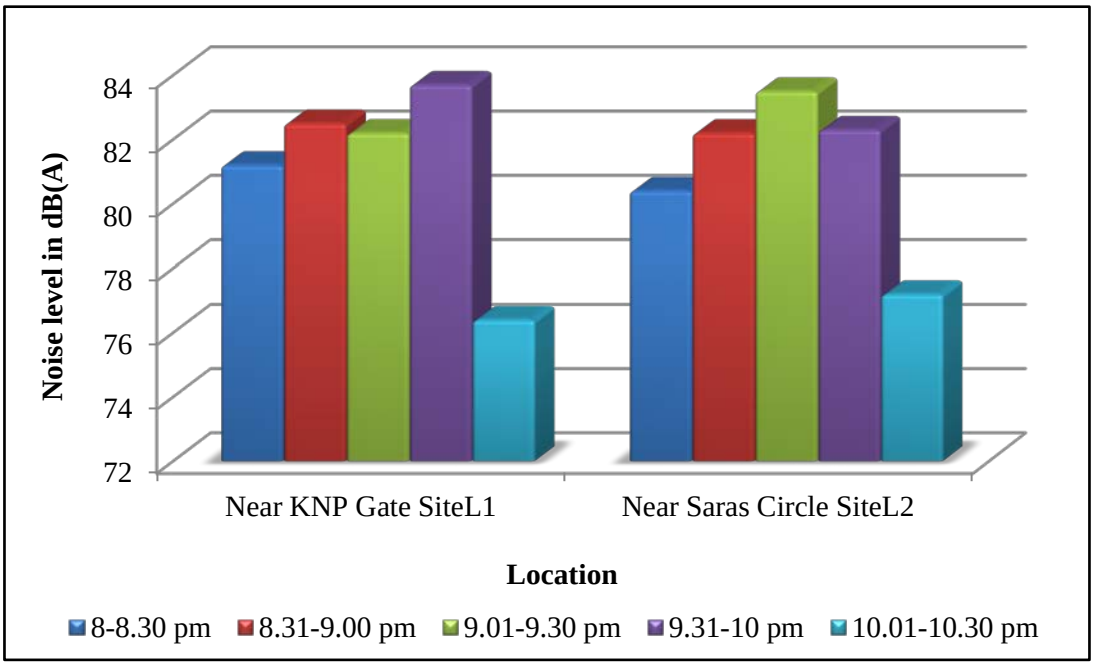


Figure 5.17: Average values of L_{eq} during marriage function around KNP

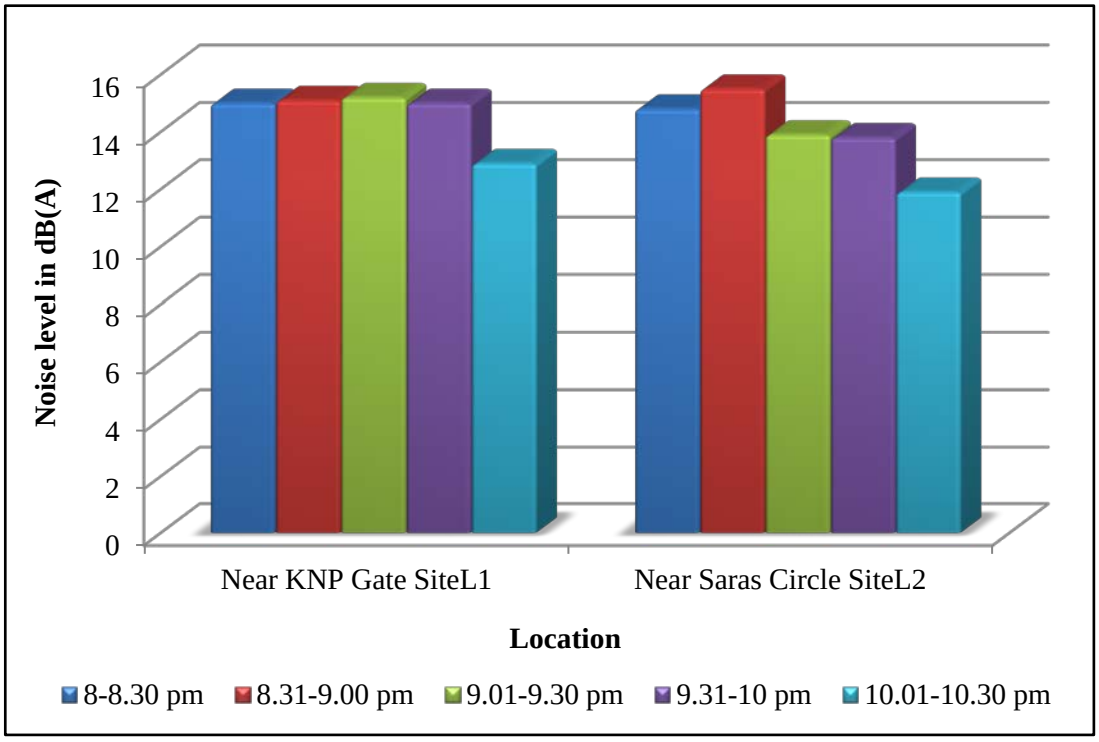


Figure 5.18: Average values of Noise Climate (NC) during marriage function around KNP

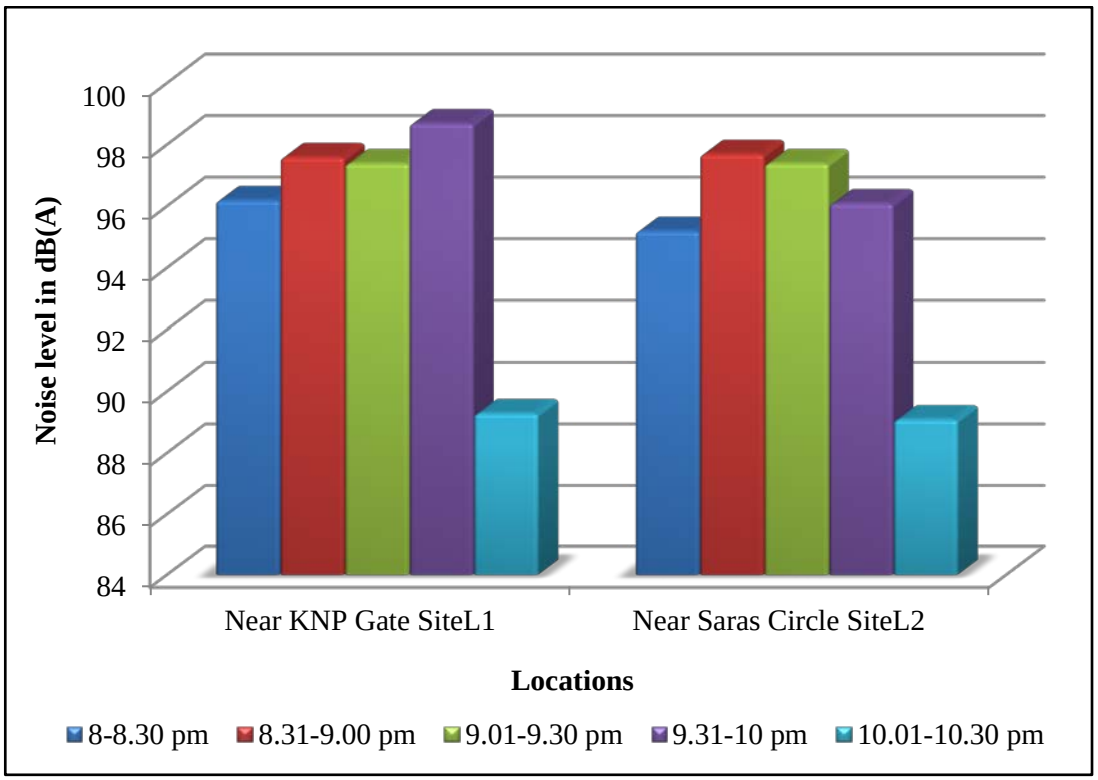


Figure 5.19: Average values of Noise Pollution (L_{np}) during marriage function around KNP

The minimum noise level L_{min} (43.2 dB(A) due to traffic flow on NH-11 around KNP at Siddhesh resort Agra road during morning time (6-8 am) and the maximum L_{max} (89.8 dB(A) at Saras circle at night (9-11 pm) were recorded. The average equivalent noise level increases from morning to night and was observed maximum during night at all the 4 sites. The traffic flow in night is more harmful for birds due to higher equivalent noise levels e.g. 62.5 to 67.7 dB(A) at KNP gate, 60.4 to 69.3dB(A) at Saras Circle. The average equivalent noise level was lower at Polytechnic College (58.4 to 60.4 dB(A) and at Siddhesh resort, Agra road (57.3 to 60.7 dB(A) which can be attributed to the smooth traffic. The average noise pollution (L_{np}) varied from 72.7 to 81.8 dB(A) at KNP gate and from 69.2 to 81.2 dB(A) at Saras Circle. Lower L_{np} values have been recorded at other two sites (varied from 71.5 and 75.5 dB(A)). The lowest equivalent noise level due to traffic in the morning was observed at Siddhesh resort Agra road 57.3 dB(A), which was higher than the prescribed noise limits for the silence area category. Similarly, the maximum average equivalent noise level in the evening and at night were observed at Saras circle 66.5 dB (A) and 69.3 dB (A) respectively, which were also much higher than the prescribed noise limits foe Eco sensitive zone area.

During marriage function in hotels around KNP L_{min} 59 dB(A) and 57.2dB(A) were observed near KNP gate and Saras circle road at night (8 pm) whereas L_{max} 96.5 dB(A) and 94.4 dB(A) was recorded near KNP gate and Saras circle road during night (8.30 pm).

During marriage season most of the hotels around KNP are engaged in ceremonial activities mainly at night from 8.00 pm to 11.00 pm. NH-11, near KNP entrance crowded with live bands, fire crackers and mixed traffic which creates noise. The average equivalent noise level increases at night from 8.00 pm to 10.30 pm around KNP and thereafter decreases. The equivalent noise level varies between 76.4 -83.7 dB(A) and 77.2-83.3dB(A) near KNP gate and Saras circle road. It shows that during marriages equivalent noise level are much higher than those due to traffic alone. These are highly disagreeable to nearby human and biota. Noise climate around KNP during night are fluctuating 13.9-16.2 dB(A) and 14.6-16.8dB(A) at KNP gate and Saras circle road respectively. Continuous loud sounds due to live

bands and traffic noise at night during marriages can annoy (physiological behaviour) resident and migratory birds in KNP. The average noise levels, around KNP, are well above the prescribed limit 50 dB(A) (CPCB, 1998); creating more stressful environment for birds and for nearby peoples.

This high noise level is enough to pose problem for birds in KNP. It distracts birds staging and breeding activity. The continuous traffic flow on National Highway (NH-11) passing along KNP and the hotel activities in the vicinity of KNP are responsible for the noise pollution.

5.2.4 Effect of noise due to NH-11 in KNP

The noise level has been recorded at four different points and a pilot study has also been done to observe its effect on birds count in KNP near highway (NH-11). In the pilot study, seven survey points in KNP are selected on the basis of noise produced along NH-11 and nearby hotels at points 1, 2, and 3, vegetated land and Mallah village at points 4, 5 and near rest houses and residential colonies at points 6 and 7. The selected points are making a Z-pattern for bird survey as shown in Figure 5.20. High traffic volume on NH-11 and other human activities around KNP has been increasing noise level.

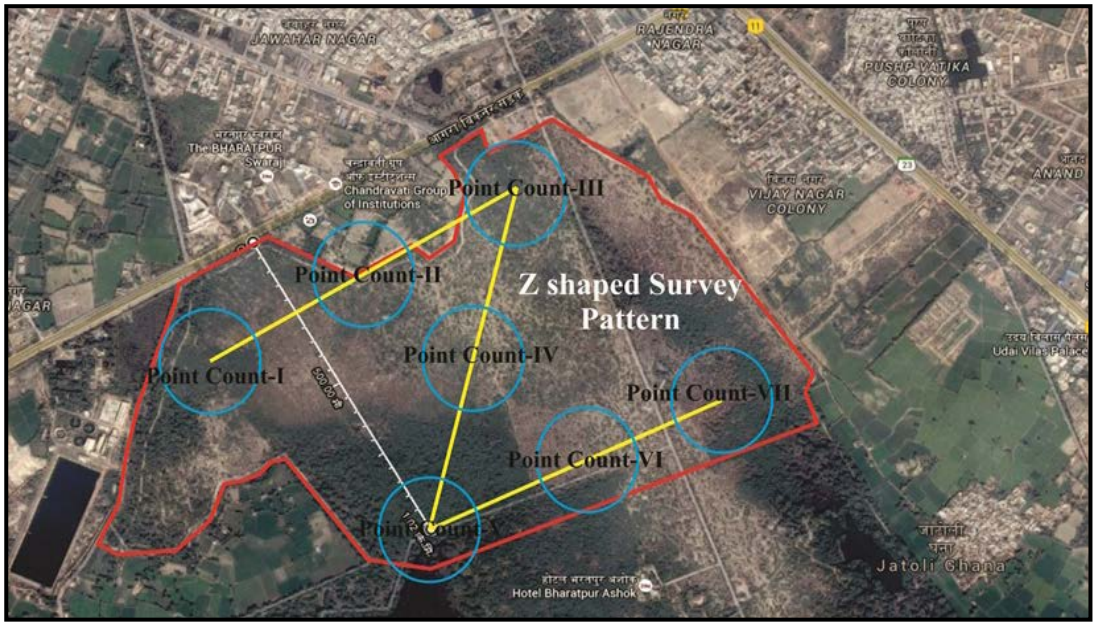


Figure 5.20: The scheme for pilot study to observe the effect of noise level on birds near highway in KNP as marked Z –pattern

Effect of noise level has been observed and bird's availability is surveyed on this Z shaped pattern in KNP. Table 5.11 shows the birds count and sound scales (sound level) at different points, as selected.

Table 5.11: Variation in the bird's count and sound level at different locations along the Z shape in KNP

	PC-1		PC-2		PC-3		PC-4		PC-5		PC-6		PC-7	
	Birds Count	**Sound Scale**	**Birds Count**	**Sound Scale**	**Birds Count**	**Sound Scale**	**Birds Count**	**Sound Scale**	**Birds Count**	**Sound Scale**	**Birds Count**	**Sound Scale**	**Birds Count**	**Sound Scale**
Morning	124	1	109	1	94	1	154	2	230	4	208	4	175	4
Noon	117	2	37	1	143	1	234	3	173	3	198	4	234	4
Evening	80	1	26	1	73	1	161	3	166	3	230	4	276	4
Average	107	1	57	1	103	1	183	3	190	3	212	4	228	4

Based on the pilot study, it was observed that

- Noise generated due to traffic and other activities was higher near highway and gradually decreased at farther points. Points 1, 2 and 3 were observed more noisy area than others.
- Bird's count at points 1, 2, and 3(200 m away from NH-11) was much less than at points 5, 6, and 7 (1000 m away from NH-11) and moderate number of birds was observed at point 4 (600 m away from NH-11).
- Bird's count was more in the morning than in the evening at points 1, 2 and 3 because sound level measured in the morning was much less than in the evening and at night. The count was least at point 2 as it is situated in noisy (due to high human pressure) and low vegetated area.
- As a whole, quite a fewer number of birds were recorded at these points compared to other areas in KNP.

Traffic noise could be the real factor limiting populations of birds in roadside habitats in KNP. It was also observed in the pilot study that the effect of high noise level has considerably depleted the number of birds from blocks near the highway in KNP.

5.3 Impact of the environmental changes on KNP

Each species of wetland-dependent bird has a unique composite set of needs. Therefore degradation of wetlands in many respects affects the biodiversity of the habitat. In general, the KNP's biodiversity mainly includes (i) vegetation (ii) birds and mammals during study. The above mentioned environmental changes have impact on the biodiversity as discussed in the subsequent paragraphs.

5.3.1 Effects on vegetation and mammals in the KNP

The aquatic vegetation contains 90 species of submerged and emergent plants and is a valuable source of food for water birds in KNP. Survival of migratory water birds mainly depends on valued source of food in aquatic vegetation(Ali and Vijayan, 1987). Inconsistent supply of water in KNP expands shrub woodland which is useful for terrestrial birds and mammals but not suitable for water birds. Excessive growth of aquatic knot-grass *Paspalum distichum*, a perennial amphibious grass, has also been observed. *Prosopis juliflora*, has also grown in the waterways which has reduced the staging site for the migratory birds. Changes in water area and vegetation in KNP are shown in Figure 5.21. It is found that the open water area has reduced whereas the non- vegetated area has increased in KNP.

Figure 5.22 shows the aquatic and terrestrial food chain in KNP which includes aquatic plants a primary food source for zooplanktons and birds. Due to reduced water area in KNP around 27 aquatic plants including *hydrilla*, *Najas*, *Ceratophyllum* and *Potamogeton* were base food for migratory birds not recorded. It has reduced primary food in aquatic blocks. On the other hand due to the increased non vegetated area i.e. increased terrestalization, the number of mammals has also been increasing in the park since 2008 onwards (Figure 5.23). Detailed data of mammals is presented in Apppendix-3. Thereby lack of suitable habitat in KNP has affected water birds adversely.

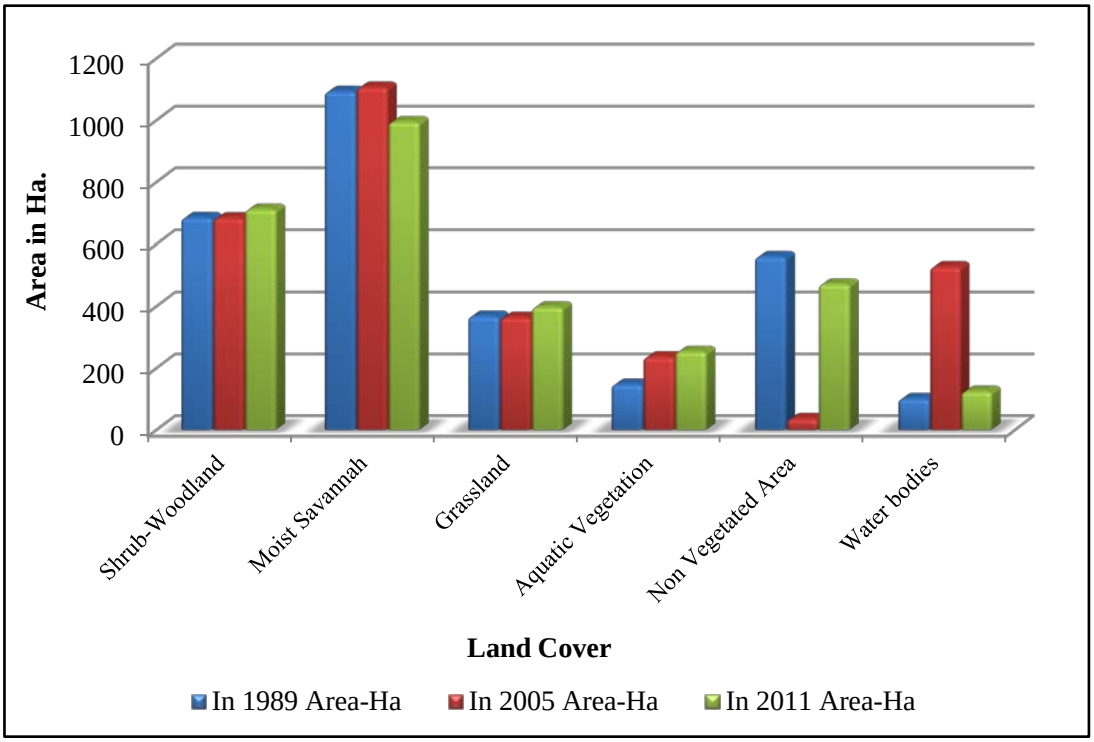


Figure 5.21: Change in land cover and aquatic area in KNP

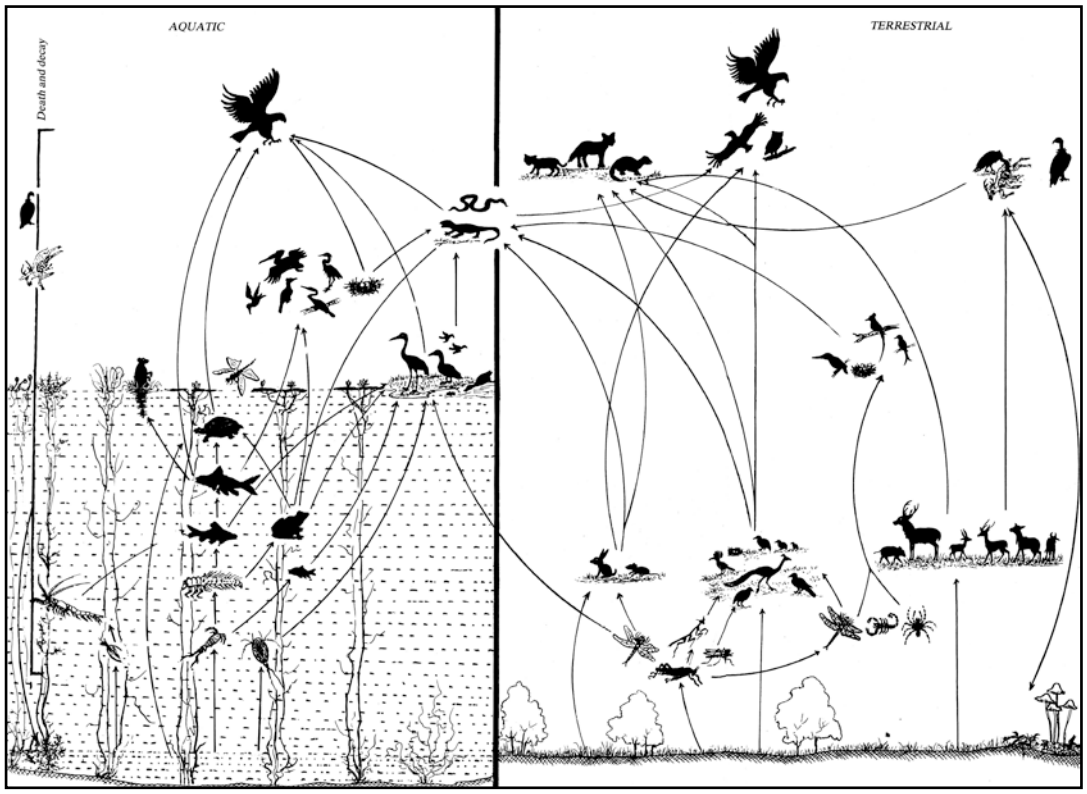


Figure 5.22: Aquatic and terrestrial food chains for bird in KNP
(Source-Sankhla, 1990)

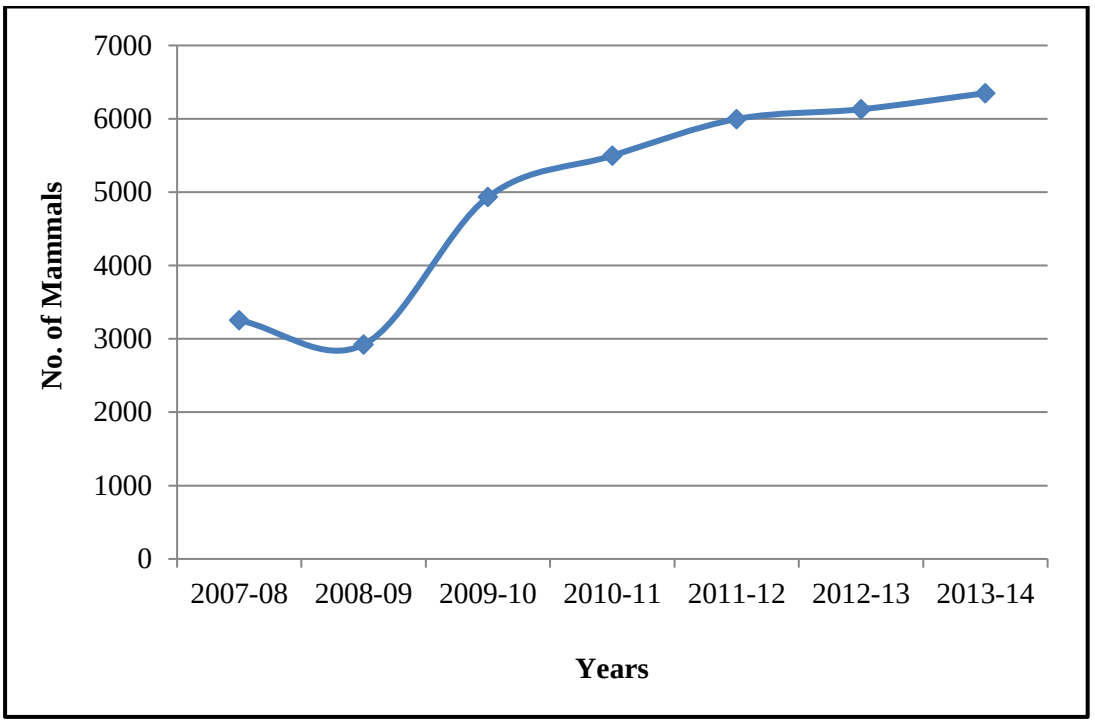


Figure 5.23: Change in population of mammals in KNP during period 2007-2014

5.3.2 Effect on the water-birds in KNP

Different species of birds have been observed in different aquatic blocks in KNP. Figure 5.24 shows birds' activity in the different blocks (viz. L, D, K and E).

Overall 84 breeding short distant resident and 71 winter migratory water birds were recorded during study period in KNP. Most of resident and migratory water birds were observed during winter time due to safe site, adequate food and suitable climate for nesting and staging. Breeding water birds such as *Large, Little, Cattle Egrets, Cormorants, Darters* and *Herons* were detected. Some of the resident and migratory birds as *Black Ibis, White Eyed Pochard, Mallard* and *Cotton pygmy Goose* are now rarely available in KNP (Appendix-4). *Dalmatian Pelican, Greater flamingos* and *Lesser Flamingo* are some migratory birds which have become rare in KNP wetland.

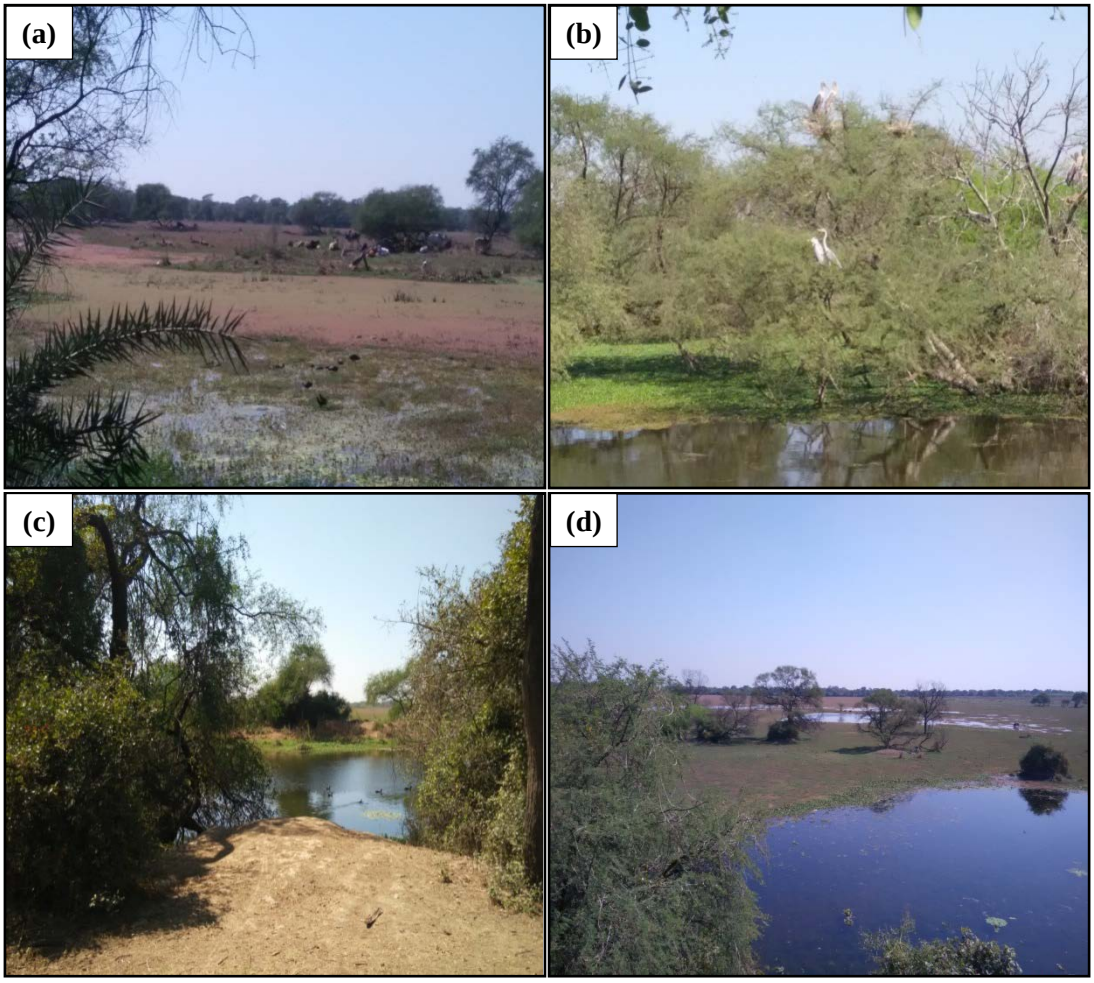


Figure 5.24: The bird activities in (a) L Block, (b) D Block, (c) K Block and (d) E Block

5.3.2.1 Impact on number of birds and species

The population trends for various selected bird species has been studied in KNP. The variation in population of selected resident and migratory bird species have been presented in the Figure 5.25 to Figure 5.28.

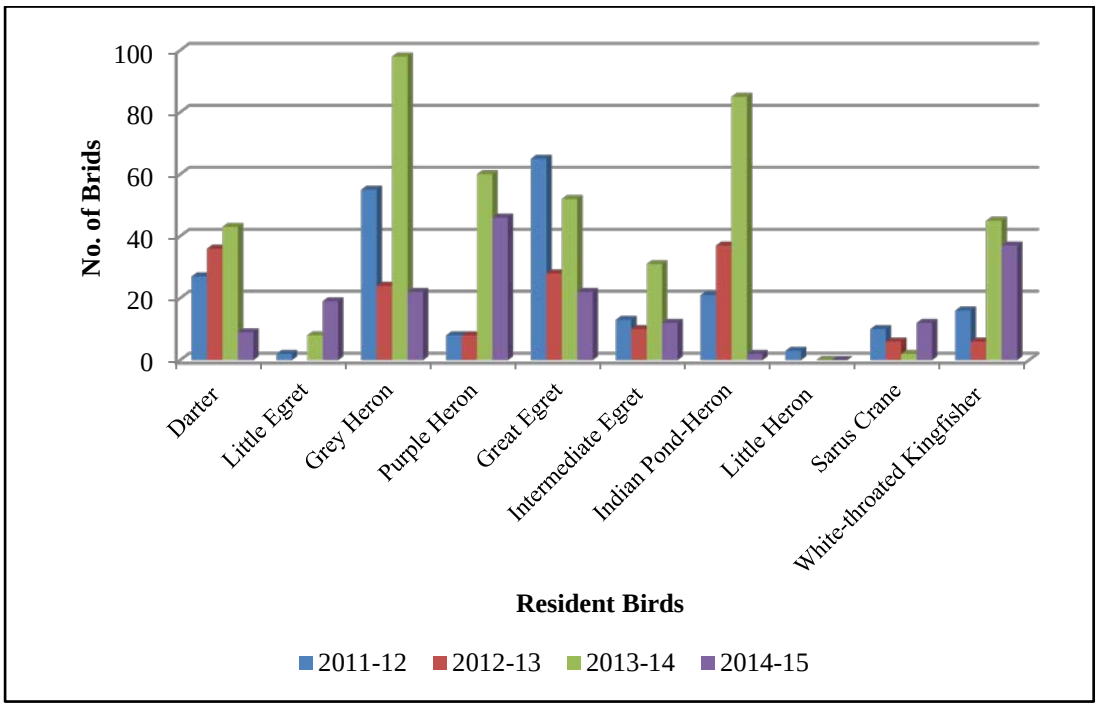


Figure 5.25: Variation in the number of vulnerable breeding resident birds in KNP

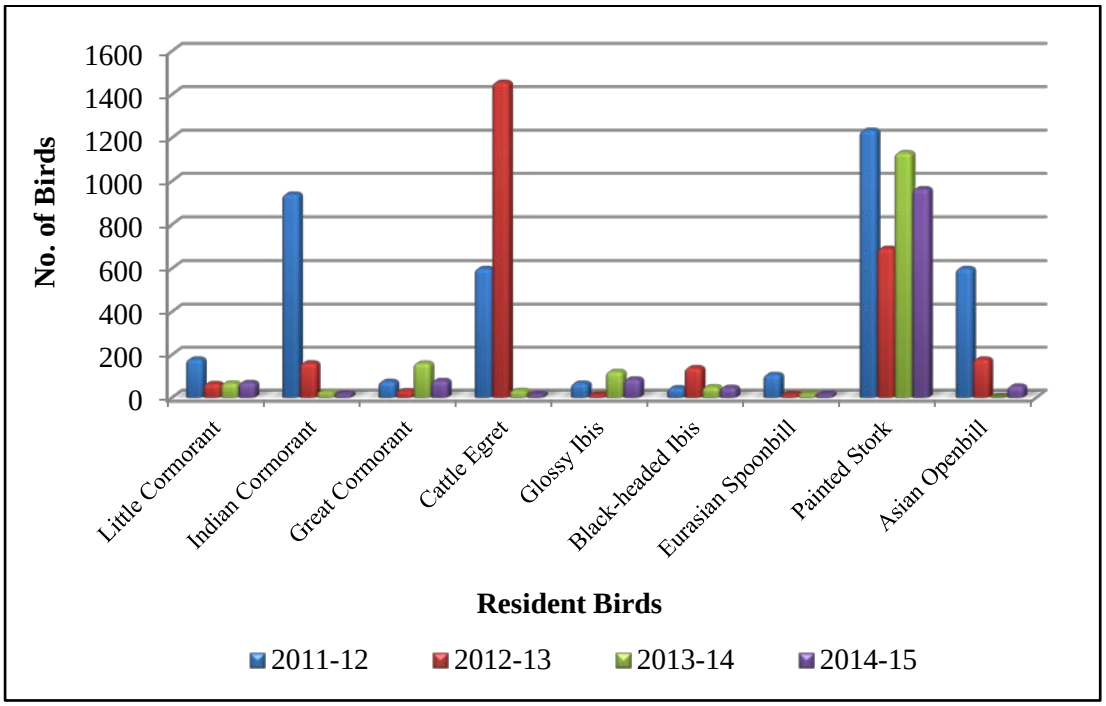


Figure 5.26: Variation in the number of common resident birds in KNP

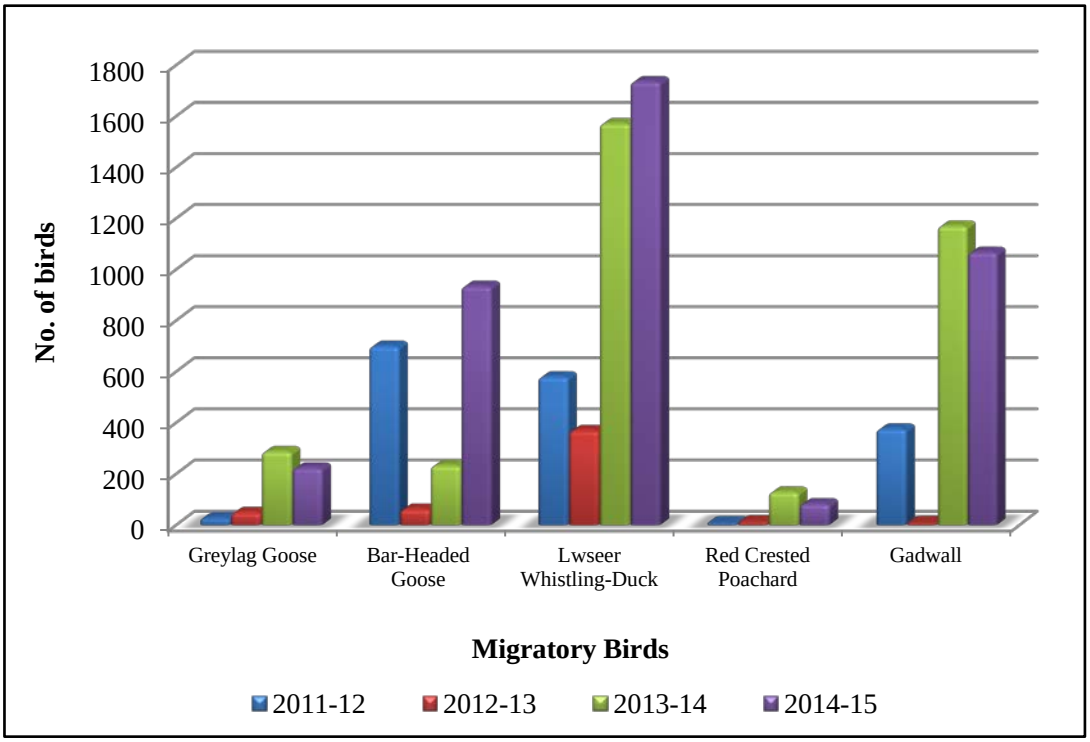


Figure 5.27: Variation in the number of common migratory birds in KNP

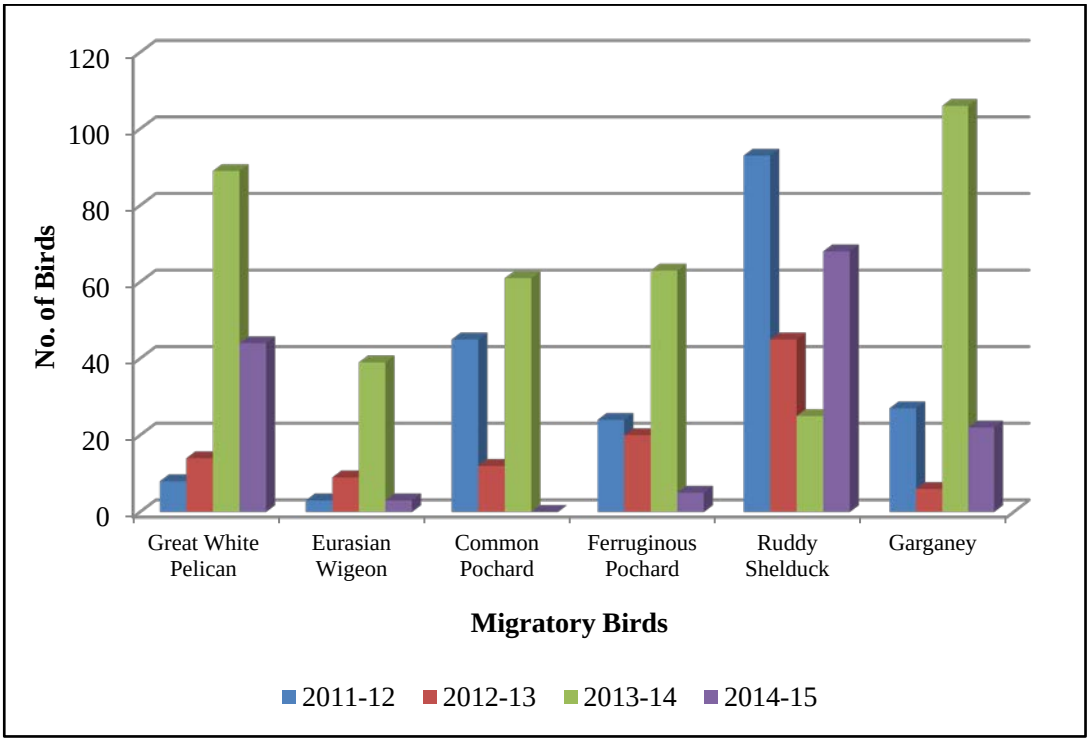


Figure 5.28: Variation in the number of vulnerable migratory birds in KNP

Data reveals that the population of birds of different species were showing inconsistent trend during the study period. The Population of vulnerable breeding resident birds such as *Grey Heron, Purple Heron, Great Egret* and *Indian Pond Heron* were much higher than the *Little Heron* and *Little Egret. Little Heron* and *Little Egret* are becoming rare in KNP. Similarly the population of common resident birds *Cattle Egret* and *Painted* Storks were more than the *Glossy Ibis, Eurasian Spoonbill* and *Great Cormorant.* However with the increase in water supplied to KNP during 2011 to 2013 population of resident birds have increased. During the same period common resident birds such as *Cattle Egret, Painted Stocks* were higher in number while *Glossy Ibis, Eurasian Spoonbill, Great Cormorant* were among the common resident birds that were reduced in KNP. In case of migratory birds *Red crested pochard, Eurasian Wigeon,* and *Garganey* were reducing and becoming rare to KNP while population of *Lwseer Whistling Duck* and *Gadwall* were higher than others. The reason for these inconsistent changes in migratory bird's population could be the frequent changes of water from other sources, its delayed supply to KNP and changed quality of water. These changes have been affecting the growth of aquatic plants (7 base food plants were not present) that subsequently impaired food chain causing declination in the bird's population and species in KNP.

The data in Figure 5.29 shows that the total number of common migratory birds is irregular and trend line is decreases up to 2014. The total water requirement of KNP is approximately 15.0 Mm^3 for maintaining KNP's biota. Inconsistency of water supply (Gambhiri river water from Ajan Dam, Figure 5.30) to KNP and frequent droughts in Bharatpur (Table 3.5) during the period of 2000-2008 were reasons for the declination of population of migratory birds in KNP. During the periods 2009-10, 2011-12 and 2012-13 overflow water from Panchana Dam through Ajan Dam was supplied to KNP. However, the trend line in Figure 5.30 is showing that the overall water supply from Ajan Dam is decreasing. Water requirement in KNP was also fulfilled from Chambal pipe line project and Goverdhan drain from 2011 onwards. Therefore total water in KNP has increased during the period 2011-2014 (from all sources). Even though, the overall water supply in the KNP

increased, despite of this, the number of migratory birds in the KNP is not increasing. The results suggest that the insufficient and irregular water availability in KNP from Ajan Dam is one of the reasons which resulted in declination of migratory bird's population in KNP.

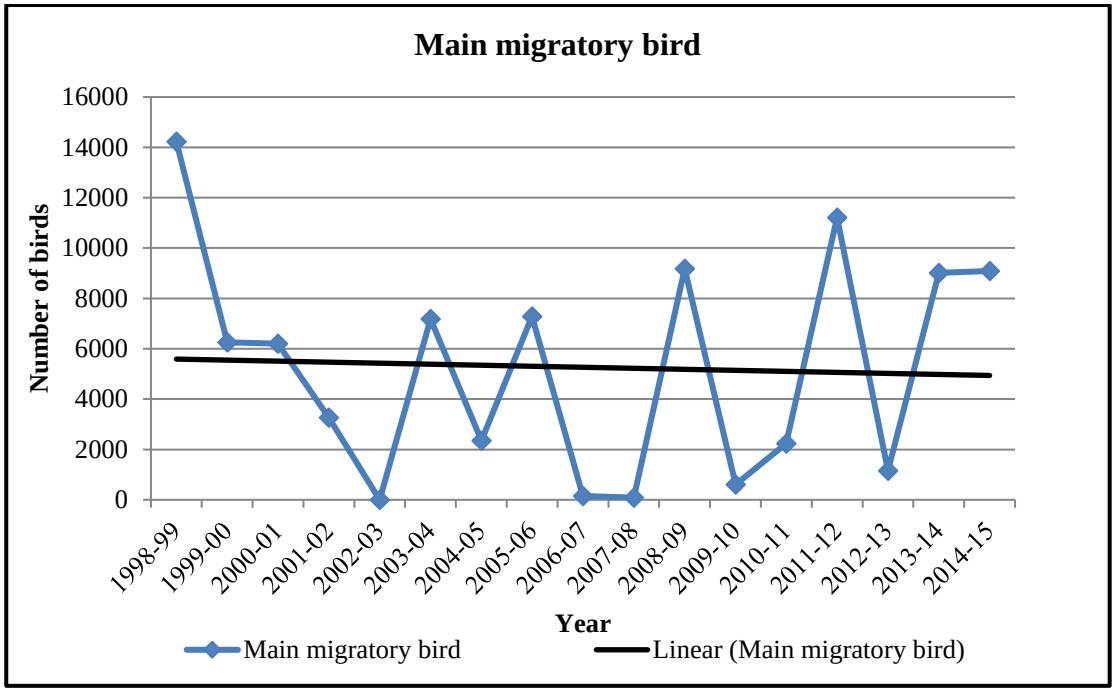


Figure 5.29: Variation in the number of migratory birds in KNP during 1998-2014

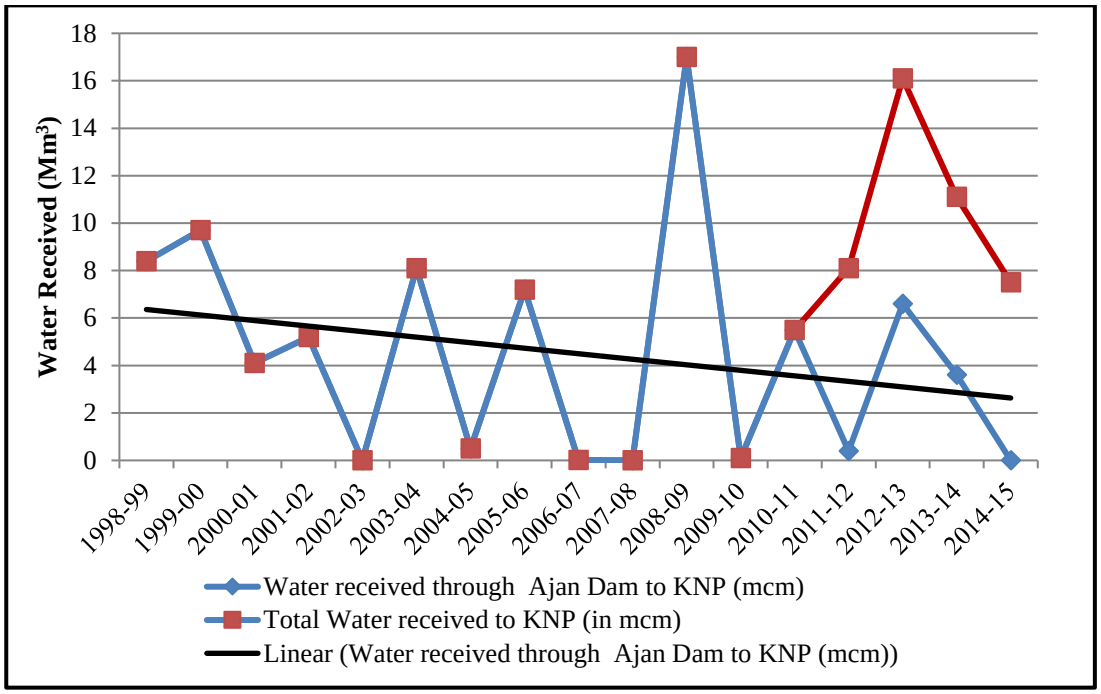


Figure 5.30: Variation in the water supply to KNP during period 1998-2014

Deshkar (2008) also studied that the birds are influenced by diverse environmental factors and should not be correlated with a single common abiotic factor of the wetlands, as studied for the semi arid zone of Gujarat. This suggests that there should be other factors responsible for decreasing number of birds. In the present case, the other possible factors are the lowering water quality in the alternative sources and the increased noise level due to the passing of NH-11. The water quality in KNP has changed due to the water supplied from alternative sources.

The noise level around the KNP has increased due to the passing of NH-11 and other human activities. The trend for noise level and number of migratory bird species, 2008 onwards is shown in the Figure 5.31. The trend shows that 2008 onward the noise level is increasing while number of migratory bird species deceasing. The noise level increased from 59.5 dB(A) to 76.4 dB(A) during the period 2008 to 2014.

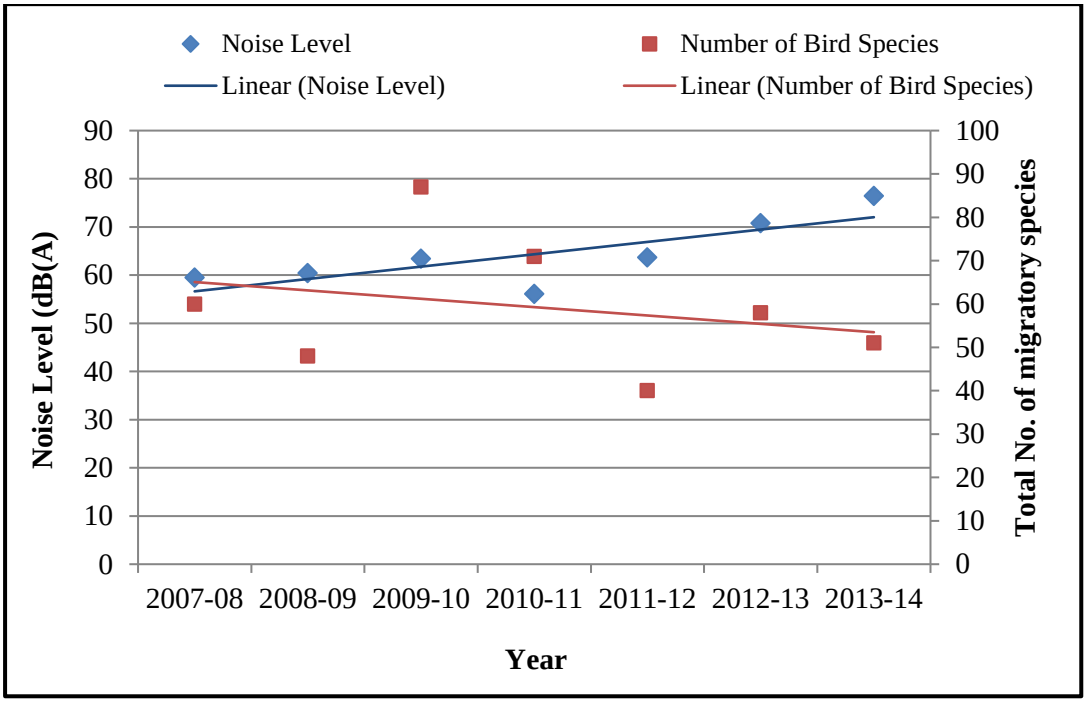


Figure 5.31: Variation in average ambient noise level and species of migratory birds in KNP

This shows that the number of species was decreasing with increasing noise level. The volume and noise of traffic may act in synergy to shift birds from habitats

next to noisy, busy roads. Parris and Schneider, (2008) investigated that a particular bird species may be more susceptible to the noise level. Susceptible bird species as Black-Ibis and Red Crested pochard might shift to other safer sites due to increased noise level around KNP (Figure5.33).

Figure 5.31 also indicates that number of migratory bird species is reducing with increasing noise level. The pilot study (section 5.2.4) has also indicated that the numbers of birds were very less near the highway in KNP. Therefore, the increased noise level is further depleting the birds near NH-11 in KNP. With the combined effect of various sound sources (viz. traffic volume and seasonal social functions) shows that the birds shift to the inner and deeper areas in KNP. As the high level of noise disturb behavioral aspects of birds (Foreman et al. 2002, Kumar and Dhankhar, 2015). Some of migratory birds such as *Black-Ibis*, *White Eyed Pochard*, *Mallard* and *Cotton Pygmy Goose* have now significantly decreased in KNP and became rare. The another consequence of inadequate water and increased noise around KNP is that the birds are shifting to other nearby satellite areas e.g. Bund Baretha, Talab-shai, Urmila Sagar etc. which is to be discussed in the coming section.

5.3.2.2 Shifting of birds in satellite wetlands areas

The birds are susceptible to the availability of aquatic areas, type of vegetation and human interventions in the habitat (Parris and Schneider, 2008). Due to these environmental changes, the bird species are also moving to nearby satellite wetlands such as *Talab-shai*, *Bund Baretha*, *Urmila Sagar* and *Redia bund* of Gambhiri and Banganga river basins. The bird's shifting phenomenon is dominant in the Bund Baretha satellite wetland area situated 60 km away from the KNP. So this wetland has been selected to record the shifting of bird population. Presence of birds has been recorded earlier in this area. Bund Baretha is situated in the drainage area of Gambhiri River having biologically rich water and low noise level. Significant number of birds, 14 species was observed in Bund Baretha during the study.

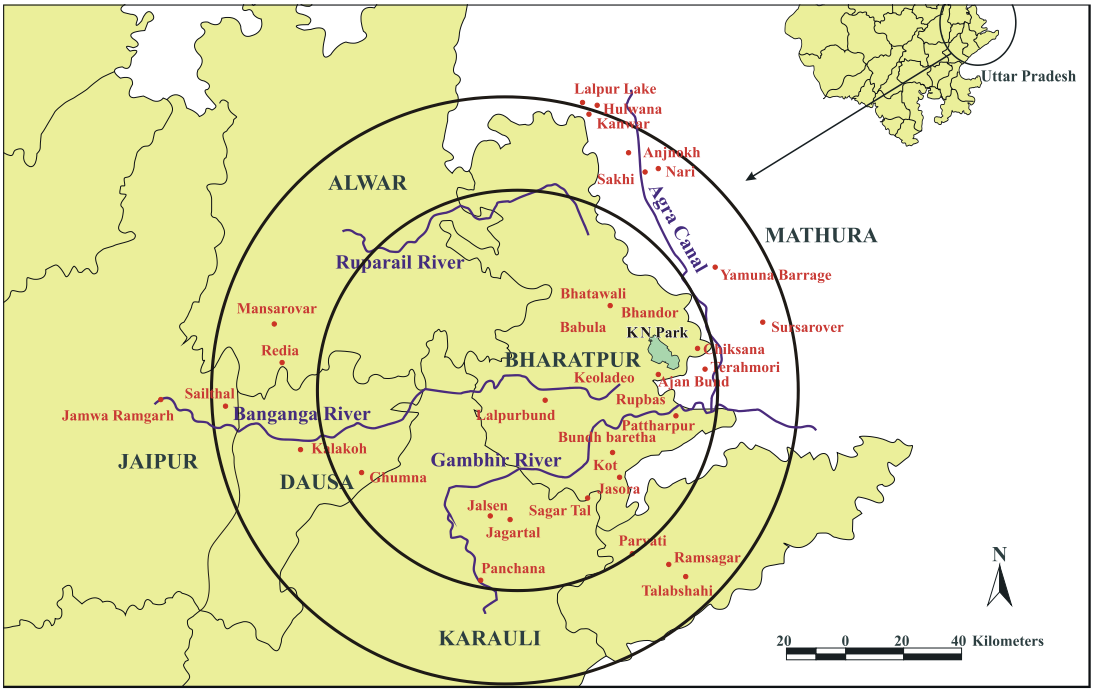


Figure 5.32: Positions of satellite wetland areas around KNP Bharatpur

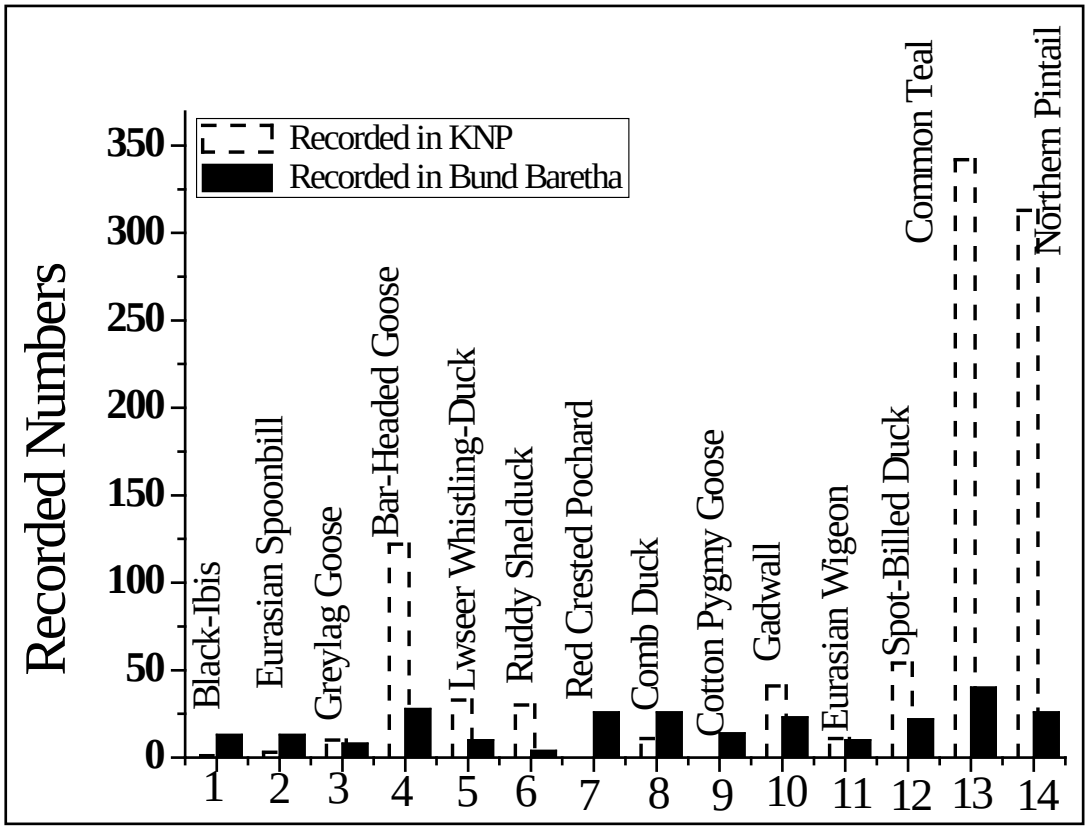


Figure 5.33: Migratory bird population in KNP and in Bund Baretha in 2013

The positions of 27 and 34 satellite areas within 100 km (smaller circle) and (bigger circle) around KNP are shown in the Figure 5.32 respectively (Bhadouria et al, 2012). The areas falling under smaller circle (100 km radius) are most dominant however the presence of birds has also been recorded in the areas falling under second circle.

A variety of birds has been recorded in the satellite areas. A comparative study of population of 14 bird species in KNP and in the Bund Baretha is presented in the Figure 5.35. Rare species to KNP as *Black-Ibis* and *Red Crested pochard* were observed in Bund Baretha indicating decline in KNP wetland. The variety of birds is also recorded in other main satellite areas in the basin of Chambal and Yamuna rivers during 2011-14, as given in Table 5.12. It shows that the birds arrived in KNP were also found in enough number at other satellite area.

Table 5.12: Main migratory birds observed in nearby satellite area of KNP during 2011-14

Species	**Satellite Wetland**					
	Talab-e-shai Dholpur	**Ram Sagar Dholpur**	**Urmila Sagar Dholpur**	**Abua Nangla Mathura**	**Mansarovar, Dausa**	**Redia Bund Alwar**
Black-Ibis	–	–	1	–	–	–
Eurasian Spoonbill	19	50	26	4	–	12
Greylag Goose	300	–	–	–	–	3
Bar-Headed Goose	–	–	245	–	136	136
Lwseer Whistling-Duck	–	–	–	–	–	–
Ruddy Shelduck	–	–	–	–	–	–
Red Crested Poachard	27	–	–	–	–	–
Comb Duck	–	–	–	–	–	–
Cotton Pygmy Goose	–	–	–	–	–	–
Gadwall	–	–	119	625	–	265
Eurasian Wigeon	–	–	76	–	–	112
Spot-Billed Duck	–	–	–	17	20	23
Common Teal	–	–	369	321	3	66
Northern Pintail	–	26	28	13	3	60

As significant number and variety of migratory birds have shifted to the nearby satellite areas, they can also be developed as eco-tourist sites for generating more income sources to dependent community.

5.4 Study of effect of the birds on the ecotourism and dependent local community

Tourism development in such natural sites needs proper balance in ecotourism and ecological structure for sustainability (Popesku, 2002). Due to some environmental changes, the number and variety of the birds have been reducing during the last decade thereby affecting the tourism pattern in KNP. Income of local people (rickshaw-pullers, guide and hotel staff) directly depends on tourism. Hence they are also facing problems and are struggling for survival.

As the variety of water birds and their activities are witnessed in winter season, thereby maximum tourists were observed during winter season as presented in the Figure 5.36. As clear from the tourist data, most of the tourists visit KNP September to February.

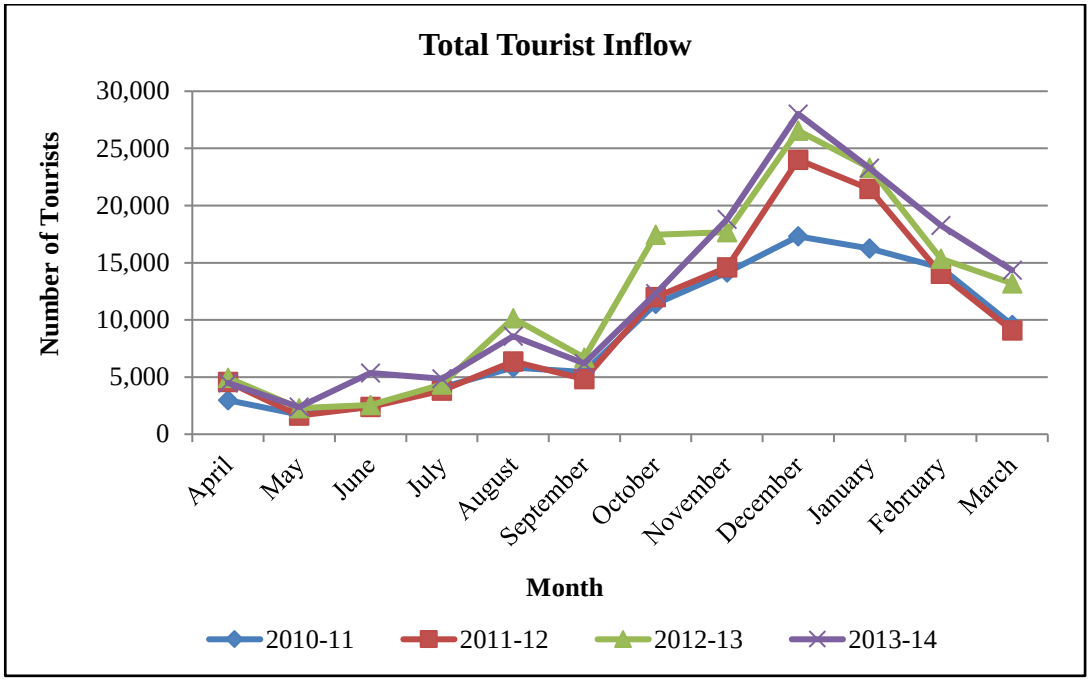


Figure 5.34: Monthly inflow pattern of total number of tourists in KNP (2011-2014)

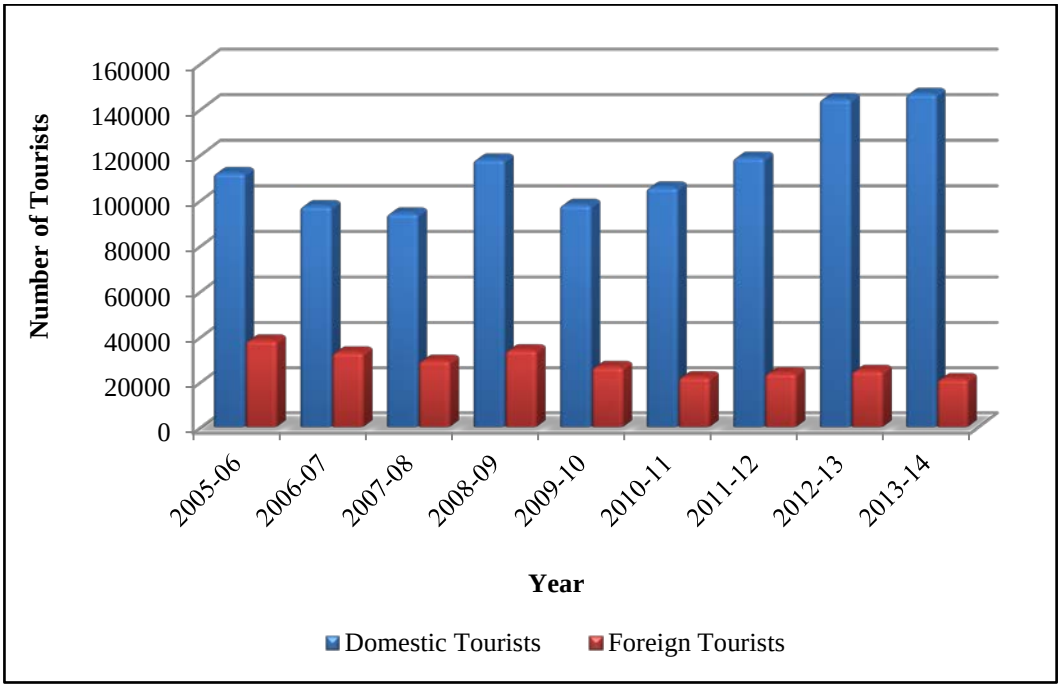


Figure 5.35: Comparison of domestic and foreigner tourists in KNP

Figure 5.35 shows the trend for domestic and foreign visitors, 2005 onwards, which indicates that the foreign visitors are reducing in number as compared to the domestic visitors in KNP. Foreign tourists generally visit KNP for long duration as compared to domestic visitors as surveyed. Major source of income of dependent local communities e.g. rickshaw pullers, guides and hotelier is due to the inflow of foreign visitors.

A study was conducted on tourists in KNP for their visiting, staying and expenditure incurred. A questionnaire was prepared and feedback was obtained from 936 tourists (Appendix 5A). Survey was conducted during the period from July to January when frequency of inflow of visitors was higher. On the basis of survey, it was found that over 69% of tourists visit KNP for up-to 4 hour/day. 15% of tourists visited for 4-8 hour/day, and 16% for full day. 66% of tourists visited KNP for the first time. The average time spent in KNP was almost 4 hours. Staying and site visiting duration in KNP is directly related to income for local dependents (guides and rickshaw pullers). Feedback of tourist survey is given in Table 5.13. 66% of tourists visit the park one session (morning/evening) and 15% for two sessions (morning and evening) respectively.

Table 5.13: Feedback of survey from tourists in KNP

N=936, Respondents, (% of frequency)		Tourist		Bird watcher/ Photographers	
		Domestic	Foreigner	Domestic	Foreigner
Visited to KNP	once	28	25	6	7
	twice	7	4	11	2
	More than twice	2	2	4	2
Average time spent in (hour/day)	<2	14	10	-	-
	2-4	16	13	9	7
	4-8	3	4	5	3
	>8	4	4	7	1
Visited park by	Foot	4	2	3	5
	Rickshaw/Guide	31	26	14	2
	Bicycle	2	3	4	4
Visited park in session-wise	one	26	21	14	5
	two	4	5	4	2
	More than two	7	5	3	4

Table 5.14: Visitor behaviour/knowledge and information about KNP

Number of respondents (% of tests N=936)		**Frequency in %**			
		Tourist		**Bird watcher/ Photographers**	
		Domestic	**Foreigners**	**Domestic**	**Foreigners**
Visitors		37	31	21	11
Gross Income (Monthly)₹	<20000	10	0	2	0
	20000 to 50000	19	10	12	3
	More than 50000	8	21	7	8
Interest in KNP	Aquatic birds	10	21	13	7
	Flora	2	2	4	1
	Mammal/Wild life	25	8	4	3

Table 5.15: Average daily expenditure by the domestic and foreign visitors

Type of visitors		Average length of stay (days)	Time spend	Average daily expenditure (in Rs.)				% of Total expenditure
			Hours	Rickshaw pullers	Guide	Hotel	Total daily expenditure	
Domestic visitor		1	3	600	-	-	600	8.33
Foreign visitor		2	6	900	600	800	2300	31.95
Bird watcher	Domestic	3	5	900	-	600	1500	20.83
	Foreign	5	8	1200	800	800	2800	38.89

51 % tourists showed interest in aquatic birds and 44% tourists having income more than 50000 Rupees were important for KNP ecotourism (Table 5.14). On the basis of feedback of tourist's average daily expenditure incurred on ecotourism in KNP has been given in Table 5.15. The feedback survey of visitors suggests 70.84% of total daily expenditure incurred by foreign tourists as compared to domestic visitors 29.16% on ecotourism in KNP. Thereby inflow of foreign tourists is significant factor for income of local dependents (rickshaw pullers, guides and hoteliers) as well as revenue generation for ecotourism in KNP. Overall reaction of visitors in KNP was such as (a) Overall condition of KNP: Good-13%, Worsen-52%, No response-35% (b) Future improvement in KNP is needed: Entrance fees should be reduced -23%, Facilities for tourist (café, rest rooms) -57%, Better means of transportation (E-rickshaw) in KNP – 20%.

As a result of decrease in number of foreign visitors, the local dependents are facing problems for their survival and are shifting their job to other domains also. The hotels, as a result of reduced number of visitors, are providing their premises to other social activities. Among 125 and 61 registered rickshaw pullers and guides only 65 and 30 are currently active in KNP respectively. The data suggests that almost half of them (50% of these local dependents) have shifted to other activities for their survival. The sources of income of nearby villagers are shown in the Figure 5.36, indicating that presently 43% of the villagers such as rickshaw pullers, guides and guards depend solely on the tourist activity. Survey result also revealed that they are more struggling for earning during summer than winter.

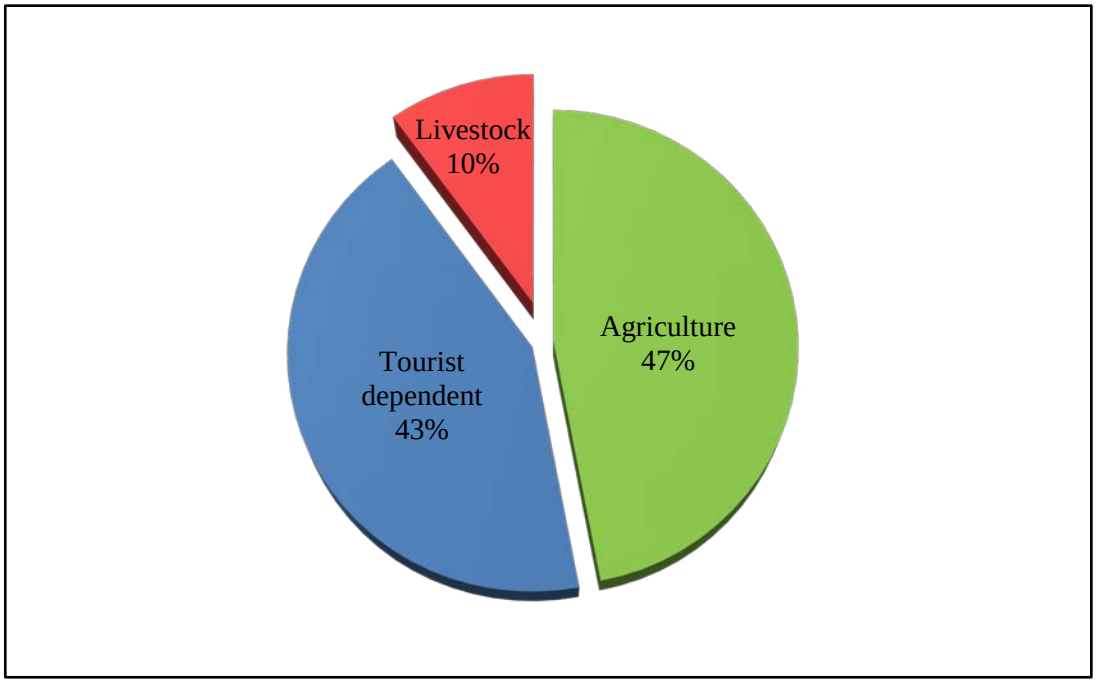


Figure 5.36: Income source of local dependents (nearby villagers)

Ecotourism in KNP is the major source of revenue generated in KNP as well as a main source of income for dependent community. Hence, it is essential to take some vital steps to increase the richness and their number of birds in the park so as to attract more number of foreign visitors.

5.5 Feedback of Public Representatives for KNP conservation

Effect of environmental changes on KNP has been decline in the wetland features as shrinking of water area, decrease in number and species of birds, etc.

Hence, feedback survey on current changes and for its conservation was obtained from public representatives including MLA, Mayor, Ward members and Sarpanch. A questionnaire was prepared (Appendix 5B) and their feedback for the KNP's conservation is presented in the Figure 5.37 to 5.40. They all agreed that timely and regular water supply to KNP must be maintained to preserve its ecosystem and 86% representative's emphasis the need to provide water in KNP from Panchana Dam.

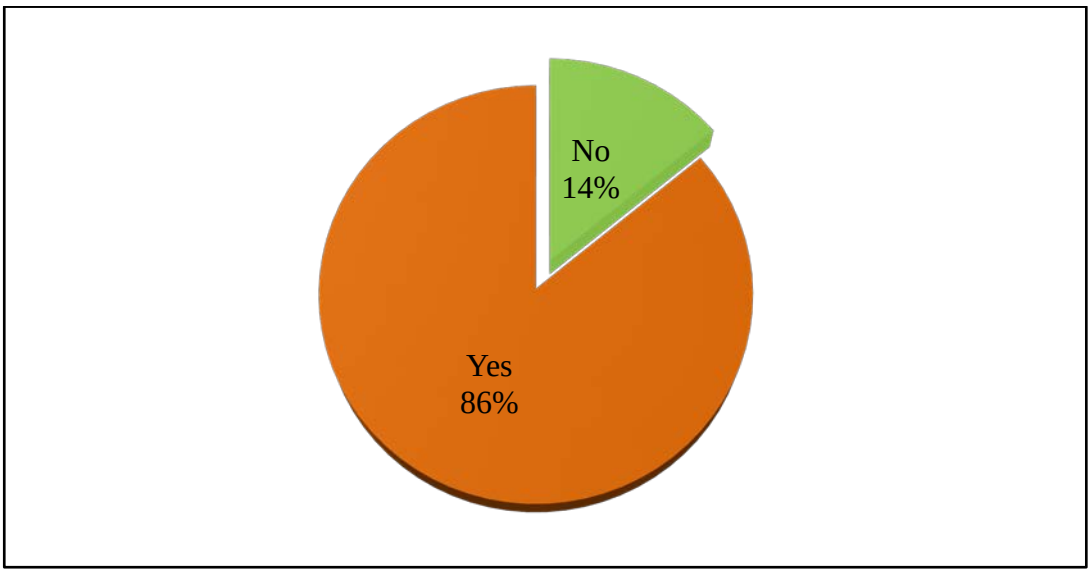


Figure 5.37: Water sources to KNP; whether the water should be supplied from Panchana Dam

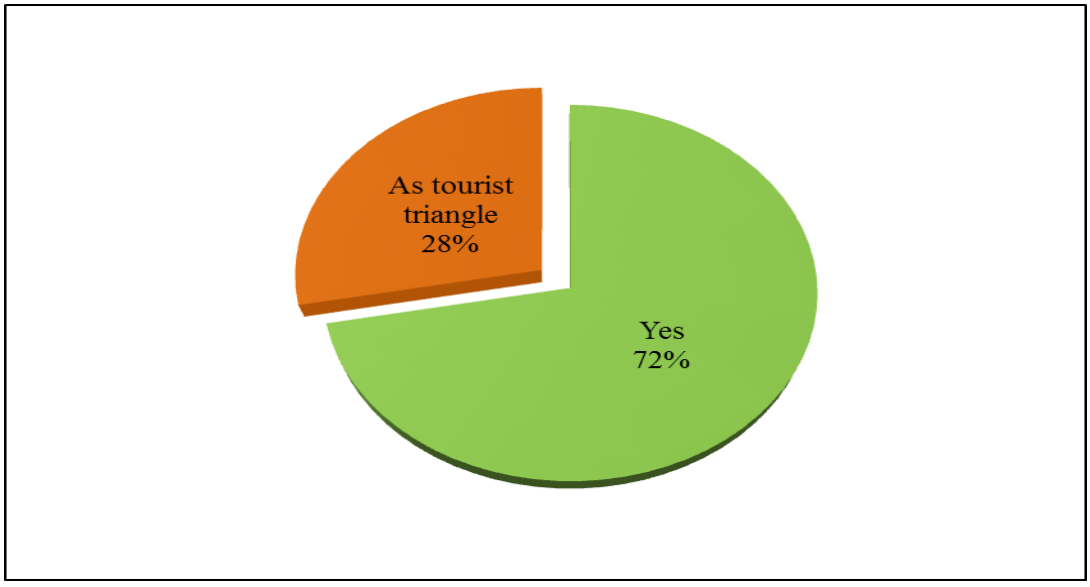


Figure 5.38: Bharatpur as tourism spot; whether the Bharatpur need special attention for developing as tourism place

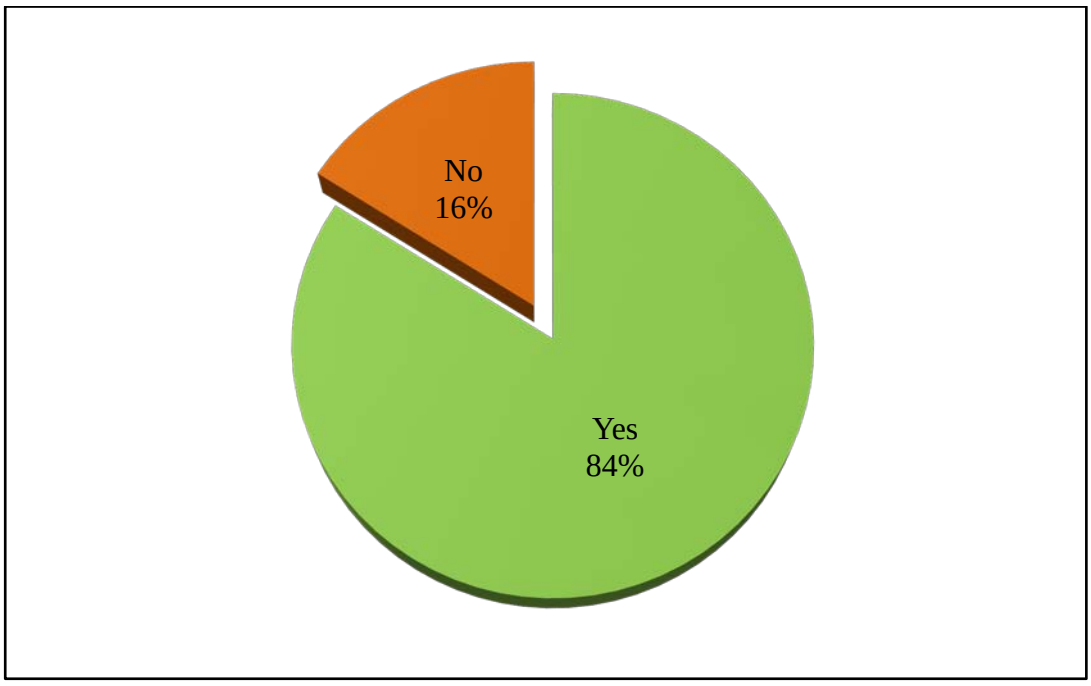


Figure 5.39: KNP as income source; whether the KNP is main income source for local dependents

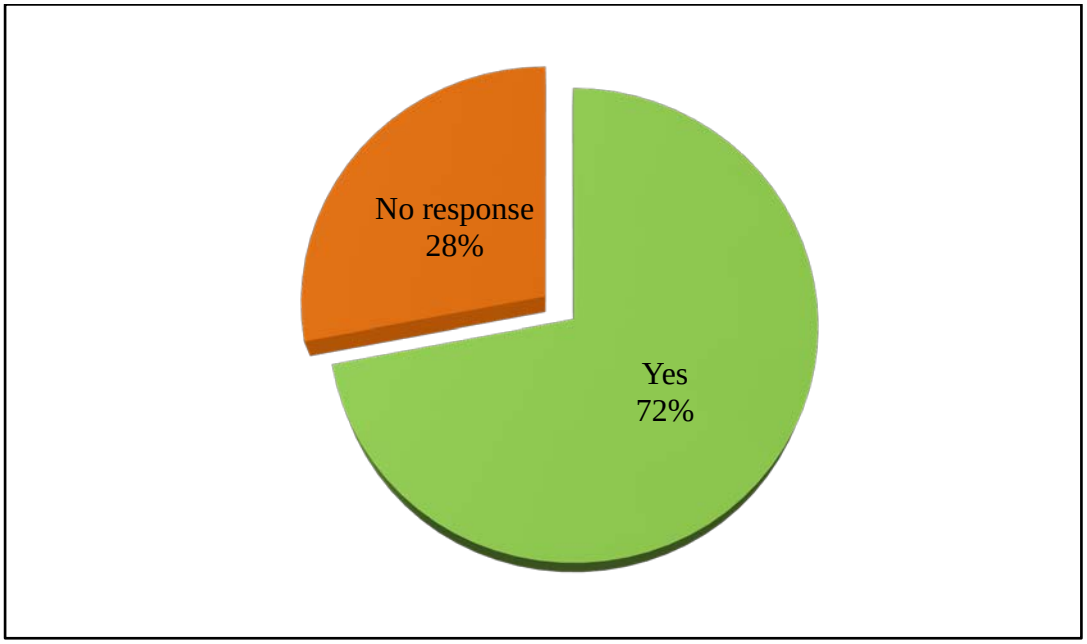


Figure 5.40: Highway along the KNP periphery; whether the NH-11 is affecting the KNP

84% representatives felt that KNP provides source of income to local dependents in Bharatpur from inflow of tourists mainly foreigners. 72% of the representatives expressed their opinion that Bharatpur should be declared as tourism district and 28% of them emphasised the need to develop ecotourism triangle (Alwar-Bharatpur-Sawaimadhopur) for development and better livelihood of local community. As Bharatpur have other historical places too, for tourists to spend more time in Bharatpur. 72% of the representatives mentioned that passing of NH-11 is affecting KNP because in the last five years continuous pressure of traffic on NH-11 has caused disturbance to nearby people and birds in KNP.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

This research work has been carried out to study some aspects of environmental changes including changes in water inflow, water quality and human associated activities. Based on the study, following conclusions have been drawn.

1. Water supply to KNP wetland from conventional source Gambhiri river through Ajan Dam has decreased significantly and practically it has been negligible for last decade 2004-2014. Alternative water sources Chambal pipe line project and Goverdhan drain fulfilled water requirement during the period from 2011 to 2014 to KNP. Water from alternative sources was not found suitable for KNP water birds.
2. Changed water sources and their quality significantly affected the KNP wetland vegetation and base food availability for the birds. Reduced water quantity resulted in increase in terrestrial areas of KNP which in turn reduced various species of migratory birds and their number in KNP.
3. Increased human activities particularly passing NH-11 along KNP and hotel activities around KNP are creating high level of noise. Increased noise level around KNP is adversely affecting staging of the migratory birds. The birds are moving to the inner areas of KNP and are also shift to the nearby satellite wetland areas as the high level of noise disturbs their behavioral aspects.
4. Reductions in species and number of migratory birds in KNP are the main causes of decrease in the number of tourists (particularly foreign visitors) and their visiting time in KNP. Lowering in the number of foreign tourists in KNP is decreasing income opportunity to dependent local community including rickshaw pullers, guides and hoteliers. The hoteliers are also struggling for their survival and are making available their premises for other social activities due to which there is high noise level around KNP at night. It also disturbs bird's at night.

As a result of reduced number and variety of birds, the park is losing its reputation at international level and thereby the ecotourism in KNP has suffered badly.

The following suggestions are given for conserving the KNP wetland:

1. The KNP administration should plan supply of water from conventional sources (Gambhiri River through Ajan Dam) rather than supplying from alternative water sources. A timely supply of water (June onwards) is also necessary for maintaining proper food chain for the water-birds.
2. In case, the water is supplied from the alternative sources, it should not be carried through pipe line. It should be carried through open canal for maintaining its biological value. A pilot study can be suggested to deliver water of Chambal River in Bund Baretha and then released to KNP through open canal system. A study of changes in KNP biodiversity can be carried out.
3. The noise level should be controlled by diverting the traffic volume in morning and during night from NH-11 around KNP. There must be restriction on social activities in the nearby hotels.

Scope of future research work is given below:

- A study on nutrients changes due to various alternative water sources in KNP can be done to check the effect on ecology in KNP.
- Aquatic-terrestrial habitat relationship in KNP can be studied in future.
- A study could be carried out for water parameter optimization in KNP, as the water from other alternative sources are also being supplied.
- A quantitative modeling and predictions could be done in future for the specific solution of these studied problems in the KNP.

Contributions of work are as under:

1. The work highlights the importance of conventional source Ajan Dam’s water for the KNP. The Ajan Dam water is the life line for maintaining the aquatic life of KNP.

2. Traffic on highway should be diverted or kept away at a significant distance from such important habitat area to conserve its value.
3. The work suggests a detailed research with field experts prior to any changes made in such important sites.
4. The conservation of nearby satellite area is important for staging of migratory birds.

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APPENDICES

Appendix-1

Block wise area and perimeter of KNP

BLOCK	AREA (km^2)	PERIMETER (km)	AREA (hectares)
A	0.6792940	4.427039	67.92940
B	1.3183100	5.515422	131.83100
C	0.5567616	4.433762	55.67616
D	1.3884040	4.812834	138.84040
E	1.5599370	5.392541	155.99370
F1	1.510726	6.101373	151.07260
F2	0.8303809	3.764960	83.03809
F3	0.3989488	2.650630	39.89488
F4	0.3283468	2.496845	32.83468
G1	1.9087720	6.485704	190.87720
G2	1.2857160	4.991667	128.57160
G3	1.0107250	4.234878	101.07250
G4	1.197627	5.840647	119.7627
H	0.6597537	3.838514	65.97537
I	1.7518300	7.892397	175.18300
J1	1.5964930	5.347342	159.64930
J2	0.5334135	3.825283	53.34135
K	2.2817700	5.966077	228.17700
L1	3.0626720	7.555257	306.26720
L2	1.4475590	5.870040	144.75590
M1	1.0358230	5.259086	103.58230
M2	0.7166310	4.554301	71.66310
N	0.6553409	3.608502	65.53409
O	1.3382760	7.084771	133.82760
Total	29.05		2905.3

Appendix-2

Salient features of constructed Panchana Dam 90 km upstream of KNP

Gambhiri River(Gambhir)	
River	Gambhiri
District	Karauli
Dam Height (above Lowest Foundation Level)	33.19 m
Gross Storage Capacity	59.45 Mm^3
Live Storage Capacity	52.65 Mm^3
Water of the Gambhiri River used to flow to the KNP wetland via	Sewla Head $\rightarrow$Pichuna Canal $\rightarrow$ Ajan Dam
Purpose of the Project	Irrigation
Bund at various places had been created for protecting the Bharatpur town from the floods brought by the Gambhiri River.	Sewla, Ajan Dam
The construction of this Dam commenced in	January, 1979
The problem for the water in World Famous bird sanctuary started with the construction of the Panchana Dam on Gambhiri River	After 1991
The Dam was finally reportedly installed during	July, 2003
The release of water to the KNP had progressively decreased as the construction was nearing completion and has now practically become nil, except overflow.	Nil
Panchana Dam has been developed for irrigation which requires almost the entire water available from the dam leaving no water for the KNP	9985 ha. area
Catchment area of various reservoirs in Drainage basin	
Panchana Dam	622 km^2
Sewla head	1926km^2
Ajan +Dam	206km^2

Appendix-2A

Physicochemical parameters of water of KNP Bharatpur, taken on 29/10/2012

Aquatic area	Block-K	Block -L	Block-D	Block-E
Temperature (°C)	24.2	23.6	23.8	23.5
pH	7.2	7.4	7.5	7.2
TDS (mg/l)	342	1061	756	312
DO (mg/l)	5.3	5.6	6.1	5.9
BOD (mg/l)	1.3	1.2	0.8	0.9
Hardness (mg/l)	70	280	160	60
Cl (mg/l)	50	210	140	40
Salinity (mg/l)	30	90	60	20
Ca (mg/l)	30	120	60	20
Mg (mg/l)	40	160	100	40
Fluoride (mg/l)	0.13	0.59	0.21	0.07
Nitrate (mg/l)	20	30	30	20

Appendix-2B

Physicochemical parameters of water of KNP Bharatpur, taken on 23/12/2012

Aquatic area	Block-K	Block -L	Block-D	Block-E
Temperature (°C)	19.8	18.9	18.3	18.4
pH	7.3	7.5	7.4	7.2
TDS (mg/l)	356	987	786	345
DO (mg/l)	4.9	5.4	5.8	5.4
BOD (mg/l)	1.4	1.5	1	1.1
Hardness (mg/l)	78	301	172	68
Cl (mg/l)	57	187	156	45
Salinity (mg/l)	39	96	67	34
Ca (mg/l)	38	132	68	34
Mg (mg/l)	40	167	103	34
Fluoride (mg/l)	0.14	0.34	0.32	0.09
Nitrate (mg/l)	30	40	20	30

Appendix-2C

Physicochemical parameters of water of KNP Bharatpur, taken on 15/02/2013

Aquatic area	Block-K	Block -L	Block-D	Block-E
Temperature (°C)	21.2	17.3	17.8	17.6
pH	7.1	7.2	7.3	7
TDS (mg/l)	367	967	768	360
DO (mg/l)	3.9	4.6	5.1	5
BOD (mg/l)	1.4	1.6	1.3	1.2
Hardness (mg/l)	76	286	165	60
Cl (mg/l)	54	178	148	42
Salinity (mg/l)	35	90	62	31
Ca (mg/l)	32	123	60	32
Mg (mg/l)	44	163	105	30
Fluoride (mg/l)	0.13	0.29	0.29	0.08
Nitrate (mg/l)	20	35	35	40

Appendix-2D

Physicochemical parameters of water of KNP Bharatpur, taken on 16/10/2014

Aquatic area	Block-K	Block -L	Block-D	Block-E
Temperature (°C)	24.6	24.3	23.8	23.6
pH	8.2	7.4	7.2	7.3
TDS (mg/l)	657	1320	1630	371
DO (mg/l)	4.9	5.6	5.9	5.4
BOD (mg/l)	1.3	1.1	1	1.2
Hardness (mg/l)	220	470	670	110
Cl (mg/l)	110	360	480	80
Salinity (mg/l)	220	470	670	110
Ca (mg/l)	90	190	310	50
Mg (mg/l)	130	280	360	60
Fluoride (mg/l)	0.49	0.69	0.58	0.43
Nitrate (mg/l)	60	40	30	20

Appendix-2E

Physicochemical parameters of water of KNP Bharatpur, taken on 16/12/2014

Aquatic area	Block-K	Block -L	Block-D	Block-E
Temperature (°C)	21.2	18.1	18.8	17.9
pH	7.4	7.4	7.6	7.3
TDS (mg/l)	437	1120	1280	342
DO (mg/l)	4.5	5.3	5.5	5.1
BOD (mg/l)	1.5	1.2	1.1	1.3
Hardness (mg/l)	320	510	690	90
Cl (mg/l)	110	360	480	80
Salinity (mg/l)	245	495	680	115
Ca (mg/l)	110	195	315	55
Mg (mg/l)	135	300	365	60
Fluoride (mg/l)	0.43	0.53	0.37	0.41
Nitrate (mg/l)	30	20	50	30

Appendix-2F

Physicochemical parameters of water of Chambal pipe project during 2011-12

Aquatic area	10/10/2011	15/11/2011	26/12/2011
Temperature (°C)	20.1	20.3	19.5
pH	8	8.1	8.1
TDS (mg/l)	430	358	377
DO (mg/l)	3.2	6.5	5.8
BOD (mg/l)	1.2	0.6	1
Hardness (mg/l)	70	105	95
Cl (mg/l)	-	-	-
Salinity (mg/l)	95	85	74
Ca (mg/l)	40	40	40
Mg (mg/l)	50	45	55
Fluoride (mg/l)	0.1	0.1	0.1
Nitrate (mg/l)	3	4	3

Appendix-2G

Physicochemical parameters of water of Chambal pipe project during 2012-2013

Aquatic area	29/10/2012	20/12/2012	22/7/2013	15/09/2013
Temperature(°C)	20.4	20.6	20.9	20.3
pH	8	8.2	8.3	8.2
TDS (mg/l)	390	449	375	395
DO (mg/l)	3.5	3.9	4.3	4.8
BOD (mg/l)	1.2	1.1	1.1	1.2
Hardness (mg/l)	60	111	65	69
Cl (mg/l)	-	-	-	-
Salinity (mg/l)	56	65	92	90
Ca (mg/l)	35	40	40	40
Mg (mg/l)	45	50	55	50
Fluoride (mg/l)	-	-	-	-
Nitrate (mg/l)	-	-	-	-

Appendix-2H

Physicochemical parameters of water of Chambal pipe project during 2014

Aquatic area	3/12/2014	2/7/2014	15/8/2014	16/10/2014
Temperature(°C)	21.3	20.8	21.9	21.2
pH	8.3	8	8.1	8.3
TDS (mg/l)	349	447	365	399
DO (mg/l)	3.6	3.5	4	3.9
BOD (mg/l)	1.2	1.2	1.1	1.3
Hardness (mg/l)	105	165	105	95
Cl (mg/l)	20	-	-	10
Salinity (mg/l)	93	60	55	60
Ca (mg/l)	60	70	50	55
Mg (mg/l)	80	80	60	60
Fluoride (mg/l)	0.2	0.1	0.15	0.1
Nitrate (mg/l)	4	2	5	3

Appendix-2I

Physicochemical parameters of water of Ajan Dam during 2012 and 2013

Aquatic area	29/10/2012	20/12/2012	20/10/2013	25/12/2013
Temperature(°C)	25.9	20.2	24.7	23.6
pH	7.6	7.2	7.3	7.1
TDS (mg/l)	987	673	730	674
DO (mg/l)	6.2	3.6	5.8	3.6
BOD (mg/l)	1.9	3.5	3.6	3.4
Hardness (mg/l)	132	133	135	301
Cl (mg/l)	357	581	385	521
Salinity (mg/l)	75	89	85	95
Ca (mg/l)	30	40	35	40
Mg (mg/l)	45	49	50	55
Fluoride (mg/l)	0.2	0.2	7	0.2
Nitrate (mg/l)	30	35	40	40

Appendix-2J

Physicochemical parameters of water of Goverdhan Drain Project during 2014

Aquatic area	20/10/2013	25/12/2013	16/10/2014	16/12/2014
Temperature(°C)	20.7	19.2	22.9	19.3
pH	7.9	7.5	8.1	8
TDS (mg/l)	2127	1971	2010	1985
DO (mg/l)	4.6	3.4	3.6	2.9
BOD (mg/l)	3.1	3.5	4.5	4.5
Hardness (mg/l)	620	510	640	590
Cl (mg/l)	665	540	670	545
Salinity (mg/l)	270	270	340	280
Ca (mg/l)	140	130	160	130
Mg (mg/l)	180	140	180	150
Fluoride (mg/l)	0.2	0.2	0.2	0.2
Nitrate (mg/l)	30	25	35	40

Appendix-2T 1

Sound level measured at all the four sites due to traffic around KNP on 10 October, 2012

Time-Period	KNP Gate Site I (L1)					Saras Circle Site 2 (L2)					Poly. College Site 3 (L3)					Agra Road Site 4 (L4)				
	Lmin	**Lmax**	**Leq**	**L10**	**L90**	**Lmin**	**Lmax**	**Leq**	**L10**	**L90**	**Lmin**	**Lmax**	**Leq**	**L10**	**L90**	**Lmin**	**Lmax**	**Leq**	**L10**	**L90**
6-8AM	50.7	82.1	61.2	65.1	56.8	52.4	74.5	60.1	65.1	55.2	43.2	74.2	56.8	63.4	47.2	43	73.5	56.3	64.6	45.1
11-1PM	54.5	81.1	64.4	68.2	58.8	54.1	78.3	65.4	68.8	55.5	46.4	78.6	59.8	64.7	54.8	49.8	84.1	58.1	66.5	52.4
4-6PM	53.9	86.3	65.8	68.9	57	50.1	85.3	66.9	70.2	60.3	46.8	75.3	60.3	66.1	52.7	47.3	75.6	59.9	66.4	53.6
9-11PM	48.2	90.4	66.9	73.6	57.8	50.1	88.4	70.1	75.8	57.8	49.9	77.8	60.6	67.2	52.9	47.9	76.1	60.3	66.7	54.1

Appendix-2T 2

Sound level measured at all the four sites due to traffic around KNP on 18 October, 2013

Time-Period	KNP Gate Site I (L1)					Saras Circle Site 2 (L2)					Poly. College Site 3 (L3)					Agra Road Site 4 (L4)				
	Lmin	**Lmax**	**Leq**	**L10**	**L90**	**Lmin**	**Lmax**	**Leq**	**L10**	**L90**	**Lmin**	**Lmax**	**Leq**	**L10**	**L90**	**Lmin**	**Lmax**	**Leq**	**L10**	**L90**
6-8AM	50	83.3	64.8	66.9	55.8	49.1	71.8	60.3	63.1	54.2	43.6	75.6	58.8	63.9	47.9	42.2	70.1	57.2	61.6	47.5
11-1PM	54.8	80.1	63.4	67.2	58.4	48.4	76.3	67.4	69.1	59.5	49.4	79.8	62.8	66.1	52.8	48.8	78.7	59.6	67.5	55.2
4-6PM	52.3	86.4	67.8	70.9	55.1	50.1	88.3	66.9	71.4	55.3	48.4	77.9	60	66.1	52.7	49.3	79.6	61.9	64.8	54.6
9-11PM	50.2	89.8	66.9	72.3	60.8	54.1	90.4	68.7	70.5	58.3	48.9	77.9	60.9	65.2	50.9	49.9	78.1	61.8	68.7	57.1

Appendix-2T 3

Sound level measured at all the four sites due to traffic around KNP on 12 December, 2013

Time-Period	KNP Gate Site I (L1)					Saras Circle Site 2 (L2)					Poly. College Site 3 (L3)					Agra Road Site 4 (L4)				
	Lmin	Lmax	Leq	L10	L90	Lmin	Lmax	Leq	L10	L90	Lmin	Lmax	Leq	L10	L90	Lmin	Lmax	Leq	L10	L90
6-8AM	51.9	80.9	60.2	65.4	54.5	47.7	81.2	60.6	60.9	54.8	44.8	76.8	59.1	65.4	48.9	45.1	79.2	58.6	64.9	51.2
11-1PM	55.4	82.4	64.2	68.9	58.8	48.4	81.6	63.2	72.4	55.6	47.1	81.4	60.8	65.4	58.8	49.1	80.9	59.4	64.8	53.6
4-6PM	54.1	81.4	64.6	70.2	57.8	52.8	87.3	65.4	68.2	56.6	47.8	77.1	60.5	66.2	53.9	47.4	76.7	60.9	66.8	53.9
9-11PM	49.4	88.8	66.8	71.5	54.8	58.6	88.6	69.7	69.6	58.6	50.9	77.9	59.4	69.5	52.1	47.3	79.6	59.8	65.6	53.2

Appendix- 2T 4

Sound level measured at all the four sites due to traffic around KNP on 19 December, 2014

Time-Period	KNP Gate Site I (L1)					Saras Circle Site 2 (L2)					Poly. College Site 3 (L3)					Agra Road Site 4 (L4)				
	Lmin	Lmax	Leq	L10	L90	Lmin	Lmax	Leq	L10	L90	Lmin	Lmax	Leq	L10	L90	Lmin	Lmax	Leq	L10	L90
6-8AM	51.2	81.3	63.8	66.9	56.6	47.6	74.1	60.4	64.4	54.3	45.2	74.9	58.8	64.8	48.7	42.4	74.2	56.9	63.9	42.1
11-1PM	53.5	80.7	65.4	68.4	59.1	49.4	77.3	64.8	70.5	58.8	49.6	79.8	63.9	69.6	48.7	49.8	77.1	60.5	64.8	53.9
4-6PM	53.6	86.3	66.5	70.1	57.1	51.1	86.8	66.8	68.6	58.8	46.6	76.3	59.8	62.9	51.9	47.3	77.6	59.9	66.8	54.9
9-11PM	49.7	88.2	70.3	69.5	57.2	54.8	91.8	68.9	67.2	60.3	49.9	76.8	60.6	65.7	51.3	48.3	77.6	60.8	65.7	55.8

Appendix-2T 5

Sound level measured at the two sites during marriage function around KNP on 12 October, 2013

Time-Period	Near KNP Gate Site 1 (L1)					Near Saras Circle Site 2 (L2)				
	Lmin	Lmax	Leq	L10	L90	Lmin	Lmax	Leq	L10	L90
8-8.30PM	58.8	94.3	81.1	85.2	70.4	56.9	85.4	80.4	83.1	68.3
8.31-9.00PM	61.5	96.5	82.5	86.1	71.2	59.1	94.4	82.2	85.4	70.1
9.01-9.30PM	63.4	89.9	82.2	83.5	68.3	61.5	91.8	83.5	83.4	69.3
9.31-10PM	65.2	92.1	83.6	85	69.9	62.4	92.5	82.3	83.8	70.1
10.01-10.30PM	62.2	87.3	76.4	80	67.3	60.4	85.3	77.4	81.1	69.1

Appendix-2T 6

Sound level measured at the two sites during marriage function around KNP on 22 October, 2013

Time-Period	Near KNP Gate Site 1 (L1)					Near Saras Circle Site 2 (L2)				
	Lmin	Lmax	Leq	L10	L90	Lmin	Lmax	Leq	L10	L90
8-8.30PM	59.1	94.6	81.3	85.7	70.8	56.6	86.5	80.2	83.1	68.8
8.31-9.00PM	61.8	96.8	82.8	86.9	70.1	59.4	94.6	82.9	85.8	70.9
9.01-9.30PM	63.2	90.1	82.4	83.1	68.1	61.8	92.2	84.3	83.9	69.7
9.31-10PM	65.6	92.5	83.2	85.2	70.6	62.6	91.3	82.2	83.9	70.2
10.01-10.30PM	62.1	87.1	76.7	79.8	66.9	60.7	86.7	77.6	81.4	69.2

Appendix-2T 7

Sound level measured at the two sites during marriage function around KNP on 8 December, 2014

Time-Period	Near KNP Gate Site 1 (L1)					Near Saras Circle Site 2 (L2)				
	Lmin	Lmax	Leq	L10	L90	Lmin	Lmax	Leq	L10	L90
8-8.30PM	58.7	94.1	81.1	85.1	69.9	57.1	85.1	80.7	82.3	68.4
8.31-9.00PM	61.9	96.5	81.9	86.3	71.6	58.4	94.1	82.1	85.5	69.6
9.01-9.30PM	63.2	90.2	82.3	83.6	68.1	61.8	91.8	83.3	83.6	69.5
9.31-10PM	65.2	91.7	83.5	84.6	69.2	62.4	93.4	82.4	83.7	70.1
10.01-10.30PM	62.5	86.1	75.9	79.9	66.6	59.8	84.4	76.6	80.9	68.6

Appendix-2T 8

Sound level measured at the two sites during marriage function around KNP on 16 December, 2014

Time-Period	Near KNP Gate Site 1 (L1)					Near Saras Circle Site 2 (L2)				
	Lmin	Lmax	Leq	L10	L90	Lmin	Lmax	Leq	L10	L90
8-8.30PM	59.4	94.2	81.3	85.6	70.5	58.1	84.6	80.3	83.9	67.8
8.31-9.00PM	61.2	96.2	82.8	85.9	71.9	59.6	94.5	81.7	85.7	69.9
9.01-9.30PM	64.2	90.1	81.9	83.8	68.7	60.9	91.8	82.9	82.1	68.8
9.31-10PM	65.6	92.8	84.5	84.9	69.9	62.2	93.8	82.4	84.1	70.1
10.01-10.30PM	61.7	88.7	76.6	81.1	68.4	60.7	84.8	77.4	80.1	68.9

Appendix- 3

Detailing of Mammals in KNP during 2008-2014

Species	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Tiger	0	0	1	0	0	0	0
Rhesus Macaque	0		400	300	289	276	255
Fishing cat	1	1	0	2	0	0	0
Jungle cat	15	14	15	16	17	15	16
Toddy cat	13	7	6	8	0	0	0
Small Indian Civet	12	3	3	6	8	7	
Jackal	194	225	275	310	344	354	357
Striped Hyaena	8	16	15	14	8	6	0
Otter	0	0	0	0	0	0	0
Indian Porcupine	32	12	10	11	18	15	
Rufos Tailed Hare	0	0	0		0	0	0
Neelgai	382	464	480	550	859	904	926
Sambar	47	38	46	57	66	76	77
Wild Boar	251	279	180	220	238	245	289
Spotted Deer	1576	1859	2000	2500	2696	2765	2957
Hog deer	1	2	0	2	0	0	0
Black Buck	0	0	0	0	0	0	0
Feral Cow	719		1500	1500	1454	1467	1473
Common Grey Mangoose	1	1	1	0	0	0	0
Small Indian Mongoose	1	1	1	0	0	0	0
Wolf	0	0	0	1	0	0	0
Sum	**3253**	**2922**	**4933**	**5497**	**5997**	**6130**	**6350**

Appendix-4

Migratory bird population in KNP Bharatpur; becoming rare to KNP

Species	Black-Ibis	White Eyed Pochard	Mallard	Cotton Pygmy Goose
2008-09	10	0	2	24
2009-10	0	0	0	0
2010-11	0	0	0	0
2011-12	0	0	0	0
2012-13	0	0	0	0
2013-14	2	0	0	0
2014-15	3	0	0	0

Appendix-5

[A]Survey and Feedback of Tourist in Keoladeo National Park

KNP Survey Questionnaire

Instruction:

"I am carrying out a survey for KNP. Your opinions and the information you provide us will be used to improve the quality of the Keoladeo National Park. The accuracy of your replies is an essential element for the success of this research project with a view to the future development of KNP."

Date: / /20

I. Visitor behaviour / knowledge

A. How many times did you visit KNP (please tick the relevant box)?

i. Once ☐ ii. Twice ☐ iii. More than twice ☐

B. Field of interest in KNP

i. Aquatic bird's ii. Mammal iii. Flora iv. In general wild life

C. Numbers of birds seen as per your estimation

i. Less than 5000 ii. 5001-20000 iii. More than 20000

D. Time spent in the park?

i. Less than 2 hours ii. 2-4 hours iii. 4-8 hours iv. More than 8 hours

E. Would you like to visit KNP again & why? .....,

F. How much did you spend in KNP (ecotourism) ?

.....

II. Visitor Reaction about KNP

A. What type of improvements would you like to see in KNP? Facilities and infrastructure.

Signboards/ Means of Transport/ Communication/ Training of park officers

B. Any other suggestion/ improvement in the KNP

.....

C. Are you satisfied with visit and facilities in the KNP?

.....

III. General information about the visitor

1) Nationality
2) Profile
   i. Male ii. Female iii. Age
3) Marital Status
   i. Single ii. Married
4) Profession
   i. Govt. sector ii. Private sector iii. Student
   iv. Retired v. Other
5) Level of education
   i. None ii. Primary
   iii. Secondary iv. Higher Education
6) Monthly income in Rs. .....

[B]Feedback for KNP conservation (Public Representatives)

Name…… Designation……

Water sources to KNP; whether the water should be supplied from Panchana Dam? Yes/No

KNP as income source; whether the KNP is main income source for local dependents? Yes/No

Bharatpur as tourism spot; whether the Bharatpur need special attention for developing as tourism place? Yes/No

Whether Highway/other human activity noise areposing a problem on KNP? Yes/No

Highway along the KNP periphery; whether the NH-11 is affecting the KNP? Yes/No

Your opinion about conservation of KNP and any effort made by you

Signature……

LIST OF PAPERS PUBLISHED
(Publications from this Research Work)

INTERNATIONAL JOURNALS

Sharma, N., Mathur, Y.P. and Jethoo, A.S. (2015) Effects of Hydrological Changes on the Biodiversity at Keoladeo National Park and Their Impact on Ecotourism, in International Journal of Civil, Structural Environmental and Infrastructure Engineering Research and Development (IJCSEIERD) ISSN (P): 2249-6866; ISSN (E): 2249-7978 Vol. 5, Issue 6, Dec 2015, 1-10,Paper Id.: IJCSEIERDDEC20151.

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Sharma, N., Mathur, Y.P. and Jethoo, A.S. (2016) Changing Water Sources in Keoladeo National Park (KNP): An Alarm for the World Heritage Site: In An International Quarterly Journal of Biology and Life Sciences, ISSN(E)2320-4257:Biolife: Global Science Publishing Group, USA,Vol.4(1),172-178-6,doi:10.17812/blj.2016.4124.

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BIO DATA OF AUTHOR

Author of the thesis Neeraj Sharma was born on 22nd July 1965 in Jaipur. He is having excellent academic records. He was a topper in Pre university (1979, University of Rajasthan).He was awarded various silver and gold medals at school and college level.

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The author started his professional career as site Engineer, Junior Engineer and Assistant Engineer from 1987 to 1992 for six year in MREC construction projects, DRDA Jhunjhunu and Neyveli lignite Corporation, Bikaner (Rajasthan Project, Barsingsar).Later he joined Technical education Rajasthan and served in various capacity of Lecturer, Senior lecturer and Head of department (Civil Engineering) in Govt. Polytechnic College Sawaimadhopur, Jaipur, Ajmer and Bharatpur from 1992 to 2011.

The author has been serving as Principal in S.G.V. Government Polytechnic college, Bharatpur since 2011 (last 5 year).He is also the District level officer for promoting Nation flagship programs of Swachh Bharat, Community development, Coordinator in community development for producing technically skilled people, Resource Person for Rehabilitation, disaster management and Earth quake management in Bharatpur region and Nodal Officer for promoting, coordinating, managing and supervising various Technical Education State and Regional level programs.

The author has also written 2 text books on hydraulics and fluid engineering for diploma student. He possesses 28 years of experience in field work, teaching and administrative works.