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STUDIES ON THE WETLANDS OF KAZIRANGA NATIONAL PARK WITH SPECIAL REFERENCE TO FEW SELECTED LIMNOLOGICAL PARAMETERS FOR SUSTAINABLE MANAGEMENT

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DIPAK KUMAR SARMA

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SCHOOL OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF ENVIRONMENTAL SCIENCE
TEZPUR UNIVERSITY

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I WISH TO DEDICATE THIS THESIS TO MY BELOVED FAMILY MEMBERS WHOSE SKYFUL OF LOVE, HELP AND ENCOURAGEMENT INSPIRED ME TO DO THIS EVENTFUL WORK SUCCESSFULLY.

Dipak Kumar Sarma

DECLARATION

==

I do hereby declare that the thesis entitled '***STUDIES ON THE WETLANDS OF KAZIRANGA NATIONAL PARK WITH SPECIAL REFERENCE TO FEW SELECTED LIMNOLOGICAL PARAMETERS FOR SUSTAINABLE MANAGEMENT***' being submitted to the Department of Environmental Science, Tezpur University, is a record of original research work carried out by me. All sources of assistance have been assigned due acknowledgment. I also declare that neither this work as a whole nor a part of it has been submitted to any other University or Institute for any other degree, diploma or award.

Date 12-1-2012

(DIPAK KUMAR SARMA)

CERTIFICATE BY SUPERVISORS

This is to certify that the matter embodied in the thesis entitled '*STUDIES ON THE WETLANDS OF KAZIRANGA NATIONAL PARK WITH SPECIAL REFERENCE TO FEW SELECTED LIMNOLOGICAL PARAMETERS FOR SUSTAINABLE MANAGEMENT*' submitted by Sri Dipak Kumar Sarma , for the award of degree of Doctor of Philosophy of Tezpur University, is a record of bonafide research work carried out by him under our supervision and guidance . The results embodied in the thesis have not been submitted to any other University or Institute for the award of any degree or diploma.

12.01.2012

(Dr.R.R.Hoque)
Associate Supervisor
Department of Environmental Science
Tezpur University

12/1/2012

(Prof.D.Deka)
Major Supervisor
Department of Energy
Tezpur University

Dr. Dhanapati Deka
Professor
Department of Energy
Tezpur University
Tezpur, Assam, India

TEZPUR UNIVERSITY
(A Central University established by an Act of Parliament)
NAPAAM, TEZPUR-784028
DISTRICT: SONITPUR: ASSAM: INDIA
Ph: 03712-267004, 267005 Fax: 03712267005(6)

CERTIFICATE

This is to certify that the thesis entitled "**Studies on the wetlands of Kaziranga National Park with special reference to few selected limnological parameters for sustainable management**" submitted to Tezpur University in the Department of Environmental Science under the School of Science and Technology; in partial fulfillment for the award of the Degree of Doctor of Philosophy in science, has been examined by us on ____________ and found to be satisfactory.

The committee recommends for the award of the degree of Doctor of Philosophy.

Principal Supervisor
Date

External Examiner
Date

Associate Supervisor
Date

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INTRODUCTION

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INTRODUCTION

Wetland ecosystem is one of the most productive ecosystems and is comparable to tropical evergreen forest ecosystem of biosphere. It plays a significant role in the ecological sustainability of a region making itself an essential component of human civilization which meets many crucial needs for life on earth such as drinking water, protein production, water purification, energy, fodder, biodiversity, flood storage, transport, recreation, research-education, sinks and climate stabilizer. Wetlands are also sources of drinking water and feeding ground for the animals living around it (Davis,1993).

Although wetlands were earlier considered as unproductive and unhealthy waste lands, there has been a growing realization of their value during the last twenty years. Governments and scientists have devoted enormous attention to wetlands and have reached a better understanding not only of their biological importance, but also of their social, economic and cultural functions. The wetlands are better realised now for their role in regulating climate and in reducing the greenhouse effect as they have capacity for retaining carbon especially as regards to peat lands which make up almost half the world's wetlands (de Groot, 1992).

Wetlands are areas with the water table at, near or above the land surface for long enough to promote hydric soil, hydrophytic vegetation and biological activities adopted to wet environment (NWWG, 1997). Wetlands may be mineral soil wetlands or peat lands depending on hydro-biological process resulting from water exchange dictated by climate and landscape factors. Mineral soil wetlands include marsh, shallow water and some swamps which produce little or no peat because of climatic and edaphic conditions (Zoltai and Vitt, 1995). Peat lands are defined as wetlands areas with an accumulation of organic sediments exceeding 40 cm and this includes bogs, fens and some swamps (NWWG, 1998). Fens and some swamps are mineratrophic peat lands receiving water and nutrients from atmosphere and telluric sources, whereas bogs are ombrotrophic receiving water and nutrients predominantly from direct precipitation.

1.1 Functions of Wetland

Wetlands are capable of performing various functions as a result of physical, chemical and biological processes. These functions can be divided into following three general categories (Ramachandra *et al* . 2002). They are

Habitat Functions

Wetlands are related to species biodiversity which are used by many of the organisms as their ecological niche. This rich biodiversity is contributed by moisture gradient caused by gentle slope and seasonally varying moisture conditions. Wetlands on habitat functions provide supports including their food and breeding sites to these organisms.

Water Quality Function

Wetlands have been shown to improve water quality by filtering out fertilizers and pesticides. The organically rich sediments of wetlands produced by decaying plant mass attract and bind other contaminants as well. For this reason, many communities are developing wetlands only to enhance sewage treatment system (USGS, 1999). A wetland's capacity to retain phosphorus depends on factors such as plant uptake; the concentration of minerals that precipitate phosphorus (e.g. Ferric iron and aluminum); soil pH which affects the P solubility and adsorption to soil constituents such as clay and organic matter(Cooper &Gilliam1987). Plants found in wetlands produce excess carbon under hot and eutrophicated conditions. In such cases, proliferation of microbial communities takes place and anaerobic conditions exist in the sediments. Under such conditions, wetlands may remove high concentration of nitrate through denitrification and hence improve the water quality.(Mitsch and Gosselink 2000).

Ecosystem Function

Wetlands perform many of the ecosystem management functionaries. For example flood mitigation, storm abetment, aesthetic and subsistence etc.

(i) Flood Storage

In natural condition, most wetlands store floodwater temporarily, protecting downstream areas from flash flood. By maintaining a constant flow regime downstream, wetlands preserve water quality and increase the biological productivity of the aquatic communities. These function become increasingly important in urban areas, where developmental activities (such as breaching of wetlands for residential, commercial, and industrial activities, paving of surfaces in catchment areas, etc) have increased the rate and volume of surface water run-off and the potential for flood damage.

(ii) Ground Water Recharge

Periodically inundated wetlands are very effective in storing rainwater and have innate capacity to recharge the ground waters. Ground water recharge occurs through mineral soils found primarily around the edges of wetlands. The extent of groundwater recharge depends on the type of soil and its permeability, vegetation, sediment accumulation in the lake bed, surface area to volume ratio and water table gradient.

(iii) Water Supply

Wetlands have a tremendous ability to meet the water requirement in the surrounding areas. Natural wetlands are underlain by aquifers with a high potential for water supply.

(iv) Shoreline Stabilization and Erosion Control

Wetland vegetation can reduce shoreline erosion in several ways, including – increasing durability of the sediment through binding (with stilt / plank root structure), dampening waves through friction and reducing current velocity through friction, improving water quality. Coastal wetlands particularly mangroves help in shoreline stabilisation and storm protection by dissipating the force by reducing the damage of wind and wave action. Water coming as flood during flood season enters the low laying wetlands and reduces the effects of flood and storms to a great extent and thereby minimizes the damage of flood and storm. (Ramachandra *et al.*,2002).

(v) Climate Control

The role of wetlands in regulating climate and in reducing the greenhouse effect through their capacity for retaining carbon has been scientifically established, especially as regards to peat lands which make up almost half of the world's wetlands (Maltby *et al.*,1992).

Apart from these, wetlands also provide economical benefits such as tourism development, growing trees as sources of timbers etc.

1.2 Loss of wetlands

54% of the 87 million hectares of wetlands has been lost primarily due to agricultural activities in USA alone. Indiana, Illinois, Missouri, Kentucky and Ohio have lost more than 80% of original wetland areas. This is more severe in the case of California and Iowa which are nearly 99%. This is the case with other countries also. An average of 61% wetlands has been lost in six countries- Netherlands, France, Germany, Spain, Italy and Greece as esteemed by the European commission, 1995. Wetlands of Belgium, Chile and South America have been lost drastically due to human activities such as agriculture activities, drainage etc. India has already lost considerable amount of wetlands. For example, approximately one third of Wullar lake of Kashmir is degraded due to siltation and human encroachment. Similar is the case for Chilka lake in Orissa (the largest brackish water lagoon in south east Asia), Kalleru lake in Andhra Pradesh and Deepar *beel* in Assam. The wetlands of India are mainly threatened on account of unplanned land use practices, over exploitation of available resources of catchment area, improper planning and encroachment for other human activities such as agriculture etc. (Ramachandra *et al.*, 2002).

1.3 Ecological Effects of loss of wetlands

1.3.1 Habitat loss

Degradations of wetlands cause lost of some ecological functions. The effects of degradation on wetland functions need not to be linear: damage to critical processes could exceed natural threshold and cause non-linear responses. Conversion represents the extreme case, in which the functions that were provided by wetlands may be completely lost. The degree to which different functions are lost is specific to the combination of the particular wetland and the impact of affecting it (Scott, 2003). The magnitude of functional loss is not proportionate the size of the wetland (Gibbs, 1993; Robinson, 1995 and Naugle *et al.*, 2000). Much of the importance is attributed to smaller, isolated wetlands which in turn relate to biodiversity. These wetlands may contain endemic species because of their physical isolation. As a result, loss of these wetlands may have disproportionate effect on regional biodiversity.

1.3.2 Cumulative loss

Loss of an individual wetland can be regionally significant if, for example, it is the only site supporting an endangered species. Usually, however, it is the cumulative loss of many wetlands that causes regional consequences. A study by King (1998) illustrated how cumulative loss of wetland could affect biodiversity. She conducted a simulation to examine species extinction curve as a function of habitat destruction. She reported that the extinction curve for a hypothetical profile was less steep than that of the actual crustacean distribution and for the hypothetical distribution, conversion of 80% of habitat resulted in 8% loss in species; only 28% of the habitat had to be converted to produce a similar losing species using the actual crustacean distribution .This study illustrates that the probability that a local loss of a species will result in regional loss of that species .

1.4 Distribution of Wetlands in India

India is blessed with water resources in the form of numerous rivers and streams. By virtue of its geographical position and varied terrain and climatic zones, it supports a rich diversity of inland and coastal wetlands. Wetlands distribute from the cold arid Trans-Himalayan zone to wet Terai regions of Himalayan foothills and Gangetic plains that extend to the floodplains of Brahmaputra and swamps of north-eastern India including the saline expanses of Gujarat and Rajasthan. Along the east and west coasts they occur in the deltaic regions to the wet humid zones of Southern peninsula and beyond, to the Andaman and Nicobar and Lakshadweep Islands. India also shares several of its wetlands with Ladakh and the Sunderbans deltas with Bangladesh. These wetland systems are directly or indirectly associated with river systems of the Ganges, Brahmaputra, Narmada, Tapti, Godavari, Krishna and Cauvery. Southern peninsular. India has a very few natural wetlands, although there are a number of man-made water storage reservoirs constructed virtually in every village known as 'tanks' providing water for human needs and nesting sites for a variety of avifauna.

India has totally 67,429 wetlands covering an area of about 4.1 million hectares (MOEF,1989).Out of these 2,175 are natural and 65,254 are manmade. Wetlands in India (excluding rivers) account for 18.4% of the country's geographic area of which 70% is under paddy cultivation. A survey conducted by the Ministry of Environment and Forests, Govt. of India, in 1990 showed that wetlands occupied an estimated 4.1 million hectares of which 1.5 million hectares were natural and 2.6 million hectares were manmade (excluding paddy fields, rivers and streams). Mangroves occupy an area of estimated 0.45 million hectares. About 80% of the mangroves were distributed in the Sunderbans of West Bengal and Andaman and Nicobar Islands, with the rest in the coastal states of Orissa, Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Goa, Maharashtra and Gujarat (Ramachandra *et al.*, 2002). According to the Directory of Asian Wetlands (Scott,1989), wetlands occupy 58.2 million hectares or 18.4% of the country's area (excluding rivers) of which 40.90 million hectares (70%) are under paddy cultivation. A preliminary inventory by the Department of Science and Technology, Govt. of India recorded a total of 1,193 wetlands covering an area of about 3,904,543 ha of which 572 were natural (Scott , 1989). The Directory of Indian Wetlands(Anon1993) published by WWF and Asian Wetland Bureau in 1995 recorded 147 sites as important of which 68 are protected under the National Protected Area Network by the Wildlife Protection Act.

1.5 Distribution of Wetlands in Assam

Assam, one of the north eastern states of India is highly blessed with huge potentials of wetland resources as given in Table 1 (Boruah *et al.*, 1997).

Table 1: Wetland Resources of Assam

Wetland class	Wetland type	Nos. of wetlands	Area (ha)	Percentage of total Area
Natural wetland	lake /pond	690	15494.00	15.30
	Ox –bow lake /cut off meander	861	15460.60	15.27
	waterlogged(seasonal)	125	3431.50	23.15
	swamp /marsh	712	43433.50	42.91
	Total	**3388**	**97819.60**	**96.63**
Manmade wetlands	Reservoirs	10	2662.50	2.63
	Tanks	115	749.50	0.74
	Total	**125**	**3412.00**	**3.37**
GRAND TOTAL		**3513**	**101231.60**	**100.00**

There are about 101232 hectares of wetlands in Assam and major portions of wetlands are contributed by *beels*. *Beels* are natural wetlands playing a significant role in socio-economic aspects of Assamese people. Though there is no such satisfactory general definition of *beels* exists, normally abandoned river beds with or without connection to the main stream are called *beels*.

These *beels* are of two types (Jhingran, 1994):

i. Lake like *beel*

ii. Oxbow *beel*

Lake like *beels* are wide and shallow and have irregular shorelines. They are connected to rivers through channels. They are either called open *beels* if they maintain connections or close *beels* if connections are cut off with the main river. Oxbow *beels* are relatively narrow and long and have either a curved or serpentine shape. North Lakhimpur and Nowgaon districts of Assam have maximum number of oxbow *beels* while lower Assam comprising districts of Goalpara ,Dhubri and Kokrajhar have large lake like *beels*.

These *beels* harbour a wide number of commercially and biologically important fish species (Table 2) along with other aquatic flora and fauna. These *beels* are highly dynamic and self fertilizing ecosystems having tremendous potentialities for fish production. Jhingran & Pathak (1987) estimated the capacity of *beels* to produce fishes annually about 1500Kg/ha. Some fish species available in *beels* of Assam are given in Table 2. *Beels* are important from biological and conservation point of view also. Open *beels* serve as breeding and nursery ground for many commercially important fishes and shell fishes because *beels* are shallow and undisturbed which provide congenial environment for breeding and larval development. During flood season, spawners of many fish species especially Indian Major Carps enter the *beels* to spawn. *Beels* also help in flood mitigation and abatement. When huge amount of water from neighbouring states enters the mighty river Brahmaputra and increase the water level during monsoon season, excess water moves to the low laying *beels* and reduce the effects of devastating flood. These *beels* are facing serious threats from several factors. Some of them are

i. Deforestation for greed for timber and wood for building and fuel, foliage for fodder

ii. Siltation

iii. Land reclamation for industrial, agricultural and residential purposes

iv. Dumping of untreated effluents and sewage disposal and

v. Jute retting etc.

Table 2: Some fish species available in *beels* of Assam

Sl. No.	Scientific Name	Vernacular name
1.	*Anabus testudineus*	Kawoi
2.	*Amblypharyngodon mola*	Banhhpati
3.	*Amphipnous cuchia*	Kuchia
4.	*Bagarius bagarius*	Garua
5.	*Xenentodon cancila*	Kokila
6.	*Badis badis*	Upor Sokoya
7.	*Catla catla*	Bahu
8.	*Chanda nama*	Chanda
9.	*Chanda ranga*	Chanda
10.	*Channa orientalis*	Chengeli
11.	*Channa marulius*	Sal
12.	*Channa punctata*	Goroi
13.	*Channa striatus*	Sol
14.	*Channa stewartii*	Chenga
15.	*Chaca chaca*	Bhutmas
16.	*Cirrhina mrigala*	Mirika
17.	*Cirrhina reba*	Bhagon
18.	*Clarius batrachus*	Magur
19.	*Colisa lalius*	Bhecheli
20.	*Colisa fasciata*	Khalihona
21.	*Eutropiichthys vacha*	Bocha
22.	*Gudiusia chapra*	Koroti
23.	*Glossogobius giuris*	Patitmutura
24.	*Heteropneustes fossilis*	Singi
25.	*Labeo angra*	Lachim bhangon

26.	*Labeo bata*	Bhangon
27.	*Labeo calbasu*	Mali
28.	*Labeo rohita*	Row
29.	*Labeo nandina*	Nadani
30.	*Labeo gonius*	Kurhi
31.	*Mastacembelus armatus*	Bami
32.	*Mystus bleekeri*	Bhotia singora
33.	*Mystus cavasius*	Borsingora
34.	*Mystus menoda*	Gagol
35.	Nandus nandus	Vedvedi
36.	*Notopterus chitala*	Chitol
37.	*Notopterus notopterus*	Kandhuli
38.	*Ompak pabo*	Pabho
39.	*Salmostoma bacaila*	Chelkona
40.	*Puntius gelius*	puthi
41.	*Puntius chellaputhi*	puthi
42.	*Puntius ticto*	Kanjouthi
43.	*Puntius sarana*	Cheniputhi
44.	*Pangasius*	Kach
45.	*Rasbora daniconius*	Dorikona
46.	*Rasbora elenga*	Eleng
47.	*Tetraodon cutcutia*	Gongatup
48.	*Wallago attu*	Barali
49.	*Anabus testudineus*	Kawai etc
50.	*Xenentodon cancila*	Kokila

Source: Master plan of KNP (ed. K.N. Vasu, IFS KNP , Assam, 2002)

1.6 Limnological parameters for wetlands' Health

Water bodies are frequently contaminated by different kinds of pollutants resulting from increasing human population, urbanization and industrialization. Disposal of domestic wastes in wetlands like lake causing a undesirable changes in physicochemical and biological characteristics of these water bodies. Organic enrichment of these water bodies results in high oxygen demand and low oxygen content (Sharma *et al.*, 2008). Water chemistry exhibits variable physical and chemical characteristics and consequently variable planktonic composition (Fathi *et al,* 2001; Fathi and Flower, 2005). These variations depend mainly on the type and nature of the area itself as well as the manmade additions or runoff minerals and chemicals from agricultural soils (Mohammed *et al,* 1986). Limnological studies on determining the different parameters such as dissolved oxygen (DO), pH, alkalinity, conductivity, total dissolved solids, plankton diversity etc. play significant roles on ascertaining the water quality of such water bodies.

1.7 Wetlands in Kaziranga National Park

Kaziranga National Park (KNP), lies between latitudes 26 ° 34' N to 26 ° 46' N and longitudes 93 ° 08' E to 93 ° 36' E , is one of the most important protected areas in Assam spread over an area of 429.93 Sq. Km in the flood plains of Brahmaputra. It harbours the World's largest population of one horned Rhino (*Rhinoceros unicornis*) (1552 Nos. in 1999), Wild Buffalo (*Bubalus bubalis*) (1431 Nos. in 2001) and the Swamp Deer (*Cervus duvauceli ranjitsinghi*) (468 Nos. in 2000). Its conservation value was much recognized when it became one of the World Heritage Sites notified in India by UNESCO in the year 1985. Commonly found Mammals and flora of KNP are given in Annexure-I & Annexure-II respectively and various types of *beels* (wetlands) and their water retention capability are given in Annexure-III.

KNP is situated in the flood plains of the Brahmaputra River and the entire area has been formed by silt deposition carried by the different river systems flowing through it. It is observed that as long as the Brahmaputra River remains below the flood level, the runoff from the rivers originated in Karbi Anglong Hills district of Assam is quickly drained out into it and the park remains free from flood. But, if the Brahmaputra River rises above the flood level, the excess water of the river Brahmaputra enters the northern boundary of the park and flows into the park through the Brahmaputra's tributaries mainly by Mori Difaloo and Mori Dhansiri. After monsoon, with the gradual receding of water level in the Brahmaputra River, water starts flowing back to the Brahmaputra carrying the discharge and the excess water from the park. Thus water from the submerged high lands clears up fast. But the low lying areas inside the park form basins, especially around the existing *Beels* of the southern boundary on the western part and remain under water for a considerable period even after the receding of the flood water from other places. The water in such areas dries up gradually through evaporation and seepage and it lasts till early December of each year. Bunds are constructed in dry months near major water bodies to stop further draining out of water to Mori Difaloo and other open areas. This helps in providing sufficient water to the *beels* (wetlands) for fish, avifauna and other animals till next rains. These *beels* are integral part of the KNP which serve as breeding and feeding ground for many aquatic vertebrates and shell fishes. These *beels* also serves as feeding ground for many terrestrial animals including world famous one horned rhinoceros.

Rationale of the present investigation

Wildlife ecosystem is complex, fragile and integrated ecosystem not only comprising of land, forest and animals but also wetlands and its related flora and fauna. Wetlands are sources of drinking water and feeding ground for the animals living around it. Therefore, the health and productivity of these wetlands become important for a wildlife sanctuary. Assam, one of the states of India, located in North-eastern region of the country homes to a variety of flora and fauna. An excellent environment and luxuriant bio-diversity makes Assam an unparalleled state, supporting a variety of wildlife. Assam has several National Parks, Wildlife and Bird Sanctuaries which home to several endangered and rare species of flora and fauna as well, including the golden langur, hoolock gibbon, pygmy hog, hispid hare, white-winged woodduck, clouded leopard, swamp deer with the highest density of tigers in the world and house the most number of one-horned rhinos. Moreover, different flocks of resident and migratory birds make their natural habitats in these areas. *Beels,* the water bodies, are playing a major role in the health and productivity of the National Park and Sancturies. The major part of the KNP has also been comprised of these *beels* which are serving as breeding and feeding ground for many aquatic vertebrates e.g. fishes and shell fishes . Therefore, it is important to study the *beels* (wetlands) of KNP in relation to their physicochemical and biological characteristics which may govern the health of the wild and aquatic life of the park. Though, considerable works are reported on the studies of different types of wetlands of Assam, but, little studies are reported on the *beels* of KNP.

Apart from varied wetland resources, Assam has also got a number of tea gardens as its unique assets in the world. There are about 860 tea gardens occupying about 2,30,000 ha of land (URL: *www.assamchronicle.com/sites*). It is one of the major industries of the state earning considerable amount of foreign exchange. KNP has also several tea gardens neighbouring the park boundary. These tea gardens have several streamlets flowing into *beels* of KNP. These streamlets carry the washing of tea gardens to the park along with hazardous chemicals using for weeds and pests control. The wild animals of the park consume the water of these streams and possibly animals might be affected by the contaminated water. Though the effects may not be apparently seen at present, but chemically polluted water may cause serious problems to the wildlife as well as aquatic life of the park in near future. Though studies were carried out by different researchers on the soil, forest and wildlife of the KNP, a little study is reported on the park's water bodies for sustainable management. Therefore, it is of interest to make detailed limnological study of *beels* exist in the KNP.

Keeping all above in view, the present investigation were undertaken with the following objectives

1. to study various limnological parameters of selected *beels* and their variations during different seasons of the year.
2. to determine the rate of siltation and its variation with respect to location of the *beels*.
3. to study plankton communities, their availabilities and diversities over the different seasons of the year.
4. to analyse the physico-chemical parameters of the water column of streams and ascertain the impact of tea estates, if any, on the streams and water bodies of the park
5. to assess the health and productivity of the *beels* of KNP based on the present study

Chapter–II

REVIEW OF LITERATURE

Chapter–II

Review of literatures

2.1 Studies on the wetland ecosystem

In just few decades ago, much importance was not given on the protection and development of the wetlands. They were rather considered as waste lands. Later on, scientists and environmental workers realised the importance of these wetlands and its related fauna, including waterfowls. The International Conference on Wetlands and Waterfowl held at Ramsar, Iran in1971 emphasised on the protection and preservation of wetlands worldwide. The most significant aspect of modern efforts for environmental protection has been the realization that conservation and development must go hand in hand. The central tenet of 1992 UN Conference on Environment and Development was the sustainable development based upon sound conservation principle. Sustainable development has been placed high on the political agenda, both internationally and nationally. Giving continued high priority to implementation of the ' wise use' concept should therefore be an important part of a strategy to strengthen and give more political weight both to the Ramsar Convention and to wetland conservation in general. This time onwards importance for wetlands gained momentum and scientists paid more attention in understanding the characteristics of this unique ecological feature. Cooper *et al.* (1986) evaluated the movement of sediment and soil nutrients from the agricultural uplands through riparian area and into downstream alluvial swamps. They found that riparian area removed the most of the nitrate from the ground water .Peter John and Correl (1984) obtained similar results but suggested that efficiency of the riparian zone varies seasonally and with hydrologic conditions.

Impacts of fresh water wetlands on water quality were studied by Whigham *et al.* (1988). They found that effects of wetland on water quality depended on its position, in the landscape and its type. They reported that riparian areas that border uplands appeared to be important site for nitrogen processing and retention of large sediment particles. Fine particles associated with high concentration of phosphorus were retained in the downstream of wetland where flow rates were slowed down and surface water passed through plant litter. Thus they opined that there was little doubt that freshwater wetlands could improve water quality.

Wardrop and Brooks (1988) studied the occurrence and impact of sedimentation in central Pennsylvania wetlands. They estimated the rate of sedimentation and characteristic of deposited sediment in 25 wetlands. They reported that the rate of sedimentation ranged from 0 to 8 cm /year and rate of sedimentation was correlated with surrounding land use pattern and hydrogeomorphic (HGM) subclass. Craft and William (2000) studied the soil accretion, sediment and nutrient accumulation in flood plain and depressional wetlands of Georgia, USA to evaluate the role of reverine versus depressional wetlands as sink for sediment and nutrients. Soil cores were collected from three floodplain wetlands (Cyprus -gum) and nine depressional (three each from Cyprus gum forest , Cyprus–savannah, and herbaceous marsh) wetlands and analysed for radio nuclides ($137C_5$, 210Pb), bulk density ,N ,P and organic C to quantify recent (30yrs) and long term (100yrs) rate of sediment and nutrient accumulation. They found no significant differences in organic C, N or sediment accumulation between depressional and floodplain wetlands but accumulation of P as 1.5 to 3 times higher in floodplain than depressional wetlands.

Wetlands remain a focus of research in mercury cycling both in terms of the mechanisms governing the production of methyl mercury *in situ* and their control on the fate and transport of both inorganic and methyl mercury as reported elsewhere (Branfireum *et al.* 1999; Heyes *et al.*,2000; Branfireum and Roulet, 2002). Branfireum *et al.* (1999) investigated the link between atmospheric sulphate deposition and production of methyl mercury in the peat. They found a clear increase in the amount of methyl mercury, a potent neurotoxin with sulphate addition made the first direct link between sulphate deposition in precipitation and mercury cycle in the peat lands. However, Galloway and Branfireum (2004) reported that the highest transport of total mercury was found in the temperate swamp when wetland and stream were connected. They observed an inverse relationship between methyl mercury and sulphate concentration with the highest and lowest conc. respectively during the period of persistent inundation and the on set of anaerobic condition in the wetland sediments .

Robert and John (2001) studied plant decomposition and litter accumulation in depressional wetland. They selected 11 nos. of 20 years and 6 nos. of 2 years old depressional wetlands for their study. They studied plant decomposition as mass loss over 507 days for both age classes and litter accumulation as detritus mass present in 20 years old wetland. Decomposition was found to be faster in 20 years old wetlands (85%) but well below for comparable species in natural wetlands (53%). In 20 years old wetlands, hydrologic variables were important for the species plant tried. They found that high percentage of mass loss by species under investigation occurred after 2 days and 161 days decomposition period. In contrast to their study, Puriveth (1980) and Thormann & Bayley (1977) reported rapid initial mass loss as a result of leaching and action of microbs was downplayed due to anaerobic condition associated with the persistent inundation.

Scott (2003) studied isolated wetlands and their functions. He recommended the Tiner's definition of isolated wetlands "that are completely surrounded by uplands". He opined that wetlands that were distributed across the landscape as geographically isolated basin should function differently from other wetland types based on landscape configuration. For example, stream and river concentrate water collected over a large surface into a relatively small area comprised of a limited numbers of channels. He reported a high loading of pollutants or nutrients per wetland area in riverine as opposite to extensive wetlands. He also suggested that zonation resulted from spatial variation in moisture conditions that might vary over the year and could affect the timing of habitat availability.

Waddington and Robert (2000) studied the global warming in relation to peat land. They opined that peat land were neither source nor sink of green house gases. But Roulet (2000) stated that land use pattern significantly altered green house emission. It was further reported that cut over peat land was a persistent source of atmospheric CO_2, losing Carbon of 300 to 400 g/m/year (Waddington *et al.*, 2002). Similar opinion was also expressed by Waddington and Mc Neil (2002) and Petrone *et al.* (2003). Many other workers also studied carbon exchange from undisturbed peat lands. Lafleur *et al.* (2001) determined the CO_2 loss from an ombrotrophic peat land during non–growing seasons and reported that amount of CO_2 was about 183g/m^2. Joiner *et al.* (1999) reported that inter annual difference of Carbon sink was linked to an earlier snowmelt and thaw of the fen surface, leading to the drier condition. Griffis *et al.*(2000) suggested that an early snow melt combined with wet and warm conditions during spring period leads large Carbon acquisition even when drier condition prevail over the majority of growing season. CO_2 exchange in an adjacent wetland forest, however was related to timing of snow melt and heat content prior to leaf out (Lafleur *et al.* 2001a, Rouse *et al.* 2002).

Wendy *et al.*(2004) studied the impacts of sedimentation and nitrogen enrichment plant community development in wetlands.They reported that anthropogenic activities produced specific stressor on wetland system that altered species composition. Species were affected differently by sedimentation and N enrichment. They observed that there were differences in plant communities' sensitivity to stressor between wetland subclass. They reported that sedimentation generally reduce seedling establishment, while N enrichment produced variable effects on height and biomass. Inter specific competition had little effect on establishment but significantly reduced biomass. Sedimentation generally reduced community biomass density and richness.

Price *et al.* (2005) highlighted the advances made in hydrology of Canadian Wetlands between 1999 and 2003. Tian and Zhou (2007) analysed the Phosphorus fractions of floodplain sediments and Phosphorus exchange on the sediment–water interface in the lower reaches of the Han River in China. They reported a total phosphorus content in the ranged of 643.86 to 985 mg /kg where inorganic phosphorus was the major fraction of tp calcium bound phosphorus. Nutrient removal in pilot and full scale constructed wetlands of Malayasia was studied by Cheng *et al.* (2008). They found nutrients removal performance to be 82.11% for total nitrogen, 70.73% for nitrate nitrogen and 84.32% for phosphate respectively. Fathi *et al.* (2009) studied water quality and phytoplankton community in Lake Al Asfar of Saudi Arsbia. Sharma and Rawat (2009) indicated possible use of macro-invertebrates as bio-indicator for assessing the health of the wetlands based on study conducted in central Himalayan region. Li *et al.* (2010) evaluated the land use policies and its effects on wetland changes in China and suggested the modification of land classification system of national land management.

2.2 Studies on the *Beel* Ecosystems

Jhingran (1974) mentioned about be morphometry, degree of precipitation and nature of catchment of *beel.* He opined that greater percentage of water with sediments even in deeper euphotic zone with warmer temperature regime due to longer sunshine hours caused intermediate to high biological productivity levels in the *beels*. Jhingran and Pathak (1987) studied about trophic structure and energetics of Assam *beels* and reported that the weed problems of Assam *beels* were generally for water hyacinth whereas *Hydrilla verticicillate* and *Vallisneria spirales* were the main macrophytes in Dhir *beel*. Other species encountered were *Salvina, Lemna , Wolfia, Potamogeton* etc. The hydro-biological conditions of the Ghorajan *beel* situated in the north bank of river Brahmaputra opposite to Gauhati city was studied by a group of scientists from Inland Fisheries Research Institute during 1971 to1985 under All India Co-coordinated Research Project on Air Breathing Fish Culture. They studied phytoplankton and zooplankton biodiversity in the *beel* and found 53 to 262 nos. /l of phytoplankton and 11 to 45 nos. / l of zooplankton. They recorded maximum numbers of phytoplankton during April and minimum numbers during May whereas for zooplankton, maximum numbered were recorded during July and minimum numbered were recorded during June.

Pal and Singh (1983) carried out preliminary observation on some limnological parameters on Sarania, an acidic swamp of Assam. They found that Sarania swamp was at the last stage of transformation process being thickly covered with *Eichhornia* spp. throughout the year and resulted in poor production of phytoplankton and zooplankton. The pH of swamp ranged between 6.0 to 6.6 the acidic nature of water might be attributed to lataritic soil condition and washing brought in from Sarania hill. The gross primary production ranged from 12.3 to 52.09mg C /m^3/hr. Eventually, phytoplankton and zooplankton counts were very low except in the month of February and March. Drying up of *Eichhornia* spp during winter month helped in increasing pH.

Yadava *et al.*(1984) studied macro benthic fauna of Dighali *beel* of Assam; according to them Oligochaetes, Dipteran larvae, and mollusks together contributed to maximum in number and dominated over other forms.The population of macro benthos ranged from 171/m^2 to 567 / m^2 and showed marked variation during the year . During summer month higher no. of macro benthos was observed .The reason was attributed to the decomposed settled organic matters and hydrophytes and rise in temperature,thus creating a conducive environment for their growth and multiplication as suggesed by Gupta (1976) who studied the fluctuation of macro benthic fauna in Loni reservoir of Madhya Pradesh .

The energy dynamics of open and closed *beel* in Ganga and Brahmaputra basins was studied by Pathak (1990) where he carried out ecological investigations in Kulia and Media beel in West Bengal and Dhir *beel* in Assam. Dhir and Kulia were open *beels* and Media was closed *beel*. He reported that when macrophytes were dominating the *beel* the average photosynthetically active radiant energy (wave length range 4000A to 8000 A.) converted to chemical energy in Kulia *beel* was 19, 60,000 cal/ $m^{2/}$day whereas during phytoplanoton domination period the energy was 20,446 cal $m^{2/}$ /day. Result was similar in Media *beel* also. The radiant energy on Dhir *beel* surface was on an average 18,55,000 cal/ m^2 /day of what 53,719 cal/ m^2 /day was fixed by producer.

The potential chemical energy of producers was not much deposited as organic detritus at the bottom. Pathak *et al.* (1985) also studied the pattern of energy utilization and productivity in *beel* system where he emphasized on the importance of detritus chain in *beel* ecosystems and concluded that the most important energy flow of *beel* leading to fish production was organic detritus. Eco energetic studies have shown that these *beels* could produce 1300 to 2150 kg ha/ year/ but at present and 18.% of the potential was harvested from Media and Dhir *beel*.

Role of inorganic phosphate in phytoplankton cycle was studied by Kalekar *et al.*(1989). In their studies phosphate in Dighali *beel* ranged between 0.013 to 0.613 ppm. They observed a gradual increase in the phosphate content of the *beel* water and a sharp fall from September onwards. Again, an increasing trend was also noticed after November reaching a peak during February. They pointed the causative factor as allochthonous source such as rain from catchment area. In the study they found that the low levels of phosphate in certain months were inversely related to peak period of phytoplankton. The lowering phosphate level with higher biomass of autotrophs could be explained when one would assume the utilization of these elements for growth and reproduction by phytoplankton community. The assumption was further evidenced by lack of precipitation of phosphate which requires higher pH, whereas *beel* water always remained in an acidic to near neutral condition.

Sugunan *et al.* (2007) conducted experiment on baseline information on physical and ecological conditions of *beel.* They studied Samuguri and Haribhanga *beel* of Nagaon. They found acidic bottom soil (pH 5.4-6) with high organic carbon (1.45-2.6%) and poor phosphorus (2.1 -5.85 g/kg). N_2 was found to be in the range of 0.12 to 0.24 g /kg with C/N ratio 11.0 -12.5. They reported 89-127u/l of plankton density in Samuguri and 111-142 u/l in Haribhanga beel. Phytoplankton dominated in both the *beels* in the temperature range of 18.8 to 33 ^{O}C and specific conductivity 70-132 μS/cm.

Dutta & Bhagawati (1994) analysed the benthic macro invertebrates of Kachadhara beel. They identified as many as 5 major taxa of benthic invertebrates which represented 92% of the total benthic population namely; chaobridae, copepoda, chironomidae, oligochaeta and gastropoda .

Choudhury *et al.* (1997) studied various *beels* of Kamrup district of Assam. They compared the fish production in managed and unmanaged beels of West Bengal. Water quality of these reflected slightly acidic pH range between 6.0 to 6.5, dissolved Oxygen between 5.6 to 9.6 ppm at Mandira ,6.8 and 10.9ppm at Arikata *beel* dissolved organic matter was considerable higher ranging between 1.48 and 3.12mg/l All the beels were found to poor in nutrients such as nitrate (0 .08to 0.28 mg/l) and phosphates (0.01 to 0.15 mg/l) poor status was attributed to high macrophytic infestation.

Das (1998) investigated the role of detritus on the food web of beel. He found that C/N ratio of detritus in beel was within the range which facilitated active mineralization supporting the fact that mostly detritus was macrophytic origin .He also observed low level of available P in some beels which he reasoned that high acidic nature of the bottom sediment ,where phosphorus might be locked up in the form of Fe and Al phosphates. Acharjee and Dutta (1999) carried out investigation on limnological parameters of Dighali *beel* of Nagaon, Assam. Among the soil parameters, soil pH ranged in between 4.8 to 5.8 where organic carbon was 1.8 to 3.5, available N 488 to 585ppm and available Phosphate 0.35 to 0.50 ppm. Plankton density was estimated as 511to 883u/l and 803 to 897 u/l in period of two consecutive years . Density of phytoplankton was more than zooplankton. The eutrophication stress on beels of upper, lower, central and southern Assam was studied by Goswami *et al.* (1999). They studied the rate of allochthonous siltation rate and determined the active life of several wetlands of Assam. They found that siltation caused by high fluvial allochthonous charges from the river meanders and other catchment sources reduced the basin depth at the rate of 0.015 to 0.09 m/year . Many wetlands that exposed to such allochthonous siltation have their physical life to continue for 3.6 to 147year depending upon the charge of load, flood intensity hydro geographic changes of the basin. The Barak valley wetlands were subjected to more pressure of siltation due to fluvial nature and sediment characteristics of the drainage. They identified three main factors for disappearance of many wetlands of Assam as allochthonous siltation autochthonous production of macrophytic biomass and impeachment as a part of human interference.

Sarma (2000) analysed the rotiferan zooplankton communities in the *beel* ecosystem. He identified 64 species of rotifer which was one fifth of the total known species of India. He carried out analysis of limnological parameters of different *beels* of Assam. Ecological status and fish production potentials of three tributaries viz. Dibang , Siang and Lohit of mighty Brahmaputra was analysed by Pathak *et al.* (2001). They explained the sediment characteristics as sand dominated (97 to 99.5 %). P^H was in the range of 7.01 to 7.72. The rivers were poor in nutrients (N_2 98.4 to 128.8 mg/kg) and Phosphorus was 4.8 to 7.2 mg/kg except Siang (1.64%).

Ahmed *et al.* (2004) studied ecological condition of Uprad *beel* in the district of Goalpara. Indigenous ornamental fish biodiversity of central Brahmaputra valley was studied by Sarma *et al.*(2004). They identified a total of 61 fish species belonging to 42 genera,22 families and 9 orders occurring in this zone having value as ornamental fish. Deka *et al.* (2005) studied 54 wetlands of 13 districts of Assam to evaluate the cause of fish depletion. The depletion rates of each of the wetlands were calculated as percentage decline in fish production over 5 year's period. The annual rate of fish depletion varied 0.21 to 75 % with a mean of 4.94%.and standard deviation (sd) of 0.24.

Bhaumik *et al.* (2005) analysed the periphytic structure in two flood plain wetlands of West Bengal –Amda and Suguma beel. The periphyton of the beels comprised of mixed population both phyto and zoo plantation. The density of periphytonic population ranged between 1346 u/ cm^2 and 2170u/cm^2 and the summer population was maximum followed by winter and monsoon. They suggested that littoral characteristics was favourable for growth of periphytonic organisms in the beel. A good growth of submersed vegetation supported periphytic growth. Gorai *et al.* (2006) raised stocking material- fingerlings of Indian Major Carps in pens installed in two flood plains wetlands of Assam.viz. Goruchara and 46- Marakollang. Apart from growth studies they also studied the soil texture and water quality of these beels . They indicated that the main components of soil was sand (40-56%)followed by silt 24-48% and clay 2-18% in Goruchara beel whereas 46 Marakollong silt was major component (46-66%) followed by sand and clay. Dutta and Bhagabati (2007) studied the limnology of ox bow lake – Dighali- closed beel and Kachadhara an open beel of Assam. They observed the fluctuation of PH , acidic to neutral range with total alkalinity of > 29.2 mg/l and total hardness>40.5mg /l. Moderate natural concentration of N, P_2O_5 , Si, Fe in water were due to their utilization by dense aquatic vegetation that restricted the plankton abundance to 756u/l in Dighali and 845 u/l in Kachadhara. The NO_2 and P_2O_5 behaved inversely suggesting excess utilization of one nutrient over the other. Dehadrai (2007) analysed the water chemistry of derelict water bodies of North Bihar and their subsequent utilization for production purposes. Physicochemical studies of closed beel of Kalyani industrial area was studied by Trivedi *et al.* (2007). In their studies, they found that the conc. of metal was within permissible limit. Copper, zinc and iron content of water varied between 0.0120 and 0.0156mg/l, trace and 0.013mg/l and 0.010and 0.0156 mg/l respectively. pH of sediment was found to be within the ranged of 6.8 to 8.3. Available phosphorus were 2.03 to 4.82 mg/100g. Macrophytes controlled limnochemistry in tropical wetlands of Assam were studied by Mana and Aftabuddin (2007). Nahar *et al.* (2010) investigated the epipelic diatoms in the two wetlands of Bangladesh viz. Sitlai beel and Joysagar. They indentified a total of 73 genera diatom taxa of which 12 taxa solely occurred in Joysagar and 21 taxa occurred in Sitlai beel and 40 taxa were found to be common to both the wetlands. The average density of epipelic diatom was higher in Sitlai beel than Joysagar *beel.*

2.3. Pesticides/ herbicides in aquatic environment

Wide spread application of insecticides and herbicides in agriculture and public health is posing a serious problem in to supplying of safe drinking water and conserving aquatic ecosystem.Neighboring the Kaziranga National Park there are several tea gardens. These gardeners apply herbicides and pesticides as control methods for weeds and insects. The persistent organic pollutants such as organochloride and organophosphate have their bearing even in remote ecosystem. These persistent, broad spectrum toxicants accumulate in organisms of lower level of food web posing a high risk to the ecosystem and to human as well as animal health through the process of biomagnifications. In India, organochloride pesticides specially DDT and HCH were extensively used till recently both for agriculture and sanitary purposes (Kumar *et al.*, 2006). DDT's levels in India was as high as 0.86 to 140 µg / g wet wt. which is much higher when compared to other south east Asian countries (Monirith *et al.*2003). It was estimated that about 250000 MT of chlorinated pesticides was used normally in India and DDT accounted for over 40% of this group (Mathur,1993). Nayak *et al.* (1995) observed that DDT concentration in mid stretch of river Ganga which was over

the safe limit prescribed by WHO, i.e.1ug/l. The reason attributed was to enhanced municipal public activities than agricultural pest management activities.Ramesh *et al.* (1990) and Rajendran & Subramanian (1997) measured DDT and HCH residues in several rivers of South India. Neither study found significant changes in DDT residue concentrations in waters of the river Vellar, Kaveri and Coleroon or in the Pichavaram mangrove wetland based on seasonal changes, wet or dry season or summer, pre-, post- or monsoon season. However, there was a significant increase in mean ΣHCH levels during the wet season for the Vellar River and the Pichavaram mangroves (Ramesh *et al.*, 1990) and among pre-monsoon season for the rivers Kaveri

and Coleroon (Rajendran and Subramanian,1997).The increase in Σ-HCH concentrations corresponding with the time of increased agricultural use of the pesticide and the absence of a similar pattern of ΣDDT strongly suggests that farmers for pest control are not employing DDT nor is it being excessively employed in public health programs in South India. Venugopalan and Rajendran (1984) reported pesticide concentration ranges in Vellar estuarine water (southeast coast of India) which ranged, for total ΣDDT (DDT+DDE+DDD) of 1.6 to 14.1 ng /l, for lindane of 0.09 to 2.8 ng /l and for endosulfan of 0.02 to 1.4 ng/l. Their observations did not show any definite seasonal variations for any of the pesticides monitored. The authors attributed the low residue concentrations in water to high surface water temperatures, which resulted in a high vaporization rate for the pesticides. Sujatha *et al.* (1994) assessed the distribution of DDT and its metabolites in the Kochi backwaters, southwest of India. Total DDT concentration was as high as 54.4μg/l and the predominant metabolite was pp'-DDE. Total HCH concentration was as high as 1.1μg/l in the Kochi (former Cochin) backwaters due to a pre-monsoonal accumulation of pesticide. However, during the monsoon Σ-HCH concentrations ranged from below detection level to 0.18 μ g/l through the estuary followed by an increase during post-monsoon period from 0.24 to 0.52 μg/l (Sujatha *et al.*, 1993). Several studies indicated organochlorine contamination in the sediments of Indian coastal waters predicting the presence of their discharge of these chemicals into the sea in this region (Pandit *et al.* 2002). Guzzela et al. (2005) also observed accumulation of various organochlorine pesticides in the surface sediments along the stretch of Ganga including Sunderban mangrove wetlands.

On the biological front Willson *et al.* (1995) studied the organochlorine contamination in fish from an arctic lake in Alaska. Organochlorine and poly chlorinated biphenyls (PCBs) were measured in muscle tissues and liver of lake trout (*Salvinus namaycush*) and Arctic greyline (*Thymallus arcticus*) . Presence of these chemicals in remote Alaska confirmed the long range transportation of these chemicals. They also observed that liver contained more of these chemicals than muscle tissues. Deposition of PCBs in liver and muscle ranged from 3.2μg/g in greyline liver to 22.8ng/g in trout liver and deposition in the muscle ranged from 1.3ng/g in greyline to 6.6ng/g in trout muscle. The biomagnification factors were similar to the ratios reported for other aquatic system. The higher concentration of pesticides in trout attributed to carnivore nature of the nature of the fish .The most abundant group in all tissues was composed of PCBs followed by organochlorine and DDT metabolites. Similar deposition of organochlorine, DDT and hexa chlorocyclohexanes isomers, chlordane compounds (CHLs) were also determined in 27 species collected and studied in Cambodia by Monirith *et al.*(1999). In contrast to Arctic study by Wilson *et al.* (1995) where predominant compounds were DDT derivatives both in freshwater and marine species. Effects of organophosphate insecticides rogor on some biochemical aspects of magur fish *Clarias batrachus* (L) was studied by Begum and Vijayaraghavan (1999). They observed changes in glycogen lactate dehydrogenase and glycogen phosphorylase content of muscle. The insecticide exerted an adverse effect on glycogen content of muscle tissue. A relatively rapid up to

96h and slow deceleration of this rate after 192h of exposure occurred in the muscle tissue. There was a significant elevation in the muscle lactate content .A significant increase in phosphorylase was observed in the muscle tissue. Results clearly indicated the disrupted carbohydrate metabolism to the sub lethal level of exposure. The decrement in glycogen content in the tissue suggested mobilization of glycogen to meet energy demands warranted by toxic environment. Kiku chi *et al.* (2000) used *Daphnia magna*, a common zooplankton for detection of organophosphate
insecticides in polluted water. They found that organophosphate insecticides caused immobilization of the zoo plankton.and suggested that *D. magna* test could be used as a low cost preliminary screening method for insecticides pollution.

Physiological aspects of some organochlorine residue in European eel (*Anguilla anguilla*), crucian carp (*Carassius carassius*) and catfish (*Ictalurus nebulosus*) were studied by Roche *et al.*(2000) . They detected organochlorine residue contamination in hepatic and muscular tissues of these fishes in Vaccares lagoon. They observed the highest organochlorine concentration in liver and muscle in fishes coming from a site located near the mouth of a canal draining irrigation water from rice field. Stefaneli *et al* (2004) reported poly chlorophenyls (PCB) and organochlorine (OC) pesticides in the tissues of swordtail (*Xiphias glalius*) from Mediterranean sea and Azores island. Pesticides in the tissue of Mediterranean swordfish ranged from 4.61 to 4651.17 ng /g on fresh tissue basis in particular P,P'-DDE had conc. appearing to be up to 3900ng/g with highest value in fatty tissue such as blabber. They opined that PCB and OC were endocrine disrupting chemicals .Levels organochlorine pesticides, poly chlorinated biphenyls and poly brominated diphenyl ethers in fish species from Turky were studied by Erdogrul *et al.* (2005). Species were *Acanthobrama murmid, Cyprinus carpio* , *Chondrostoma regium* (nose carp) and *Silurus glanis.* They found that DDT dominated organohalogenated contaminants in all species, other OCPs such as Chlordans, hexa chlorobenzine (HCB) were found at much lower levels. They found that carnivore animals deposited more pesticides than herbivore animals in agreement with the process of biomagnification.

Yeh *et al.* (2005) studied the effects of an organ phosphorusinsecticides, trichlorfan on hematological parameters of the giant freshwater prawn *Macrobracium* *rosenbergi*(de Man) .They observed significant depression in hemolymph osmolarity and Cl-1 when exposed to trichlorfan . Phenoloxidase activities in the monocytes of prawn decreased significantly with exposure greater than 0.2mg/l of trichlorfan. This indicated that trichlorfan reduced the immune ability of the prawn. Similar observation was also reported by Smith and Johnson (1992) on common shrimp, *Crangon crangon.* Vives *et al.* (2005) studied the deposition of organochlorine in relation to age of the fish brown trout (*Salmo trutta*) from a high mountain lake in Pyrenees (Catalonia, Spain). An increase of 2 to 20 folds between fish age of 1 year and 20 years were found. Higher molecular weight compounds (higher lipophilicity) were better co –related with age than lower molecular weight compounds. A transformation from 4, 4'-DDT to 4 4' DDE occurred in fish after ingestion. Deposition of hydrophobic compounds were selectively in younger fishes was observed. Zhu *et al.* (2006) studied the presence of organochlorine pesticides in the air of Mt Everest region. Interestingly they found organochlorine pesticides (OCP) in the samples in the ranges of 19.2, 11.2, 7.7, 8.9, 10.4, 27.6, 5.1 and 3.7 pg/m^3 for alpha HCH, beta HCH, gama HCH, HCB, Hepta chlor, Endosulfan, DDE, and DDT respectively. Storelli *et al.* (2007) analysed muscle tissue of eel for metals i.e. Hg, Cd, Cu and Zn poly chlorinated bi phenyl, organochlorine pesticides (DDT) to ascertain the concentration of these chemicals. They found that Zn deposition was maximum followed by Cu, Hg, Cd. Eel muscles showed mean conc. of PCB to range of 19.2 and 30 ng/g wet wt. basis. The impacts of organophosphate pesticides in orchards on earth worms in South Africa were studied by Reinecke and Reinecke (2007). They found that earthworms were detrimentally affected by pesticides Chlorpyrifos and azinphos methyl. The residual effects of organochlorine isomers (DDT, aldrin and endosulfan) and organophosphate (chlorpyrifos) insecticides were studied by Singh *et al.*(2008) on flesh of fish ,chick , goat and man. The catfish, *Rita* was captured from unpolluted reference point and polluted river Gomti during pre spawning phase. The results indicated that in *Rita rita*, the DDT, HCH, endosulfan , aldrin , chlorpyrifos in blood levels in the preferential order of DDT> HCH > endosulfan> aldrin>chlorpyrifos.

The preferential order of bioaccumulation was goat> chick > man > fish. The gonadosomatic index, T and E2 declined in the catfish captured from polluted water when compared to unpolluted reference sites. The results indicated that in of pesticides in blood levels in vertebrates caused reproductive dysfunction .They also suggested that should avoid fish, goat and chick etc. those which contained the pesticides beyond permissible level. Thomaz *et al.* (2009) studied the cardio –respiratory function , oxidative stress ,and antioxidant activities in Nile tilapia exposed to organophosphate insecticides They exposed tilapia to 96 h at a conc. 0.5mg/l. The chemical induced oxidative stress in the heart of the fish which was manifested by glutathione –s – transferase depletion and hydroparoxide elevation. They found that the heart was most sensitive organ when exposed the trichlorfon. Similar organophosphate induced oxidative stress were also reported by Hai *et al.* (1997, Mohmmad *et al.* (2004) and Monterio *et al.* (2006).

Bioaccumulation of organochlorine pollutants in fishes were studied by Sarma *et al.* (2009) in Norwegian waters and in some fishes in Turky by Kalyoncu *et al.* (2009). These results indicated bioaccumulation and biomagnification of insecticides in the body tissues of aquatic animals.

Chapter -III

MATERIALs AND METHODs

Chapter -III

MATERIALs AND METHODs

The flow diagram of systematic methodologies for the present investigation has been presented in Figure-1

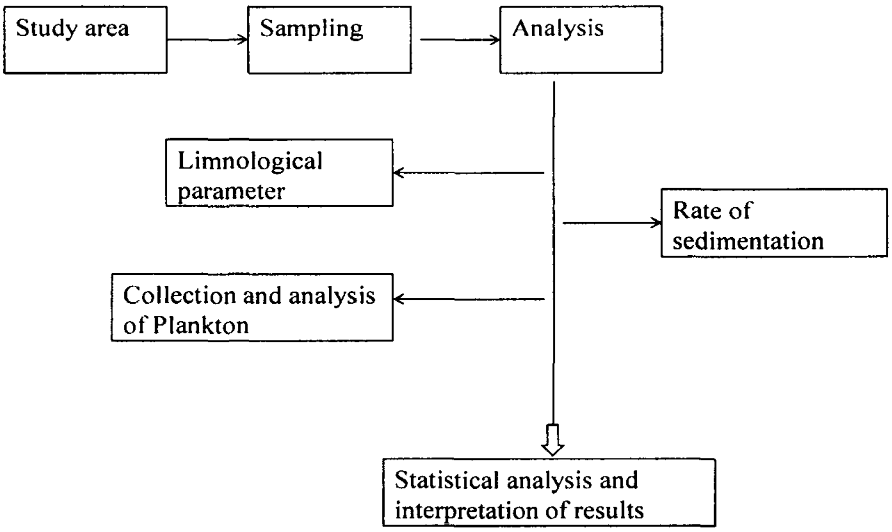

Figure-1: Flow diagram of systematic methodologies

3.1 Study Area

3 *beel*s viz. Gahari *beel*, Jamuguri nala and Tapacia *beel* of KNP along with 7 streamlets flowing from nearby tea gardens to the *beels* of KNP ranging from Amguri to Kohora locality of the park covering a distance of 35 Km were selected for the present investigation. Location detail of the KNP has been shown in the following figures (Figure 2-4).

Figure-2: KNP in Assam

Figure-3: Location of KNP with political boundary

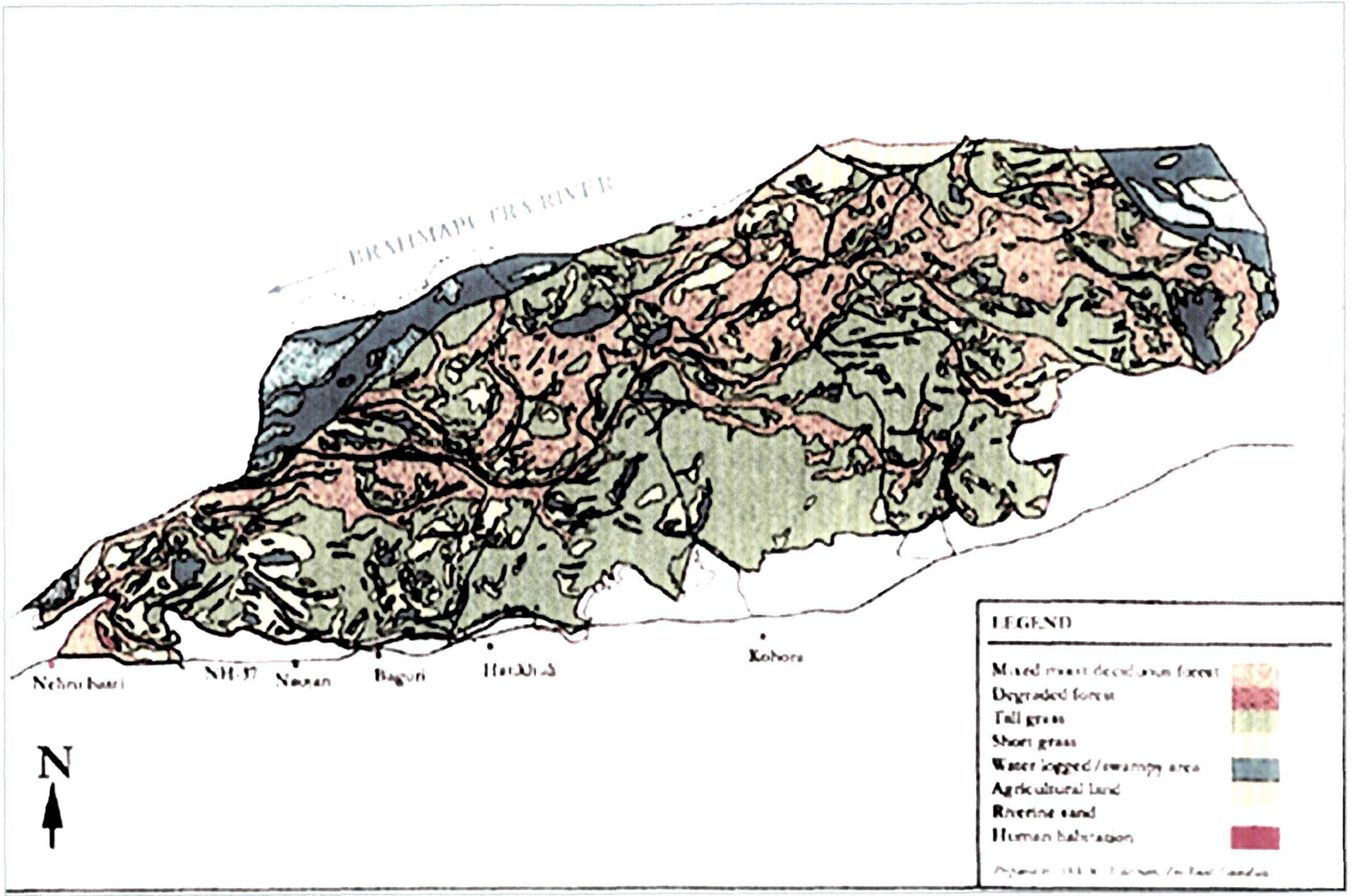

Figure-4: Vegetation map of KNP

3.1.1 Brief description of the Kaziranga National Park (KNP):

As discussed in Chapter-I Kaziranga National Park is situated at the mid part of Assam covering areas of Sonitpur, Nagaon and Golaghat districts of Assam. Total area of KNP is about 429.93 sq. Km. Geographically, KNP is mainly comprised of alluvial deposits of the mighty river Brahmaputra and its smaller tributaries. During rainy season a great amount of silt and clay are carried by these flooding rivers and deposit in the park area.

3.1.1.1. Geology, Rock and Soil of KNP

From the geological and geo-morphological mapping of Kaziranga area, it is seen that the area of the KNP predominantly comprises of recent composite alluvial plains and floodplains. The channels and point bars, back swamps deposits are quite conspicuous in the active flood plain of the park area. Lithologically, the Kaziranga formation is represented by grey silt and fine to medium sands which form the recent composite flood plain with numerous meander scars and scrolls. Palaeochannels and abandoned channels of the Kaziranga unit belong to the Holocene period of quaternary ages. The area is swampy and is criss-crossed by a number of channels flowing through the park area. The park is characterized by numerous permanent and temporary "*beels*". The Brahamputra river flowing along the northern boundary of the Park exhibits braiding pattern with numerous river island (*char / chapory*). Two types of *Chars or Chapories* are encountered- stable and unstable. Stable islands have large extent tall grass cover whereas unstable islands are devoid of grass cover. The left bank of the Brahmaputra river which forms the boundary of the national park is very steep and its height varies from 3 meters to 7 meters. Due to the changing pattern of the river, the left bank of the river erodes away considerable stretch of the land along its banks severely affecting the National Park. The KNP is characterized by a numerous swamps / *beels* complexes, along with a thick vegetation cover. The soil overlying the sandy deposits at places is very deep while at some places it is of very recent origin consisting mainly of sand, devoid of any humus or decomposed organic matter. As such, the soil at various places varies from sandy soil, sandy loam, clayey loam to purely clayey soil.

3.1.1.2 Terrain

The terrain of the Kaziranga National Park is flat with gentle almost imperceptible slope from east to west and from north to south. It is bound by the Brahamputra River on the north and the Karbi Anglong Hills on the south. The Kukurakata Reserved Forest (RF) is hilly and the Panbari RF is flat with hilly slopes along Karbi Anglong Boundary.

3.1.1.3 Climate

The study area falls under high rainfall zone. The mean annual rainfall for last ten years is 1881 mm. The months from May to September contribute towards major precipitation during a year. The months of July-August are the hottest months whereas the months of December-January are the coldest. The mean Maximum and the Minimum temperatures recorded during last ten years are 41° C and 6° C respectively. The relative humidity is generally high in most part of the year. It rises as high as above 90 percent during monsoon.

3.1.2 Description of Study sites

Sampling sites of the *beels* and streamlets of KNP are presented in Figure-5. 3 *beel*s viz. Gahari *beel* , Jamuguri nala and Tapacia *beel* were chosen for limnological study and chemical contamination study were conducted in 7 streamlets from Amguri to Kohora covering a distance of 35 Km.

The park area is divided into Agaratoli- Eastern range ,Kohora – Central zone, Bagari and Burapahar-Western range. There are numerous numbers of *beels* in these ranges and three *beels* were selected from these *beels* to study their limnological characteristics and their variation over the year. The selections of *beels* were done on the basis of the distance from the main river and adjacent to National Highway so that effects of the main river on the changes of limnological parameters could be understood.

Apart from these *beels*, a survey was conducted on the streamlets carrying water to KNP. Streams were selected based on their location which possibly carry washings from the tea gardens. All together seven streams were selected from the area between Amguri to Kohara and they were named as Stream-1 to Stream -7 (ST1 to ST7). The distance between two points was about 35 km.

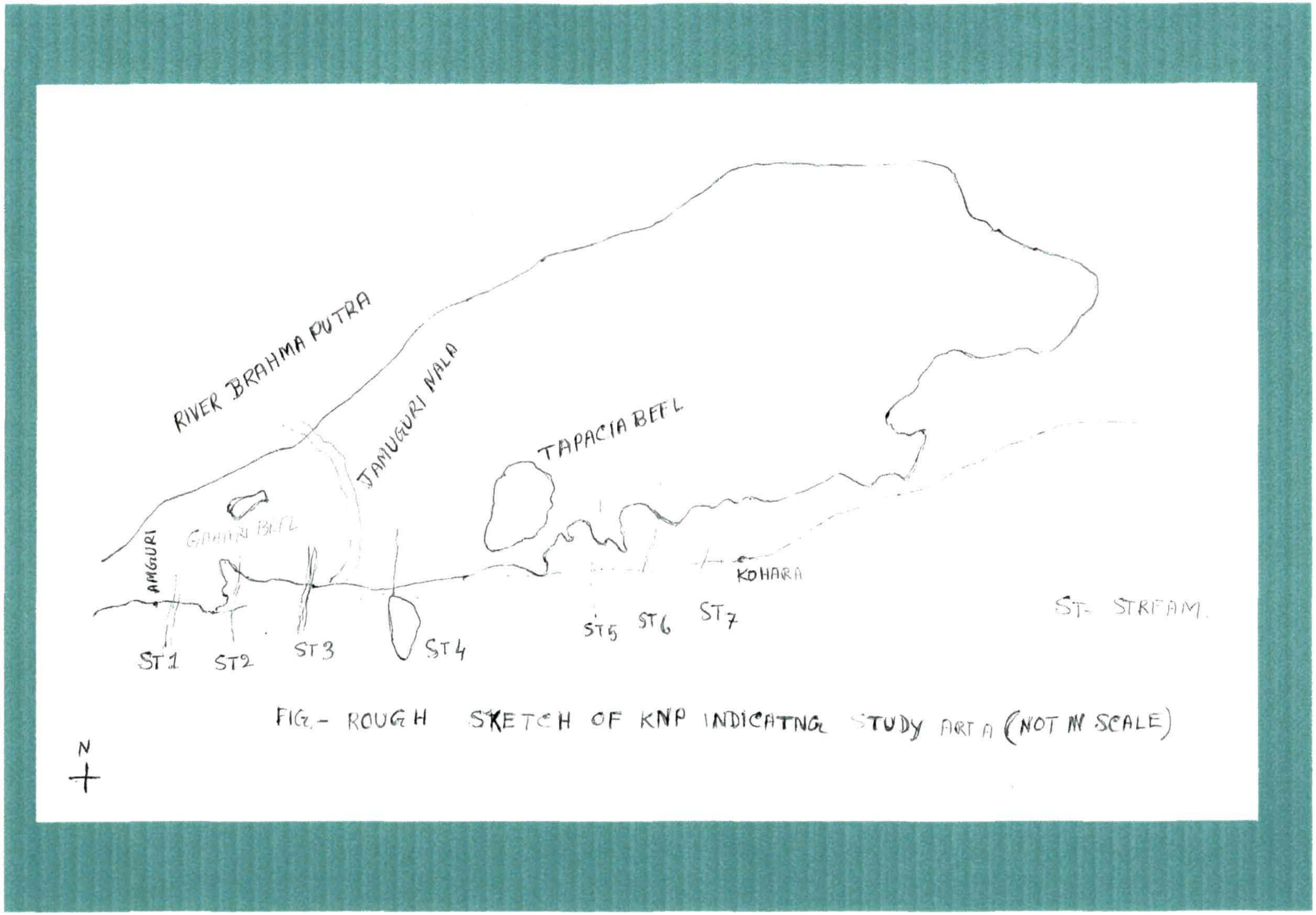

Figure-5: Sketch of KNP with selected study sites (not to scale)

3.1.2.1 Brief description of the selected *beels*

Gahari ***beel*** – It is a perennial beel situated at about 1 Km away from the main river Brahmaputra. Two third of its boundary is covered by hills. This water body is infested partly with submersed vegetation

Figure-6: Gahari *beel*

Jamuguri nala – It is permanent wetland collecting water from national park and carrying water to the main river Brahmaputra specially during rainy season. Water samples were collected at a distance of about 2.5 km away from the main river. This wetland is mostly covered by floating aquatic weed *Eichhornia* sp.

Figure-7: Jamuguri nala

Tapacia beel – It is wide water body adjacent to national highway The distance from the main river is about 3 km The water body is partly covered by floating weeds and submersed vegetation .

Figure-.8: Tapacia *beel*

3.1.2.2 Selection of perennial and temporary streamlets

Stream–1(ST1): It is a small perennial stream carrying water from Karbi Anlong hill and flows across the Amguri tea estate. Bottom of the stream is sandy in nature . Stream contains clear cool water through out the year .Both sides of the stream covered by tea garden and paddy fields.

Figure-9:.Stream-1

Stream –2 (ST2): It is also a perennial stream carrying water from Karbi Anglong hills and discharge water in the national park throughout the year . Bottom of the stream contains coarse sand and stream carries cool clear water round the year.

Figure-10: Stream –2

Stream – 3(ST3): It is a perennial , stagnant type of wetland for most part of the year. It receives water from Burapahar tea estate. During flood season excess water flows to the national park through a small channel. The wetland bottom is muddy in nature and contain lot of peat over it . Part of the water body covered by floating and submersed aquatic vegetation.

Figure-11: Stream -3 (Burapahar wetland)

Stream – 4 (ST4): It is also a perennial stream carrying water from Karbi Anglong Hills to KNP . It flows through Burapahar tea estate.

Figure-12: Stream -4

Stream –5 (ST5): It is perennial stream originated in Karbi Anglong hills. It flows through Hatikhuli tea garden.

Figure-13: Stream –5

Stream –6: It is a seasonal nala carrying water from Hatikhuli tea estate. It discharge water in the *beels* of national park .Bottom of the nala has fine sand.

Figure-14: Stream –6

Stream- 7: It is also kwon as Kohara nala. It is a perennial nala having fine sand at the bottom. It carries water from Hatikhuli tea estate.

Figure-15: Stream-7

3.2 Sample collection

Four samplings were carried out at various seasons in 2008-2009. The seasons were Monsoon (June-July), Autumn (Sep.-Oct.), Winter (Dec-Jan) and Summer (April-May). During monsoon, seasonal flood water enters into the KNP and inundates almost all parts of the park. Therefore, monsoon sampling was carried out during the month of June at the onset of monsoon. From each wetland, three sub-stations were selected for collection of samples. From each sub-station, three samples were collected for analysis and average of the three samples was taken as reporting value.

3.3 Limnological parameters selected for the study

Sl. No.	Parameters
1.	Dissolved oxygen content in water of different *beels*
2.	Dissolved CO_2 content in water
3.	Water temperature
4.	pH of water
5.	Conductivity of water
6.	Total alkalinity
7.	Total dissolved solids
8.	Hardness of water
9.	Phosphate content of water
10.	Nitrate content of water
11.	Dissolved organic matter of the water
12.	Determination of rate of siltation over the year
13.	Chemical contamination of water
14.	Phytoplankton and zooplankton communities and their variation in the selected wetlands

3.4 Methods for analyzing different parameters

3.4.1 Estimation of dissolved oxygen (Clesceri *et al.*, 1989; pp 4-149 to 4-152)

Dissolved oxygen in the wetlands were estimated employing Iodometric method. Samples were collected in narrow mouth glass stopper BOD bottles of 300 ml capacity. Soon after collection, samples were added with $MnSO_4$ solution followed by alkali-iodide solution. The resultant precipitation was dissolved by using conc. H_2SO_4. Then samples were stored for 3-4 hours for titration. The solution was titrated against standard sodium thiosulphate (0.025N) using starch as indicator.

Dissolved oxygen was calculated employing the formula-

$$\text{DO ppm} = \frac{\text{Vol. of } Na_2S_2O_3 \text{ xNx8x1000}}{\text{Vol. of the sample in ml}}$$

3.4.2 Estimation of free CO_2 (Chattopadhyay, 2007; pp 59 to 62).

The free CO_2 was estimated by adding phenolphthalein indicator and titrating against NaOH. The principle of estimation based on that CO_2 reacts with NaOH or Na_2CO_3 to produce $NaHCO_3$. The completion of reaction is indicated by the appearance of pink colour which is the characteristic of phenolphthalein used as indicator (Chattopadhya, 2008) . The free CO_2 is estimated using the following formula

$$CO_2 \text{ ppm} = \frac{\text{VxNx50x1000}}{\text{Volume of the sample in ml}}$$

Where

V =Volume of NaOH in ml.

N= Normality of NaOH.

3.4.3. Measurement of pH

pH of water was estimated with the help of electronic pH meter (make- Ecotest). Variation of pH was measured for the whole year.

3.4.4 Estimation of conductivity of water

Electrical conductivity (EC) of water was measured with the help of electronic conductivity meter (make-Hariba).

3.4.5 Estimation of total alkalinity (Clesceri *et al.*, 1989; pp 2-35 to 2-39)

The amount of acid required to titrate the base in water is the measure of alkalinity. The alkalinity of water sample is measured by measuring the OH^- or CO_3^- ions turn pink to phenolphthalein indicator. The water becomes colourless at pH below 8.4 when titrates with acid to convert these ions to HCO_3^-. Again water samples with HCO_3^- can be titrated to the critical pH level of 5.3 with an acid by using methyl orange indicator where colour changes take place from yellow to faint orange. Both of these indicators are used for determination the total alkalinity expressed in ppm of calcium carbonate ($CaCO_3$).

Calculation

If the volume (ml) of 0.02N H_2SO_4 is used for titration with phenolphthalein is P and volume of 0.02N H_2SO_4 consumed during titration with methyl orange is Q, total acid consumed is equal to M (M=P+Q).The total alkalinity as ppm of $CaCO_3$ will be M x 10 .

3.4.6 Phosphate content of water (Chattopadhyay, 2007; pp 52 to 54).

In natural waters, P occurs as Phosphate. This form of P was estimated colorimetrically using spectrophotometer (make-Systronic). Standard solutions were prepared using anhydrous potassium dihydrogen orthophosphate (KH_2PO_4) at different concentrations. These solutions were measured at optical density 660 nm and standard curves were prepared. From the standard curve and standard solutions, concentration of p is estimated.

Calculation

If the conc. 25ml volumetric flask is X ppm and the initial volume of the sample taken in the flask is V ml,

$$\text{Then, the conc. of P (ppm) in water sample is} = \frac{X}{V} \times 25$$

3.4.7 Nitrate in water (Chattopadhyay, 2007; pp 48 to 50).

To determine the NO_3 form of nitrogen in water NH_4-N is first distilled with alkali to release ammonia which is absorbed in an acid. Then NO_3 form of N is reduced to NH_4^+ with hydrogen in alkali solution and the produced NH_4 is absorbed in boric acid to form ammonium borate. This ammonium borate is titrated back to original H_3BO_3 with a standard acid and concentration of NH_4 was determined from the amount of standard acid required for titration.

Calculation

$$\text{N (ppm) in the form of } NH_4 \text{ or } NO_3^- \text{ OR } NH_4^+NO_3 = \frac{A}{V} \times 280$$

Where,

A is ml of 0.02 N H_2SO_4 required for titration in respective case.

V is volume (ml) of water sample used.

3.4.8 Determination of dissolved organic matter content of water (Chattopadhyay, 2007; pp 61 to 62).

Oxygen consumed during oxidation of organic matters may be considered as an index of DOM content of water. As $KMnO_4$ is used for this purpose the value is also referred as potassium permanganate demand of water (Chattopadhyay, 2007). When $KMnO_4$ is used for oxidizing soluble organic matter (OM), the MnO_4 is reduced to MnO_2^- and the pink colour becomes faint. This change of colour is used to determine the amount of oxygen required to oxidize the OM. For estimation, 50ml water sample was taken in 250 ml conical flask to which 5ml 1:3 H_2SO_4 was added. Then 10ml of $KMnO_4$ was added and heated in a water bath. After keeping half an hour in water bath, 10ml of ammonium oxalate was added to disappear the pink colour. Again $KMnO_4$ was added with a burette to reappear the pink colour.

Calculation

OM (ppm) = ml of $KMnO_4$ x 2

3. 4. 9 Determination of total solid and total dissolved solids (Clesceri *et al.*, 1989; pp 2-72 to 2-73)

Total solids of water sample represent dissolved matters, particulate organic matters, dissolved inorganic matters excluding gases and suspended inorganic substances. For determination of Total Solid (TS), a clean porcelain basin was heated in an oven at 105°C and then cooled in a dessiccator and weighed accurately (W_1). A thoroughly shaked water sample of 100 ml was taken in the clean porcelain basin and evaporated to dryness at 100°C and cooled again in a desiccator and weighed the basin along with the residue (W_2). For estimation of Total Dissolved Solid (TDS), same procedure was followed but samples were filtered using Whateman no–42 and filtrate was used for drying (W_3).

Calculation –

TS (PPM) = (W_2-W_1) mg x 10

TDS (PPM) = (W_3-W_1) mg x 10

3.4.10 Determination of hardness (Clesceri *et al.*, 1989; pp 2-53 to 2-57)

For determining the hardness of water, concentration of Ca and Mg in water was first determined .The values are then converted to respective equivalent of $CaCO_3$ and added to get total hardness of water. For determination Ca and Mg, titration was carried out with EDTA adding Eriochrome black T as indicator.

Calculation

(a) Observed ppm of Ca as $CaCO_3$ = ppm of Ca in water x 50.04/20.04

(b) Observed ppm of Mg as Ca CO_3= ppm of Mg in waterx50.04/12.16

Total hardness of water = (a)+(b) ppm as $CaCO_3$.

3 .5 Determination of rate of sedimentation

The rate of sedimentation was determined following the method developed by Kleisis (1993) and Wardrop and Brooks (1998). Sediment disks were constructed of a .05 cm thick plexi glass, 20 cm in diameter sanded on one side to create a rough surface that was able to retain sediment particles. For installation of disks, a 30 cm long steel rod of 0.6 cm in diameter was pushed into the surface so that approximately 5 cm remained above the ground level. The disks were placed on rod, seated into sediment until top of the disks were flashed with the top of the wetland surface and secured on both the sides with wing nuts. The disk was then stable on wetland surface and was resistant to water movement. In a particular wetland, 3 disks were placed in a selected station. Installation of disks was done from May to April. Altogether 27 nos. of disks were installed in 3 different wetlands. After the installation period, the depths of the sediments were determined by measuring the total height of disk minus depth of the glass.

3. 6 Collection and analysis of plankton (Clesceri *et al.*, 1989; pp10-23 to10-31)

For collection of phyto and zoo plankton simple conical tow net of <60 μ mesh size was used. To determine the amount of water filtered, mouth area of the net was multiplied with distance traveled. Collected samples were preserved in Lugol's solution (20g KI, 10g I, 200ml distilled water and 10 ml glacial acetic acid). For separation of zooplankton, collected samples were filtered using filtering cloth having >60 μ mesh. Plankton were identified to the generic level (Clesceri *et al.*, 1989; pp 10-137 to203) and counting was done with the help of Sedgewick –Rafter Counting Cell as mentioned by Clesceri *et al.* (1989) in standard method .

The number of organisms was counted based on the formula

$$NO/ml = \frac{C \times 1000\ mm^3}{L \times D \times W \times S}$$ (Clesceri *et al.*, 1989;pp 10-23 to 31)

Where

C= number of organism counted ,

L= length of each strip (S-R cell length),mm ,

D = depth of each strip (S-R cell depth),

W=width of a strip (Whipple grid image width), mm and

S= number of strip counted.

3.7 Collection and analysis of samples for pesticides and herbicides(Christian 2003)

Water samples during monsoon and post-monsoon were collected from streamlets for chemical analysis. For the monsoon season, water samples were collected in the first week of June and for post monsoon season, samples were collected in the month of October. Each sample contained five sub samples. About 3 to 4 litres of water was collected for one sample.

Step-1: Cleaning of the samples

After collection, samples were brought to laboratory. Samples were filtered to remove the other remaining materials such as debris etc..

Step-2: Extraction of chemicals

After cleaning, samples were treated with ethyl ether in the ratio of 1 : 6 : : ether : water.

Step-3: Concentrating the samples

After extraction, samples were evaporated at 80 ^{O}C in a water bath.

Step-4 : Chemical Analysis

After concentration, samples were taken to State Forensic Laboratory, Khilipara, Assam, India for analysis of the samples with the help of Thin Layer Chromatography (TLC). The samples were tested against three standards. They were

1. Organochloride - benzine hexachloride
2. Organophosphate - rogor
3. Carbamite - bagon

For the samples collected during monsoon seasons, endosulfan was also used as standard.

3.8 Statistical analysis

Collected data have been presented in tabular form. Analysis of variance (ANOVA) to bring out difference among *beels* and difference between seasons has been carried out to establish the statistical difference significantly. To test between pairs of *beels* and pairs of seasons Student's ' t' tests were carried out. Multivariate treatment of data and interrelations between parameters has been done using SPSS software.

Chapter - IV

RESULTS AND DISCUSSION

Chapter - IV

RESULTS AND DISCUSSION

4.1 Limnological parameters

Limnological parameters determine productivity and the health of the water body .A water body to be healthy, limnological parameters are expected to be within the optimal range .It is, therefore, imperative to analyse these parameters to understand the health of a water body for better management. The following limnological parameters have been studied in the present study.

4.1.1 Dissolved oxygen (DO)

Oxygen, being one of the most important parameters of aquatic life for their survival, has been studied extensively. The optimum range of oxygen is considered to be above 5 ppm. In the present investigation, the lowest oxygen concentration was observed in the Jamuguri nala wetland during the summer season which was 3.16±.07 ppm (Table-3,Figure-16). The lower concentration of oxygen creates trouble in breathing and related activities such as growth, breeding etc.

The lowest DO observed in the present study was found to be contrary to the findings of Acharjee and Dutta (1999).They found that the lowest DO during summer in Dighali *beel* wetland was 6.13 to 6.66 ppm. They also observed the lowest DO not in summer but during July –September which might be due to cloudy condition of the sky. Similarly, Rana and Sengupta (1996) studied the DO of Kalyani *beel* of West Bengal where they recorded lowest DOof 5.5 ppm during pre -monsoon season which could be rather considered as summer season in that part of India. Dutta and Bhagawati (2007) recorded the lowest DO levels in Dighali and Kachadhara *beels* of Nagaon district to the level of 5ppm in the month of June whereas the lowest DO was observed in the month of April (6ppm) in the case of Kachadhara *beel*. Choudhury *et al.* (1997) studied various *beels* of Assam and opined that *beels* were rich in DO content and it ranged between 5.6 to 11.73 ppm.

The observation of very low levels of DO in Kulia *beel* of West Bengal is comparable to present study. Pathak (1990) noticed very low DO level in the Kulia *beel* of West Bengal. He compared water parameters of Media and Kulia beels of West Bengal and Dhir *beel* of Assam. Lower levels of oxygen conc. in the Kulia *beel* was also observed by Trivedi *et al.* (2007). The very low levels of oxygen in Kulia *beel* was attributed to closed nature of the wetlands as well as to the extent of pollution. Very low levels of DO were also recorded in swamps in and around Guwahati (foothills of Sarania hill) by Pal and Singh (1983). They observed dissolved oxygen ranged between 0.12 and 1.0 ppm which they opined as detrimental to aquatic life .They attributed this anaerobic condition of swamps to the thick cover of macro vegetation decaying of organic matters and pollution of water caused by human waste dumped in the swamp.

The lower levels of oxygen found in the present study in Jamuguri nala wetland during the summer season could be attributed to shading of the wetland by macro vegetation specially *Eicchornia sp.* This might also be the result of narrow width of the channel or low level of oxygen production from primary production since there were very less no. of phytoplankton (Table-15) when compared to other wetlands under study. Goswami *et al.* (1999) recorded low DO levels in the wetlands of central zone of Assam in their siltation and eutrophication studies. Apart from these spatial differences, seasonal or temporal variations were noticed among the *beels* with reference to DO content of water. During monsoon, no significant differences were observed among the wetlands at $p<.05$. Statistically similar values in all the wetlands indicated that during that period water got mixed up due to flood. After the monsoon season significant differences were observed in wetlands. This might be due to the isolation of different *beels* after flood and limno-chemistry were governed by macrophytes . The highest O_2 content (7.13±0.25ppm) was observed in Tapacia *beel* during the winter season. The high level of O_2 content in this *beel* is probably due to wideness of the wetland and low temperature prevailing during winter.

Table -3: DO (ppm) of *beels* of Kaziranga

Beel	Summer Season				Monsoon Season			
	S1	S2	S3	Pooled (Mean & SD)	S1	S2	S3	Pooled (Mean & SD)
Gahari *beel*	4.20	4.50	4.50		5.60	4.50	5.2	
	4.15	4.00	4.00		5.30	5.00	5.0	
	4.00	4.70	4.10		5.70	5.00	5.4	
Mean	4.12	4.40	4.20	4.24	5.53	4.83	5.2	5.19
SD	0.10	0.36	0.26	0.15	0.21	0.29	0.2	0.05
Jamuguri	3.00	3.00	3.30		5.40	5.30	5.3	
nala	3.50	3.30	3.00		5.20	5.40	5.0	
	3.20	3.00	3.10		5.55	5.60	5.3	
Mean	3.23	3.10	3.13	3.16	5.38	5.43	5.2	5.34
SD	0.25	0.17	0.15	0.07	0.18	0.15	0.17	0.01
Tapacia	5.20	5.70	5.60		5.40	6.00	5.40	
beel	5.60	5.60	5.60		5.80	6.10	5.50	
	5.80	5.80	5.20		5.60	5.90	5.50	
Mean	5.53	5.70	5.47	5.57	5.60	6.00	5.47	5.69
SD	0.31	0.10	0.23	0.12	0.20	0.1	0.06	0.28
	Post monsoon				Winter			
Gahari *beel*	5.20	5.60	5.20		5.50	7.00	6.70	
	5.00	5.00	5.30		6.10	6.50	7.00	
	5.00	5.20	4.80		5.80	6.50	7.00	
Mean	5.07	5.27	5.10	5.14	5.80	6.67	6.90	6.46
SD	0.12	0.31	0.26	0.11	0.30	0.29	0.17	0.58
Jamuguri	3.20	3.20	3.60		4.00	4.00	4.00	
nala	3.20	3.20	3.40		4.20	4.20	4.00	
	3.50	3.20	3.50		4.30	4.00	3.40	
Mean	3.30	3.20	3.50	3.33	4.17	4.07	3.80	4.01
SD	0.17	0.00	0.10	0.15	0.15	0.12	0.35	0.19
Tapacia	5.50	5.80	5.80		6.90	7.50	7.00	
beel	5.70	6.00	5.80		6.60	7.50	7.30	
	5.60	6.20	5.90		7.20	7.20	7.00	
Mean	5.60	6.00	5.83	5.81	6.90	7.40	7.10	7.13
SD	0.10	0.20	0.06	0.20	0.30	0.17	0.17	0.25

S- Substation. Data showing for S1, S2, & S3 are average of triplicate value

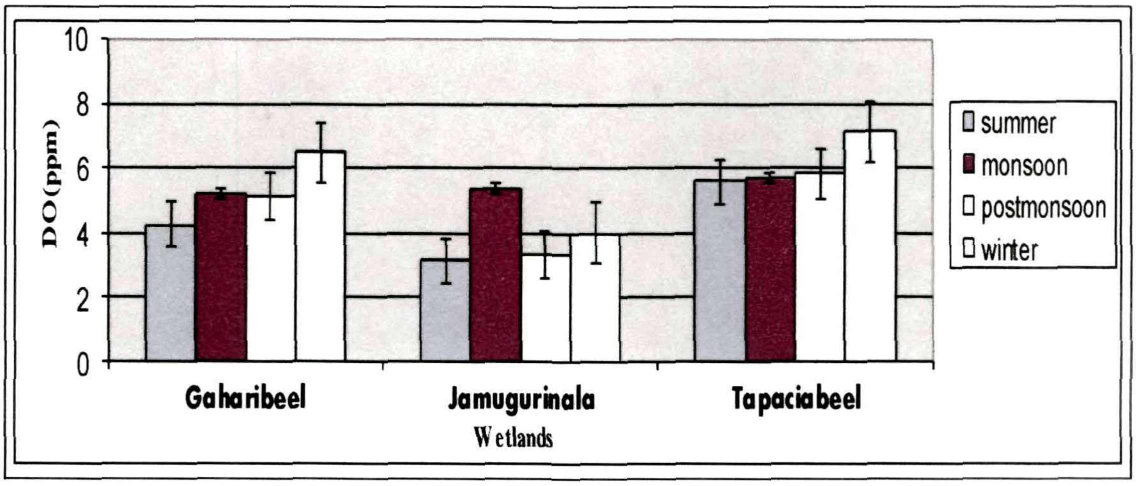

Figure- 16: Illustration showing seasonal variation of DO.

4.1.2. Temperature of water

Though there were apparent seasonal variation of temperature due to annual change of season,the variations were not statistically significant ($p<0.05$). The highest temperature recorded was 32.17±0.29 ^{O}C in the Tapacia wetland during monsoon season (Table -4 fig.17). The lowest temperature were recorded in the Jamuguri nala in all the seasons . This might be due to the shading effects of macrophytes and forest through which the channel flows. The water temperature of Tapacia *beel* showed slightly higher values than the Gahari *beel.* The difference,however,was not significant ($p<0.05$). The higher values could be the result of openness of the *beel* because of which the *beel* water received enormous amount of sunshine through out the day .The range of temperature varied from 19.43±0.12 ^{O}C in the winter to32.17±0.29 ^{O}C in the monsoon season during the year. The recorded values were similar to the work done by Sugunan *et al.*(2007) in Haribhanga and Samuguri *beels* of Nagaon district . The recorded water temperature varied from 18.8 to 33.0 ^{O}C which they opined as favourable water temperature for fish growth and other biological activities of fish. Similar to these studies Acharjee and Dutta (1999) recorded the lowest temperature during the month of January –March as 21.2 and 21.4 ^{O} C in the year 1992 and 1993 and the highest temperature recorded were 30.2 ^{O}C and 30 ^{O}C during the period of April –June . Differences obtained in the present study and observation made by Acharjee and Dutta (1999) in relation to water temperature, might be due to various climatic factors prevailing during the investigation period Dutta and Bhagawati (2007) observed the lowest temperature 20°C and 18°C during the month of December in Dighali and Kachadhara *beels* respectively Similar to present investigation Sharma (2000) also recorded water temperature in different floodplain wetlands of NE India viz Balak, Senijan, Dhekia, Naruathan and Samuajan *beel* wetlands where he found summer temperature ranged from 23 to 26°C monsoon 31 to 33°C, post monsoon 26 to 30°C and winter temp 17 to 21°C

Table -4: Temperature(°C) of water at different seasons of the year

Beel	**Temperature (°C)**	
	Summer	**Monsoon**
Gahari *beel*	27 50	32 00
	27 60	32 00
	27 50	32 00
Mean	**27.53**	**32.00**
SD	0 06	0 00
Jamuguri nala	26 00	30 00
	26 20	30 56
	26 00	30 00
Mean	**26.07**	**30.19**
SD	0 12	0 32
Tapacia *beel*	28 50	32 00
	28 80	32 50
	28 50	32 00
Mean	**28.60**	**32.17**
SD	0 17	0 29
	Post monsoon	**Winter**
Gahari *beel*	28 00	20 00
	28 00	20 50
	28 00	20 70
Mean	**28.00**	**20.40**
SD	0 00	0 36
Jamuguri nala	26 00	19 30
	26 50	19 50
	26 00	19 50
Mean	**26.17**	**19.43**
SD	0 29	0 12
Tapacia *beel*	28 50	21 00
	28 50	21 50
	28 50	21 00
Mean	**28.50**	**21.17**
SD	0 00	0 29

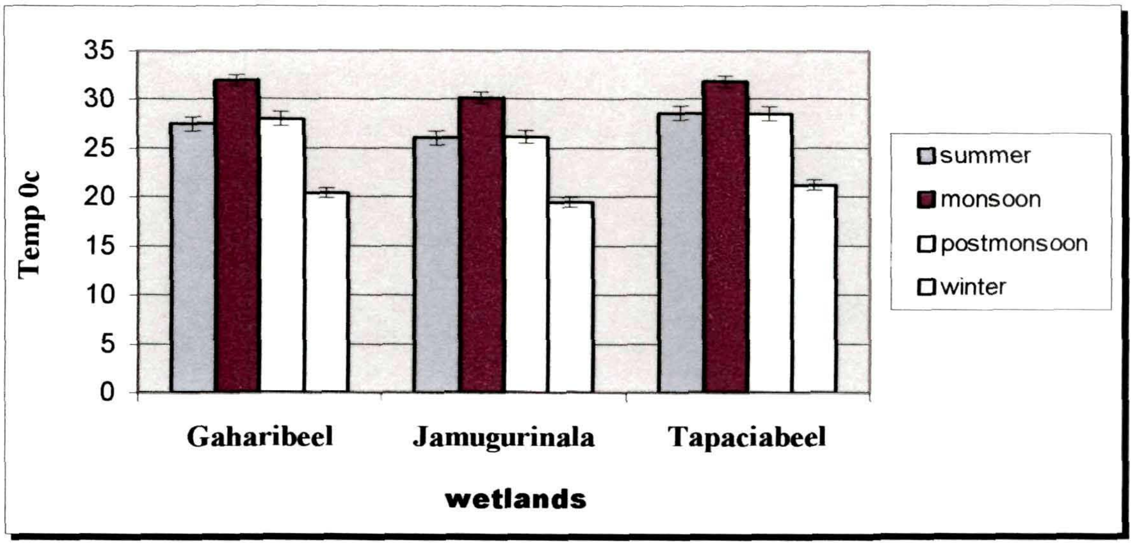

Figure -17: Temperature of water in different wetlands over the year

4.1.3 pH

pH of water of the wetlands showed no significant variation ($p<0.5$) with respect to time and location. In general water was acidic in nature throughout the year .The maximum mean pH value recorded was 6.38 ± 0.11 in the Tapacia *beel* during winter season and the minimum mean pH value was observed (6.11±0.09) in the Gahari *beel* during post monsoon season (Table-5). The results were similar to the different studies carried out in various *beel* wetlands of Assam. Sharma (2000) observed the pH of water ranged from 5.5 to 6.2 in Balak, 5.5 to 6.5 in Senijan, 5.5 to 7.2 in Dhekia, 5.5 to 7.2 in Naruathan and 6.2 to 7.2 in Samuajan *beel* wetands of Assam. Similarly Acharjee *et al.* (1999) recorded pH in the range of 6.6 to 7.2 in Dighali *beel* wetlands of Assam. In the present study pH value did not go beyond 6.37± 0.11 indicating acidic water. As there was no seasonal change of pH, it could be mentioned that pH was mainly governed by intrinsic factors rather than external factors such as flood, temperature etc. When comparison was made between the *beels* of West Bengal and Assam, the pH of the *beels* of West Bengal found to be higher than Assam. Pathak (1990) recorded water pH of Kulia *beel* of West Bengal to be 7.6 to 8 and in the same study he recorded pH of 6.4 to 7.6 in Dhir *beel* of Assam.

Table-5: pH of water in different wetlands

Beel	Summer Season				Monsoon Season			
	S1	S2	S3	Pooled (Mean ±SD)	S1	S2	S3	Pooled (Mean ± SD)
Gahari *beel*	6.10	6.20	6.20		6.30	6.05	6.40	
	6.20	6.20	6.30		6.30	6.20	6.20	
Mean	6.20	6.20	6.30		6.30	6.30	6.20	
SD	**6.17**	**6.20**	**6.27**	**6.21**	6.30	6.18	6.27	6.25
	0.06	0.00	0.06	0.05	0.00	0.13	0.12	0.06
Jamuguri nala	6.30	6.10	6.30		6.50	6.20	6.40	
	6.30	6.00	6.30		6.30	6.20	6.40	
	6.30	5.90	6.30		6.40	6.20	6.40	
Mean	6.30	6.00	6.30	**6.20**	6.40	**6.20**	**6.40**	**6.33**
SD	0.00	0.10	0.00	**0.17**	0.07	**0.20**	0.00	0.12
Tapacia *beel*	6.05	6.10	6.10		6.30	6.00	6.30	
	6.10	6.30	6.10		6.10	6.10	6.30	
	6.10	6.40	6.10	**6.15**	6.20	5.90	6.30	
Mean	**6.08**	**6.27**	6.10	0.10	6.20	6.00	6.30	6.26
SD	0.03	0.15	0.00		0.10	0.1	0.00	0.05
	Post monsoon				**Winter**			
Gahari *beel*	6.00	6.20	6.10		6.30	6.20	6.20	
	6.05	6.20	6.10		6.40	6.20	6.20	
	6.00	6.20	6.10		6.40	6.20	6.20	
Mean	**6.02**	**6.20**	**6.10**	**6.11**	**6.37**	**6.20**	**6.20**	**6.26**
SD	0.03	0.00	0.00	0.09	0.06	0.00	0.00	0.10
Jamuguri nala	6.30	6.10	6.10		6.20	6.30	6.20	
	6.20	6.00	6.10		6.20	6.10	6.20	
	6.30	6.20	6.10		6.20	6.20	6.20	
Mean	6.27	**6.10**	**6.10**	**6.16**	**6.20**	**6.20**	**6.20**	**6.20**
SD	0.06	0.10	0.00	0.10	0.00	0.10	0.00	0.00
Tapacia *beel*	6.20	6.50	6.10		6.60	6.30	6.40	
	6.20	6.40	6.10		6.40	6.30	6.40	
	6.20	6.40	6.10		6.50	6.30	6.20	
Mean	**6.20**	**6.43**	**6.10**	**6.24**	**6.50**	**6.30**	**6.33**	**6.38**
SD	0.00	0.06	0.00	0.17	0.10	0.00	0.12	0.11

S- Substation. Data showing for S1, S2, & S3 are average of triplicate value

In contrast to lower pH of water, Gorai *et al.* (2006) recorded slightly alkaline pH in the Goruchara and Morikolong wetlands of Assam where pH ranges were 7.12 to 8.99 and 7.28 to 9.02 respectively. Accordingly, they recorded higher pH for soil also. Therefore it could be opined that water pH mainly governed by soil pH rather than other factor.

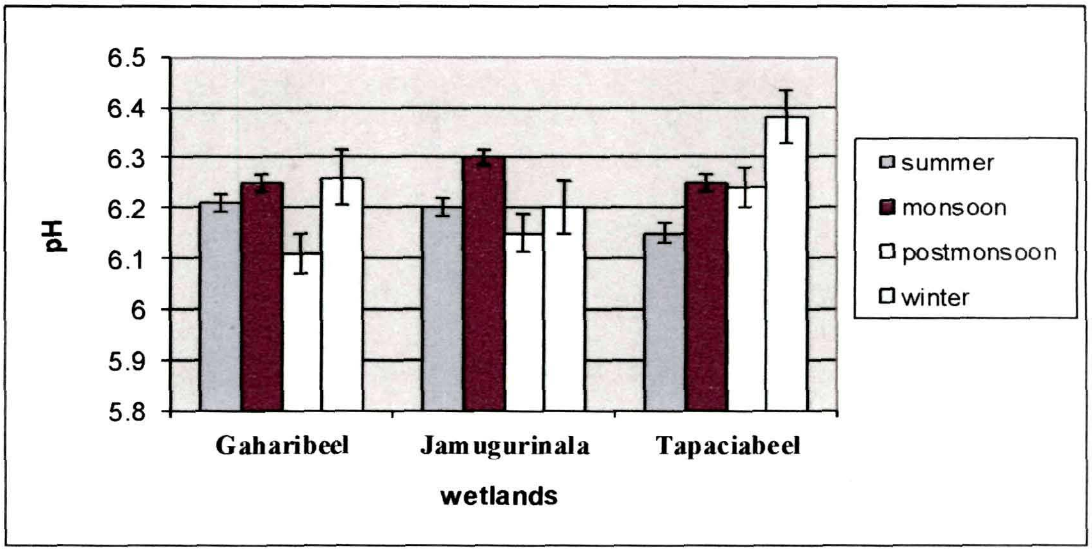

Figure- 18: Illustration showing variation of pH of water .

4.1.4 Electrical Conductivity

Values of electrical conductivity (EC) of water indicates the total concentration of ionized constituent of water samples. It is related to amount of total dissolved solids. It is also used as an index of salt content of water. The EC reflects the nutrients status of water and thereby controls the macrophytes (Crowder *et al.*1977). In the present study, EC were measured seasonally and comparisons were made between different seasons and among the different wetlands. The Gahari *beel* contained statistically significant higher levels of conductivity (Table-6, Figure-19) than Jamuguri and Tapacia wetlands. The highest mean value recorded in this wetland was 172±3μS/cm in the summer season and lowest mean value recorded was 94.67±4.44 μS/cm in the monsoon season. The highest mean values Jamuguri nala and Tapacia *beels* were 149±3 and 145±2 μS/cm in post monsoon and winter season respectively. The lowest values were observed in all three wetlands during monsoon season. The lowest values recorded were 94.67±4.44, 95.33±9.29 and 92±3 µS/cm for Gahari *beel*, Jamuguri nala and Tapacia *beels* respectively. Though there were numerical differences between values of EC of Jamuguri and Tapacia *beels*, they were not significantly different at $p < 0.05$ from each other. Sharma (2000) recorded very low conductivity in Balak (17µS/cm), Senijan (47µS/cm), Dhekia (102 µS/cm) during summer season and relatively higher range of EC i.e. 150 and 174 µS/cm in Naruathan and Samuajan *beels* of Assam. He categorized these *beels* as class I category based on EC values. Though Balak wetlands showed very low range of conductivity; rest three wetlands were comparable to other *beels* of Assam. He also observed highest EC during summer period. Acharjee and Dutta (1999) also observed lower ranges of conductivity in Dighali *beel* of Assam They recorded 55 to 76.3 µS/cm EC range in the above mentioned wetlands.

The higher values of EC in Gahari *beel* might be due to increased amount of inflow of ions from the washings of weathered materials from the adjacent hills when compared to other two wetlands. During monsoon season mean EC values came down which significantly differed from previous season ($p<.05$). In monsoon season the lowest value was observed in Tapacia *beel* followed by Gahari and Jamuguri nala and no difference was observed among the wetlands at $p<05$. Contrary to the recent findings of Sharma(2000) who observed much lower values in the monsoon season in various wetlands of Assam . Low levels of EC during monsoon season observed in the present study could be due to mixing of water of the river Brahmaputra which was low in ion content and heavy rain during monsoon season.

Post monsoon season showed an rising trend of EC (Table-6). Among all the three wetlands, Jamuguri nala recorded the highest conductivity i.e.149±3 µS/cm followed by Gahari *beel* which were not significantly different from each other($p<.05$).Among three wetlands Tapacia *beel* showed the lowest EC and it was significantly different from rest two wetlands. The winter values, however, statistically remained same. Significant differences between monsoon – post monsoon, monsoon –winter, post monsoon –winter were also seen.

Similarly, in the case of Jamuguri nala significant differences between seasons were seen, except in the case of post monsoon–winter seasons ($p<.05$). In the Tapacia *beel*, each season was found to be significantly different from the other .The difference between seasons in the same wetland could be attributed to dilution in the monsoon and subsequent concentration during non rainy season reaching peak in the summer.

Contrary to present findings Gorai *et al.* (2006) recorded very high range of EC in Goruchara and Mora kolong *beel* wetlands. They recorded 146 to 260 µS/cm in Goruchara and 195 to 650 µS/cm in 46Mora kolong *beel*. The lower values of EC in wetlands of Kaziranga National Park when compared to above wetlands could be due to the sediment characteristics below the water column or flooding during monsoon.

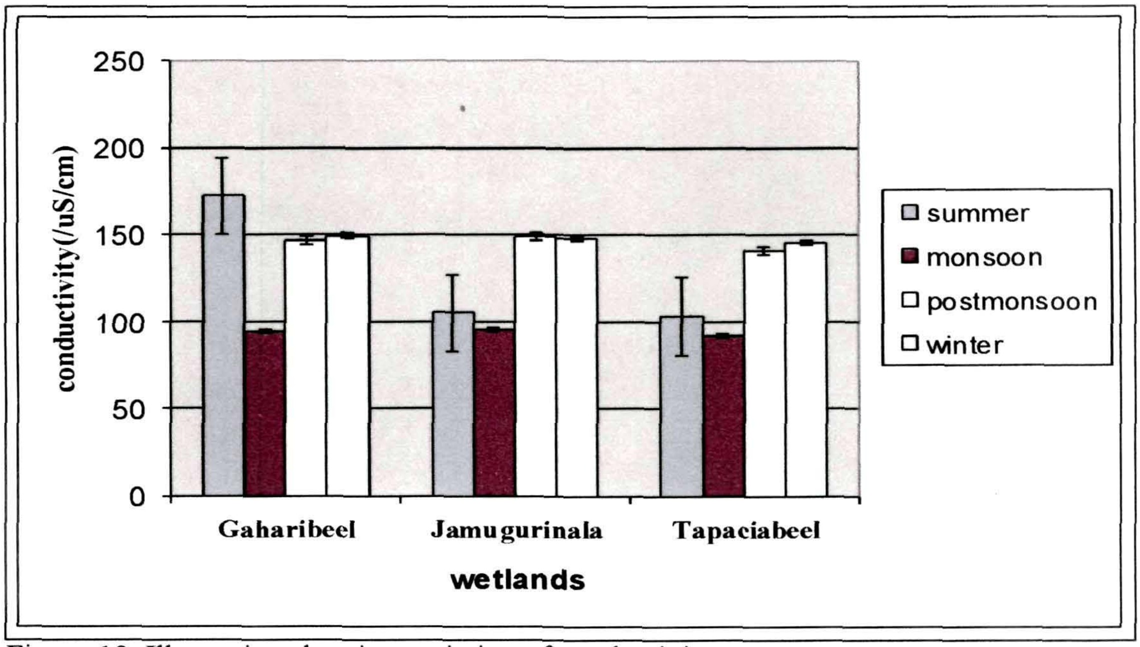

Figure-19: Illustration showing variation of conductivity

Table -6: Electrical Conductivity(/"S/cm) in different wetlands

Beel	Summer Season				Monsoon Season			
	S1	S2	S3	Pooled (Mean & SD)	S1	S2	S3	Pooled (Mean & SD)
Gahari *beel*	180.00	170.00	172.00		101.50	82.00	90.50	
	172.00	175.00	172.00		98.00	87.00	89.00	
	173.00	162.00	172.00		97.50	98.00	108.50	
Mean	175.00	169.00	172.00	172.00	99.00	89.00	96.00	94.67
SD	4.36	6.56	0.00	3.00	2.18	8.19	10.85	4.44
Jamuguri nala	105.00	105.50	101.00		95.50	83.00	95.00	
	100.50	109.50	107.00		100.50	84.00	105.00	
	103.50	109.00	107.00		98.00	88.00	109.00	
Mean	103.00	108.00	105.00	105.33	98.00	85.00	103.00	95.33
SD	2.29	2.18	3.46	0.71	2.50	2.65	7.21	9.29
Tapacia *beel*	102.00	98.00	108.00		96.00	94.00	86.00	
	110.00	99.00	101.00		94.00	98.00	85.00	
	106.00	105.00	103.00		86.00	93.00	96.00	
Mean	106.00	100.67	104.00	103.56	92.00	95.00	89.00	92.00
SD	4.00	3.79	3.61	2.69	5.29	2.65.1	6.08	3.00
	Post monsoon				Winter			
Gahari *beel*	142.50	140.00	147.00		155.50	150.00	150.00	
	150.50	152.50	147.00		148.00	144.50	145.00	
	151.00	139.50	147.00		152.50	152.50	146.00	
Mean	148.00	144.00	147.00	146.33	152.00	149.00	147.00	149.33
SD	4.77	7.37	0.00	2.08	3.77	4.09	2.65	2.52
Jamuguri nala	156.00	151.00	148.00		145.00	145.00	146.00	
	143.00	143.00	156.00		153.00	139.00	153.00	
	148.00	144.00	152.00		155.00	145.00	148.00	
Mean	149.00	146.00	152.00	149.00	151.00	143.00	149.00	147.67
SD	6.56	4.36	4.00	3.00	5.29	3.4	3.61	4.16
Tapacia *beel*	145.00	142.00	143.00		143.00	150.00	143.00	
	140.00	140.00	140.00		143.00	145.00	146.00	
	141.00	132.00	143.00		143.00	146.00	146.00	
Mean	142.00	138.00	142.00	140.67	143.00	147.00	145.00	145.00
SD	2.65	5.2	1.73	2.3	0.00	2.65	1.73	2.00

S- Substation. Data showing for S1, S2, & S3 are average of triplicate value

4.1.5 Alkalinity of water

The total alkalinity of water of the wetlands varied considerably from season to season. The minimum mean alkalinity was recorded to be 53.75±2.14 ppm in jamuguri nala wetland during monsoon season. The highest alkalinity value (73.45±2.36ppm) was recorded in Gahari *beel* during winter season . (Table-7,Figure-20) .Overall lower values of alkalinity were recorded during monsoon season. Values were being 59 ±3.28, 53.75±2.14, 60.67± 2.36 ppm in Gahari *beel*, Jamuguri nala and Tapacia *beel* respectively. From the monsoon season onwards, there was a gradual increase in alkalinity reaching peak in the winter season except in the case of Jamuguri nala, which showed slightly higher mean value in the post monsoon than winter. However, the values did not differ significantly from winter value at $p< 0.05$.

When analysis was carried out between different wetlands in the same season, no significant difference was observed ($p<0.05$). Only the seasonal variations in all the wetlands under study was observed. The range of total alkalinity was found to be 53.75±2.14 to 73.33±3.11 ppm which could be comparable to studies carried out by Sugunan *et al.* (2007) in Samuguri and Haribhanga *beel* wetlands of Assam. When compared to studies by Sugunan *et al.* (2007), Acharjee and Dutta (1999) recorded much lower alkalinity in Dighali *beel* of Nagaon district of Assam. Sharma (2000) also reported lower alkalinity values in different wetlands of Assam similar to Acharjee and Dutta(1999) . He reported 6 to 14, 28 to 40, 56 to 76, 56 to 72 and 40 to 90 ppm in Balak Senijan , Dhekia , Naruathan and Samuajan *beels* of Assam respectively. The lower pH of soil and incoming water might be responsible for this lower range of alkalinity. Similarly, Dutta and Bhagawati (2007) recorded lower range of alkalinity in Dighali and Kachadhara *beels* of Nagaon where the range for Dighali was 32.8-39.5ppm and for Kachadhara 29.2 to 41.5 ppm. This might be due to the fact that these *beels* fall under same agro- climatic zone . In contrast to the results of beels of Assam, Saha *et al.* (1999) and Trivedi et *al.* (2007) recorded much higher range of alkalinity in Kulia and Kalyani *beel* wetlands of West Bengal. This clearly indicated that alkalinity depended on soil characteristics mainly. The results of present investigation show moderately higher range of alkalinity when compared to *beels* of lower Assam. It might be due to soil characteristics and quality of flooding water.

Table -7: Total alkalinity (ppm) of water in different seasons of the year

Beel	Summer Season				Monsoon Season			
	S1	S2	S3	Pooled (Mean± SD)	S1	S2	S3	Pooled (Mean± SD)
Gahari *beel*	70.50	72.60	66.40		56.15	63.10	56.55	
	68.25	71.70	68.50		55.35	60.35	57.00	
	72.35	73.20	66.50		56.05	63.75	62.70	
Mean	70.37	**72.50**	67.13	**70.00**	**55.85**	**62.40**	**58.75**	**59.00**
SD	2.05	0.75	1.18	2.70	0.44	1.80	3.43	3.28
Jamuguri nala	63.80	71.50	66.85		53.50	54.83	54.55	
	61.10	68.85	69.50		50.50	56.08	51.35	
	62.00	71.00	62.34		52.70	57.70	52.55	
Mean	**62.30**	**70.45**	66.23	**66.33**	**52.23**	**56.20**	**52.82**	**53.75**
SD	1.37	1.41	3.62	4.08	1.55	1.44	1.62	2.14
Tapacia *beel*	72.55	75.08	68.35		64.00	60.80	58.53	
	72.30	71.50	69.18		61.35	62.50	57.03	
	72.45	80.65	71.95		61.25	62.25	58.28	
Mean	72.43	75.74	69.83	**72.67**	**62.20**	**61.85**	**57.95**	**60.67**
SD	0.13	4.61	1.89	2.97	1.56	0.92	0.80	2.36
	Post monsoon				Winter			
Gahari *beel*	68.55	78.34	72.50		73.05	70.88	73.15	
	71.35	72.30	67.51		69.85	77.05	74.35	
	68.24	72.86	70.33		69.6	78.3	74.82	
Mean	**69.38**	**74.50**	70.11	**71.33**	**70.83**	**75.41**	**74.11**	**73.45**
SD	1.71	3.34	2.50	2.77	1.92	3.97	0.86	2.36
Jamuguri nala	73.50	74.20	69.85		69.7	67.5	74.05	
	69.30	77.50	74.05		67.35	71.35	72.5	
	73.65	74.40	75.00		69.1	69.8	74.65	
Mean	**72.15**	**75.37**	72.97	**73.49**	**68.72**	**69.55**	**73.73**	**70.67**
SD	2.47	1.85	2.74	1.67	1.22	1.94	1.11	2.69
Tapacia *beel*	67.60	68.50	71.05		76.12	76.35	70.15	
	69.05	66.35	68.18		76	73.15	68.36	
	68.85	66.85	68.30		75.45	73.35	71.05	
Mean	**68.50**	**67.23**	69.18	**68.30**	**75.857**	**74.28**	**69.85**	**73.33**
SD	0.79	1.13	1.62	0.99	0.357	1.79	1.37	3.11

S- Substation. Data showing for S1, S2, & S3 are average of triplicate value

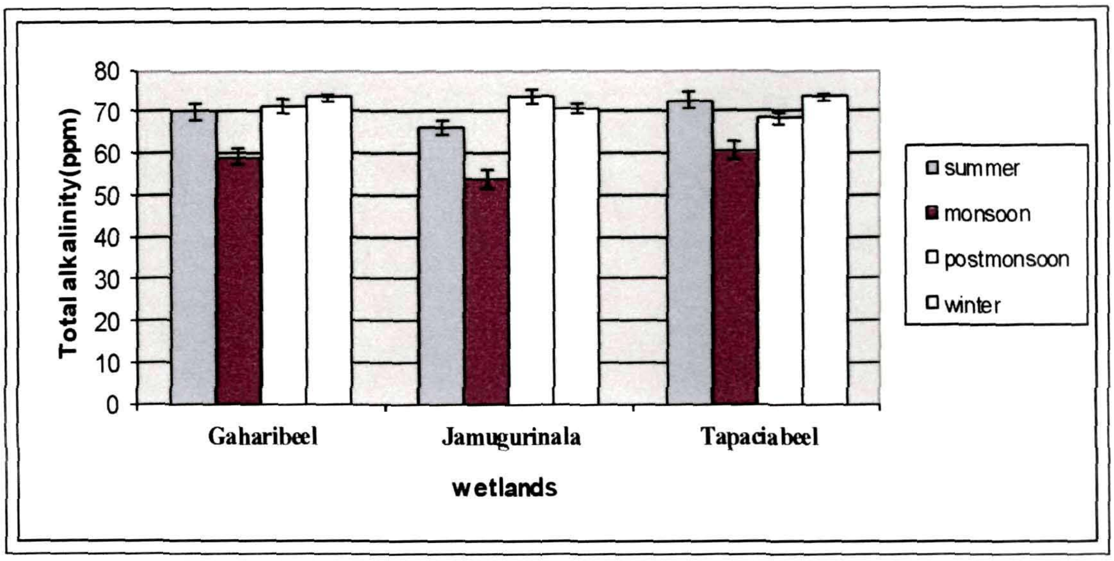

Figure-20: Illustration showing variation of alkalinity of KNP

4.1.6. Total dissolved solids (TDS)

The trend of variation of total dissolved solids was found to be similar with conductivity. It might be due to the fact that conductivity depends on TDS to a great extent (Chattopadhyaya, 2007). The maximum values of TDS were recorded in the summer season in the Gahari *beel* . The highest mean value recorded in the Gahari *beel* was 54.33±0.87ppm in summer season. Accordingly, mean highest values of Jamugurinala and Tapacia *beel* were 52.68±3.09 and 49.34±2.58 ppm respectively (Table-8 ,fig 21). The mean values during this season did not vary significantly with respect to topographical location of wetlands ($p < 0.05$). In other seasons also the mean TDS values did not vary significantly ($p < 0.05$) with respect to their geographical location and due to isolation during non rainy season. The lowest values were noticed during the monsoon season in all the wetlands under investigation. After the monsoon season TDS showed an increasing trend when comparison was made among the seasons. Summer and monsoon, summer and post monsoon were different in all *beels*.

The possible cause of significant difference between monsoon and summer might be dilution of wetland water with reverine water. When summer and winter seasons were compared no significant difference were noticed in Gahari and Tapacia *beels* except for Jamuguri nala. Much similarity between summer and winter could be due to the closeness of the seasons or it could be due to fact that evaporation already led to summer concentration during the winter season itself.The differences between the seasons except summer were not consistent. It might be due to fact that TDS conc. was influenced by the prevailing climatic conditions over wetlands.

Das and Bandyopadhayay (1998) made similar observations i.e., enhanced TDS in summer followed by winter. The lowest values were recorded during monsoon period in Kulia *beel* of West Bengal, however, compared to present study the TDS values were much higher. The values were 595, 494 and 319 ppm in summer, winter and monsoon season respectively. In the present study conductivity values were also very high indicating relationship between TDS and conductivity. Trivedi *et al.* (2007) also noticed higher levels of total dissolved solids in Kalyani *beel* situated in industrial area of West Bengal. They assumed that industrial effluents might have caused rise in dissolved solids contents and subsequent rise in conductivity. Lower range of TDS in *beels* of Assam might be due to the fact that the *beels* wetlands of Assam are still in virgin conditions. Similar results obtained by Acharjee and Dutta (1999) in Dighali *beel* confirmed the fact. Gorai *et al.* (2006) also recorded total dissolved solids in the range of 59.9 to 111.3 ppm. Choudhury *et al.* (1997) studied the TDS in unpolluted *beels* of Kamrup district viz. Arikata, Bidhanjiha and Rangai where they mentioned about lower levels of total dissolved solids.

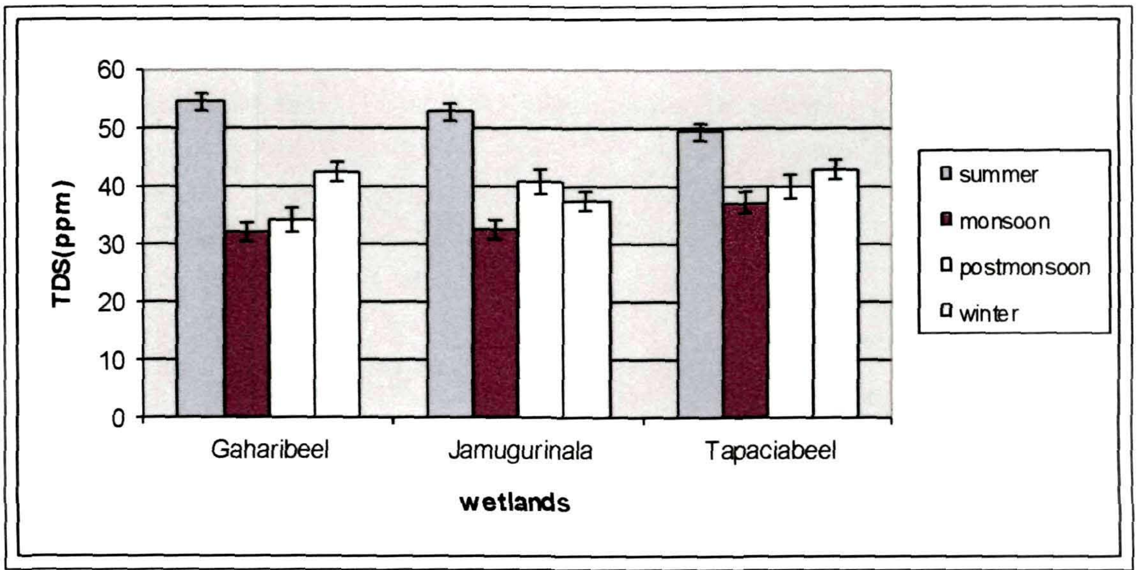

Figure-21:Illustration showing variation of dissolved solids

Table -8: Total dissolved solids (ppm) in various seasons

Beel	Summer Season				Monsoon Season			
	S1	**S2**	**S3**	**Pooled (Mean ± SD)**	**S1**	**S2**	**S3**	**Pooled (Mean ± SD)**
Gahari *beel*	53.61	54.23	55.23		34.16	32.63	29.59	
	51.25	56.18	52.35		32.35	33.05	27.18	
	56.10	55.51	54.49		35.06	33.69	27.57	
Mean	**53.65**	**55.31**	54.02	**54.33**	**33.86**	**33.12**	**28.11**	**31.70**
SD	**2.43**	**0.99**	**1.50**	**0.87**	**1.38**	**0.53**	**1.29**	**3.13**
Jamuguri nala	54.30	51.23	56.35		32.82	29.56	32.85	
	52.35	48.56	53.75		36.35	30.61	29.56	
	53.65	48.06	55.88		36.54	31.73	31.14	
Mean	**53.43**	**49.28**	55.33	**52.68**	**35.24**	30.63	**31.18**	**32.35**
SD	0.99	1.70	1.39	3.09	2.10	1.09	1.65	2.51
Tapacia *beel*	45.93	53.58	47.35		38.50	34.37	38.52	
	46.34	50.25	46.30		37.02	38.53	35.36	
	48.98	52.66	52.68		37.92	38.14	35.41	
Mean	**47.08**	**52.16**	48.78	**49.34**	**37.81**	**37.01**	36.43	**37.09**
SD	1.66	1.72	3.42	2.58	0.75	2.30	1.81	0.69
	Post monsoon				**Winter**			
Gahari *beel*	31.73	32.63	35.19		44.08	45.13	38.45	
	33.16	36.42	34.25		42.15	46.00	40.13	
	33.58	36.34	32.72		40.84	44.59	39.77	
Mean	**32.82**	**35.13**	34.05	**34.00**	**42.36**	**45.24**	**39.45**	**42.35**
SD	**0.97**	**2.17**	**1.25**	**1.15**	**1.63**	**0.71**	**0.88**	**2.90**
Jamuguri nala	40.85	40.05	40.15		39.25	36.28	38.36	
	43.16	42.12	38.36		36.56	32.53	42.52	
	44.42	38.02	38.90		35.29	34.80	40.82	
Mean	**42.81**	**40.06**	39.14	**40.67**	**37.03**	**34.54**	**40.57**	**37.38**
SD	1.81	2.05	0.92	1.91	2.02	1.89	2.09	3.03
Tapacia *beel*	37.51	39.55	39.58		44.80	42.56	39.36	
	38.50	40.85	42.36		46.30	40.23	42.10	
	38.78	37.62	42.33		45.31	39.78	42.22	
Mean	**38.26**	**39.34**	41.42	**39.68**	**45.47**	**40.86**	**41.23**	**42.52**
SD	0.67	1.63	1.60	1.61	0.76	1.49	1.62	2.56

S- Substation. Data showing for S1, S2, & S3 are average of triplicate value

4.1.7 Dissolved Organic Matters (DOM)

Dissolved organic matters (DOM) varied greatly from season to season except in one wetland that was Tapacia *beel*. In the Tapacia *beel* wetland variation in DOM was not significant ($p<0.05$). But differences between seasons were observed in Gahari *beel* and

Jamuguri nala. Almost constant DOM content was observed in Tapacia *beel.* The highest was being 3.44±0.11ppm in the monsoon period and the lowest was being in the summer season i.e 3.23±0.06 ppm in the case of Tapacia *beel.* No significant differences at $p<0.05$ was noticed in the *beel* during the year. Over all the highest DOM content 3.48±0.13 ppm was observed in Jamuguri nala during winter season (Table-9,fig.-22).

Lowest DOM (2.33±0.17ppm) was recorded in the Gahari *beel* wetland during monsoon season. In contrast to highest value observed in Tapacia during monsoon season, the highest value in the Jamuguri nala was recorded in winter. But the values of monsoon and winter in the case of Tapacia *beel* did not vary significantly. This explicitly explained that DOM variation was region specific rather than season specific. From this point of view DOM variation could be related to the death and decay of macrophytes specially *Eicchornia* sp.. Tapacia *beel* contained very less amount of macrophytes throughout the year which could be the possible reason for near constant DOM content of water. The range of DOM significantly varied in Gahari *beel* and Jamuguri nala , where minimum being 2.33±0.17 ppm and 2.48±0.18 ppm and maximum were 3.48 ±0.13 and 3.56±0.05 ppm respectively. This was not observed in Tapacia *beel* where macrophytes were less. The lowest conc.of DOM were recorded during the monsoon season in both the wetlands. Both the wetlands showed similar pattern of DOM variation since both were infected with macrophytes. For this reason, the variation could be related to death and decay of vegetation. Choudhury *et al.* (1997) also recorded similar higher range of dissolved organic matters content in the *beels* of Kamrup district of Assam which they related to macrophytic infestation. They estimated DOM content between 1.48 to 3.12 ppm. Similar to present investigation, Acharjee and Dutta (1999) also recorded same type of DOM conc. which varied 2.0 to 3.16 ppm. Pathak (1990) recorded low DOM values in *beels* of Assam when compared to Kalyani and Media *beels* of West Bengal. Again Trivedi *et al.* (2007) recorded higher DOM values in Kalyani *beel.* They recorded 9.94 to 15.15 ppm in Kalyani *beel.* According to them this higher values in the *beels* of West Bengal might be due to industrial pollution.

Table -9: DOM (ppm) in various seasons

Beel	Summer Season				Monsoon Season			
	S1	**S2**	**S3**	**Pooled (Mean ± SD)**	**S1**	**S2**	**S3**	**Pooled (Mean ± SD)**
Gahari *beel*	2.50	2.75	2.15		2.55	2.30	2.40	
	2.20	2.50	2.00		2.45	2.15	2.25	
	2.20	2.84	2.05		2.50	2.01	2.34	
Mean	**2.30**	**2.70**	2.07	**2.35**	2.50	2.15	2.33	2.33
SD	0.17	0.18	0.08	0.32	0.05	0.15	0.08	0.17
Jamuguri nala	2.80	2.74	2.53		2.52	2.15	2.55	
	2.82	2.60	2.50		2.61	2.30	2.45	
	2.73	2.74	2.50		2.80	2.42	2.50	
Mean	**2.78**	**2.69**	2.51	**2.66**	**2.64**	**2.29**	**2.50**	**2.48**
SD	0.05	0.08	0.02	0.14	0.14	0.14	0.05	0.18
Tapacia *beel*	3.25	3.40	3.25		3.45	3.40	3.45	
	3.15	3.20	3.20		3.25	3.70	3.40	
	3.15	3.30	3.20		3.50	3.60	3.25	
Mean	**3.18**	**3.30**	3.22	**3.23**	**3.40**	**3.57**	**3.37**	**3.44**
SD	0.06	0.10	0.03	0.06	0.13	0.15	0.10	0.11
	Post monsoon				**Winter**			
Gahari *beel*	3.35	3.35	3.00		3.45	3.34	3.25	
	3.15	3.30	3.25		3.50	3.55	3.38	
	3.16	3.25	3.33		3.95	3.30	3.60	
Mean	**3.22**	**3.30**	3.19	**3.24**	**3.63**	**3.40**	**3.41**	**3.48**
SD	0.11	0.05	0.17	0.06	0.28	0.13	0.18	0.13
Jamuguri nala	3.00	3.10	3.30		3.20	3.45	3.50	
	3.20	3.15	3.00		4.00	3.60	3.80	
	3.10	3.10	3.20		3.30	3.65	3.50	
Mean	**3.10**	**3.12**	3.17	**3.13**	**3.50**	**3.57**	**3.60**	**3.56**
SD	0.10	0.03	0.15	0.03	0.44	0.10	0.17	0.05
Tapacia *beel*	2.80	3.70	3.45		3.50	3.35	3.35	
	3.20	3.35	3.26		3.60	3.40	3.50	
	3.00	3.45	3.18		3.10	3.25	3.55	
Mean	**3.00**	**3.50**	3.30	**3.27**	**3.40**	**3.33**	**3.47**	**3.40**
SD	0.20	0.18	0.14	0.25	0.26	0.08	0.10	0.07

S- Substation. Data showing for S1, S2, & S3 are average of triplicate value

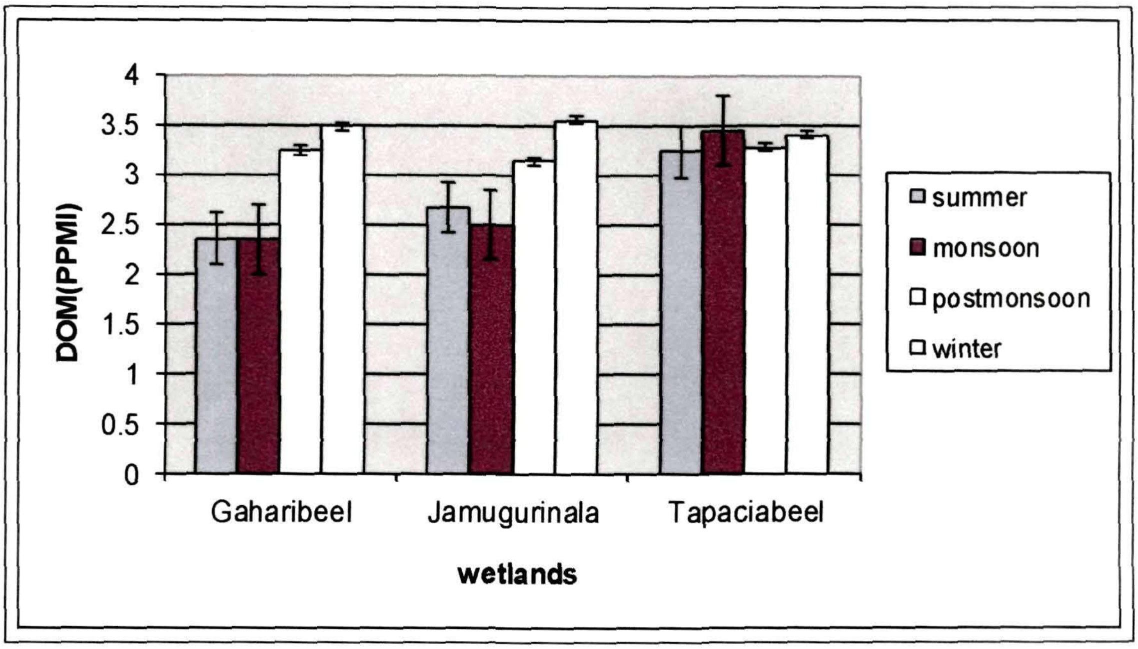

Figure-22: Illustration showing variation of dissolved organic matters

4.1.8 Total hardness

Variation of hardness in all the wetlands were minimum and found to be controlled by allochthonous factors since there were no significant difference between summer and monsoon seasons . This was assumed that during monsoon period entire water was exchanged with reverine flood water. In the Gahari *beel* the range of hardness was found to be 27.41±0.15ppm to 34.64±1.0ppm. The lowest being in the summer season and the highest being in the winter season of the year. Similarly in the Jamuguri nala wetland lowest was observed in the summer season (28.68±0.16 ppm) and the highest (35.67±0.29ppm) in the winter season (Table-10 fig.23). Similar scenario existed in the Tapacia *beel* also where lowest hardness (28.5± 0.40ppm) was recorded in the monsoon season and 28.83±1.04 ppm of hardness was observed in the summer season. Both the values were not significantly different from each other at $p < 0.05$. The highest value of hardness was also observed in the winter season like other wetlands. The variations of hardness among different wetlands were not significant ($p < 0.05$). It indicated that there were no changes due to isolation during non- rainy seasons. Only seasonal variations in wetlands were observed. Das and Bandyopadhyay (1998) found highest hardness values of 165 ppm in the month of summer and lowest of 120 ppm in the monsoon in the paper mill polluted Kole *beel* of West Bengal. They reported that the higher range of hardness in Kole *beel* was due to paper mill effluent which contained high amount of carbonate and bicarbonate ions. The values were also considerably higher (58.87 to 133.75 ppm). Rana *et al.*(1996) also noticed higher hardness value in Kalyani lake. Pathak (1990) evaluated the hardness of Kulia and Media *beels* of West Bengal and Dhir *beel* of Assam where he found that in Kulia *beel* macrophytes dominated phase showed higher hardness than plankton dominated phase. Values during macrophyte dominated phase were between 98.8 to 112.2 ppm and whereas during plankton dominated phase hardness values were much lesser (58.9 to 85.4 ppm). He established a negative correlation between plankton growth and hardness value. In comparison to Media and Kulia *beels*, Dhir *beel* of Assam showed lower hardness values i.e.13.9 to 35.6 ppm during the same investigation period.

When hardness values of wetlands of KNP compared to the hardness value of forerunner of river Brahmaputra, the results showed higher range of hardness of later which ranged between 35.72 to 63.92 ppm (Pathak 2001). Moreover there were no change between summer and monsoon season and the changes surfaced only after monsoon season. Therefore, it could be indicated that the factors of changes were indigenous rather than external factors. Similar to present values, Acharjee and Dutta (1999) recorded hardness values ranging from 26.7 to 35.6 ppm in Dighali *beel* wetland of Assam.

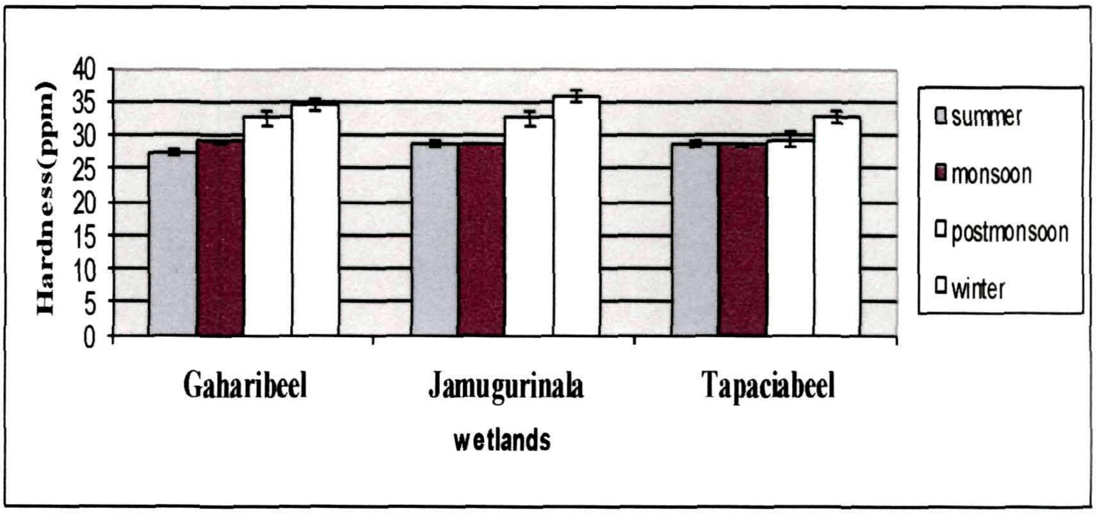

Fig.23 Illustration showing variation of total hardness

Table -10: Total hardness (ppm) during various season

Beel	Summer Season				Monsoon Season			
	S1	**S2**	**S3**	**Pooled (Mean ± SD)**	**S1**	**S2**	**S3**	**Pooled (Mean ± SD)**
Gahari	27 40	27 60	27 50		29 50	28 00	30 00	
beel	27 33	27 50	27 80		28 00	28 45	29 65	
	27 00	27 40	27 20		31 00	29 00	26 47	
Mean	**27.24**	**27.50**	27 50	**27.41**	**29.50**	**28.48**	**28.71**	**28.90**
SD	0 21	0 10	0 30	0 15	1 50	0 50	1 94	0 53
Jamuguri nala	29 25	29 50	29 00		29 30	29 50	29 00	
	27 50	29 00	28 55		28 00	28 50	27 80	
	28 80	28 50	27 95		27 33	29 00	28 75	
Mean	**28.52**	**29.00**	28 50	**28.68**	**28.21**	**29.00**	**28.52**	
SD	0 91	0 50	0 53	0 16	1 00	0 50		**28.58**
							0 63	0 40
Tapacia	27 50	31 50	27 85		28 40	28 35	28 00	
beel	30 50	28 60	30 20		27 86	29 50	28 75	
	27 50	29 90	25 95		29 25	29 15	27 25	
Mean	**28.50**	**30.00**	28 00	**28.83**	**28.50**	**29.00**	**28.00**	**28.50**
SD	1 73	1 45	2 13	1 04	0 70	0 59	0 75	0 50
	Post monsoon				**Winter**			
Gahari	32 83	33 65	34 50		35 45	34 35	36 25	
beel	31 00	29 50	32 50		35 00	32 50	34 50	
	33 68	32 86	32 00		35 75	33 65	34 28	
Mean	**32.50**	**32.00**	33 00	**32.50**	**35.40**	**33.50**	**35.01**	**34.64**
SD	1 37	2 20	1 32	0 50	0 38	0 93	1 08	1 00
Jamuguri nala	32 50	34 00	33 55		36 50	35 65	35 00	
	33 00	31 00	33 50		34 00	35 85	35 50	
	30 50	32 50	31 96		36 00	36 50	36 00	
Mean	**32.00**	**32.50**	33 00	**32.50**	**35.50**	**36.00**	**35.50**	**35.67**
SD	1 32	1 50	0 90	0 50	1 32	0 44	0 50	0 29
Tapacia	28 00	30 50	29 50		33 00	32 00	33 00	
beel	27 00	29 00	30 22		32 15	31 00	33 00	
	30 50	27 50	29 70		32 40	34 40	33 00	
Mean	**28.50**	**29.00**	29 81	**29.10**	**32.52**	**32.47**	**33.00**	**32.66**
SD	1 80	1 50	0 37	0 66	0 44	1 75	0 00	0 29

S- Substation Data showing for S1, S2, & S3 are average of triplicate value

4.1.9 Free CO_2 Content of water

CO_2 content of water of the wetlands varied remarkably with the seasons (p< 0 05) The spatial variations was not significant The highest concentration of CO_2 was observed in the monsoon season (Table-11, fig 24) The highest value recorded in the

Jamuguri nala (5.62±0.13 ppm, Table-18).The lowest CO_2 conc. was also observed in the same wetland i.e. 2.5 ppm with average 2.68±0.16 ppm in the summer season. The post monsoon and summer season showed no significant difference in CO_2 content indicating proper utilization by phytoplankton communities since nos. of phytoplankton were more in these seasons (Table-14). Goswami *et al.* (1999) recorded variable range of CO_2 in wetlands of upper, central, lower and southern Assam zone. They recorded 0.1 to 6.3 ppm in upper Assam zone, 2.7 to 21 ppm in central zone 1.5 to 15 ppm in lower Assam 6.5 to 24 ppm in southern Assam zone. Higher limit of CO_2 probably indicated improper utilization of CO_2 as mentioned by Choudhary *et al.* (1994) in their studies done on Gorajan *beel* of Kamarup District. Dutta and Bhagawati (2007) recorded slightly higher range of free CO_2 in Dighali and CO_2 Kachadhara beel, where they recorded 3ppm to 20.5 ppm in Dighali and 2.5 to 8.5 ppm in Kachadhara *beel.* Acharjee and Dutta (1999) also recorded `moderate range of CO_2 in Dighali *beel.* In the present investigation comparatively higher range of free CO_2 in monsoon season could be related lower phytoplankton production and cloudiness of the sky.

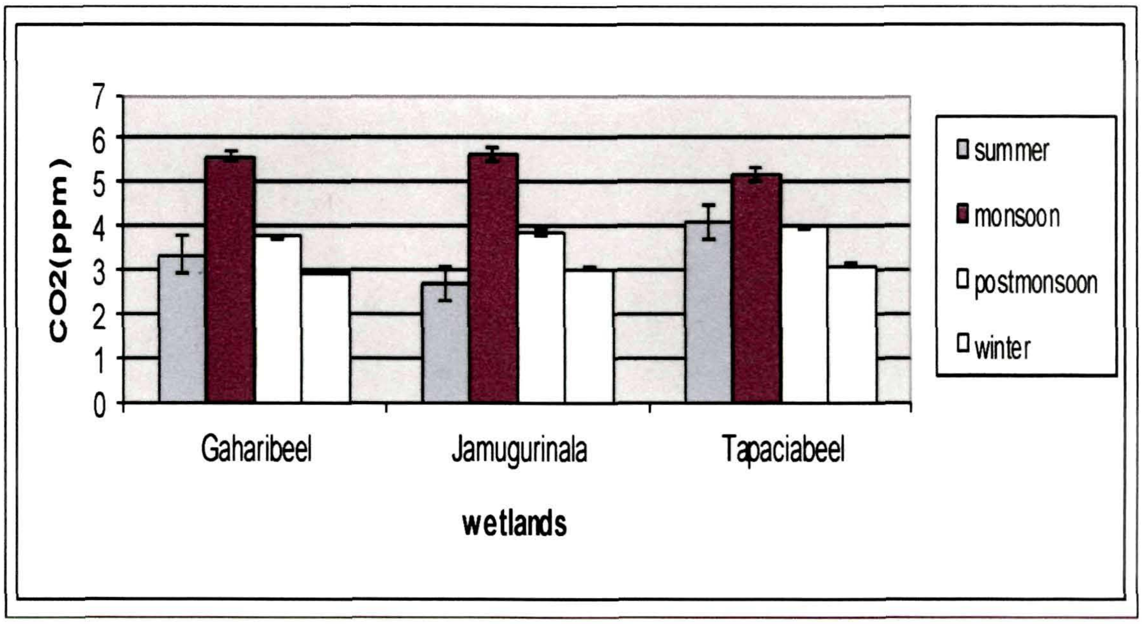

Figure-24: Variation of Free CO_2 content of water

Table –11: Free CO_2 (ppm) content during different seasons.

Beel	Summer Season				Monsoon Season			
	S1	**S2**	**S3**	**Pooled (Mean ± SD)**	**S1**	**S2**	**S3**	**Pooled (Mean ± SD)**
Gahari *beel*	3.10	3.60	3.50		5.70	5.80	5.70	
	2.90	3.45	3.50		5.30	5.30	5.80	
	3.00	3.40	3.50		5.80	5.40	5.60	
Mean	3.00	3.48	3.50	**3.33**	5.60	5.50	5.70	**5.60**
SD	0.10	0.10	0.00	0.28	0.26	0.26	0.10	0.21
Jamuguri nala	2.70	2.70	2.70		5.60	5.40	5.3	
	2.70	2.80	2.80		5.80	5.80	5.0	
	3.00	2.70	2.70		5.90	5.60	5.3	
Mean	**2.80**	**2.73**	2.73	**2.68**	**5.77**	**5.60**	5.2	**5.62**
SD	0.17	0.06	0.06	0.16	0.15	0.20	0.17	0.13
Tapacia *beel*	4.40	4.00	3.90		5.50	5.20	5.00	
	4.40	4.00	4.00		5.30	5.30	5.00	
	4.20	3.70	4.10		5.10	5.10	5.00	
Mean	**4.33**	**3.90**	**4.00**	**4.08**	**5.30**	**5.20**	**5.00**	**5.17**
SD	0.12	0.17	0.10	0.23	0.20	0.10	0.00	0.15
	Post monsoon				**Winter**			
Gahari *beel*	4.20	3.20	3.60		3.40	2.50	3.50	
	3.90	3.00	4.20		3.10	2.00	2.90	
	4.60	2.80	4.20		3.40	2.40	3.20	
Mean	**4.23**	**3.00**	**4.00**	**3.74**	**3.30**	**2.30**	**3.20**	**2.93**
SD	0.35	0.20	0.35	**0.66**	0.17	0.26	0.30	**0.55**
Jamuguri nala	3.40	4.20	3.70		3.50	2.50	3.60	
	3.60	4.20	4.00		3.20	2.50	3.50	
	3.50	4.30	3.80		3.50	1.90	3.10	
Mean	**3.50**	**4.23**	**3.83**	**3.86**	**3.40**	**2.30**	**3.40**	**3.03**
SD	0.10	0.06	0.15	0.37	0.17	0.35	0.26	0.64
Tapacia *beel*	3.50	4.40	4.00		3.10	3.00	3.40	
	3.50	4.10	4.20		3.20	3.00	3.10	
	3.80	4.20	4.00		3.00	3.00	3.10	
Mean	**3.60**	**4.23**	**4.07**	**3.97**	**3.10**	**3.00**	**3.20**	**3.10**
SD	0.17	0.15	0.12	0.33	0.10	0.00	0.17	0.10

S- Substation. Data showing for S1, S2, & S3 are average of triplicate value

4.1.10 Phosphate (PO_4) content of water

Variation of Phosphate content of water of wetlands of Kaziranga National Park showed similar pattern. The maximum conc. of PO_4 occurred during the monsoon season in all the wetlands. The mean values of PO_4 concentration were 0.05±0.01, 0.05±0.02 and 0.06±0.01ppm during summer in Gahari *beel*, Jamuguri nala and Tapacia *beel* respectively (Table-12). Accordingly, mean values for monsoon were 0.15±0.03, 0.12±0.03 and 0.14±0.01ppm for respective wetlands. Values during post monsoon were 0.13±0.02, 0.11±0.02 and 0.12±0.03ppm and during winter 0.08±0.01, 0.09±0.01 and 0.11±0.03ppm respectively (Table-12). The PO_4 values were similar to other wetlands of Assam. Acharjee and Dutta (1999) recorded PO_4 range in Dighali *beel* as 0.04 to 0.09 ppm. Pathak (1990) also recorded very low levels of PO_4 in Dhir *beel* of Assam (0.02 - 0.1 ppm). Lower PO_4 content of water was also recorded in Kulia and Media *beel* wetlands of West Bengal. Choudhary *et al.* (1997) also recorded lower range of PO_4 i.e. 0.01 to 0.15 ppm in Mandira, Arikata and Rangai *beels* of Kamrup district. Kolekar *et al.* (1989) recorded low PO_4 content in Dighali ox-bow lake of Assam .The range of PO_4 was 0.013 to0.613 ppm. Based on their studies, they indicated that PO_4 content of natural water varied from low i.e. less than 1ppm to very high as in the case of few saline lakes. They also opined that PO_4 was often considered to be the most critical factor in maintenance of biogeochemical cycle. Das (1998) recorded very less available P in detritus of Saraskha wetland of West Bengal. He suggested that high acidic nature of bottom sediment, where PO_4 might be locked in the form of Fe and Al PO_4. Contrary to this hypothesis, Hopkinson (1992) suggested that N and P should be more in open floodplain wetlands than closed wetlands. Christopher (2000) recorded 1.5 times more accumulation of P in floodplain wetlands. Similarly Cooper and Gilliam (1987) also found that in floodplain wetlands P increased with increase of clay content. In the present investigation, lower levels of PO_4 possibly be related to the acidic bottom sediment detritus as suggested by Das (1998). In contrast to findings of Cooper and Gilliam (1987), low levels of PO_4 in soil and subsequently to water also might be due to the fact that soil of *beels* of Assam in general contained higher percentage of sand and lower level of clay (Gorai *et al.* 2006). However, Goswami *et al.* (1999) recorded very high percentage of PO_4 with a wide range in the wetlands of central and lower Assam zone. The range PO_4 in the central zone were 0.0 to 44 ppm and in lower Assam 0.3 to o.21ppm. This wide variation of PO_4 might be due to soil characteristics or differences in incoming water. When seasonal changes were compared, there were significant differences existed among different seasons. There were significant difference between monsoon and summer seasons in all the wetlands at $p< 0.05$ (Table19). The differences might be due to complete exchange of water because of flood as there were sudden rise of PO_4 content of the water from summer to monsoon. Kolekar *et al.* (1989) also observed a gradual increase in PO_4 content in the water of the *beels* during monsoon season and then a sharp fall from September onwards. The seasonal variation in the PO_4content of water largely depended on allochthonous sources such as rain washing from the catchment area. Seshappa (1953) also noticed an increase in the inorganic PO_4 in pond water during July –August. He determined the causative agent was to be evidently rain washing. The summer season also varied significantly from post monsoon season because of higher values. It might be due to the fact that macrophytes and planktonic algae utilized PO_4 to some extent. During summer and winter seasons difference was not significant ($p<0.05$) because of lower values in the winter season. This could be related to utilization of PO_4 by phytoplankton and macrophytes. **contd**

Table -12: Phosphate content (ppm) of water at different seasons of the year

Name of the Wetland	Phosphate content															
	Summer				Monsoon				Post monsoon				Winter			
	S-1	S-2	S-3	Mean &SD	S-1	S-2	S-3	Mean&SD	S-1	S-2	S-3	Mean&SD	S-1	S-2	S-3	Mean &SD
Gahari *beel*	0.05	0.04	0.05	**0.05** 0.01	0.12	0.15	0.17	**0.15** 0.03	0.15	0.13	0.12	**0.13** 0.02	0.09	0.07.	0.08	**0.08** 0.01
Jamuguri nala	0.03	0.07	0.05	**0.05** 0.02	0.13	0.09	0.14	**0.12** 0.03	0.13	0.09	0.13	**0.11** 0.02	0.10	0.08	0.09	**0.09** 0.01
Tapacia *beel*	0.07	0.05	0.06	**0.06** 0.01	0.12	0.15	0.14	**0.14** 0.01	0.13	0.13	0.09	**0.12** 0.03	0.12	0.13	0.08	**0.11** 0.03

S- Substation. Data showing for S1, S2, & S3 are average of triplicate value

Higher values in the Gahari beel might be due to the washings of rain water from the adjacent hill as stated by Kolekar *et al.*(1989).

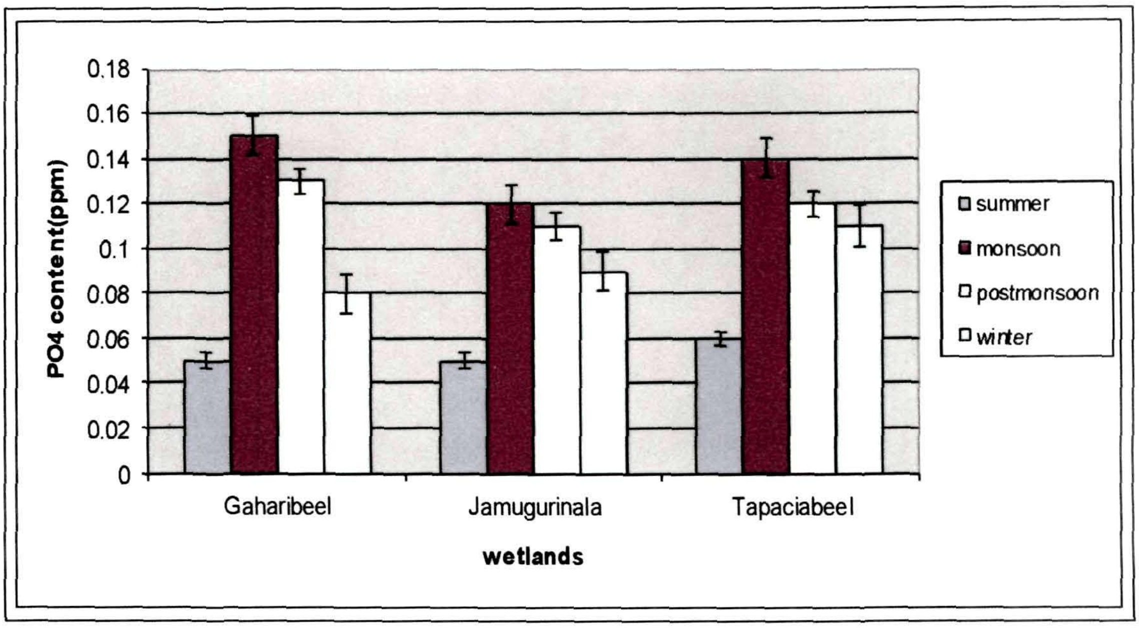

Figure.25: Illustration showing Variation of phosphate content

4.1.11.Nitrate

Unlike phosphate, the nitrate concentration showed different type of variation where maximum concentration of nitrate observed in winter season in all the wetlands. There were no significant differences between wetlands with respect to their spatial location in the Kaziranga National Park. The maximum concentration of NO_3 was recorded in the Gahari *beel* during winter season among all these wetlands. The maximum concentration was 0.67±0.03 ppm (Table-13). The minimum conc. was recorded in the Jamuguri wetland during summer season which was 0.09±0.01ppm. When variation of concentration was analysed, it was noticed that there was sudden rise of concentration towards monsoon season from the summer season (Figure-26). The range of mean concentration of Summer was 0.09 to 0.31 ppm which raised to 0.37±.04 to 0.53±0.06ppm in monsoon season. The ranges of winter season were 0.44±0.03 to 0.67±0.03ppm and 0.41±0.03 to 0.63±0.03ppm during post monsoon season. Mean concentration values were not significantly different from each other among monsoon, post monsoon and winter ($p<0.05$). Similar observations on nitrate were also made by

Acharjee and Dutta (1990) in Dighali *beel* wetland of Assam where they recorded nitrate range from 0.21 to 0.65 ppm. The maximum conc. was recorded during October-December (winter) which was 0.65 ppm. However, Choudhary *et al.*(1997) recorded poor range of nitrate in the *beels* of Assam. Goswami *et al.* (1999) recorded similar very low range of NO_3 in the *beels* of all four zones of Assam. They recorded almost nil to trace NO_3 in the *beels* of Assam. They reported that it might be due to the different soil characteristics. Dutta and Bhagawati (2007) and Pathak(1990) also recorded slightly higher range of nitrate in different *beel* wetlands of Assam . When compared to beel wetlands of Assam, the Kulia *beel* of West Bengal showed higher values of nitrate (Pathak1990) which was implicated due to industrial pollution. Saha *et al.* (1990) also recorded high range of nitrate in the Kulia *beel* of W.B. where the range was 0.08 to 1.8 ppm in planktonic phase of the *beel* and 0.12 to 0.25 in macrophytic phase (June–July). He also expressed that removal of macrophytes made ecosystem highly productive in January to June. The relatively higher range of nitrate concentration in the wetlands of KNP could be related to the fact that neighbouring tea gardens might have applied lot of nitrogenous chemical fertilizers during the monsoon season. In that season, which was the production season for tea gardens, the fertilizers got their way to the wetlands of KNP with rain washings and probably thereby increase the nitrate concentration.

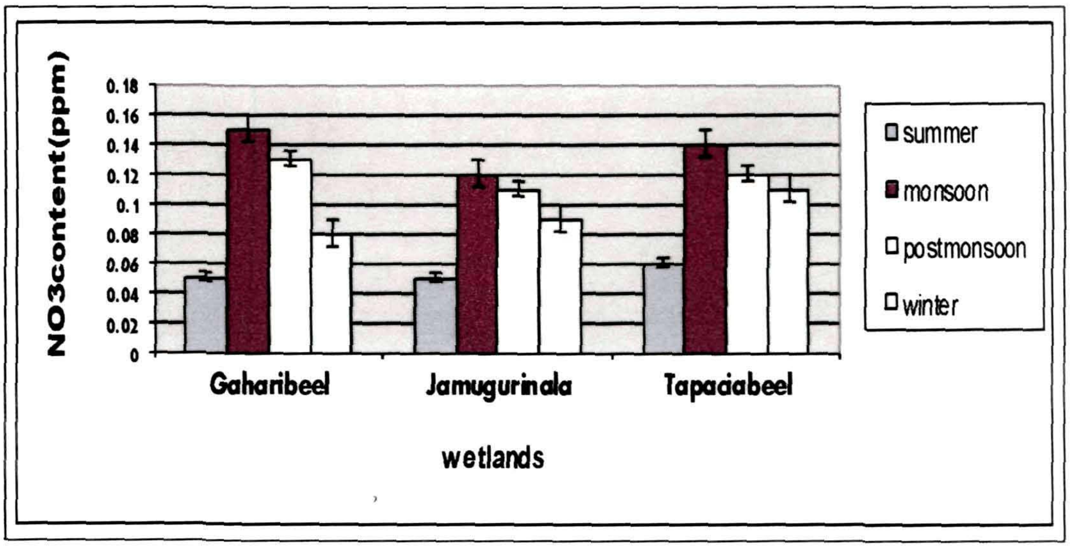

Figure-26: Illustration showing nitrate content of water

Table -13: Nitrate content (ppm) of water

Name of the Wetland	Nitrate content at different Seasons in ppm															
	Summer				Monsoon				Post monsoon				Winter			
	S-1	S-2	S-3	Mean ±sd	S-1	S-2	S-3	Mean ±sd	S-1	S-2	S-3	Mean ±sd	S-1	S-2	S-3	Mean ±sd
Gahari *beel*	0.30	0.28	0.35	**0.31** 0.03	0.50	0.60	0.50	**0.53** 0.06	0.60	0.60	0.70	**0.63** 0.06	0.65	0.65	0.70	**0.67 0.03**
Jamuguri nala	0.09	0.09	0.10	**0.09** 0.01	0.40	0.35	0.35	**0.37** 0.04	0.42	0,44	0.38	**0.41** 0.03	0.48	0.42	0.45	**0.44 0.03**
Tapacia *beel*	0.20	0.25	0.20	**0.22** 0.01	0.38	0.45	0.40	**0.41** 0.04	0.45	0.40	0.44	**0.43** 0.03	0.48	0.43	0.45	**0.45 0.03**

S- Substation. Data showing for S1, S2, & S3 are average of triplicate value

4.2 Biological parameters

Phytoplankton ,as primary producer, determines the productivity of a wetland. For the production of this plant community optimal limnological parameters are most essential. Zooplankton as primary consumer depends on phytoplankton for their growth and reproduction. Study of these plankton is important because they determine the ultimate protein production from a wetland i.e fish. Besides,, these are the indicators of an aquatic body for health and productivity.

4.2.1 Phytoplankton and zooplankton in wetlands

Phytoplankton and zooplankton showed temporal as well as spatial variation over the experimental period. Phytoplankton no.density was maximum in the Tapacia wetland during post monsoon season (Table -14). This was the highest no.density in all wetlands under study among different seasons. The lowest density of phytoplankton was observed in Jamuguri wetland during winter season. The mean no.density was 533.36 ±8.25 unit /l (Table -14,). In Gahari *beel*, the maximum mean density of 1610±62.96 unit/l was also noticed during post monsoon season followed by summer and the lowest mean density of 903.3±55.58 was recorded in the monsoon season. (Table-14).Station with highest density was observed in the Tapacia wetland during post monsoon season. When comparison was made among seasons in the same wetlands, significant differences ($p<0.05$) were observed. However, Jamuguri nala did not show any seasonal difference in phytoplankton density except in summer and monsoon .During this period i.e.from summer to monsoon, there was a drastic reduction in nos. of phytoplankton communities.

Zooplankton showed similar variation in number over the year (Table-14). The highest number density 773.6±92.79 unit /l of zooplankton was recorded in the Tapacia wetland followed by Ghahari *beel* (721±42.52unit /l) in the same season i.e. post monsoon season . Like in the case of phytoplankton, lowest number density of zooplankton was recorded in Jamuguri nala. This wetland did not show any statistical difference between seasons with respect to number of zooplankton. The seasonal differences were prominent only in the Tapacia wetland where summer and post monsoon seasons were completely different from other productive seasons i.e. winter and monsoon.

Table-14: Phytoplankton and Zooplankton number density in different seasons

Beel	Summer (U/L)				Monsoon (U/L)				Post monsoon (U/L)				Winter (U/L)			
	S-1	S-2	S-3	Mean &SD	S-1	S-2	S-3	Mean & SD	S-1	S-2	S-3	Mean & SD	S-1	S-2	S-3	Mean& SD
Phytoplankton																
Gahari *Beel*	1360	1320	1350	**1343.3** 21.39	960	890	860	**903.3** 55.58	1550	1600	1680	**1610** 62.96	1050	850	760	**886.6** 149.79
Jamuguri nala	650	600	680	**643.3** 44.38	580	530	620	**576.6** 43.00	650	680	490	**606.6** 101.53	580	560	460	**533.36** 8.25
Tapacia ***beel***	1650	1820	1350	**1606.6** 236.92	950	830	920	**900** 51.03	1950	2600	1550	**2033.3** 526.28	1150	1250	950	**1116.6** 153.42
Zooplankton																
Gahari ***Beel***	480	560	550	525 43.59	245	289	265	266.3 22.03	720	680	765	721.6 42.52	340	455	255	350 100.37
Jamuguri nala	235	285	315	278.3 40.41	158	155	110	141 26.89	320	344	267	310.3 39.40	185	208	275	222.6 46.76
Tapacia ***beel***	675	643	655	657.6 16.17	210	235	255	233.3 22.55	876	750	695	773.6 92.79	490	385	495	456.6 62.12

S- Substation. Data showing for S1, S2, & S3 are average of triplicate value

The ratio between phytoplankton and zooplankton varied from 1.95:1 to 4.09:1 (phytoplankton: zooplankton). The lowest ratio (1.95:1) was observed in the post monsoon season where numbers of both varieties of plankton were abundant. The highest ratio (4.09:1) was recorded in monsoon season (Table-15) in the case of Jamuguri nala.

Table -15: Phytoplankton and zooplankton ratio at different seasons

Name of the wetlands	Ratios in different seasons							
	summer		monsoon		post monsoon		winter	
	unit/l	ratio	unit/l	ratio	unit/l	ratio	unit/l	ratio
Gahari ***beel***								
phytoplankton	1343.3	(2.16:1)	903.3	(3.39:1)	1610	(2.23:1)	886	(2.53:1)
zooplankton	525		266.3		721.6		350	
Jamuguri nala								
phytoplankton	643.3	(2.42:1)	576.60 .	**(4.09:1)**	606	**(1.95:1)**	533.3	(2.4:1)
zooplankton	266.3		141		310.3		222.5	
Tapacia ***beel***								
phytoplankton	1606.6	(2.44:1)	900	(3.86:1)	2033. 37	(2.62:1)	1116.6	(2.45:1)
zooplankton	657.6		233.3		773.6		456.6	

There was inverse relationship between numbers of organisms and the ratios. It was found that the higher the nos. of organisms the lesser was difference between them. There were two distinct peaks of phytoplankton and zooplankton abundance. One was observed in the post monsoon and another was in the summer season. The possible factor might be the congenial water temperature for plankton growth. The *beels* were found to be less productive and dominated by phytoplankton as stated by Choudhary *et al.*(1997). Sugunan *et al.*(2007) studied the plankton density in *beels* where they recorded very less density of plankton in Samuguri (89-127 unit/l) and Haribhanga (111-412 unit/l). Phytoplankton dominance was 72% and 78% in their in the respective wetlands..

Winter season was marked by comparatively lesser nos. of plankton in the present study. Bhaumik *et al.*(2005) also noticed lesser density of planktons in the winter season in Amda and Saguna floodplain wetlands of West Bengal. In Saguna, they recorded 1346 nos./cm^2 in winter whereas 1930 nos./cm^2 in the summer. As in the case of monsoon season, lower density was also recorded in Amda wetland. The numbers they recorded in different seasons were 1030 nos../cm^2, 1432 no/cm^2 and 1704 no/cm^2 during monsoon, winter and summer seasons respectively. Like Bhaumik *et al.* (.2005), summer peak was also observed by Srivastava and Prakash (1996) in Mahanadi river and related to this to intensity of illumination. Low density of plankton observed during monsoon season might be due to change in ecological parameters or also might be due to effect of water flow , turbulence and increased depth of water as expressed by Bhaumik *et al.*(2005) and Datta & Banik (1997).

When community structure of phytoplankton were analysed (Table-16) it was observed that Gahari *beel* and Tapacia *beel* were dominated by Chlorophyceae group of phytoplankton followed by Bacillariophyceae but in Jamuguri nala no such dominance was noticed . Similar observation was made by Dasgupta *et al.* (2007) in some ox-bow lake of new alluvial zone of West Bengal .They found that phytoplankton community was constituted by Chlorophyceae followed by Bacillariophyceae and Myxophyceae.

In the present study (Table-16) green algae was represented by seven genera. The summer and monsoon seasons were represented by several nos. of genera whereas monsoon and winter were represented by few nos. of genera. Gahari *beel* and Tapacia *beel* were also similar abundance of species. The relative abundance of different genera was much less in Jamuguri nala when compared to other two wetlands. This might be due to ecological stress faced by this wetlands because of macrophytic infestation. Only the highly tolerant varieties with less number were present in that wetland.

The community structure of phytoplankton showed that among *Chlorophyceae, Chara , Eugleana,and Scenedismus* were found in all the wetlands throughout the year. *Chlorella* and *Padiastrum spp.* were in the conducive period of summer and post monsoon with only moderate number of *Volvox and Spirogyra spp.* represented the samples of two *beels* except Jamuguri nala. It could be indicated that these spp. required sufficient sunlight for propagation which was affected by macrophytes. *Chara* spp. and *Eugleana* spp. were found to be comparatively highly tolerant varieties of Chlorophyceae. Diatom, *Asterinella spp., Cosnidiscus* spp. and *Skeletonema* spp. were present in moderate to high range. On the other hand, physicochemical properties of *beels* were not found to be optimum for *Cyclotella* and *Biddulphia* since they were present in small number and absent in most of the cases. Among the blue green algae, *Anabaena,microcystis* and *Nostoc* were present in moderate to high range with few exception in the case of Jamuguri nala. It was observed that when the growth of other algae was higher, *microcystis* numbers were low. But during the lean period their growth was dominant over the other algae. The group desmidiaceae was mainly represented by *Desmidian.* they were present in all the wetlands over the year. *Pleorotaenium* was present round the year but nos. was abundant in summer and post monsoon season, which could be attributed to optimum temperature prevailing during that period.

The zooplankton communities in the wetlands were represented by Rotifers, Cladocerans, Protozoans and Ostracods. Among Rotifers *Brachionus sp. Rotaria spp, Tricocera spp.* were found to be more dominant in Gahari *beel* wetland. Among Cladocerans, *Daphinia spp.* and *Moina spp.* were more prevalent when compared to other Cladocerans.Among Protozoans,*Ceratium spp.*and *Eudorina* were comparatively more abundant. Ostracod was represented by only one sp. i.e. *Cypris spp.*The Jamuguri nala was represented by all the spp. available in Gahari *beel* but *Bosmia spp* and *Conchilus spp.* were conspicuously absent. This might be due to the fact that these spp. were less tolerant to the ecological stress such as less sunshine .

In Tapacia *beel* apart from dominant spp. of Ghari *beel,* Brachionu sp. was also found to abundant (+++). Among copepods, *Cyclopes* were found to be dominant over other two genera. Among cladocerans, apart from *Daphnia spp.* and *Moina* spp., *Cerodaphnia* was also found to be abundant in summer and post monsoon peaks of zooplankton. This indicates that *Ceriodaphnia* spp. is available only during optimal ecological conditions. Like in the case of Gahari *beel* dominant protozoans were *Ceratium* and, *Eudorina* in summer and post monsoon. Their presence were also recorded in winter season . Unlike other two wetlands , *Actinophrys* was absent in this wetland due certain ecological factors. Similar observation was also made by Das gupta *et al.*(2007) in oxbow lake of West Bengal. They noticed that zooplankton community was constituted by micro crustaceans such as *Maina* ,*Daphnia*, *Cypris* and rotifer (*Bosmina* , *Keratella* ,*Brachionus* and *Asplanchna* spp.) among rotifers *Brachionus* spp. and *Keratella* spp. were dominant .This variation when compared to present study might be due to ecological conditions prevailing in the wetlands of the KNP wetlands .

Zooplankton communities closely followed the abudance of phytoplankton growth for their growth and reproduction. Sharma (2000) mentioned that the rotifers component was dominant zooplankton in the *beels* of Assam like findings of present studies . It was clear that zooplankton were not single spp .community and there were variation among wetlands probably due to different ecological conditions.

Table-16: Abundance of phytoplankton in different wetlands

Group of phytoplankton	SEASONS											
	Summer			Monsoon			Post monsoon			Winter		
	GB	JN	TB	GB	JN	TB	GB	JN	TB	GB	JN	TB
Chlorophyceae												
Chara	++	++	++	++	+	++	+++	+	+++	+++	+	+++
Chlorella	+	-	+	+	-	+	+	-	+	++	-	++
Euglena	+++	++	+++	++	++	++	++	++	++	++++	+++	++++
Pediastrum	++	-	++	+	-	+	+++	+	+++	+	+	+
Scenedismus	++	+	++	+	+	+	+	+	+	++	++	++
Spirogyra	+++	+	+++	+	-	+	+	-	+	++	++	++
Volvox	+++	+	+++	+	-	+	+++	++	+++	+	+	+
Diatom-Bacillariophyceae												
Aserionella	+++	++	+++	++	+	++	+++	+++	+++	++	+	++
Biddulphia	+	-	+	+	-	+	++	-	++	+	-	+
Coscinodiscus	+++	++	+++	+	+	+	+	++	+	++	+	++
Cyclotella	-	-	-	-	-	-	-	+	-	-	-	-
Diatoma	++	++	++	+	+	+	++	+	++	+	++	+
Nitzchia	++	-	++	-	-	-	++	+	++	+	+	+
Pinnularia	++	+	++	+	+	+	+++	+	+++	-	-	-
Skeletonema	++++		+++	++	-	++	+++	++	+++	+	-	+
Blue-green algae												
Anabaena	+++	+	+++	+	-	+	+++	-	+++	++	+	++
Lyngbya	+	+	+	+	+	+	++	+	++	-	+	-
Microsystis	+	+++	+	+++	++	+++	++	+++	++	++	+	++
Nostoc	++	++	++	+	+	+	++	+	++	++	+	++
Oscellatoria	++	-	++	+	-	+	+	-	+	+	-	+
Spirulina	+	-	+	+	-	+	++	-	++	+	-	+
Desmidiaceae												
Closterium	+	+	+	+	+	+	+	+	+	++	+	++
Desmidium	+++	+++	+++	+	+	+	+++	+++	+++	++	++	++
Genicularia	+	-	+	+	-	+	+	+	+	+	+	+
Microsterias	+	+	+	+	+	+	++	++	++	++	++	++
Netrium		+	-	++	+	++	-	++	-	++	+	++
Pleorotaenium	+++	++	+++	++	-	++	+++	++	+++	+	+	+

Table-17: Abundance of zooplankton in different wetlands

Groups of zooplankton	SEASONS											
	Summer			Monsoon			Post monsoon			Winter		
	GB	JN	TB	GB	JN	TB	GB	JN	TB	GB	JN	TB
ROTIFERS												
Asplanchna	+	+	+	-	+	-	-	+	+	-	+	+
Brachionus	++	++	+++	+	+	++	++	++	+++	++	+	+
Conchilus	+	-	+	+	-	-	-	-	+	-	-	-
Filinia	+	+	++	-	+	+	+	+	+++	-	+	++
Hexarthra	+	++	+	-	+	+	-	++	++	-	-	+
Rotaria	++	-	+++	+	+	++	+	-	+++	+	+	+++
polyarthra	+	+	++	+	+	+	-	++	++	+	+	+
Synchaeta	-	-	+	-	-	-	+	+	++	-	-	+
Trichocerca	++	++	++	++	+	++	++	++	+++	++	+	+
COPEPODS												
Cyclops	++	++	+++	+	-	+	+++	++	+++	++	+	++
Diaptomus	+	+	+	+	+	+	+	+	++	++	-	+
Nauplius	+	+	++	+	-	++	+	+	+	+	+	+
CLADOCERANS												
Bosmina	+	-	+	+	-	+	-	-	+	-	-	+
Ceriodaphania	++	++	+++	-	+	+	++	++	+++	++	+	++
Daphnia	+++	++	++	++	+	+	+++	++	+++	+++	++	++
Moina	+++	++	+++	++	+	+	+++	++	++	+	++	+
Sida	-	+	+	-	+	+	-	-	-	-	-	-
PROTOZOANS												
Actinophrys	+	+	++	-	+	-	+	+	++	-	+	+
Arcella	+	-	+	-	-	-	-	++	++	+	+	-
Actinospaerium	-	+	+	-	+	-	++	-	++	-	+	+
Centropyxis	+	-	++	+	-	-	+	+	++	+	-	+
Ceratium	++	++	+++	-	+	+	++	++	+++	++	+	++
Eudorina	++	+	+++	+	+	+	+	++	+++	++	+	+
Paramaecium	+	++	++	-	-	+	+	+	++	+	++	+
Peridium	-	+	++	-	-	+	+	++	+++	-	+	+
Polytoma	-	-	+	-	-	+	+	+	+	-	-	+
OSTRACODS-												
Cypris	+	+		+	-	+	++	+	+++	++	+	++

GB- Gahari beel , JN- Jamuguri nala, TB- Tapacia beel .

4.3 Multivariate treatment of the data

4.3.1 Interrelationship.

The interrelationship among various limnological and biological parameters were statistically analysed. Correlation matrix of the data were built. The pairs of parameters showing high significant correlation were considered to have close relationship with each other chemically as well as biologically.

4.3.1.1 Interrelationship of different parameters during summer season.

During summer season the relationship of temperature in Gahari *beel* with CO_2 TDS, DOM , and alkalinity was found to be negatively correlated but with pH and hardness, it was positive at insignificant level (Table 18). It was observed that there was high significant correlation between zooplankton and temperature. This might be due to the fact that there was a direct effect of raising temperature on the growth and reproduction of zooplankton. On the other hand temperature maintained a negative significant correlation with phytoplankton. This might be assumed that the raising temperature had a negative impact on the phytoplankton communities during summer season.

Similar was the case with Jamugurinala (Table-18). Here PO_4 and phytoplankton growth was found to be highly significant ($p<0.01$). Apart from above two *beels*, Tapacia *beel* also showed a strong positive correlation between PO_4 and phytoplankton (Table-20). Similar to this, zooplankton also had a positive significant relationship with PO_4 in the Tapacia *beel*

When interrelationship of parameters in all the wetlands during summer season was correlated it was observed that temperature had a negative significant relation with O_2 but there was significant positive correlation with CO_2 (Table-21) This could be attributed to the fact that abundant growth of phytoplankton and subsequent respiration by both the groups the plankton triggered the production of CO_2. But on the other hand high temperature during summer season prevented the dissolution of atmospheric O_2. Overall conductivity of water showed a positive significant correlation with TDS. TDS might have helped in increasing conductivity due to presence of salt in it .During summer season temperature had significant role in the growth of phytoplankton .

Table- 18: Interrelationship of different parameters during summer season in the Gahari *beel*

	Temp	pH	O_2	CO_2	TDS	Alkali nity	Condu ctivity	DOM	Hard ness	NO_3	PO_4	Phytop lankt on	Zooplaton
Temp	1 00												
pH	0 28	1 00											
Oxygen	-0 54	-0 27	1 00										
Carbon dioxide	-0 13	0 46	0 34	1 00									
TDS	-0 48	-0 14	0 18	0 30	1 00								
Alkalinity	-0 15	-0 43	0 22	-0 09	0 42	1 00							
Conductivity	0 16	-0 35	-0 65	-0 32	-0 16	-0 26	1 00						
DOM	-0 30	-0 55	0 64	0 15	0 33	0 80*	-0 37	1 00					
Hardness	0 42	0 17	0 18	0 59	-0 34	-0 08	-0 06	0 12	1 00				
Nitrate	0 72*	0 13	0 24	-0 02	0 52	0 20	-0 43	0 11	-0 69*	1 00			
Phosphate	-1 00**	-0 28	0 54	0 13	0 48	0 15	-0 16	0 30	-0 42	0 72*	1 00		
Phytoplankton	-0 94**	-0 42	0 58	0 18	0 36	0 09	0 00	0 33	-0 21	0 45	0 94**	1 00	
Zooplankton	0 91**	0 45	-0 58	-0 19	-0 32	-0 07	-0 05	-0 33	0 14	-0 36	-0 91**	-0 99**	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

Table- 19:Interrelationship of different parameters during summer season in the Jamuguri nala

	Temp	pH	O_2	CO_2	TDS	Alkalinity	Conductivity	DOM	Hardness	NO_3	PO_4	Phytoplankton	Zooplankton
Temp	1 00												
pH	0 00	1 00											
Oxygen	0 46	0 22	1 00										
Carbondioxide	-0 19	-0 65	-0 64	1 00									
TDS	-0 29	0 91**	0 05	-0 38	1 00								
Alkalinity	0 03	-0 71*	-0 50	0 79*	-0 56	1 00							
Conductivity	0 08	-0 68*	-0 58	0 71*	-0 58	0 56	1 00						
DOM	-0 13	-0 17	0 10	-0 38	-0 38	-0 19	-0 26	1 00					
Hardness	-0 38	-0 24	-0 48	0 24	-0 10	0 54	0 20	0 04	1 00				
Nitrate	-0 50	-0 16	-0 23	0 24	-0 04	-0 22	0 27	-0 03	-0 30	1 00			
Phosphate	0 87**	-0 09	0 40	-0 08	-0 35	-0 10	0 25	-0 17	-0 62*	0 00	1 00		
Phytoplankton	-0 96**	-0 05	-0 44	0 23	0 22	-0 09	0 02	0 09	0 21	0 72*	-0 70*	1 00	
Zooplankton	0 16	-0 18	0 07	0 14	-0 25	-0 23	0 37	-0 13	-0 62	0 78*	0 63	0 11	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

Table- 20: Interrelationship of different parameters during summer season in the Tapacia *beel*

	Temp	pH	O_2	CO_2	TDS	Alkalinity	Conductivity	DOM	Hardness	NO_3	PO_4	Phytoplankton	Zooplankton
Temp	1 00												
pH	0 11	1 00											
Oxygen	0 11	0 45	1 00										
Carbondioxide	0 18	-0 68*	-0 48	1 00									
TDS	-0 42	0 47	0 19	-0 56	1 00								
Alkalinity	-0 35	0 65	0 33	-0 35	0 62	1 00							
Conductivity	-0 04	-0 11	0 15	0 21	-0 41	-0 08	1 00						
DOM	-0 61	0 00	-0 07	-0 53	0 47	0 13	-0 21	1 00					
Hardness	0 39	0 20	0 59	-0 20	0 06	0 32	-0 15	0 05	1 00				
Nitrate	1 00**	0 11	0 11	0 18	-0 42	-0 35	-0 04	-0 61	0 39	1 00			
Phosphate	-1 00**	-0 11	-0 11	-0 18	0 42	0 35	0 04	0 61	-0 39	-1 00**	1 00		
Phytoplankton	0 77*	-0 19	-0 04	0 26	-0 55	-0 50	-0 17	-0 18	0 48	0 77*	-0 77*	1 00	
Zooplankton	-0 79*	-0 35	-0 21	-0 03	0 11	0 05	-0 10	0 76	-0 13	-0 79*	0 79*	-0 21	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

Table -21: Interrelationship of different parameters during summer season in all the *beels*

	Temp	pH	O_2	CO_2	TDS	Alka linity	Condu ctivity	DOM	Hard ness	NO_3	PO_4	Phyto plankton	Zoopla nkton
Temp	1 00												
pH	-0 16	1 00											
Oxygen	-0 96**	-0 15	1 00										
Carbondioxide	0 93**	-0 29	0 91**	1 00									
TDS	-0 40	0 60	-0 42	-0 48	1 00								
Alkalinity	0 60**	-0 26	0 60**	0 60**	-0 19	1 00							
Conductivity	0 07	0 11	-0 09	-0 06	0 46*	0 05	1 00						
DOM	0 50**	-0 29	0 64**	0 56**	-0 54**	0 42*	-0 70**	1 00					
Hardness	0 03	-0 04	0 13	0 06	-0 27	0 20	-0 52**	0 39*	1 00				
Nitrate	0 63**	0 03	0 50**	0 49**	0 15	0 37	0 77**	-0 23	-0 35	1 00			
Phosphate	0 37	-0 21	0 46*	0 38	-0 35	0 27	-0 35	0 51**	-0 05	-0 09	1 00		
Phytoplankton	0 96**	-0 16	0 89**	0 88**	-0 34	0 52**	0 22	0 37	0 03	0 74**	0 19	1 00	
Zooplankton	0 98**	-0 16	0 93**	0 90**	-0 35	0 59**	0 14	0 44*	-0 06	0 65**	0 39*	0 94**	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

4.3.1.2 Interrelationship of different parameters during monsoon season.

Unlike in the case of summer season, interrelationship between different parameters during the monsoon season were found to insignificant in most of the cases. During this season, significant correlations existed between PO_4 and phytoplakton and NO_3 with zooplankton in the Gaharibeel.(Table-22). Similar was the case with Jamugurinala and Tapacia *beel* (Table-23&24) where PO_4 maintained a positive significant correlation with phytoplankton . Insignificant correlation between parameters might be due to complete mixing of new flood water in the wetlands.

Correlation co-efficient were found to be significant in some cases when all the wetlands were brought together. Here temperature was found to inversely correlated with CO_2 at probability <0.01. Both zooplankton and phytoplanktons maintained a significant correlation with temperature and NO_3 (Table-25). Apart from this zooplankton also had a positive significant correlation with phytoplankton ($p<0.05$).

The interrelationship between PO_4 and zooplankton were found to be insignificant or negatively correlated as in the case of Jamugurinala. This could be explained from the general food chain point of view that exists in the aquatic body. The zooplankton utilize the phytoplankton for their growth but do not utilize inorganic nutrient directly from environment apart from nutrient obtained through saprophytic food chain.

Table 22: Interrelationship of different parameters during monsoon season in the Gahari *beel*

	Temp	pH	O_2	CO_2	TDS	Alkalinity	Conductivity	DOM	Hardness	NO_3	PO_4	Phytoplankton	Zooplankton
Temp	1 00												
pH	-0 24	1 00											
Oxygen	-0 53	0 65	1 00										
Carbondioxide	-0 54	-0 18	0 12	1 00									
TDS	-0 30	0 12	0 18	-0 20	1 00								
Alkalinity	0 34	-0 57	-0 59	-0 07	-0 07	1 00							
Conductivity	-0 26	0 41	0 76*	-0 02	-0 05	-0 06	1 00						
DOM	-0 48	0 28	0 64	0 46	0 11	-0 72*	0 30	1 00					
Hardness	-0 56	0 51	0 32	0 28	0 36	-0 59	-0 23	0 24	1 00				
Nitrate	0 43	-0 12	-0 18	-0 61	-0 22	-0 31	-0 31	-0 19	-0 11	1 00			
Phosphate	-0 32	0 06	0 29	-0 28	-0 03	0 24	0 49	-0 35	-0 12	0 11	1 00		
Phytoplankton	0 22	-0 03	-0 25	0 38	0 07	-0 17	-0 41	0 38	0 14	-0 30	98**	1 00	
Zooplankton	0 21	-0 08	-0 02	-0 64	-0 20	-0 15	-0 03	-0 32	-0 15	0 89**	0 55	-0 70*	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

Table 23: Interrelationship of different parameters during monsoon season in the Jamugurinala

	Temp	pH	O_2	CO_2	TDS	Alkalinity	Conductivity	DOM	Hardness	NO_3	PO_4	Phytoplankton	Zooplankton
Temp	1 00												
pH	-0 22	1 00											
Oxygen	-0 58	-0 23	1 00										
Carbondioxide	0 33	-0 04	0 38	1 00									
TDS	-0 05	0 29	0 31	0 66	1 00								
Alkalinity	-0 36	-0 57	0 66	-0 19	-0 39	1 00							
Conductivity	0 10	0 71*	-0 47	0 09	0 25	-0 78*	1 00						
DOM	-0 10	0 63	0 17	0 54	0 84**	-0 50	0 61	1 00					
Hardness	-0 49	-0 19	0 16	-0 67**	-0 51	0 56	-0 48	-0 65	1 00				
Nitrate	-0 50	0 22	-0 02	-0 65	-0 17	0 18	-0 35	-0 29	0 71*	1 00			
Phosphate	-0 98**	0 20	0 64	-0 21	0 09	0 36	-0 03	0 17	0 38	0 33	1 00		
Phytoplankton	-0 86**	0 13	0 68*	0 01	0 16	0 31	0 09	0 29	0 14	-0 01	0 94**	1 00	
Zooplankton	0 41	0 03	-0 57	-0 38	-0 23	-0 15	-0 27	-0 40	0 29	0 58	-0 58	-0 82**	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

Table 24: Interrelationship of different parameters during monsoon season in the Tapacia *beel*.

	Temp	pH	O_2	CO_2	TDS	Alka linity	Condu ctivity	DOM	Hard ness	NO_3	PO_4	Phyto plankton	Zoopla nkton
Temp	1 00												
pH	-0 08	1 00											
Oxygen	-0 31	-0 07	1 00										
Carbondioxide	-0 14	0 05	0 23	1 00									
TDS	0 05	-0 10	-0 08	0 34	1 00								
Alkalinity	0 12	-0 18	0 40	0 85**	0 55	1 00							
Conductivity	-0 05	0 15	0 49	0 62	0 02	0 58	1 00						
DOM	-0 03	0 23	0 45	0 16	0 59	0 47	0 07	1 00					
Hardness	-0 21	0 04	0 46	0 16	0 42	0 42	-0 12	0 88**	1 00				
Nitrate	0 50	0 33	-0 25	0 29	0 02	0 15	0 00	-0 06	-0 26	1 00			
Phosphate	-0 76*	-0 22	0 31	-0 16	-0 04	-0 16	0 02	0 05	0 27	-0 94**	1 00		
Phytoplankton	0 98**	-0 01	-0 33	-0 07	0 05	0 14	-0 04	-0 04	-0 23	0 64	0 86**	1 00	
Zooplankton	-0 15	0 43	-0 06	0 43	-0 02	0 08	0 04	-0 04	-0 14	0 78*	-0 53	0 03	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

Table 25: Interrelationship of different parameters during monsoon season in all the *beels*.

	Temp	pH	O_2	CO_2	TDS	Alk linity	Condu ctivity	DOM	Hard ness	NO_3	PO_4	Phyto plankton	Zoopla nkton
Temp	1 00												
pH	-0 40*	1 00											
Oxygen	-0 03	0 11	1 00										
Carbondioxide	-0 39*	0 10	-0 35	1 00									
TDS	0 20	0 00	0 52**	-0 46*	1 00								
Alkalinity	0 70**	-0 54**	0 16	-0 36	0 31	1 00							
Conductivity	-0 14	0 48*	0 15	0 25	-0 08	-0 24	1 00						
DOM	0 27	0 00	0 69**	-0 64**	0 79**	0 35	-0 06	1 00					
Hardness	-0 09	0 14	0 16	0 10	-0 01	-0 07	-0 25	-0 09	1 00				
Nitrate	0 69**	-0 22	-0 34	0 02	-0 27	0 34	-0 10	-0 32	0 15	1 00			
Phosphate	0 27	-0 13	0 20	-0 20	0 02	0 43*	0 12	0 00	0 14	0 43*	1 00		
Phytoplankton	0 92**	-0 34	0 11	-0 37	0 29	0 71**	-0 16	0 37	0 07	0 64**	0 39*	1 00	
Zooplankton	0 72**	-0 14	-0 06	-0 16	0 05	0 51**	-0 09	0 08	0 05	0 76**	0 28	0 69**	1 00

4.3.1.3 Interrelationship of different parameters during post- monsoon season

During post monsoon season it was observed that temperature had a negative significant relationship with O_2 (Table-26,27&28). Similar to other seasons NO_3 and PO_4 had positive significant relationship with the phytoplankton communities . NO_3 also showed positive significant correlation with zooplankton. A strong positive correlation between zooplankton and phytoplankton were observed (Table-:29) . This could be clearly assumed that the growth of phytoplankton enhanced the growth of zooplankton in this season which might have been influenced by congenial water temperature .In this season apart from water temperature, conductivity ,hardness ,alkalinity might have also helped in increasing phytoplankton communities .

When compared to other season temperature had a positive correlation with O_2. This might be due to the fact that abundant phytoplankton numbers and subsequent production of enormous O_2 might have surpassed the effect of water temperature on O_2 content as there was lowering of temperature in the season.

When comparison was made taking all three wetlands, it was observed that there were significant correlation between parameters unlike monsoon season. It might indicate that after flood period the water had been stabilized and intrinsic factor like soil might have influenced in determining the characteristics of water of the wetlands .

Contd.

Table 26: Interrelationship of different parameters during postmonsoon season in the Gahari *beel.*

Post monsoon GB	Temp	pH	O_2	CO_2	TDS	Alkal inity	Condu ctivity	DOM	Hard ness	NO_3	PO_4	Phyto plankton	Zoopla nkton
Temp	1 00												
pH	-0 44	1 00											
Oxygen	-0 74**	0 36	1 00										
Carbondioxide	0 33	-0 89**	-0 35	1 00									
TDS	0 31	0 60	-0 08	-0 65	1 00								
Alkalinity	-0 80**	0 72*	0 54	-0 74*	0 13	1 00							
Conductivity	0 50	-0 32	-0 66	0 37	0 17	-0 44	1 00						
DOM	-0 36	0 26	0 14	-0 11	-0 33	0 12	-0 38	1 00					
Hardness	-0 28	-0 23	0 47	0 22	-0 24	0 10	-0 51	-0 35	1 00				
Nitrate	0 25	-0 05	-0 47	0 15	0 09	-0 19	-0 08	0 06	0 17	1 00			
Phosphate	-0 47	-0 02	0 64	-0 13	-0 31	0 38	-0 35	-0 04	0 37	-0 76*	1 00		
Phytoplankton	0 36	-0 03	-0 57	0 15	0 19	-0 28	0 09	0 06	-0 04	0 96**	0 90**	1 00	
Zooplankton	0 01	-0 09	-0 21	0 12	-0 09	0 00	-0 37	0 05	0 51	0 88**	-0 35	0 72*	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

Table 27: Interrelationship of different parameters during post-monsoon season in the Jamugurinala

	Temp	pH	O_2	CO_2	TDS	Alkal ınity	Condu ctıvıty	DOM	Hard ness	NO_3	PO_4	Phyto plankton	Zoopla nkton
Temp	1 00												
pH	-0 41	1 00											
Oxygen	-0 30	-0 05	1 00										
Carbondıoxıde	0 18	-0 66	-0 36	1 00									
TDS	0 19	0 35	-0 03	-0 53	1 00								
Alkalınıty	0 04	-0 34	-0 25	0 54	-0 20	1 00							
Conductıvıty	-0 24	0 17	0 24	-0 29	-0 39	0 10	1 00						
DOM	-0 09	-0 37	0 44	-0 05	0 15	-0 44	-0 55	1 00					
Hardness	0 00	-0 21	-0 09	0 19	-0 54	-0 48	0 32	0 03	1 00				
Nıtrate	-0 87**	0 28	0 17	-0 22	-0 17	-0 19	0 37	0 07	0 31	1 00			
Phosphate	-1 00**	0 41	0 30	-0 18	-0 19	-0 04	0 24	0 09	0 00	0 87**	1 00		
Phytoplankton	0 58	-0 36	-0 32	0 00	0 09	-0 23	0 11	-0 05	0 51	-0 10	-0 58	1 00	
Zooplankton	0 74*	-0 40	-0 34	0 04	0 12	-0 18	0 03	-0 06	0 42	-0 30	-0 74*	0 98**	1 00

**Correlatıon ıs sıgnıficant at the 0 01 level (2-taıled)

*Correlatıon ıs sıgnıficant at the 0 05 level (2-taıled)

Table 28: Interrelationship of different parameters during postmonsoon season in the Tapacia *beel*

	Temp	pH	O_2	CO_2	TDS	Alkal inity	Condu ctivity	DOM	Hard ness	NO_3	PO_4	Phyto plankton	Zoopla nkton
Temp	1 00												
pH	-0 39	1 00											
Oxygen	-0 34	0 42	1 00										
Carbondioxide	-0 16	0 46	0 66	1 00									
TDS	-0 24	-0 33	0 20	0 45	1 00								
Alkalinity	0 54	-0 54	-0 41	-0 17	0 01	1 00							
Conductivity	0 07	-0 42	-0 76*	-0 36	0 23	0 43	1 00						
DOM	-0 12	0 55	0 64	0 81**(	0 19	0 10	-0 37	1 00					
Hardness	0 03	-0 08	-0 15	0 54	0 58	0 26	0 37	0 21	1 00				
Nitrate	-0 35	-0 11	0 35	-0 02	0 37	-0 41	-0 49	-0 12	-0 17	1 00			
Phosphate	-0 25	0 06	-0 32	-0 08	0 04	0 17	0 41	0 16	-0 07	-0 28	1 00		
Phytoplankton	-0 46	-0 01	-0 09	-0 09	0 27	-0 10	0 09	0 08	-0 18	0 36	0 80	1 00	
Zooplankton	0 10	0 10	-0 42	-0 03	-0 23	0 37	0 57	0 17	0 07	0 84**	0 75**	0 20	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

Table 29: Interrelationship of different parameters during postmonsoon season in all the *beels*

	Temp	pH	O_2	CO_2	TDS	Alkalinity	Conductivity	DOM	Hardness	NO_3	PO_4	Phytoplankton	Zooplankton
Temp	1 00												
pH	0 10	1 00											
Oxygen	*0 93***	*0 23*	*1 00*										
Carbondioxide	0 10	-0 16	0 04	1 00									
TDS	-0 32	0 32	-0 32	-0 02	1 00								
Alkalinity	0 67**	-0 22	0 60**	-0 33	0 01	1 00							
Conductivity	0 51**	-0 35	0 61**	-0 06	-0 06	0 36	1 00						
DOM	0 29	0 34	0 40**	0 24	-0 10	-0 22	-0 44	1 00					
Hardness	0 54**	-0 43*	0 53**	0 03	-0 28	0 45*	0 47*	-0 16	1 00				
Nitrate	0 30	-0 33	0 28	-0 15	0 80**	-0 02	0 09	0 12	0 36	1 00			
Phosphate	-0 01	-0 03	0 13	-0 18	-0 42*	0 12	0 15	0 13	0 21	0 38	1 00		
Phytoplankton	0 88**	0 17	0 90**	0 05	-0 25	0 61**	-0 51**	0 33	-0 54**	0 27	0 22	1 00	
Zooplankton	0 94**	0 11	0 93**	0 03	-0 45*	0 55**	-0 47*	0 35	-0 41*	0 43*	0 20	0 90**	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

4.3.1.4 Interrelationship of different parameters during winter season .

During winter season ,temperature had a positive significant correlation with phyto and zooplankton (Table- 33) at $p<0.05$ though there were variation among different wetlands (Table-30,31&32). Temperature had a negative impact on phytoplankton in Gaharibeel and Jamugurinala except in the case of Tapacia *beel* .This could be assumed that temperature along with shorter photoperiod accompanied by shading effect of macrophytes influenced the phytoplankton growth in these wetlands. This impact was probably might have overcome in the Tapacia *beel* which received enormous sunshine due to openness . Sufficient sunlight helped in production of phytoplankton in spite of lower temperature to some extent.

Similar to other seasons, in the winter season also zooplankton showed a positive significant correlation with phytoplankton .The hardness of water showed a negative significant correlation with PO4.

From the above discussion this could be assumed that limnological parameters showed temporal as well as spatial variations with regards to location of the wetlands and seasonal changes. Parameters were controlled by intrinsic factors like soil and degradation of macrophytes and extrinsic factor like in coming flood to the park.

Table 30: Interrelationship of different parameters during winter season in the Gahari *beel*.

	Temp	pH	O_2	CO_2	TDS	Alkalinity	Conductivity	DOM	Hardness	NO_3	PO_4	Phytoplankton	Zooplankton
Temp	1.00												
pH	0.18	1.00											
Oxygen	0.05	-0.77*	1.00										
Carbondioxide	-0.20	0.47	-0.37	1.00									
TDS	-0.10	-0.09	-0.20	-0.76*	1.00								
Alkalinity	0.28	-0.71*	0.32	-0.57	0.28	1.00							
Conductivity	-0.33	0.37	-0.68*	0.40	0.16	-0.24	1.00						
DOM	0.53	0.64	-0.44	0.23	-0.11	-0.39	0.02	1.00					
Hardness	-0.39	0.47	-0.36	0.93**	-0.66	-0.68*	0.52	0.09	1.00				
Nitrate	0.84**	0.12	-0.01	0.02	-0.16	0.23	0.07	0.53	-0.15	1.00			
Phosphate	-0.69*	-0.16	-0.10	0.39	-0.03	-0.20	0.69*	-0.27	0.51	-0.19	1.00		
Phytoplankton	-1.00**	-0.18	-0.05	0.19	0.10	-0.28	0.32	-0.54	0.39	-0.85**	0.68*	1.00	
Zooplankton	-0.26	0.00	0.08	-0.28	0.16	-0.06	-0.53	-0.28	-0.22	-0.74*	-0.52	0.27	1.00

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

Table 31: Interrelationship of different parameters during winter season in the Jamugurinala

	Temp	pH	O_2	CO_2	TDS	Alkalinity	Conductivity	DOM	Hardness	NO_3	PO_4	Phytoplankton	Zooplankton
Temp	1 00												
pH	-0 50	1 00											
Oxygen	0 12	-0 18	1 00										
Carbondioxide	-0 21	0 00	-0 24	1 00									
TDS	-0 14	0 30	-0 67	0 60	1 00								
Alkalinity	0 07	-0 36	-0 63	0 28	0 49	1 00							
Conductivity	0 34	0 29	0 05	0 56	0 42	-0 15	1 00						
DOM	0 53	-0 15	0 15	-0 18	0 03	-0 08	0 25	1 00					
Hardness	-0 05	-0 06	-0 09	-0 32	-0 06	0 15	-0 38	-0 69*	1 00				
Nitrate	-0 87**	0 58	-0 21	0 10	0 10	0 00	-0 25	-0 74*	0 33	1 00			
Phosphate	-0 94**	0 57	-0 18	0 14	0 12	-0 02	-0 30	-0 68*	0 24	0 98**	1 00		
Phytoplankton	-0 59	0 06	0 10	0 26	0 11	-0 14	-0 27	0 14	-0 44	0 11	0 30	1 00	
Zooplankton	0 70*	-0 14	-0 07	-0 27	-0 12	0 14	0 30	-0 03	0 38	-0 25	-0 42	-0 99**	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

Table 32: Interrelationship of different parameters during winter season in the Tapacia *beel*

	Temp	pH	O_2	CO_2	TDS	Alkal inity	Condu ctivity	DOM	Hard ness	NO_3	PO_4	Phyto plankton	Zoopla nkton
Temp	1 00												
pH	-0 07	1 00											
Oxygen	0 00	-0 33	1 00										
Carbondioxide	0 35	0 39	-0 79*	1 00									
TDS	0 11	0 54	-0 51	0 69*	1 00								
Alkalinity	-0 21	0 33	-0 15	0 49	0 61	1 00							
Conductivity	-0 11	-0 62	0 66	-0 45	-0 31	-0 02	1 00						
DOM	0 47	-0 13	-0 47	0 56	0 20	-0 18	-0 02	1 00					
Hardness	-0 49	0 04	-0 27	-0 13	-0 22	-0 28	-0 04	-0 13	1 00				
Nitrate	-0 80**	0 27	0 00	-0 16	-0 11	0 25	0 12	-0 22	0 23	1 00			
Phosphate	0 65	0 23	0 00	0 39	0 04	-0 04	-0 02	0 52	-0 53	-0 08	1 00		
Phytoplankton	0 76*	0 18	0 00	0 40	0 06	-0 07	-0 04	0 54	-0 55	-0 23	0 99**	1 00	
Zooplankton	-1 00**	0 06	0 00	-0 36	-0 11	0 21	0 10	-0 48	0 50	0 78*	-0 68*	-0 78*	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

Table 33: Interrelationship of different parameters during winter season in all the *beels*

	Temp	pH	O_2	CO_2	TDS	Alka linity	Condu ctivity	DOM	Hard ness	NO_3	PO_4	*Phyto plankton*	*Zoopla nkton*
Temp	1 00												
pH	0 60**	1 00											
Oxygen	0 89**	0 45*	1 00										
Carbondioxide	-0 04	0 16	-0 11	1 00									
TDS	0 57**	0 47*	0 56**	0 00	1 00								
Alkalinity	0 38	0 09	0 40*	-0 10	0 59**	1 00							
Conductivity	-0 26	-0 20	-0 19	0 36	0 09	-0 14	1 00						
DOM	-0 16	-0 10	-0 35	0 02	-0 17	-0 29	0 20	1 00					
Hardness	-0 81**	-0 45*	-0 73**	0 16	-0 57**	-0 44*	0 29	0 13	1 00				
Nitrate	0 07	-0 08	0 30	-0 10	0 31	0 26	0 32	-0 04	0 14	1 00			
Phosphate	0 31	0 41*	0 15	0 18	0 07	-0 04	-0 27	-0 17	-0 39*	-0 47*	1 00		
Phytoplankton	0 84**	0 58**	0 86**	0 06	0 60**	0 29	-0 19	-0 29	-0 73**	0 09	0 49**	1 00	
Zooplankton	0 75**	0 54**	0 80**	-0 13	0 52**	0 35	-0 27	-0 38*	-0 64**	0 03	0 08	0 73**	1 00

**Correlation is significant at the 0 01 level (2-tailed)
*Correlation is significant at the 0 05 level (2-tailed)

4.3.2 Dependency of zooplankton on the phytoplankton

The dependency of zooplankton on phytoplankton was analysed applying regression equation. It was found that dependency of zooplankton on the phytoplankton very high. The regression co-efficient was as high as (R^2) 0.79. It was also obvious from the plankton numbers in different seasons. The peak of phytoplankton was followed by peak of zooplankton. During summer season and post monsoon seasons abundant growth of phytoplankton were observed and in the same period comparatively higher nos. of zooplankton was also recorded specially in the case of Tapacia and Gahari *beel*. It is probably due to fact that greater density of phytoplankton provided enormous amount of food for zooplankton for their growth and reproduction. Apart from this ,congenial water temperature might have helped them for the above purpose. Dependency of zooplankton was found to maximum in Gaharibeel followed by Tapacia and Jamugurinala (fig.28.29&30).

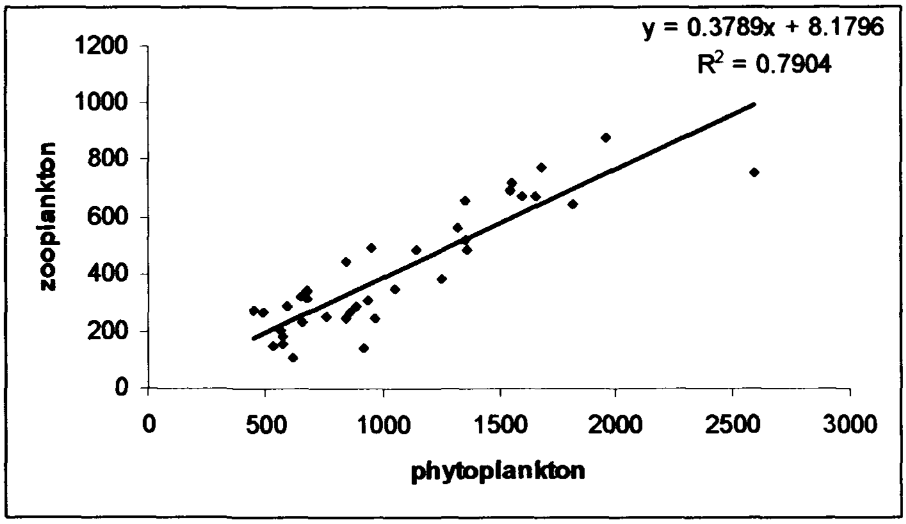

Figure- 27: Dependency of zooplankton on the phytoplankton

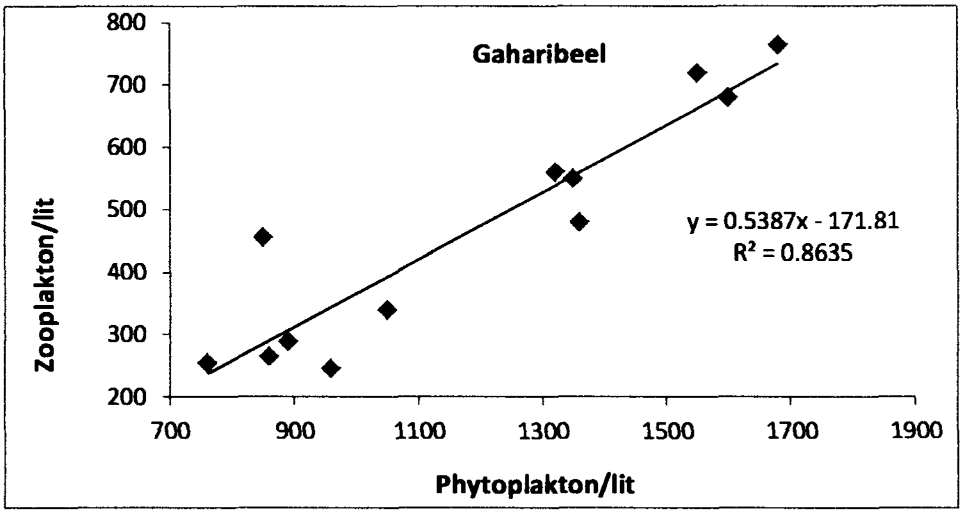

Figure-28: Dependency of zooplankton on the phytoplankton in Gaharibeel

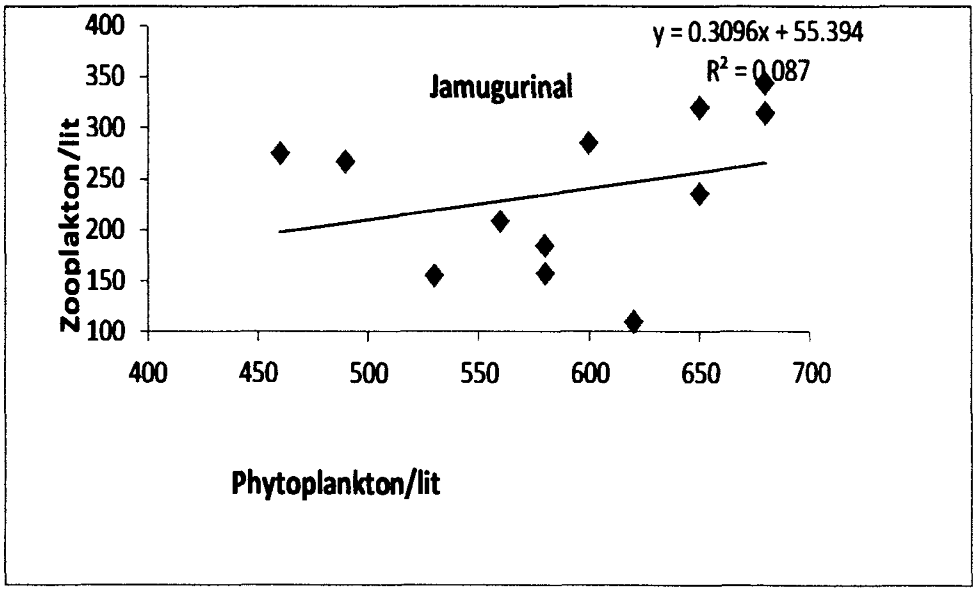

Figure-29: Dependency of zooplankton on the phytoplankton in Jamugurinala

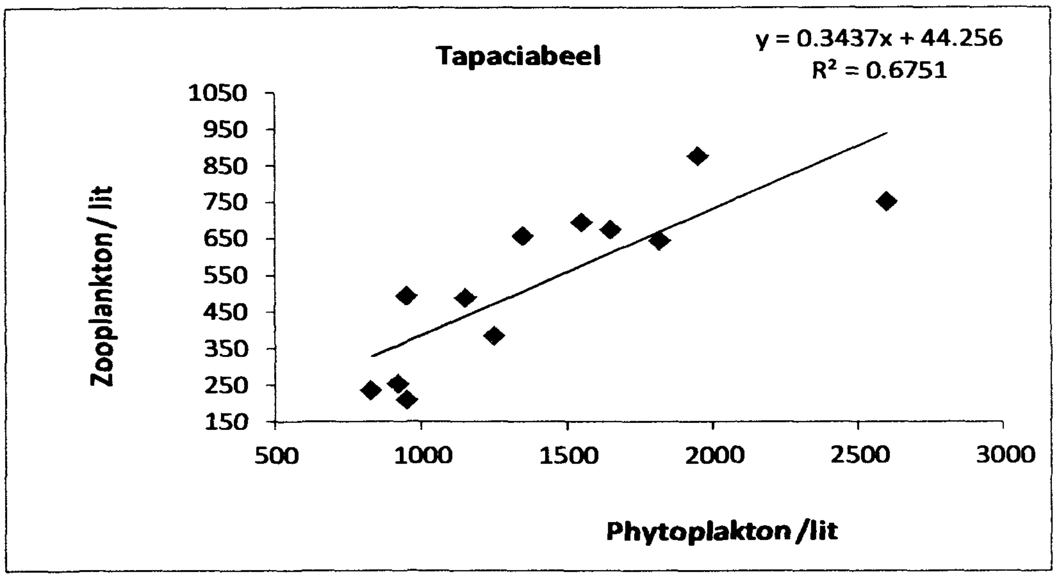

Figure-30: Dependency of zooplankton on the phytoplankton in Tapaciabeel

4.3.3 Principal component analysis:

By extracting the correlation matrix , the no. of significant factors and % of variance were calculated. Eigenvalues of greater than 1.0 were selected for further analysis. Eigenvalues ,thus extracted, were cleaned up by means of varimax rotation. The PCA, in most of the operations, was explained by four factors. The rotated matrices are shown in Table- 33 to Table-37. During summer season, principal guiding factors were temperature, NO_3, PO_4 phytoplankton and zooplankton in the case of Gahari and Tapacia *beel* (Table 33A,&33B). These parameters appeared in the factor 1 (explained about 35% of the total variance) with high significant loadings. Whereas, in the case of Jamuguri nala (Table 33C) ,major guiding factors were pH ,O_2 ,CO_2 NO_3, PO_4 , TDS, alkalinity and conductivity, that appeared in the factor 1 (explained about 31% of the total variance in Table-33 C).

However, when the PCA was operated with the complete data set, taking all the 3 beels together, the parameters temperature, NO_3, PO_4, phytoplankton and zooplankton appeared in the factor 1 with high loading (explained about 45% of the total variance). This could be, therefore, assumed that during this period the higher productivity were supported by the parameters like temperature, NO_3 and PO_4 (Table-33D).

In the case of monsoon season, when plankton production went down, the planktons appear in the factor 2 (22% variance explained) and 3 (18% of variance explained) in case of GB and TB respectively, though O_2 and temperature remained in the factor 1 itself. In case of JN, however, the zooplankton and phytoplankton grouped with O_2, temperature, which appeared in the factor 1 (31% variance explained). This could be inferred that JN being a moving water body the limnological characteristics were different from the rest two (34A, 34B &34C).

During post monsoon season, like summer season, primary guiding factors were PO_4, phytoplankton, zooplankton and O_2. But unlike summer, temperature had lesser role in determining the characteristics of water of the wetlands under study. When compared to this season ,in the winter season, temperature played a significant role where it occupied a place in primary guiding factors (Table-35A,35B 35C&35D). The winter season showed a similar trend like summer where temperature, NO_3, PO_4, phytoplankton and zooplankton in the case of Gahari *beel* and Tapacia *beel* but they were different in Jamuguri nala where primary guiding factors were found to be temperature ,DOM, $NO_3$and PO_4 (36A,37B, 36C&37D).When comparison was made season wise in the same wetland, major guiding factors were almost similar in determining water characteristics except during post monsoon season. In summer, ,monsoon and winter season guiding factors were temperature, O_2, NO_3, PO_4, phytoplankton and zooplankton whereas during post monsoon season NO_3 and PO_4, shifted to the place of secondary factors. This might be due to the complete change of physicochemical properties of water after the flood in the park.

Table -34: principal component analysis of different parameters in the summer season

A

Elements analysed	Varimax rotated principal component loadings			
	F1	F2	F3	F4
Temp	-0 89	-0 09	-0 44	-0 06
pH	-0 40	-0 60	0 18	0 64
Oxygen	0 57	0 47	-0 06	0 49
Carbondioxide	0 22	-0 07	-0 25	0 83
TDS	0 28	0 32	0 53	0 16
Alkalinity	-0 06	0 90	0 22	-0 04
Conductivity	0 08	-0 33	-0 34	-0 76
DOM	0 25	0 93	-0 04	0 15
Hardness	-0 11	0 06	-0 84	0 47
Nitrate	0 34	0 02	0 90	0 18
Phosphate	0 89	0 09	0 44	0 06
Phytoplankton	0 98	0 10	0 13	0 00
Zooplankton	-0 99	-0 11	-0 04	0 02
Eigen values	4 33	2 51	2 46	2 23
Percent of variance	33 32	19 29	18 96	17 12
Cumulative frequency	33 32	52 61	71 57	88 69

C

Elements analysed	Varimax rotated principal component loadings			
	F1	F2	F3	F4
Temp	0 01	-0 99	0 07	0 03
pH	-0 85	0 03	-0 08	0 44
Oxygen	-0 58	-0 53	0 14	-0 26
Carbondioxide	0 87	0 20	0 05	0 28
TDS	-0 71	0 30	-0 13	0 62
Alkalinity	0 87	-0 06	-0 39	0 04
Conductivity	0 88	-0 03	0 24	0 12
DOM	-0 18	0 12	-0 08	-0 92
Hardness	0 37	0 36	-0 73	-0 05
Nitrate	0 13	0 56	0 81	-0 01
Phosphate	0 09	-0 82	0 54	0 03
Phytoplankton	0 03	0 97	0 20	-0 03
Zooplankton	0 15	-0 08	0 97	0 01
Eigen values	4 06	3 48	2 73	1 59
Percent of variance	31 26	26 76	21 02	12 25
Cumulative frequency	31 26	58 03	79 05	91 29

B

Elements analysed	Varimax rotated principal component loadings			
	F1	F2	F3	F4
Temp	-0 93	-0 20	0 29	-0 10
pH	-0 25	0 86	0 12	-0 05
Oxygen	-0 09	0 51	0 65	0 36
Carbondioxide	-0 19	-0 70	-0 31	0 23
TDS	0 31	0 76	-0 10	-0 38
Alkalinity	0 20	0 80	0 06	0 10
Conductivity	0 02	-0 14	0 00	0 90
DOM	0 79	0 11	0 25	-0 40
Hardness	-0 18	0 17	0 88	-0 07
Nitrate	-0 93	-0 20	0 29	-0 10
Phosphate	0 93	0 20	-0 29	0 10
Phytoplankton	-0 50	-0 56	0 55	-0 30
Zooplankton	0 93	-0 23	0 08	-0 14
Eigen values	4 59	3 26	1 95	1 45
Percent of variance	35 30	25 09	14 98	11 18
Cumulative frequency	35 30	60 39	75 36	86 54

Extraction Method Principal Component Analysis
Rotation Method Varimax with Kaiser Normalization

D

Elements analysed	Varimax rotated principal component loadings		
	F1	F2	F3
Temp	0 98	0 01	-0 16
pH	-0 05	0 09	0 89
Oxygen	0 95	0 18	-0 16
Carbondioxide	0 90	0 08	-0 29
TDS	-0 26	-0 32	0 77
Alkalinity	0 67	0 11	-0 12
Conductivity	0 15	-0 91	0 29
DOM	0 46	0 71	-0 37
Hardness	0 06	0 75	0 11
Nitrate	0 69	-0 66	0 19
Phosphate	0 30	0 28	-0 47
Phytoplankton	0 95	-0 12	-0 09
Zooplankton	0 96	-0 07	-0 16
Eigen values	5 82	2 59	2 05
Percent of variance	44 77	19 93	15 74
Cumulative frequency	44 77	64 69	80 43

Extraction Method Principal Component Analysis
Rotation Method Varimax with Kaiser Normalization

Table-35: principal component analysis of different parameters in the summer season

A

Elements analysed	Varimax rotated principal component loadings				
	F1	F2	F3	F4	F5
Temp	-0 28	-0 31	0 26	-0 81	-0 22
pH	0 77	-0 01	0 05	-0 03	0 39
Oxygen	0 91	0 25	-0 09	0 24	0 07
Carbondioxide	-0 04	-0 25	-0 52	0 74	-0 32
TDS	0 06	0 00	-0 18	0 01	0 85
Alkalinity	-0 68	0 32	-0 49	-0 42	-0 11
Conductivity	0 72	0 49	-0 36	-0 17	-0 22
DOM	0 68	-0 38	-0 10	0 45	-0 16
Hardness	0 20	-0 16	0 15	0 64	0 61
Nitrate	-0 08	0 06	0 96	-0 18	-0 13
Phosphate	0 06	0 99	0 07	0 01	0 00
Phytoplankton	-0 04	-0 97	-0 25	0 02	0 03
Zooplankton	-0 04	0 50	0 84	-0 15	-0 11
Eigen values	3 00	2 92	2 48	2 14	1 50
Percent of variance	23 04	22 44	19 06	16 45	11 57
Cumulative frequency	23 04	45 48	64 54	80 99	92 56

C

Elements analysed	Varimax rotated principal component loadings			
	F1	F2	F3	F4
Temp	-0 92	0 01	0 04	-0 38
pH	0 17	0 83	0 22	0 28
Oxygen	0 68	-0 58	0 42	-0 05
Carbondioxide	-0 10	-0 12	0 77	-0 54
TDS	0 10	0 20	0 93	-0 03
Alkalinity	0 37	-0 83	-0 23	0 09
Conductivity	0 05	0 93	0 04	-0 31
DOM	0 23	0 55	0 75	-0 18
Hardness	0 27	-0 36	-0 51	0 63
Nitrate	0 13	-0 03	-0 16	0 97
Phosphate	0 97	0 00	-0 01	0 20
Phytoplankton	0 99	0 01	0 05	-0 14
Zooplankton	-0 73	-0 02	-0 13	0 67
Eigen values	4 09	3 07	2 63	2 50
Percent of variance	31 47	23 64	20 21	19 20
Cumulative frequency	31 47	55 11	75 32	94 53

B

Elements analysed	Varimax rotated principal component loadings				
	F1	F2	F3	F4	F5
Temp	0 99	-0 03	-0 14	-0 06	-0 01
pH	-0 02	0 26	0 72	-0 01	-0 38
Oxygen	-0 25	0 46	-0 12	0 67	-0 27
Carbondioxide	-0 07	0 00	0 34	0 70	0 58
TDS	0 06	0 45	-0 04	-0 05	0 79
Alkalinity	0 17	0 31	-0 02	0 70	0 60
Conductivity	-0 01	-0 07	0 03	0 93	-0 02
DOM	0 02	0 97	0 06	0 11	0 17
Hardness	-0 19	0 91	-0 08	0 04	0 18
Nitrate	0 62	-0 14	0 73	0 03	0 14
Phosphate	-0 84	0 12	-0 50	0 00	-0 10
Phytoplankton	1 00	-0 05	0 03	-0 04	0 02
Zooplankton	0 00	-0 14	0 94	0 07	0 16
Eigen values	3 20	2 40	2 34	2 32	1 66
Percent of variance	24 63	18 47	18 01	17 83	12 78
Cumulative frequency	24 63	43 10	61 11	78 94	91 72

Extraction Method Principal Component Analysis

Rotation Method Varimax with Kaiser Normalization

D

Elements analysed	Varimax rotated principal component loadings			
	F1	F2	F3	F4
Temp	0 87	0 18	-0 24	-0 20
pH	-0 27	0 02	0 75	0 20
Oxygen	-0 04	0 79	0 26	0 25
Carbondioxide	-0 23	-0 68	0 20	0 09
TDS	0 03	0 85	-0 05	-0 02
Alkalinity	0 67	0 35	-0 36	-0 13
Conductivity	0 01	-0 05	0 89	-0 27
DOM	0 06	0 95	-0 03	-0 10
Hardness	0 04	-0 02	-0 06	0 95
Nitrate	0 86	-0 39	-0 06	0 13
Phosphate	0 58	0 09	0 22	0 27
Phytoplankton	0 87	0 29	-0 19	-0 01
Zooplankton	0 85	-0 02	-0 04	0 01
Eigen values	3 91	3 10	1 76	1 26
Percent of variance	30 06	23 87	13 52	9 65
Cumulative frequency	30 06	53 93	67 45	77 11

Extraction Method Principal Component Analysis

Rotation Method Varimax with Kaiser Normalization

Table-36: principal component analysis of different parameters in the post-monsoon season

A

Elements analysed	Varimax rotated principal component loadings			
	F1	F2	F3	F4
Temp	0 23	-0 76	-0 22	0 36
pH	0 00	0 19	0 93	-0 21
Oxygen	-0 42	0 78	0 21	-0 01
Carbondioxide	0 09	-0 19	-0 95	0 06
TDS	0 12	-0 34	0 79	0 41
Alkalinity	-0 16	0 58	0 65	-0 14
Conductivity	-0 15	-0 83	-0 15	0 18
DOM	0 08	0 15	0 03	-0 94
Hardness	0 19	0 76	-0 31	0 52
Nitrate	1 00	-0 05	-0 04	0 01
Phosphate	-0 74	0 57	-0 10	0 11
Phytoplankton	0 95	-0 27	0 01	-0 04
Zooplankton	0 89	0 35	-0 13	0 09
Eigen values	3 57	3 53	3 06	1 58
Percent of variance	27 50	27 16	23 53	12 16
Cumulative frequency	27 50	54 66	78 18	90 34

C

Elements analysed	Varimax rotated principal component loadings				
	F1	F2	F3	F4	
Temp	-0 97	0 14	0 05	-0 05	-0 11
pH	0 42	-0 17	-0 78	0 23	-0 21
Oxygen	0 17	-0 11	-0 08	-0 01	0 95
Carbondioxide	-0 10	-0 08	0 89	-0 16	-0 34
TDS	-0 28	-0 20	-0 77	-0 34	-0 10
Alkalinity	-0 14	-0 62	0 52	0 32	-0 27
Conductivity	0 20	0 22	0 00	0 91	0 26
DOM	0 08	0 16	0 05	-0 83	0 50
Hardness	0 17	0 88	0 30	0 12	0 00
Nitrate	0 87	0 31	-0 07	0 11	0 03
Phosphate	0 97	-0 14	-0 05	0 05	0 11
Phytoplankton	-0 52	0 77	-0 02	0 08	-0 17
Zooplankton	-0 68	0 67	-0 01	0 05	-0 17
Eigen values	3 76	2 50	2 37	1 84	1 55
Percent of variance	28 95	19 24	18 21	14 19	11 90
Cumulative frequency	28 95	48 18	66 39	80 58	92 47

B

Elements analysed	Varimax rotated principal component loadings				
	F1	F2	F3	F4	F5
Temp	-0 08	0 16	-0 42	-0 16	0 76
pH	0 56	0 28	-0 08	-0 25	-0 66
Oxygen	0 79	-0 44	-0 09	-0 07	-0 24
Carbondioxide	0 84	0 03	-0 10	0 47	-0 15
TDS	0 11	-0 37	0 26	0 85	0 05
Alkalinity	-0 06	0 31	0 07	0 15	0 87
Conductivity	-0 61	0 54	0 19	0 46	0 15
DOM	0 95	0 16	0 15	0 12	0 05
Hardness	0 10	0 21	-0 19	0 90	0 06
Nitrate	-0 01	-0 94	0 19	0 03	-0 18
Phosphate	-0 03	0 47	0 87	-0 01	-0 01
Phytoplankton	-0 03	-0 13	0 97	0 01	-0 12
Zooplankton	-0 01	0 91	0 36	-0 03	0 12
Eigen values	2 97	2 83	2 23	2 09	1 94
Percent of variance	22 81	21 80	17 16	16 07	14 96
Cumulative frequency	22 81	44 62	61 77	77 85	92 81

Extraction Method Principal Component Analysis

Rotation Method Varimax with Kaiser Normalization

D

Elements analysed	Varimax rotated principal component loadings			
	F1	F2	F3	F4
Temp	0 97	0 14	0 02	0 07
pH	0 17	-0 39	0 68	-0 32
Oxygen	0 92	0 18	0 23	-0 02
Carbondioxide	0 05	-0 07	0 08	0 93
TDS	-0 21	-0 86	0 11	-0 08
Alkalinity	-0 73	0 16	-0 04	-0 33
Conductivity	-0 57	0 19	-0 47	-0 05
DOM	0 21	0 18	0 83	0 29
Hardness	-0 67	0 52	-0 16	0 18
Nitrate	0 19	0 88	-0 13	-0 03
Phosphate	-0 05	0 66	0 27	-0 31
Phytoplankton	0 91	0 18	0 17	-0 05
Zooplankton	0 90	0 35	0 12	-0 01
Eigen values	4 87	2 68	1 60	1 31
Percent of variance	37 45	20 61	12 32	10 06
Cumulative frequency	37 45	58 06	70 38	80 44

Extraction Method Principal Component Analysis

Rotation Method Varimax with Kaiser Normalization

Table-37: principal component analysis of different parameters in the winter season

A

GB

Elements analysed	Varimax rotated principal component loadings			
	F1	F2	F3	F4
Temp	0 96	0 02	-0 10	-0 23
pH	0 16	0 94	0 24	-0 06
Oxygen	0 03	-0 88	0 08	-0 29
Carbondioxide	-0 06	0 32	0 87	0 27
TDS	-0 18	0 18	-0 95	0 09
Alkalinity	0 24	-0 63	-0 54	0 07
Conductivity	-0 19	0 46	0 01	0 83
DOM	0 61	0 61	0 14	-0 06
Hardness	-0 27	0 34	0 82	0 32
Nitrate	0 95	-0 03	0 02	0 30
Phosphate	-0 47	-0 08	0 22	0 82
Phytoplankton	-0 96	-0 02	0 10	0 22
Zooplankton	-0 50	0 09	-0 17	-0 83
Eigen values	3 82	2 90	2 81	2 52
Percent of variance	29 39	22 32	21 59	19 42
Cumulative frequency	29 39	51 71	73 30	92 71

C

Elements analysed	Varimax rotated principal component loadings			
Temp	-0 83	0 54	-0 05	0 03
pH	0 62	-0 04	-0 13	0 62
Oxygen	-0 18	-0 10	-0 81	-0 01
Carbondioxide	0 04	-0 30	0 58	0 49
TDS	0 08	-0 10	0 80	0 44
Alkalinity	-0 10	0 11	0 87	-0 32
Conductivity	-0 25	0 20	0 10	0 91
DOM	-0 80	-0 26	-0 13	0 22
Hardness	0 45	0 60	0 05	-0 47
Nitrate	0 97	-0 06	0 07	0 00
Phosphate	0 95	-0 25	0 06	-0 01
Phytoplankton	0 09	-0 98	-0 01	-0 06
Zooplankton	-0 22	0 96	0 00	0 06
Eigen values	3 95	2 83	2 45	2 03
Percent of variance	30 38	21 74	18 85	15 60
Cumulative frequency	30 38	52 11	70 97	86 57

B

Elements analysed	Varimax rotated principal component loadings				
Temp	0 60	-0 79	0 13	-0 04	0 02
pH	0 19	0 26	-0 01	0 29	0 85
Oxygen	0 16	0 00	-0 84	-0 15	-0 46
Carbondioxide	0 25	-0 15	0 72	0 52	0 31
TDS	-0 02	-0 13	0 33	0 79	0 32
Alkalinity	-0 02	0 23	-0 02	0 93	0 03
Conductivity	0 07	0 17	-0 23	-0 01	-0 90
DOM	0 44	-0 16	0 81	-0 08	-0 20
Hardness	-0 61	0 30	0 29	-0 45	0 14
Nitrate	-0 01	0 99	-0 05	0 04	0 03
Phosphate	0 98	-0 06	0 14	-0 01	0 07
Phytoplankton	0 96	-0 21	0 15	-0 02	0 06
Zooplankton	-0 62	0 77	-0 13	0 04	-0 02
Eigen values	3 32	2 53	2 19	2 07	2 00
Percent of variance	25 52	19 47	16 82	15 93	15 39
Cumulative frequency	25 52	44 99	61 81	77 74	93 13

Extraction Method Principal Component Analysis

Rotation Method Varimax with Kaiser Normalization

D

Elements analysed	Varimax rotated principal component loadings			
Temp	0 94	-0 06	-0 10	0 04
pH	0 69	-0 31	0 20	-0 05
Oxygen	0 88	0 15	-0 12	0 23
Carbondioxide	-0 01	-0 19	0 88	0 04
TDS	0 74	0 34	0 15	0 15
Alkalinity	0 41	0 36	-0 14	0 48
Conductivity	-0 16	0 47	0 68	-0 21
DOM	-0 12	0 09	0 01	-0 94
Hardness	-0 84	0 16	0 23	-0 02
Nitrate	0 13	0 84	0 10	0 08
Phosphate	0 32	-0 77	0 17	0 11
Phytoplankton	0 90	-0 14	0 07	0 17
Zooplankton	0 79	0 01	-0 18	0 26
Eigen values	5 16	1 98	1 47	1 35
Percent of variance	39 72	15 22	11 31	10 39
Cumulative frequency	39 72	54 95	66 26	76 64

Extraction Method Principal Component Analysis

Rotation Method Varimax with Kaiser Normalization

4.4 Parameters related to threat to the wetlands

After a detailed study of different parameters, the following parameters were found to have a threat potential for the ecological degradation of the wetlands of Kaziranga . High rate of siltation not only reduce the depth of the water body but also it becomes detrimental to seed germination and ultimately affect the biodiversity. Apart from this, unrestricted use of chemicals in the form of herbicides and pesticides might create a serious threat to the wildlife of the sanctuary in the years to come.

4.4.1 Determination of rate of siltation in wetlands.

Experiments on rate of siltation in different wetlands over the year were carried out .The highest siltation rate was recorded in Tapacia wetland where mean value was 4.16±0.34 cm /year. The lowest siltation was recorded in the gahari *beel* wetland (2.2cm/year) with average 2.38±0.29 cm/year. The variation observed might be due to topographical location of wetlands (Table-38). Goswami *et al.*(1999) studied rate of siltation in upper, central, lower and southern Assam wetlands. They recorded maximum siltation in Dhaka *beel* of lower Assam while minimum was0.09cm /year in Sialekhiti wetland of central Assam. The rate of allochthonous siltation was more in these wetlands.When comparison was made in four different zones of Assam, it was noticed that siltation was more evident in the wetlands of southern Assam with variation 0.37 to 0.93 cm/year followed by lower Assam . The maximum depth of sedimentation recorded in the present study was 4.16cm/year which was less than recorded values earlier in central Assam wetlands. The results were more similar to upper Assam wetlands (0.28cm/year). The intensity of deposition was more in Tapacia wetland compared to other wetlands. This might be due to the fact that flood water rested over the Tapacia wetland because of obstruction from existing National Highway 37.This higher rate of siltation could be related to low growth of submerged vegetation as observed in Tapacia *beel*. Sedimentation might have reduced the establishment of many species. Several species cannot germinate in the darkand low oxygen environment created by sediment layers (Bewly & Black1994; Baskin & Baskin1998). This increased rate of sedimentation might have resulted from the agricultural practices conducted in the Nation Park as it disturbed the soil surface and caused erosion of soil as stated by Adamus & Brandt(1990) and Cole *et a*l. (1997).

Table-38: Rate of sedimentation (cm/year) in different wetlands

Parameters	Gahari *beel*					Jamuguri nala						Tapacia *beel*					
Period of estimation (in month)	12					12						12					
Nos of plates installed	9					9						9					
Nos of plates recovered	4					5						5					
Height of the sediment(in cm)	P-1	P-2	P-3	P-4	Mean ±sd	P-1	P-2	P-3	P-4	P-5	Mean ±sd	P-1	P-2	P-3	P-4	P-5	Mean ±sd
	2.2	2.2	2.8	2.3	2.38 0.29	2.4	2.3	3.0	2.5	2.6	2.56 .27	4.2	3.6	4.3	4.2	4.5	4.16 0.34

4.4.2 Chemical contamination of streamlets water

Analysis of streams entering Kaziranga National Park was conducted employing thin layer chromatography. A survey was conducted in the neighbouring tea gardens of KNP on their method of controlling weeds and pests. Out of four surveyed tea gardens, three of them were employing chemical methods for controlling weeds and pests. Only one tea garden was employing organic method of tea husbandry and electric machine for cutting weeds and grasses .Though presence of chemical contamination in streams flowing through KNP, the world's most protected sanctuary, was remote possibility, the results of analysis of water chromatographically found paradoxical. For analysis, samples were collected during monsoon and post monsoon season. Because during monsoon season normally chemicals are used to control the pests and weeds and chemicals might have gained entry to the streams along with monsoon rain . But during post monsoon season there might be some residues in the water.

In the present investigation, concentrated water samples of post monsoon season were analysed at Forensic Laboratory, Guwahati, Assam. Two of the wetlands were found to be organochlorine positive and another two wetlands were found to be organophosphate positive. Stream I and Stream III were organochlorine +ve and stream II and Stream IV were found to be organophosphate +ve against the standard used. Carbamite insecticides were found negative in all the samples. Remaining other three streams were found to be free from these chemical contaminations.

During the monsoon season, apart from using BHC and Rogar for organochlorine and organophosphate as standards, endosulfan was also used. In thin layer chromatography dark spots appeared along with standard endosulfan and BHC . This indicated the presence of organochlorine pesticides. The RF value of organochlorine was similar with endosulfan . Therefore it could be mentioned that these streams i.e. I, II , III and IV were infected with endosulfan insecticides . Studies on the chemical contamination of water of the streams of KNP probably have been done for the first time in the present investigation. There was no such contamination earlier reported. It was clear that the wetlands flowing through the organically cultivated tea gardens nearby KNP did not contain any chemical contamination in their water. The chemical used for controlling pests and weeds might have gained entry to the stream water. The absence of these chemical in the *beels* were noticed in the present study. None of the *beels* showed presence of any such chemical contamination in any season of the year .It might be due to the fact that amount in the water beyond detectable range or organic peat of the sediment might have blocked the chemicals as mentioned by USGS (1999).

Chapter-V

Summary

The study on the *beels* of Kaziranga Natioal Park (KNP) were carried out to know the present ecological conditions, health and productivity of the water. *Beels* are natural wetlands playing a significant role in socio-economic aspects of Assamese people. Though there is no such satisfactory general definition of *beels* exists, normally abandoned river beds with or without connection to the main stream are called *beels*. These *beels* habour a wide number of commercially and biologically important fish species along with other aquatic flora and fauna. These *beels* are highly dynamic and self fertilizing ecosystems having tremendous potentialities for fish production. The major part of the KNP has also been comprised of these *beels* which are breeding and feeding ground for many aquatic vertebrates e.g. fishes and shell fishes. Thes *beels* also serve as feeding ground of many terrestrial animals like world famous one-horned rhinoceros, bisons etc.. Therefore, it is important to study the *beels* (wetlands) of KNP in relation to their physicochemical and biological characteristics which may govern the health of the wild and aquatic life of the park. Though, considerable works are reported on the studies of different types of wetlands of Assam, but, little studies are reported on the *beels* of KNP.

Three *beel*s viz. Gahari *beel*, Jamuguri nala and Tapacia *beel* of KNP along with 7 streamlets flowing from nearby tea gardens to the *beels* of KNP ranging from Amguri to Kohora locality of the park covering a distance of 35 Km were selected for the present investigation. Altogether four samplings were carried out at different seasons in 2008-2009. The seasons were Monsoon (June-July), Autumn (Sep.-Oct.), Winter (Dec-Jan) and Summer (April-May). Limnological parameters such as dissolved oxygen(DO), pH, alkalinity, conductivity, total dissolved solids, plankton diversity etc. have been ascertained to know the health of the water body. Besides, parameters which could create threat to park such as siltation and chemical contamination of stream water were also analysed.

Oxygen content of Jamuguri nala contained less value than the other study areas. Tapacia *beel* contained good range of dissolved oxygen through out the year. The summer season could be attributed to shading of the wetland by macro vegetation specially *Eicchornia spp.*.This might be also result of narrow width of the channel. Temperature of water showed no location variation which was mainly controlled by seasonal variation of temperature. The range of temperature varied from 19.43^{O}c in the winter to 32.17 ^{O}c in the monsoon season. Overall pH of water of the wetlands was found to be acidic in nature and slightly below the optimum level of primary production. The maximum mean pH value recorded was 6.38 in the Tapacia *beel* during winter season and the minimum mean pH value was observed (6.11) in the Gahari *beel* during post monsoon season. Gahari *beel* showed maximum electrical conductivity indicating ionic inflow from adjacent hills. The highest mean value recorded in this wetland was 172±3µS/cm in the summer season and lowest mean value recorded was 94.67±4.44µS/cm in the monsoon season. Seasonal variation of conductivity was probably affected by temperature, total dissolved solids and flood water entering the park. The range of total alkalinity (73.45±2.36 to 53.75±2.14 ppm) found to be similar with the other *beels* of Assam. The maximum values of TDS recorded in the summer season in the Gahari *beel* was 54.33±0.87 ppm. Accordingly mean highest values of Jamuguri nala and Tapacia *beel* were 52.68±3.09 and 49.34±2.58 ppm. The lowest values were noticed during the monsoon seaso in all the wetlands under investigation. Variation of dissolved organic matter could be related to death and decay of the macrophytes. Concentration of CO_2 varied from 5.62±0.13 ppm to 2.68±0.16 ppm. Maximum conc. was observed during monsoon season which could be related to cloudiness of sky and under utilization by phytoplankton. PO_4 conc. was found to be lower than optimum(<0.2ppm) in all the wetlands which could be the result of acidic bottom sediment. NO_3 conc. was found to optimum in all wetlands under study. The lowest hardness values were recorded in the summer season and the highest values were recorded the winter season of the year. The range of hardness were 27.41±0.5 ppm to 34.64±1.0 ppm, 28.67±0.16 to 35.67±0.29 ppm and 28.5±0.5 to 28.83±1.04 ppm in Gahari *beel,* Jamuguri nala and Tapacia *beel* respectively.

Plankton community structure showed the phytoplankton dominance over the zooplankton. Spatial as well as temporal variations were recorded in phytoplankton and zooplankton communities. Two distinct peaks, one in post monsoon and other in summer were observed in the present investigation . In the analysis of the ratio between both the plankton, it was noticed that the higher number of plankton the closer was the ratio. The ratio between phytoplankton and zooplankton varied from 1.95:1 to 4.09:1(phytoplankton : zooplankton).The lowest ratio (1.95:1) was observed in the post monsoon season where number of both varieties of plankton were abundant. The highest ratio (4.09:1) was recorded in monsoon season. The *beels* were found to be more productive when compared to other *beels* already reported in other parts of Assam. The maximum depth of sedimentation recorded in the present study was4.16±0.36cm/year which was less than recorded values earlier in the wetlands of central Assam. The results were more similar to siltation rate of the wetlands of upper Assam (2.8cm/year). In chemical analysis study it was found that Stream I and Stream III were contaminated with organochlorine and stream II and Stream IV with organophosphate in the post monsoon season. During monsoon season these streams were found to be contaminated with endosulfon .*Beels* were devoid of any contamination.

Important outcomes of present investigation:

*It was observed that the *beels* of KNP were considerably in good state in terms of primary production.

*Ecological parameters were by and large in optimum range.

*Macro-vegetation might cause serious problem by reducing O_2 content of wetlands when they become stagnant after monsoon.

*Phytoplankton and zooplankton communities showed temporal as well as spatial variations depending on ecological conditions of wetlands.

*Stress regulated plankton communities were identified based on their availability to proliferate in all the seasons and *beels* .

*Ratio between phytoplankton and zooplankton vary in relation with their abundance.

*Rate of sedimentation was found to be very high in *beels* which may cause damage to the biodiversity of the park.

*Presence of chemicals in the streams of KNP have been reported for the first time.

Limitations of study.

Soil analysis should be carried out to determine the impact of soil on the water parameter variaton. Soil contamination arising out of pesticides and herbicides is imperative to study. Deposition of heavy metal in the *beel* sediment should thoroughly be tested throughout the year. Macrophytic infestation should be properly investigated for proper management of the wetlands.

Recommendation and future work of research.*Unrestricted use of herbicides and pesticides should be stopped to maintain the sustainability and health of the ecosystem of KNP.

*The tea gardeners should be encouraged to adopt organic form of cultivation.

*Disturbance of soil surface should be minimized by preventing unlawful agricultural practices inside the KNP.

*Though it is difficult task to prevent sedimentation completely, measures should be taken to reduce the sedimentation rate to the possible extent by creating thick vegetation near the bank of river Brahmaputra.

* Soil conservation methods should be adopted to reduce soil erosion in upper stretch of the river Brahmaputra.

*There should be a full fledged laboratory for analysis of water periodically and systematically.

* Ecological assessment should be carried out in all important *beels* of KNP.

* There should be an annual periodical analysis of streams and *beels'* water for presence of any harmful chemicals even in trace level.

* Presence of heavy metal in wetland sediment and plants species should be thoroughly investigated.

* Ecological impacts of highway on aquaticflora benthic fauna should be investigated .

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Annexure-I

MAMMALS COMMONLY ENCOUNTERED IN KAZIRANGA NATIONAL PARK

English Name	Scientific Name	Vernicular Name (Assamese)
1 Great Indian Horned Rhinoceros	*Rhinoceros unicornis* (Lennaeus)	Gorh
2 Wild Buffalo	*Bubalus bubalis* (Lennaeus)	Bonoria Moh
3 Indian Elephant	*Elephas maximus* (Lennaeus)	Hati
4 Royal Bengal Tiger	*Panthera tigris* (Lennaeus)	Dhekiapatia Bagh
5 Indian Wild Boar	*Sus scrofa* (Lennaeus)	Bonoria Gahori
6 Indian Gaur	*Bos gaurus* (H.Smith)	Gaur
7 Swamp Deer	*Cervus duvauceli* (G. Cuvier)	Dol Horina
8 Sambar	*Cervus unicolor* (Kerr)	Hor Pahu
9 Barking Deer	*Muntiacus muntjak* (Rafinesque)	Hugori Pahu
10 Hoolock or White Browed Gibbon	*Hylobates hoolock* (Harlan)	Halou Bandar
11 Hog Deer	*Axis porcinus*(Zimmermann)	Khotia Pahu
12 Capped Langur or Leaf Monkey	*Presbytis pileatus*	Tupipindha Hanuman Bandar
13 Common Langur	*Presbytis entellus*	Hanuman Bandar
14 Rhesus Macaque	*Macaca mulatta* (Zimmermann)	Molua Bandar
15 Assamese Macaque	*Macaca assamensis* (McClelland)	Jati Bandar
16 Leopard	*Panthera pardus* (Lennaeus)	Naharphutuki Bagh
17 Sloth Bear	*Melursus ursinus* (Shaw)	Mati Bhaluk
18 Indian Porcupine	*Hystrix indica* (Kerr)	Ketela Pahu
19 Fishing Cat	*Felis viverrina* (Bennett)	Masuoi Mekuri
20 Jungle Cat	*Felis chaus* (Schreber)	Ban Mekuri

21 Large Indian Civet	*Viverra zibetha* (Lennaeus)	Johamal
22 Small Indian Civet	*Viverricula indica* (Desmarest)	Haru Johamal
23 Common Mongoose	*Herpestes edwardsi* (E.GeoffroySaint-Hilaire)	Neul
24 Small Indian Mongoose	*Herpestus auropunctatus*	
25 Indian Fox	*Vulpes bengalensis* (Shaw)	Ram Hial
26 Jackal	*Canis aureus* (Lennaeus)	Hial
27 Common Otter	*Lutra lutra* (Lennaeus)	Ud
28 Chinese FerretBadger	*Melogale moschata* (Gray)	
29 Hogbadger	*Arctonyx collaris* (Cuvier)	
30 Eastern Mole	*Talpa micrura*	Utonua
31 Pangolin	*Manis crassicaudata* (Gray)	Bon Row
32 Gangetic Dolphin	*Platanista gangetica)* (Lebeck,Roxburg)	Hihu
33 Squirrel	*Dremnomys lokriah* (Hodgson)	Kerketua
34 Himalayan Bear	*Selenarctos thibetanus* (Cuvier)	Kolabhaluk
35 Bat	Various Spp.	Baduli

(Source: KNP Master plan for 2003 to 2013 ,2002)

Annexure-II

Flora of Kaziranga National Park

RARE AND ENDANGERED PLANTS

APOCYNACEAE:

1.*Rauvolfia serpentina* (L.) Benth. ex Kurz.

GNETACEAE:

2. Gnetum montanum

ASTERACEAE:

3. *Artemisia caruifolia* Buch-Ham.

ORCHIDACEAE:

4. *Eulophia mannii* Hook.f.

LAMIACEAE:

5 .Biermannia bimaculata King & Pant.

6 .*Stachys oblongifolia* Benth.

ENDEMIC PLANTS

ELAEOCARPACEAE:

7.*Ehinocarpus assamicus* Benth.

ZINGIBERACEAE:

8.*Eurcumorpha longiflora* (Wall.)

IMPORTANT MEDICINAL & ECONOMIC PLANTS

ACANTHACEAE:

9.Adhatoda vasica Nees

ASTERACEAE:

10.Artemisia nilagirica (Cl.) pamp.

CAESALPINIACEAE:

11. Cassia fistula L

MENISPERMACEAE:

12.Cissampelos pareira L.

CLEOMACEAE:

13.Cleome gynandra L.

CASTACEAE:

14.Costus speciosus (Koen.) Smith.

CAPPARACEAE:

15.*Crataeva unilocularis* Buck.Hans

POACEAE:

16.Cynodon dactylon (L) Pers.

DILLENIACEAE

17.Dillenia indica L.

DIOSCOREACEAE:

18.Dioscorea alata L

19.D. bulbifera L.

20.D. pentaphylla L.

ELAEOCARPACEAE:

21.Echinocarpous asamicus . Benth.

EUPHORBIACEAE :

22.Emblica officinalis . Gaertn.

SALICACEAE:

23.Flacourtia janqomas Lour.

CLUSIACEAE:

24.Garcinia tinctoria (Dc.) Wight.

VERBENACEAE:

25.Gaelina arborea L.

CUCURBITACEAE:

26.*Hodjsonia macrocarpa* (BI.) Cogn.

MALPIGHIACEAE:

27.*Hiptqge bengalensis* (L.) Kurz..

MALVACEAE:

28.*Kydia calycina* Roxb.

ARACEAE:

29.*Lasia spinosa* Thw.

MAGNOLIACEAE:

30.*Magolia pterocarpa* Roxb.

NYMPHAEACEAE:

31.*Nymphaea nouchali* Burm.

BIGONIACEAE:

32.*Oroxylom indicum* Vent.

ANNONACEAE:

33.Polyalthia simiarum Hook f & Thom.

POLYGALACEAE:

34.Polygala chinensis L.

PORTULACACEAE:

36.Portulaca oleracea L.

RUBIACEAE:

37.*Randia spinosa* (Thunb.)

BRASSICACEAE:

38.Rorippa indica (L). Heirn.

BOMBACACEAE:

39.Salmalia malabarica
(DC.)Schott & Endl.

MARANTACEAE:

40.Schumannianthus dichotomus (Roxb.) Gagnep.

CARRYOPHYLLACEAE:

41.Stellaria media L. Vill.

MENISPERMACEAE:

42.Stephania japonica var. discolor (BI)Forma.

STERCULIACEAE:

43.Sterculia villosa Roxb.

BIGNONIACEAE:

44.Stereospermum personatum (Hassk) Chatt.

MYRTACEAE:

45.Syzygium cumini (L) Skees

TAMARICACEAE:

46.Tamarix dioica Roxb. Ex. Roth

COMBRETACEAE:

47.Terminalia bellirica Roxb.

48. Terminalia chebula Retz.

TILIACEAE:

49.Triumfelta homboidea Jacquem.

MALVACEAE:

50.Urena lobata L.

LIST OF PLANTS NOT INCLUDED IN KANJILAL'S LIST OF FLORA

CARYOPHYLLACEAE:

51.Stellaria media L.

PORTULACACEAE:

52.Portulaca oleracea L.

MALVACEAE:

53.Sida cordata (Burm.f) Boiss.

STERCULIACEAE:

54.Streculia guttta Roxb.

LINACEAE

55.Linum usitatissimum L.

OXALIDACEAE:

56.Oxalis corniculata L.

BALSAMINACEAE:

57.Impatiens tripetala De.

PAPILIONACEAE:

58.Atylosia elongate (L.) Benth.

59.Crotalariaana gyroides H.B.& K.

60.Crotalaria albidia Heyne ex Roth.

61.Mellettia pachycarpa Benth.

ONAGRACEAE:

62.Ludwiqia adscandans(L).Hara

CUCURBITACEAE:

\63.Actinostemma tenerum Griff.

64.Mukia maderaspatana (L.) Roemer.

RUBIACEAE:

65.Hedyotis lineata Roxb.

ASTERACEAE:

66.Adenostemma lavenia Ktza

67.Ageratum conyzoides L.

68.Artemisia caruifolia Buch.-Ham.

69.Bidens biternata (Lour.) Merr. & Sherff.

70.Cotula hemispherica (Boxb.) Wall ex CL.

71.Dicrocephala inteqrifolia (L.f.) Kuntz.

72.Eriqeron bonariensis L.

73.Ethulia conyzoides L.f.

74.Lactuca squarrosa (Th.) Mif.

75.Mikania micrantha HB

76.Sonhus oleraceus L.

77.Thespis divaricata Dc.

78.Tridax procumbens L.

79.Vernonia saligna Dc.

80.Wedelia wallichii lees.

81.Youngia japonica (L.) Dc.

BORAGINACEAE:

82.Heliotropoium indicum L.

LENTIBULARIACEAE:

83Utricularia flexuosa Vahl.

SCROPHULARIACEAE:

84.Torenia violaces (Azaola) Penn.

85.Tore-nia diffusa D.Don.

86.Lindernia cordifolia (Colsm.) Merr.

SOLANACEAE:

87.Physalis minima L.

THUMBERGIACEAE:

88.Thunberqia fragrans Roxb.

ACANTHACEAE:

89.Eranthemum scabrum Wall.Ex.T .

LAMIACEAE:

90.Stachys oblongifolia Wall.

91.Hyptis suaveolens (L.) Poir.

92.Achyrospermum allichianum (Benth.)

AMARANTACEAE:

93.Amaranthus viridis L.

94.Alternanthera sessilis (L.)

95.Alternanthera purgens H.B.K.

POLYGONACEAE:

96.Polygonum visicarius L.

97.Polygonum strigosum .Br.

98.Polygonum pulchrum Bl.

URTICACAE:

99.Pouzolzia reptans Hook.f.

CERATOPHYLLACEAE:

100.Ceratophyllum demersum L.

RANUNCULACEAE:

101.Naravelia zeyanca

DILLENIACEAE:

102.Tetracera sarmentosa (L.)

MAGNOLIACEAE:

103.Magnolia hodqsonii
Hook.f. Thoms

ANNONACEAE:

104.Artabotrys caudatus Wall.
Ex. Hook f.

MENISPERMACEAE:

105.Cissampelosa pareira

106.Stephania japonica
Burm.f. (Wild)

NYMPHAEACEAE:

107.Nymphaea nonchali Burm.

CAPPARIDACEAE:

108.Cleom gynandra L.

109.Capparis olacifolia Sw.S.
Sp.

CAPPARACEAE:

110.Crateva religiosa Buch. Ham.

FLOUCOURTIACEAE:

111.Flacourtia cataphracta

112.Casearia vareca Roxb

CARYOPHYLLACEAE:

113.Stellaria media L.

MYPERICACEAE:

114.Hypericum elodeides Choisy.

CLUSIACEAE:

115.Garcinia cowa (Roxb.)

THEACEAE:

116.Kitomera sinensis (L.) O.Ktza.

MALVACEAE:

117.Bombax ceila Dc.

118Abelmoschus moschatus Medic,. Malv.

119.Hibiscus fraqrans Roxb.

120.Sida rhombifolia L.

121.Urena lobata L.

STERCULIACEAE:

122.Sterculia guttata Roxb.

TILIACEAE:

123.Grewia sapida Roxb.

*124.Grewia hetiofolia*Dc

ELEOCARPACEAE

125.Echinocarpus tomentosus Benth.

126.Eleocarpus tectorus (Lour.) Poir

OXALIDACEAE:

127.Oxalis corniculata L.

BALSAMINACEAE:

128.Impatien grangulifera.

129.Impatien balsamina L

RUTACEAE:

130.Murraya Koenigii (l.) Spreng.

MELIACEAE:

131.Aglaia hiernii

132.Aglaia spectabilis Miq.

133.Aphanamixis polystachya (Wall).

134.Dysoxylum alleoria

135.Leoseneriella macrantha (Korth.) A.C.

136.Reissantia arborea (Roxb.

RHAMNACEAE:

137.Gouania tilliaefolia Lamk.

138.Ziziphus funiculosa Buch.

CRUCIFEREAE:

139.Ziziphus mauritiana Lamk.

VITACEAE:

140.Cissus rependa Roxb.

141.Cissus qudrangularis

142.Tetrastigma bracteolata (Wall.)

143.Tetrastigma dubium Planch.

144.Vitis barbata Wall.

145.Vitis beyneana Roem . & Schult.

LEEACEAE:

146.Leea acuminata Wall. Ex Clarke.

147.Leea crispa Willd. L. Mant.

148.Leea indica (Burm.) Merrill.

149.Leea trifoliata laws.

150.Leea umbraculifera C.B. cl.

151.Aphania rubra (Roxb.

SAPINDACEAE:

152.Cardiospermum helicacabum L.

153.Lepisanthes tetraphylla (Vahl.)

MELIOMACEAE (SABIACEAE):

154.Meliosma simplicifolia (Roxb.)

CONNARACEAE:

155.Connaris paniculatus Roxb

PAPILIONACEAE

156.Atylosia scarabaeoides (L.) Benth.

157.Butea parviflora Roxb.

158.Crotalaria pallida Aiton.

159.Crotalaria sessififlora L.

160.Derris indicus Benth.

161.Desmodium laxiflorum De

162.Flemingia lineata (L.) Roxb.

163.Flemingia strobilifera (L.)

164Melilotus alba Lamk.

165.Milletia pachycarpa Benth.

166.Pueraria subspicata Benth.

167.Phynchosia viseosa De.

168.Uraria picta(Jacq.)Derv.De

169.Caesalpinia cinclidocarpa Miq.

170.Cassia mimosoides L.

171.Cassia tora L.

172.Acacia farnesiana (L.) Willd.

173.Acacia pennata (L.) Willd.

174.Albizia procera (Roxb.) Benth.

175.Mimosa pudica L.

176.nnDuchesnea indica (Andr.) Focke.

177.Carallia brachiata (Lour.)

MYRTACEAE:

178.Syzygium cumini (L)

179.S. tetragonum (Wt.)

180.Caraya arborea Roxb.

BARRINGTONIACEAE:

181.Barringtenia acutangula (L.)

MELASTOMATACEAE:

182.Melastoma malabathricum L

183.Osbeckia stellata Var. *Crinita.*

LYTHRACEAE:

184.*Lagerstroemia parviflora Roxb.*

185.*L. reginae Roxb.*

186.Rotala rotundifolia (D.Don.)

187.Ludwigia prostrata Roxb.

TRAPACEAE:

188.Trapa natan L

189.Actinostemma tenerum Griff

CUCURBITACEAE:

190.Hodgsonia macrocarpa (Bl.)

191.Solena hetrophylla Lour

192.Clinus lotoides (O.Ktze.)

193.*Sesali daucifolium* C.B.cl.

RUBIACEAE:

194.Canthium gracillipes Kurz.

195.Coffea bengalensis Wall.

196.C. Khasiana Hook.

197.Hedyotis scandens D. Don

198.Ixora acuminara Roxb.

199.Morinda angustifolia Roxb.

200.Pavetta indica L.

201.Psychotria monticola Kurz.

202.P. subintegra Hook.

203.Randia fasciculata Dc

204.R. longiflora Lamk.

205.R. spinosa (Thunb.)

206.Uncaria sessilifructus Roxb.

ASTERACEAE:

207.Adenostemma lavenia (L.)

208.Ageratum conyzoides

209.Artemisia caruifolia Buch.

210.Blumea laaera (Burm.f.)

211.Eupatorium odoratum L.

212.Dichrocephala integrifolia. Eclipta alba (L.)

213.Ethulia conyzoides L.

214.Gnaphalium luteoalbum L.

215.Grangea maderaspatana (L.)

216.Mikenia micrantha HBK.

217.Sphaeranthus indicus L.

218.Thespis divaricata Dc.

219.Xanthium strumarium L.

220.Youngia japonica (L.)

MYRSINACEAE:

221.Ardisia solanaceae Roxb.

222.*A. paniculata* Roxb.

EBENACEAE:

223.Diospyros variegata Kurz.

OLEACEAE:

224.Jasminum amplexicaule D. Don.

APOCYNACEAE:

225.Rauvolfia serpentina (L.)

*226.Trachelospermum lucidum*D.Don

VALLARINIACEAE:

227.Vallaris solanacea (Roth).

228.Dischidia benghalensis Cobb.

229.Hoya arnothiana Wight.

230.Oxystelma secamone (L.)

231.Pentanura Khasiana Hook.

232.Wattakaka volubilis (L.f.)

233.Nymphoides cristata (Roxb.)

BORAGINACEAE:

234.Cordia myxa L.

235.Heliotropium indicum L.

236.H. ovalifolium Forsk.

SOLANACEAE:

237.Solanum nigrum L.

238.S. Torvum Sw.

239.S. viarum Dunal

240.Curanga amara Juss.

LAURACEAE:

241.Lindernia cordifolia (Colsm)

242.S. ruelloides (Colsm.)

243.L. viscosa (Hornom)

SCOPHULARIACEAE:

245. Limnophila indica (L.)

LENTIBULARIACEAE:

246.Utricularia aurea Lour.

CESNERIACEAE:

247.Rhyncotechum ellipticum (Dietr.)

BIGNONIACEAE:

248.Oroxylum indicum (L.)

249.Stereospermum 250.personatum (Hassk.)

THUNBRGIACEAE:

251.Thunbergia fragnans Roxb.

ACANTHACEAE:

252.Hygrophila phlomoides Nees.

253.H. Polysperma (Roxb.)

254.Justicia gendarussa Burn.

255.Lepidagathis incurva Buch.

256.Phlogaganthus tubiflora Nees.

257.Rungia parviflora (Retz.)

VERBENACEAE:

258.Callicarpa arborea Roxb.

259.Clerodendrum serratum (L.) Spring

260.C. viscosum Vent.

261.C. wallichii Merr.

262.Lantana indica Roxb.

263.Lippia alba (Mill.)

264.Premna latiflora Roxb

265.P. bengalensis Clarke.

266.Stachytarpheta indica (L.)

267.Verbena officianalis L

LABIATEAE:

268.Gomphostemma parviflorum wall.

269.Leucas lavandulifolia J.E. Sm.

270.Pogostemon auricularius (L.)

271.Stachys oblongifolia Wall

AMARANTHACEAE:

272.Alteranthera hybridus

273.A. sessilis (L.)

274.Amaranthus spinosus (L.)

275.Cyathyla prostrata (L.)

276.Deeringia amaranthoides (Lamk.) Merr

CHENOPODIACEAE:

277.Chenopodium album L.

POLYGONACEAE:

278.Polygonum barbatum L

279.P. chinese L

280.P. hydropiper L

281.P. hydropiper var flaccidum (Meissn.)

282.P.orientale L.

283.P. perfoliatum L

284.P.plebejum R.

285.P.posumbu Book Ham

286.P. pulchrum Blume

287.P.strigosum R.

288.P.viscosum D. Don.

*289.Rumex vesicarius*L.

ARISTOLOCHIACEAE:

290.Aristolochia catheartii Book.

PIPERACEAE:

291.Piper peepuloides Roxb.

292.P. sylvaticum Roxb.

CHLORANTHACEAE

293.Chloranthus officinalis Bl.

LAURACEAE:

294.Cinnamomum bejolghota (Buch-Ham)

295.Cryptocarya amygdalina Nees

296.Litsea monopetala (Roxb.)

297.Litsea nitida (Roxb.ex Nees)

298.L. salicifolia Roxb.

LORANTHACEAE:

299.Macrosolen ochinchinensis (Lour)

EUPHORBIACEAE:

300.Antidesma acuminatum Wall

301.A. diandrum (Roxb.)

302.A. bunius (L.)

303.Aporusa ocandra (BooK and Ham.)

304.Baliospermum calycinum Muell.

305.Bischofia javanica Bl.

306.*B. stipularis* (L.) BI

307.Croton caudatus Geisl.

308.C. tiglium L

309.Drypetes eglandulosa (Kurz.)

310.Emblica officinalis Gaertn.

311.Euphorbia hirta L.

312.E. nerijolia L.

313.Glochidium khasicum (Muell. - Arg.)

314.G. lanceolarium (Roxb.)

315.G. multiloculare Muell.-Arg.

316.G. oblatum Hook f

317.Kirganelia reticulata (Bir)

318.Malotus albus (Roxb.)

319.M. philippensis (Lamk.)

320.Ricinus communis L.

321.Sauropus androgynus (L.)

322.Securinega virosa (Roxb. Ex wild)

323.Trewia nudiflora L

URTICACEAE:

324.Boehmeria nivea Hook.

325.Neodistemon indicum (Wedd.)

326.Pouzolzia bennetiiana Wight.

327.P. pentandra Benth.

328.P. Zeylanica (L.)

329.Trema orientalis (L.)

CANNABICEAE:

330.Cannabis sativa L.

331.Cudrania ccchinchinensis (Lour)

MORACEAE

332.Ficus benjamina L.

333.*F. curtipes* Corner

334.F. heterophylla L.F. *var assamica*

335.F. hispida Vahl.

336.F. obscura Bl.

337.F. rumphii Bl.

FAGACEAE:

338.. Castanopsis tribuloides (Sm.)

CERATOPHYLLACEAE:

339.Ceratophyllum demersum L.

GNETACEAE:

340.Gnetum montanum Mg.F

HYDROCHARITACEAE

341.Hydrilla verticillata (L.f.) Royle

342.*Ottelia alismodies* (L.)

343.Ottelia alismodies (L.)

ARACEAE:

344.Ottelia alismodies (L.)

345.Vallisneria spiralis L.

ORCHIDACEAE:

346.Acampe papillosa Lindl

347.Burmannia bimaculata . K & P

348.Dendrobium acinaciforme Foxb

349.D. lindleyi steudel

350.Gastrochillus dasypogon (Sm. Ex)

351.Phynchostylis retusa (L.)

252Vanda teres Lindla

ZINGIPERACEAE:

353.Alpina nigra Burta

354.Amomum aromaticum Roxb

355.Costus speciosus (Koen.)

356.Curcuma aromatica Salisb.

357.C. zeodaria (Roase.)

358.Curcumorpha longiflora (Wall.)

VARANTACEAE:

359.Phrynium parviflorum Roxb.

360.Schumannianthus dixhotomus (Roxb.)

AMARYLIDACEAE:

361Crinum amoenum Roxb.

HYPOXIDACEAE:

362.Curculigo orchioides Gaerth

DIOSCORIACEAE:

363.Dioscorea glabra Roxb.

364.Ophiopogon intermedius D.Don

SMILACACEAE:

365.Smilax macrophylla L

PONTADERIACEAE:

366.Eichhornia crassipea (Mart.)

367.Monocharia hesteta (L.)

COMMELLINACEAE:

368.Aclisia secundiflora (Bl)

*369.Commelina be*ngalensis L

370.C. paludosa Bl.

371.C.sikkimensis Clarko

372.Ploscopa scandens Lour

373.Murdannia loriformis (Hassk.)

374.Pollia subumbellata C.B. Clarke

ARECACEAE:

375.Calamus flagellum

376.C. floribundus

377.C. tenuis Roxb.

378.C. viminalis Willd .

TYPHACEAE:

379.Typha elephantina Roxb.

ARACEAE

380.Alocasia fornicata (Roxb.

381.Lasia spinosa (L.)

382.Pothos scandens L.

383.Najus indica (Willd.)

POTAMOGETONACEAE:

384.Potemogeton octandrus Poir

CYPERACEAE:

385.Carex speciosa Cl. Boot.

386.Cyperus brevifolius (Rottb.)

387.*C. compressus* L.

388.C. digitatus Roxb.

389.C. difusua Vahl.

390.*C. distans* L.f.

391.C. imbricatus Rotz.

392.C. iria L.

393.C. kyllingia Endl.

394.C. pumilus L.

395.C. silletensic Nees.

396.Fimbristylis aestivalis (Retz.)

397.F. dichotoma (L.)

398.Scirpus articulatus L.

POACEAE:

399.Acroceras zizanioides (HBK)

400.Apluda mutica L.

401.Arundinella engalensis(Spreng)

402.Centotheca leppacea (L.

403.Cyrtococeum oxphyllum (Steud.)

404.Chrysopogon aciculatus (Retz.)

405.Cynodon dactylon

406.*Cyrtococeum oxphyllum* (Steud.)

407.Dendrocalamus hamiltonii Nees.

(Source :KNP Master plan for 2003 to2013,2002) **(Corrected list)**

Annexure-III

NATURAL WATER RESOURCES IN KAZIRANGA NATIONAL PARK

KAZIRANGA RANGE	
Name of the Wetland	**Water availability**
1 Honuman Negur - Ganga-Jamuna Beel	All throughout the year
2 Agora Beel	Seasonal
3 Ajogar Beel	All throughout the year
4 Baghmari beel	All throughout the year
5 Bandarmari Beel	All throughout the year
6 Banhodoloni Beel	Seasonal
7 Benga Beel	Seasonal
8 Bengena Ati Beel	Seasonal
9 Bhaisamari beel	All throughout the year
11 Bhehena Beel	All throughout the year
12 Bheselimari Beel	Seasonal
13 Bogi Beel	Seasonal
14 Boka beel	Seasonal
15 Bor – beel	All throughout the year
16 Borbheroni Beel	Seasonal
17 Borbokani Beel	All throughout the year
18 Bordoloni beel	Seasonal
19 Chamguri Beel	All throughout the year
20 Chengamora Beel	Seasonal
21 Cherkudoloni Beel	Seasonal
22 Daflong beel	All throughout the year
23 Dhekeramari – beel	All throughout the year
24 Dhekiatoli beel	All throughout the year
25 Dhokuachola Beel	All throughout the year
26 Digholi beel	All throughout the year
27 Dimoru guri Beel	All throughout the year
28 Ekorani Beel	Seasonal

29 Ekorani-II Beel	Seasonal
30 Eraltoli Beel	Seasonal
31 Gobrai Beel	All throughout the year
32 Goraimari beel	Seasonal
33 Gordubi beel	Seasonal
34 Hanhchora Beel	All throughout the year
35 Hatichora Beel	All throughout the year
36 Hilekhunda Beel	All throughout the year
37 Jalki beel	Seasonal
38 Jaru beel	Seasonal
39 Jengoni Beel	All throughout the year
40 Joor Beel	All throughout the year
41 Kanchi Beel	All throughout the year
42 Kapurkhosa beel	All throughout the year
43 Karsing beel	Seasonal
44 Kathpora beel	All throughout the year
45 Kawaimari beel	All throughout the year
46 Koroikathoni Beel	Seasonal
47 Koroipora Beel	All throughout the year
48 Laodubi Beel	All throughout the year
49 Magurmari Beel	All throughout the year
50 Menamari beel	All throughoutthe year
51 Mer - beelfens and some swamps are	Seasonal
52 Meteka Beel	All throughout the year
53 Mihi beel	All throughout the year
54 Miridoloni Beel	Seasonal
55 Mirikamari Beel	All throughout the year
56 Mohpara - Doloni(wallow)	Seasonal
57 Moirakati Beel	All throughout the year
58 Mona beel	All throughout the year
59 Naltoli Beel	All throughout the year

60 Naranora beel	All throughout the year
61 Nawbhangi beel	Seasonal
62 Padma beel	Seasonal
63 Padumoni Beel	Seasonal
64 Pichola Beel	All throughout the year
65 Pohu Beel	Seasonal
66 Polash Doloni beel	Seasonal
67 Potoa-chola beel	Seasonal
68 Raja Beel	Seasonal
69 Rajapukhuri Beel	All throughout the year
70 Rajmari Beel	Seasonal
71 Saru Bheroni Beel	Seasonal
72 Shikari Beel	Seasonal
73 Soru tiyontoli	Seasonal
74 Sorubokani Beel	All throughout the year
75 Tengramari beel	All throughout the year
76 Teteliguri Beel	Seasonal
77 Thungru Beel	Seasonal
78 Tilaidubi	Seasonal
79 Tinsuki Beel	All throughout the year
80 Tiyoatoli	All throughout the year
81 Tuplungi Beel	All throughout the year
82 Ubhota beel	All throughout the year
BURAPAHAR RANGE, GHORAKATI:	
1 Bag beel	All throughout the year
2 Borhola beel	Seasonal
3 Jamuguri beel	All throughout the year
4 Janata beel	All throughout the year
5 Lohorani Beel	Seasonal
6 Sagali beel	All throughout the year
7 Potahi Beel	Seasonal

EASTERN RANGE, AGARATOLI:	
1 Ahotguri beel	All throughout the year
2 Amoraguri beel	All throughout the year
3 Arasuti beel	Seasonal
4 Arikati beel	All throughout the year
5 Balidubi beel	All throughout the year
6 Batludubi beel	All throughout the year
7 Batomari beel	All throughout the year
8 Beli beel	All throughout the year
9 Belipora beel	All throughout the year
10 Bhalukmari beel	All throughout the year
11 Bherveri beel	All throughout the year
12 Bijuli bel	Seasonal
13 Book bezel	All throughout the year
14 Bokpora beel	All throughout the year
15.Boralimora beel	All throughout the year
16 Boralomora beel	All throughout the year
17 Borbeel	All throughout the year
18 Dhodang beel	All throughout the year
19 Digholi beel	All throughout the year
20 Dimow beel	All throughout the year
21 Duramari beel	All throughout the year
22 Gerela beel	Seasonal
23 Hahchora beel	All throughout the year
24 Hatichora beel	Seasonal
25 Kalduwar beel	All throughout the year
26 Kaowimari beel	All throughout the year
27 Kapurkhocha beel	All throughout the year
28 Khalihamari beel	All throughout the year
29 Kilakili beel	All throughout the year
30 Kurhimari	All throughout the year

31 Lahori beel	All throughout the year
32 Mahurmari beel	All throughout the year
33 Meteka beel	Seasonal
34 Meteka beel (2)	All throughout the year
35 Mohkhuti beel	All throughout the year
36 Mohpora beel	All throughout the year
37 Mowamari beel	All throughout the year
38 Muwamari Beel	All throughout the year
39 Natunbeel	All throughout the year
40 Noloni beel	All throughout the year
41 Pahumari beel	All throughout the year
42 Rajamari	All throughout the year
43 Rongamotia	All throughout the year
44 Salmora beel	All throughout the year
45 Saru boralimora beel	All throughout the year
46 Sarubherani beel	All throughout the year
47 Sohola beel	All throughout the year
48 Tini beel	All throughout the year
WESTERN RANGE, BAGURI:	
1 Bahu beel	All throughout the year
2 Basanti beel	All throughout the year
3 Bhaisamari beel	All throughout the year
4 Bhelengi beel	All throughout the year
5 Bherbheri-1 beel	All throughout the year
6 Bherbheri-2 beel	All throughout the year
7 Bimoli beel	All throughout the year
8 Boithamari beel	Seasonal
9 Borakata beel	All throughout the year
10 Borbeel	All throughout the year
11 Borme beel	All throughout the year
12 Bornaloni beel	All throughout the year

13 Borseleka beel	All throughout the year
14 Chitalmari beel	Seasonal
15 Daflong beel	All throughout the year
16 Deodubi beel	All throughout the year
17 Dhar beel	All throughout the year
18 Dherapora beel	Seasonal
19 Dhigoli-3 beel	Seasonal
20 Digholi beel	All throughout the year
21 Digholi-2 beel	All throughout the year
22 Dunga beel	All throughout the year
23 Duramari beel	All throughout the year
24 Gahori beel	All throughout the year
25 Gandamari beel	All throughout the year
26 Garaimari beel	All throughout the year
27 Garo beel	All throughout the year
28 Gerakati beel	Seasonal
29 Gholapani beel	Seasonal
30 Hanhsora beel	All throughout the year
31 Jharu beel	All throughout the year
32 Jhau beel	All throughout the year
33 Kachadhara beel	Seasonal
Kani beel	All throughout the year
35 Kathpara beel	All throughout the year
36 Kawaimari beel	All throughout the year
37 Majunoloni beel	Seasonal
38 Moamari beel	All throughout the year
39 Murphuloni beel	All throughout the year
40 Namduar	All throughout the year
41 Rowmari -1 beel	All throughout the year
42 Rowmari-2 beel	All throughout the year
43 Rowmari-3 beel	Seasonal

44 Rutikhowa beel	Seasonal
45 Sapekhati beel	All throughout the year
46 Saru Naloni beel	All throughout the year
47 Saru seleka beel	All throughout the year
48 Singimari beel	All throughout the year
49 Soisola beel	Seasonal
50 Sukani beel	All throughout the year
51 Tapacia beel	All throughout the year
52 Tanti beel	Seasonal
53 Tunikati beel	All throughout the year
54 Ujantoli beel	All throughout the year