Chapter -I

INTRODUCTION
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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 & Gilliam 1987). 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 abatement, 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), Kalluru 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 (Anon 1993)
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**

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

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Scientific Name</th>
<th>Vernacular name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Anabas testudineus</em></td>
<td>Kawoi</td>
</tr>
<tr>
<td>2</td>
<td><em>Amblypomys molitrix</em></td>
<td>Banhhpati</td>
</tr>
<tr>
<td>3</td>
<td><em>Amphiopnous eucharis</em></td>
<td>Kuchia</td>
</tr>
<tr>
<td>4</td>
<td><em>Bagarius bagarius</em></td>
<td>Garua</td>
</tr>
<tr>
<td>5</td>
<td><em>Xenentodon cancila</em></td>
<td>Kokila</td>
</tr>
<tr>
<td>6</td>
<td><em>Badis badis</em></td>
<td>Upor Sokoya</td>
</tr>
<tr>
<td>7</td>
<td><em>Catla catla</em></td>
<td>Bahu</td>
</tr>
<tr>
<td>8</td>
<td><em>Chanda nama</em></td>
<td>Chanda</td>
</tr>
<tr>
<td>9</td>
<td><em>Chanda ranga</em></td>
<td>Chanda</td>
</tr>
<tr>
<td>10</td>
<td><em>Channa orientalis</em></td>
<td>Chengeli</td>
</tr>
<tr>
<td>11</td>
<td><em>Channa marulius</em></td>
<td>Sal</td>
</tr>
<tr>
<td>12</td>
<td><em>Channa punctata</em></td>
<td>Goro</td>
</tr>
<tr>
<td>13</td>
<td><em>Channa striatus</em></td>
<td>Sol</td>
</tr>
<tr>
<td>14</td>
<td><em>Channa stewartii</em></td>
<td>Chenga</td>
</tr>
<tr>
<td>15</td>
<td><em>Chaca chaca</em></td>
<td>Bhutmas</td>
</tr>
<tr>
<td>16</td>
<td><em>Cirrhina mrigala</em></td>
<td>Mirika</td>
</tr>
<tr>
<td>17</td>
<td><em>Cirrhina reba</em></td>
<td>Bhagon</td>
</tr>
<tr>
<td>18</td>
<td><em>Clarius batrachus</em></td>
<td>Magur</td>
</tr>
<tr>
<td>19</td>
<td><em>Colisa lalirius</em></td>
<td>Bhecheli</td>
</tr>
<tr>
<td>20</td>
<td><em>Colisa fasciata</em></td>
<td>Khalihona</td>
</tr>
<tr>
<td>21</td>
<td><em>Eutropiichthys vacha</em></td>
<td>Bocha</td>
</tr>
<tr>
<td>22</td>
<td><em>Gudiusia chapra</em></td>
<td>Koroti</td>
</tr>
<tr>
<td>23</td>
<td><em>Glossogobius giuris</em></td>
<td>Patimutura</td>
</tr>
<tr>
<td>24</td>
<td><em>Heteropneustes fossilis</em></td>
<td>Singi</td>
</tr>
<tr>
<td>25</td>
<td><em>Labeo angra</em></td>
<td>Lachim bhangon</td>
</tr>
</tbody>
</table>
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. *Salmoestoma 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 physico-
chemical 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