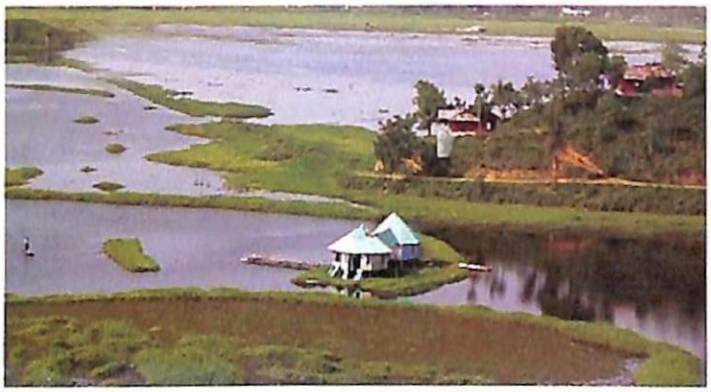
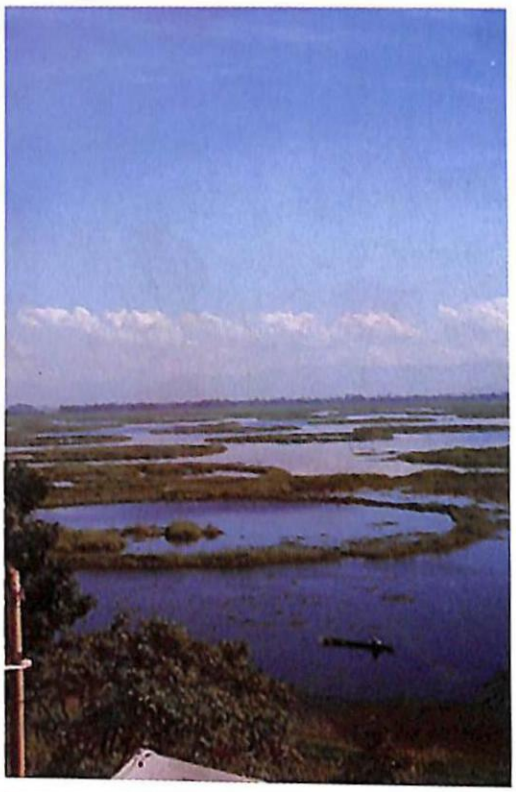
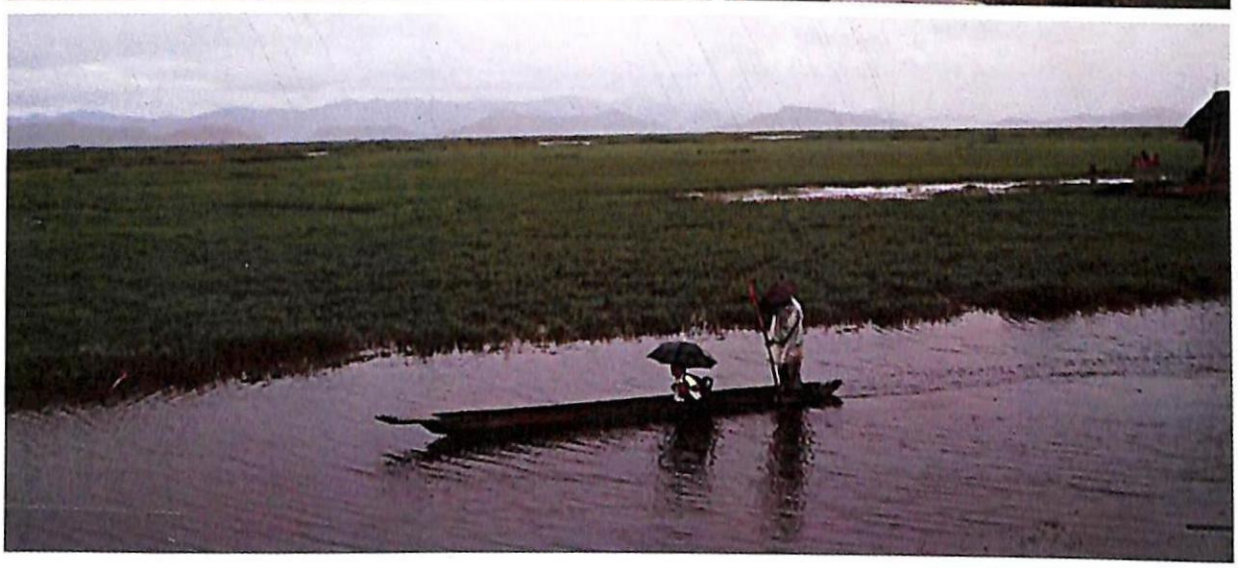
WETLANDS OF NORTH EAST INDIA

Ecology, Aquatic Bioresources and Conservation







Edited by
LAISHRAM KOSYGIN

WETLANDS OF NORTH EAST INDIA

Ecology, Aquatic Bioresources and Conservation

Edited by
LAISHRAM KOSYGIN

AKANSHA PUBLISHING HOUSE
NEW DELHI-110002 (INDIA)

AKANSHA PUBLISHING HOUSE
4649-B/21, Ansari Road
Darya Ganj, New Delhi - 110 002
Ph.: 23263193 / 9811582579 / 09435116718
Telefax: 011-23263193
Email: ektabooks@yahoo.com
visit us: www.akanshapublishinghouse.com

Wetlands of North East India: Ecology, Aquatic Bioresources and Conservation

First Published 2009

ISBN: 978-81-8370-187-7

Editor: Laishram Kosygin

Citation

Kosygin, L. (ed.) 2009. *Wetlands of North East India: Ecology, Aquatic Bioresources and Conservation*. Akansha Publishing House, New Delhi.

PRINTED IN INDIA

Published by Akansha Publishing House, New Delhi and *Printed at* : Mehra Offset Printers, Delhi.

Contents

Foreword

The northeast states of India are enriched with wetlands with enormous diversity. Loktak lake (Manipur); Deepor Beel (Assam); Rudrasagar (Tripura) and Palak and Tamdil (Mizoram) are few of the freshwater wetlands of the region known for their resources, biodiversity and aesthetic beauty. These wetlands also play a tremendous role in regulating flow regimes which is critical to providing food and water security to entire northeast. These wetlands have also been for centuries the cornerstones of civilizations and inextrivably linked to local culture and livelihoods.

Conservation and wise use of these 'kidneys of landscape' requires integrated planning and management at river basin level recognizing their interconnectedness with catchments. This needs to be based on understanding the carrying capacity of the basin with a view to produce desired outputs from limited resource base and achieving quality of life while maintaining desired environmental quality. The challenge therefore is to conserve wetland ecosystems and their rich biodiversity while providing sustained benefits to the communities dependent upon these resources for sustenance.

Despite their immense contribution, developmental planning has failed to recognize the rich spectrum of ecosystem services provided by wetlands and their role in regional ecological and economic security. This has promoted lopsided investments into infrastructure development including hydropower, agriculture, roads etc. without considering their implications on wetlands. As a result wetlands are affected by changes in hydrological regimes, pollution, encroachments and other anthropogenic pressures. These changes magnify into long term livelihood stresses and poverty, particularly within most marginalized sections of the society who depend on wetlands for sustenance. This calls for mainstreaming the full range of ecosystem services of wetlands, including their importance for environmental food security into development planning and policy making.

Climate change is expected to further enhance the vulnerabilities in the region bringing in changes in rainfall patterns, temperatures and biodiversity. The current rates of climate change are among the most rapid known and are superimposed on severe, and equally, uncertain socioeconomic pressures. The role of wetland ecosystem in the context of climate change, particularly in the northeast becomes far more critical. Their ability to regulate

Preface

Wetlands are areas where water is the primary factor controlling the environment and its associated plant and animal life. According to Ramsar Convention, wetlands include a wide variety of habitats such as marshes, peatlands, floodplains, rivers and lakes, and coastal areas such as saltmarshes, mangroves, and seagrass beds, coral reefs and other marine areas no deeper than six metres at low tide, as well as human-made wetlands such as waste-water treatment ponds and reservoirs. Wetlands of North East India has rich variety of habitats, which includes lakes, flood plain wetlands, reservoirs, beels, rivers, ponds, etc. and are among the most productive life supporting systems having immense socioeconomic and ecological importance to the people of the region. The rich assemblage of aquatic fauna and flora in the wetlands of this region is attributed to 1) the drainage pattern consisting of three entirely different river systems namely, the Barak drainage system, the Koladyne system and the Chindwin-Irrawaddy system; 2) unique mode of its geological formation and the formation of a geographically isolated central valley at a high altitude and 3) climatic factors which has variations in temperature, rainfall, elevations etc. These factors suggest a distinctive nature in its aquatic biota. However, most of the biodiversity components of the region are still under the discovery state. Considering the importance of these water bodies, the Ramsar Convention on Wetlands designated Loktak lake of Manipur, Deepor beel of Assam and Rudrasagar lake of Tripura as Ramsar Sites (Wetlands of International Importance). There are still many wetlands of the NE region which are needed to be designated as Ramsar Sites, keeping in view of their important roles in the ecology and socioeconomic conditions of the people. Most of the wetlands of the region are under pressure due to over exploitation and other anthropogenic activities leading to deterioration of water quality and degradation of bioresources etc. Therefore, it is necessary to obtain current and accurate information regarding ecology and bioresources of these wetlands in order to conserve and manage them holistically. The present book is compiled with a hope that it would provide baseline information about the wetlands of this region for conservation and sustainable utilization of these water bodies.

My special thanks and appreciation go to the scientists whose contributions have enriched the book. I express my deep sense of gratitude to Prof. Waikhom Vishwanath,

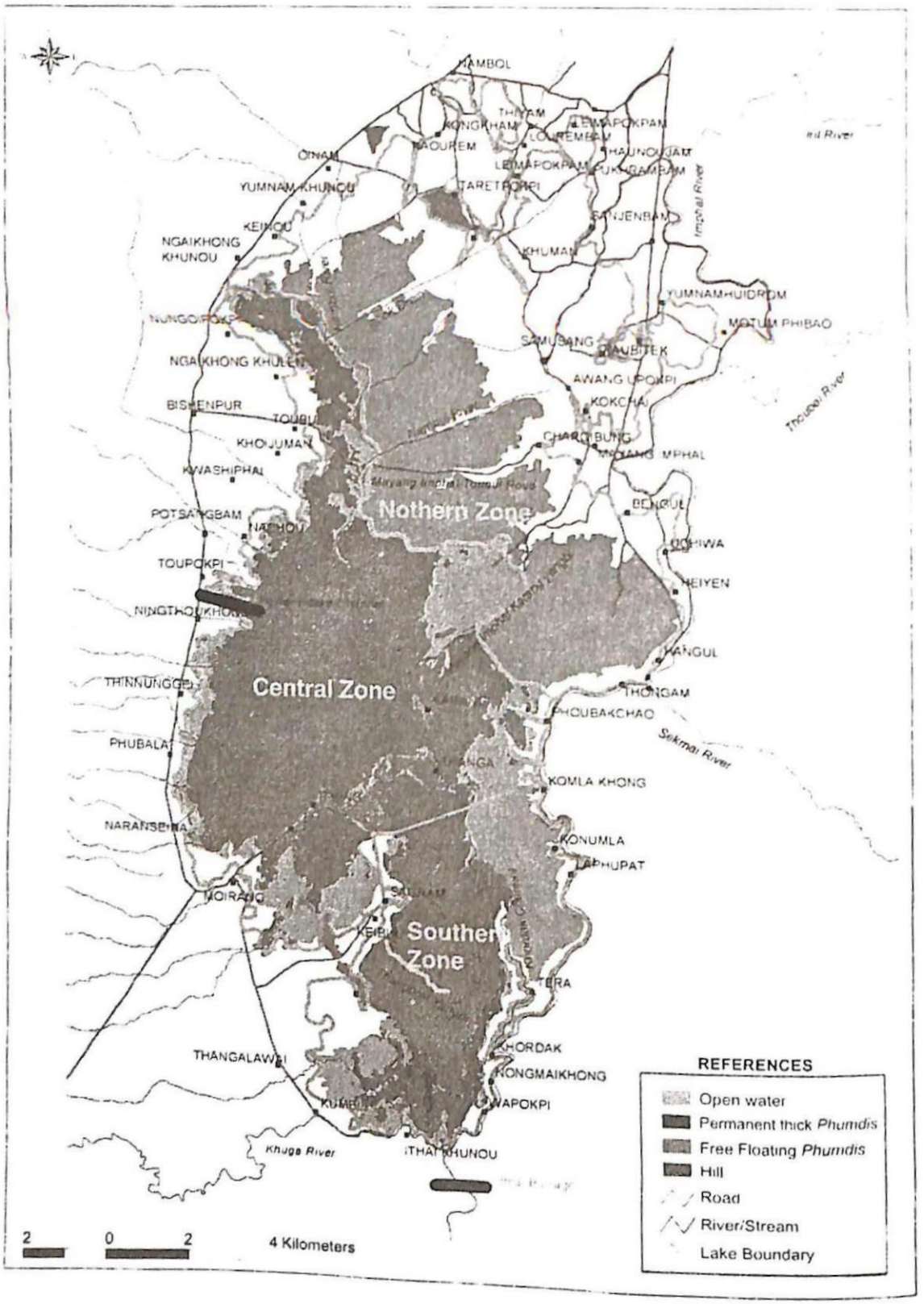


Figure 1.1: Map of Loktak Lake and its associated rivers and tributaries

provides refuge to numerous migratory birds, mostly migrating from different parts of the northern hemisphere beyond the Himalayas (Manihar, 1999). While visiting the Manipur Valley, Dr. N. Annandale remarked on the Loktak lake that "I have not seen any other place in India, where such enormous swarms of ducks and geese could be observed on the water as was the case in February on this lake, and wading birds were almost as abundant in the surrounding swamps" (Annandale *et al.*, 1921). In recognition of the lake's rich biodiversity and its socio-economic importance, the Ramsar Convention on Wetlands designated the Loktak lake as a Ramsar Site (Wetlands of International Importance) in 1990.

The lake is situated in the southern part of Manipur valley, surrounded by hills on the west and the Manipur river in the east flowing southwards parallel to the lake. There are about 53 human settlements in and around the lake. Tombi Singh and Shyamananda Singh (1994) reported that origin and evolution of Loktak lake may be ascribed to tectonic activity and neotectonism remarkably influenced by a long history of fluviolacustral processes. The isotopic data of the lake sediments suggest that it existed from the middle of the last glacial period about 25,000 years ago (Mitre *et al.*, 1986). A map of Loktak lake along with its associated rivers and tributaries is shown in Figure 1.1.

Figure 1.2: A view of Loktak Lake showing the floating *phumdis*.

The characteristic feature of the lake is the presence of *phumdis*. It has been reported that *phumdis* play an important role in the ecological process and functions of the lake ecosystem (Tombi Singh and Shyamananda Singh, 1994; Trisal and Manihar, 2002a; Kosygin, 2002; Devi and Sharma, 2008; LDA and WISA, 2004). The Keibul Lamjao National Park in the southern part of the Lake is considered the only floating National Park in the world as it is covered by the floating *phumdis*. This park is the only natural habitat of a highly endangered brow antlered deer, *Cervus eldi eldi* (McClelland) locally known as *Sangai*. The lake continues to be a vital fisheries resource providing livelihood to a large population. The lake water is being used for hydropower generation, irrigation, domestic water supply, fishery and wildlife. A view of Loktak lake is shown in Figure 1.2.

Physical Features of the Lake

Loktak lake is a shallow, wind-swept freshwater lake. It is located in Manipur between longitudes 93° 46′ - 93° 55′E and latitudes 24° 25′ – 24° 42′ N. The lake is oval in shape with maximum length and width of 32 km and 13 km respectively. It has a surface area of 287 sq. km at 768.5 m above msl at Ithai (LDA and WISA, 2004). At present the average depth of the lake is 2.7 m with a maximum depth of 4.6 m. There are 14 hills varying in size and elevation, appearing as islands, in the middle and southern part of the lake. The most prominent of them are Karang, Sendra, Ithing and Thanga islands. There are a number of streams originating from the western hill ranges, which directly discharge into the lake. Of these, Nambul, Nambol, Thongjaorok, Moirang, Awang Khujairok, Ngingthokhong, Potsangbam, Merakhong and Irumbi contribute maximum discharge into the lake. The indirect catchment area covers watersheds of 5 important rivers viz., Imphal, Iril, Thoubal, Khuga and Sekmai. All these rivers join together forming Manipur River and flow towards south by passing the Loktak lake and drain out into the Chindwin river of Myanmar.

Table 1.1
Morphometric features of Loktak lake, Manipur (Trisal and Manihar, 2004)

Maximum length (km)	32
Maximum width (km)	13
Maximum depth (m)	4.6
Mean depth (m)	2.7
Open water area (sq km)	43.9
Phumdi area (sq km)	134.6
Fish farm-cum-agricultural area (sq km)	106.5
Island (sq km)	2.0
Surface area (sq km)	287.0
Total volume (M cum)	519
Western Catchment area directly draining into the lake (sq km)	1046
Shape	Oval

The Loktak lake basin may be considered as a sub-basin of Manipur river basin. The Loktak Watershed has a direct catchment area of 1,046 sq km. The elevation varies from 780 m at the foothills adjoining the central valley to about 2,068 m above MSL at the peak. The lake also has an indirect catchment of 3,992 sq km. The lake receives water from various streams/rivers flowing directly from the western hills, indirect water input from the Manipur River system via Ungamel and Khordak channel and direct precipitation. Outflow from the lake includes abstraction for hydropower generation, domestic purposes, outflow through Ungamel and Khordak channels, evaporation and evapotranspiration. The flows to the lake through Ungamel and Khordak channels are bi-directional depending upon the relative level of water in the lake and the Manipur river.

Ecology of Loktak Lake

Physico-chemical characteristics: The physico-chemical characteristics of Loktak lake have been studied by Bhatia (1979), Shyamanda (1991), Tombi Singh (1992), Kosygin (2002). Recently more detail study was made by the Loktak Development Authority (LDA) and the Wetlands International South Asia (WISA) during 1999 - 2003 at various points of the lake.

The lake water quality showed well marked seasonal fluctuation. The surface water temperature, in general, ranges from 16.0° in winter to 34.6°C in summer with an average value of 24.1°C. The maximum light penetration values (2.98m) are recorded during post-monsoon at Thanga and minimum (0.51m) during monsoon at Loktak Proper near Moirang. The lake water is usually turbid; the low value of transparency being attributed to several factors, of which silt derived from catchment areas and plankton are significant. The lake water is slightly acidic. It ranges from 5.4 to 9.6. In general, lower pH values were found in the northern and southern zones of the lake. The maximum and minimum pH values of the lake water often exceeds both the upper and lower tolerance limits (6.0- 8.5) prescribed by ISI (1982) for inland surface waters. Recent extensive studies on the Keibul Lamjao National Park (KLNP) showed that park water is acidic in nature and it may lead to change in microbial population, generally implicated for degeneration of *phumdis*. A very low value of pH (3.8) has been reported from the core zone area of KLNP (Trisal and Manihar, 2004). The acidic nature of the park water may be attributed to dissolution of high concentration of carbon dioxide, which forms carbonic acid and high percentage of organic matter in the *pumdis* and soil.

The dissolved oxygen (DO) content varies greatly at different parts of the lake and at different seasons. The maximum dissolved oxygen content was observed in open water area of Takmu (12.3 mg/l) during pre-monsoon and the lowest at Patangkhong (1.6 mg/l) during monsoon. In general, level of DO is also often hypoxic (< 4 mg/l) in the northern and southern part of the lake. It is may be due to poor flushing of water and decaying of *phumdis*. In addition the northern zone receiving heavy discharge of sewage from the Nambul and Nambol Rivers. Depletion of DO is an indicator of several types of pollution in water.

The biochemical oxygen demand (BOD) varied between 2.9 mg/l at Takmu and 13.8 mg/l near Toubul. The higher level of BOD at Toubul may be attributed to high pollution load brought in by the rivers from the urbanized areas of Imphal and Bishnupur. The average value is more than the permissible level (3 mg/L) for class 'D' water prescribed by ISI (1982). The free CO_2 values ranged between 1.7mg/l at Takmu during pre-monsoon and 35.2 mg/l at Keibul during monsoon. Usually, free CO_2 was lower in open water area of the western side of the central zone compared to the eastern side of this zone.

The higher concentration of nutrients, particularly nitrogen and phosphorus, are naturally to be expected in the polluted waters (Munawar, 1970). Presence of nitrite-nitrogen indicates the organic pollution in the lake water (Trivedi and Goyal, 1986). High value of nitrite-nitrogen concentration (0.034 mg/l - 0.061mg/l) in the *phumdi* area of the lake was reported by Kosygin (2002). The concentration of dissolved inorganic phosphate phosphorus (DIPP) during water year 2002 – 2003 varies from 0.006 mg/l at Phubala to 0.110 mg/l at Patangkhong with an average value of 0.04 mg/L. The average value is found to be higher than the standard permissible limit recommended by USEPA (1976) for any receiving water bodies.

In the recent years there is high concern about the fast deterioration of water quality in the lake. Human population growth, urbanization and associated land use change have led to increase wastewater discharges into the aquatic environments. Human settlements within and around the edges of the lake have also added nutrient-rich seepage and effluent. Large amounts of nutrients are discharged into the lake from its tributary rivers and channels. The direct discharge from hutment on *phumdis* and latrines has added human waste in the system thereby deteriorating water quality. Increases in agricultural activity and the reduction of vegetative cover on the catchment areas of the lake with the consequential increase in surface erosion and leaching of soil nutrient have added increasing quantities of nutrient-rich runoff. However, studies made by Edmondson (1970), Mackereth (1965), Hasler (1969), Schindler (1974) have indicated that eutrophic lakes can recover to an oligotrophic condition when the nutrient input from the watershed slows or ceases.

Sediment composition: The bottom sediments of the Loktak lake are black in colour, soft and highly clayey in texture. Tombi Singh and Shyamananda Singh (1994) reported 60- 80% clay content in the bottom sediments of the lake. In general, sediments are rich in mineral nutrients. The pH of the lake sediments is usually acidic in nature which ranges from 4.8 - 5.3 with an average value of 5.0. Usually, nutrient concentrations were higher in the sediments of northern and southern zones of the lake. Mineral composition, percentage of organic matter and pH of bottom sediments of Loktak lake at different zones are given in Table 1.2.

Faunal diversity: Loktak lake has rich biodiversity but detail works are yet to be done. Annandale *et al.* (1921) remarked that conditions in the lake are favourable to the growth and reproduction of protozoa and many water-plants were observed that bore a profuse growth of vorticellids. Bhatia (1979), Shyamananda (1991), Tombi Singh and Shyamananda Singh (1994), Romi Singh (2002), Ningombam and Bordoloi (2007) made some important faunal diversity studies. Tombi Singh and Shyamananda Singh (1994) reported 12 species of Chlorophyceae, 10 species of Myxophyceae, 7 species of Bacillariophyceae and 3 species of Euglenophyceae. A total of 55 species of zooplanktons were also reported, which includes Protozoa (16 species), Rotifera (15 species), Cladocera (14 species) and Copepoda (10 species). Among the macrofauna they have reported 425 species of animals, which comprise

of 249 vertebrates and 176 invertebrates. The invertebrates included 16 species of annelids, 150 species of arthropods and 10 species of mollusks. The vertebrate fauna included 64 species of fishes, 6 species of amphibian, 106 species of birds and 32 species of mammals. They also remarked that the faunal diversity may be much higher as many species have not been properly identified.

Sharma (2007) observed interesting zoogeographical distribution of rotifer fauna of Loktak lake. He reported eleven rare species of Rotifera, belonging to seven families and seven genera from the lake. Out of these, he remarked that one species (*Euchlanis semicarinata*) was new record from the oriental region, six species (*Lepadella bengamini, Lecane elegans, L. tenuiseta, Trichocerca insignis, T. tenuior* and *Rotaria tardigrada*) from India, three species (*Lapadella bicornis, Ascomorpha ecaudis* and *Rotaria macroceros*) from northeastern India and one species (*Habrotrocha angusticollis*) from Manipur.

The lake harbours a wide range of fish fauna. Annandale *et al.* (1921) found abundant fish in the lake. While reporting on fishes of the Manipur, Hora (1921) and Menon (1954) included fish fauna of the lake. Recently, Romi Singh (2002) reported a total of 54 fish species representing 18 families and categorized under 3 groups viz., Endangered (6 species), Vulnerable (14 species) and Exotic (7 species). Trisal and Manihar (2004) pointed out that 12 fish species earlier reported by Tombi Singh and Shyamananda Singh (1994) were not observed and an exotic catfish *Clarias gariepinus* and a riverine species *Aplocheilus panchax* were recorded in the lake for the first time. Before construction of Ithai barrage indigenous air breathing fishes like *Anabas testudineus, Channa punctatus, C. striatus* and *Clarius batracus* were dominant fish species (Chaudhury and Banerjea, 1965). Changes in flow regime gradually altered the species composition and presently exotic carps are the most dominant group in lake fisheries, followed by Indian major carps and Murrels. At present many migratory fishes are disappearing from the lake due to the construction of Ithai barrage and deterioration of water quality. Some of the important fish species which used to migrate to the lake from the Chindwin-Irrawadi river of Myanmar along the Manipur river for breeding and spawning purposes are *Labeo angara, L. bata, L. dero, Osteobrama belangiri* etc. These fishes are now almost disappeared from the lake. Recently, restocking of *Osteobrama belangiri* (locally known as *Pengba*) in the lake is being done by the state fisheries department and Loktak Development Authority along with local NGOs. However, the survival and growth rate of the fish needs to be monitored and overall improvement in the lake ecosystem is required for successful stocking of the fish.

Ningombam and Bordoloi (2007) reported a total of 25 amphibian species from the Loktak lake out of which 10 species namely *Xenophrys major, X. wuliangshanensis, X. parva, Amolops formosus, A. gerbillus, Humerana humeralis, Euphlyctis hexadactylus, Fejervarya teraiensis, F. nepalensis* and *F. syhadrensis* were reported for the first time from the state. They remarked that the lake is suitable breeding ground of diverse groups of frogs and extensive survey in the Keibul Lamjao National Park may lead to discovery of many species not recorded so far from the region.

Floral diversity: The studies on the flora of Loktak lake has been made by various workers (Tombi Singh and Shyamananda Singh, 1994; Shyamjai Singh, 2002; Devi and Sharma, 2008). The lake is covered with thick vegetation which includes emergents, submerged and floating type life forms. Vegetation plays an important role in the ecological processes and functions of lake ecosystem besides being of great cultural significance to the people (LDA and WISA, 2004). The rich plant diversity of the lake is of considerable importance as food, fodder, fuel and gene pool.

Tombi Singh and Shyamananda Singh (1994) reported a total of 233 species of macrophytes from the lake. Later, Shyamjai Singh (2002) reported a total of 145 plant species from the Keibul Lamjao National Park. He further categorized them as 123 terrestrial and 22 aquatic. Vegetation in the lake can be broadly categorized into *phumdi* and *non-phumdi* areas. The macrophytic species in *non-phumdi* areas are represented by emergent, submerged, floating and rooted floating leaf types depending upon the water depth. The Central Zone, which is relatively free of *phumdis*, excepting *athaphums*, is dominated by *non-phumdi* vegetation. LDA and WISA (2004) reported 132 plant species from different parts of the lake. The species widely distributed are *Echinocloa, Salvinia, Eichhornia, Phragmites, Zizania, Capillipedium, Hydrilla* and *Brachiaria*. The highest number of species has been observed in southern zone (108) followed by northern zone (92) and central zone (78) in decreasing order.

Phumdis: The characteristic features of the lake is the floating mats or islands locally known as *phumdis* (Figure 1.3). These *phumdis* are heterogeneous mass of soil, vegetation and organic matter at various stages of decomposition and occurs in all sizes and thickness. The bases of it normally have thickness ranging from 0.2 m to 2.95 m (LDA and WISA, 2004). The high proportion of plant matter in the *phumdi* gives it a low specific gravity and high buoyancy to keep it afloat. Tombi Singh and Shyamananda Singh (1994) remarked that about one meter thick *phumdi* easily supports the weight of animals and human beings and larger size of about 2 meters thick with an area of 150 sq. m readily supports one small hut with 4 to 5 people. The assessment of mineral accumulation within the *phumdis* indicates that 1626.8 tonnes of nitrogen, 136 tonnes of phosphorous and 621 tonnes of potassium are accumulated (Trisal and Manihar, 2004). *Phumdis* play as nutrient sink and purifies the lake water. Nutrient compositions in different components of *phumdis* are shown in Table 1.3 and 1.4. On the other hand they affect the ecological processes by obstructing the sun light from entering the water body. They also deteriorate the water quality and enhance the shallowing process when they sink inside the lake. The main species found in the *phumdis* are *Alpinia, Capillipedium, Echinochloa, Hedychium, Impatiens, Phragmites, Saccharum, and Zizania*. Overall 60

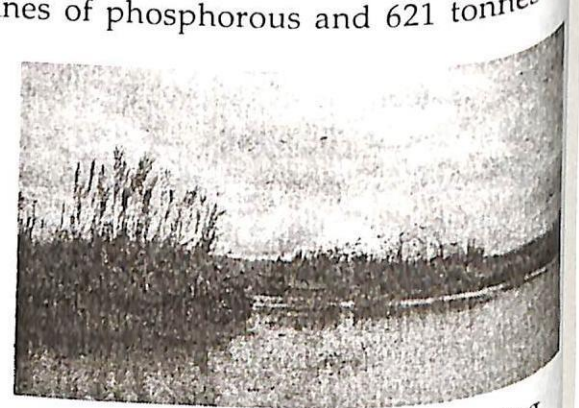


Figure 1.3: A close view of floating *Phumdis* in the Laktak Lake

species are common to *phumdis* in all the zones. *Phumdis* are also used by the local communities for fishing purposes. These *phumdis* are locally called *athaphums* and are usually round in shape. They are either naturally present in the lake area or have been brought from different parts of the lake for aquaculture purposes.

According to Devi and Sharma (2008) structure of *phumdi* is composed of three vertical zones viz., (1) uppermost root zone (10-15 cm in thickness), (2) mat zone (25-65 cm) which is a layer of densely interwoven live, dead and decaying roots with some litter accumulation, located just below the root zone and (3) the peat zone (10-25 cm) below the mat zone which mainly compose of decomposed materials. However, *phumdi* supports rich luxuriant vegetative growth of different plant species above the water surface. A vertical section of *phumdi* is shown in Figure 1.4. Therefore, *Phumdis* may be divided into 4 zones namely:

1. Vegetative zone
2. Root zone
3. Mat zone
4. Peat zone.

The formation of *phumdis* initiated with a dense growth of floating aquatic plants like *Salvinia, Eichhornia, Pistia, Azolla* etc., which accumulates some suspended silt and organic matter with their rich branching root system. The plants associated with the *phumdis* may be classified into primary and secondary plants. Those macrophytes, which initiated the formation of *phumdis* may be considered as primary plants. They usually float on water and form interlocking of roots. They trap silts from the water and also receive soil particles from the atmosphere thereby making favourable habitat for secondary plants to invade. Plants like grasses and other herbs invade first and later semi-terrestrial and terrestrial plants establish their growth on the *phumdis*. These plants absorb nutrients from the lake in order to sustain their life. As the nutrient supply is abundant in the lake, vegetation of different species of tall weeds and bushes grow up to three meters tall. The dead organic matters of these plants are also deposited on the *phumdis*, making them more fertile and thicker. In due course of time, the formation becomes more firm and their thickness increases both horizontally as well as vertically.

Figure 1.4: Vertical section of *Phumdi*.

Threats to Loktak Lake

An important feature of present-day Indian wetlands is that many natural lakes and rivers are progressively being degraded. However, natural wetlands are still one of the world's most productive ecosystems and they support valuable biodiversity, including habiat diversity or heterogeneity (Sanjit *et al.* 2005). Based on the analysis of various issues confronting the Loktak lake, Singh (1999) remarked that the root-cause problems of the lake are due to loss of vegetal cover in the catchment area and construction of Ithai Barrage. During 1983, a multipurpose project was commissioned for generation of hydel power and irrigation by constructing a barrage down stream across Manipur River at Ithai. At present the water level of the lake has been regulated by the barrage draining the lake water to the adjoining Barak river through a water conductor system for hydropower generation and irrigation (Meitei, 2002). The Loktak Multipurpose Project has brought about hydrological changes and converted a natural wetland with fluctuating water levels into a reservoir with much less fluctuation water level (Tombi Singh and Shyamananda Singh, 1994; Trisal and Manihar, 2002b). At present the lake facing numerous threats/problems such as siltation, eutrophication, water quality deterioration, proliferation of *phumdis*, loss of biodiversity, decline in fish production, reduction in flood holding capacity, encroachment etc. Deterioration of lake ecosystem is further enhanced by the inflow of nutrient rich sewage and domestic waste from Municipal area, rapid population growth; urbanization and associated land use change and increase in wastewater discharges into the lake. Some of the important ecological problems of the lake are discussed below.

Siltation: The Large-scale deforestation, land slides, erosion, excessive human activities in the stream corridors, construction of roads, practice of shifting cultivation, in the catchment area of the lake are the main sources of siltation. Further, significant amount of sediment load is also contributed by autochthonous factors like undecomposed organic matter and degradation of *phumdis*. It is estimated that about 50% (3,36,325 tonnes) of the total soil loss from the catchment are deposited in the lake every year (WAPCOS, 1995; Tombi Singh and Shyamananda Singh, 1994). LDA and WISA (2008) remarked that degraded catchments of Loktak and associated lakes annually lead to erosion of 4.5 mt of topsoil, of which 0.65 million mt is deposited into the lake. The rate of soil loss has increased by 69% since 1966 due to enhanced area under shifting cultivation. Bidyabhusan Singh (2007) remarked that the fast expanding human habitation has exploited the catchment area and if something substantial is not done, the lake may vanish within a short period of time. Since the lake is shallow, proper measures may be taken up on priority basis to control the rate of siltation.

Eutrophication: It is a natural process of enrichment of nutrients. However, eutrophication become excessive when abnormally high amount of nutrients from sewage, fertilizers, animal wastes and detergents enter the water bodies causing excessive growth or bloom of microorganisms and aquatic vegetations. The Loktak lake at present is suffering

from both natural and cultural eutrophication. The high nutrients level in the lake ecosystem may be attributed to the fact that the lake is receiving sewage and domestic waste from the municipal areas and human settlements including those dwelling in the *phum huts*, residue of fertilizers from the surrounding agricultural fields and erosion of nutrient rich top soil of the catchment area. As a result the lake is heavily infested with aquatic weeds and *phumdis*. At present the lake is heavily eutrophic and is under delicate balance of phytoplankton-macrophyte competition and is always ready to tilt in any direction of either rapid water quality deterioration or rapid shallowing due to unchecked biomass accumulation (Tombi Singh and Shyamananda Singh, 1994). It is reported that the lake receives 137.74 tonnes of P and 1152.14 tonnes of N per sq km per year from its catchment (Shyamananda, 1991).

The nutrient inflow into the lake from its feeder rivers were studied in the recent years. Trisal and Manihar (2004) reported that a large population living within Nambul catchment generates daily 72.23 million tonnes of solid waste and 31,207 cum of sewage. Nambol also contributes 4.9 million tonnes of solids waste and 2,121 cum of sewage annually. All these wastes directly or indirectly discharged into the lake. Further, rivers like Awang Khujairok, Ningthoukhong, Potsangbam, Merakhong and Irumbi draining the agricultural fields having high amount of fertilizer, contributes high concentration of nitrogen and phosphorus. A significant outcome of the water quality assessment shows that the river Nambul and Nambol discharged a heavy load of nutrients (2,338 and 243 tonnes/year of nitrogen; 270 and 34 tonnes/year of phosphorus and 2,081 and 198 tonnes/year of potassium for Nambul and Nambol respectively) into the lake. The processes of eutrophication combined with siltation accelerate the aging process of the lake.

Water quality deterioration/Pollution: Pollution is one of the main problems, which many lakes are facing in northeast India. The Loktak lake is receiving pollutants from both point and non-point sources. It receives organochlorine pesticides and insecticides from the surrounding agricultural fields. Due to insufficient scientific knowledge many farmers utilized pesticides and fertilizers in their fields more than what they required in order to produce more products. This also enhances the process of pollution in the lake. Nitrates can be converted in the human digestive tract by certain bacteria to nitrites. Nitrites when react with haemoglobin in the blood, the ability of the latter to take up oxygen is greatly reduced (Verma and Agarwal, 1987). The lake also receives huge amount of polythene and other waste plastic items from the human settlements. The mouth of Nambul river in the lake is often piled-up with huge quantity of plastic wastes and broken glass. These substances are non-biodegradable in nature and create numerous problems in the lake ecosystem.

The excess amount of nutrients may also cause pollution due to over-production of aquatic weeds, planktons and *phumdis*. Under the prolonged cloudiness during rainy season, they may decay and consume more oxygen than they produce, leading to oxygen depletion in the water. The bacterial decomposition of organic waste also consumes huge amount of oxygen from the water, which may diminish below the point (anoxic condition),

where most fish can not survive. When the condition in the water becomes anaerobic, the breakdown products become reduced rather than oxidized molecules, many of which produce offensive odours and tastes. Annandale *et al.* (1921) remarked that large part of the Loktak lake was covered with floating islands formed of living and decayed plants and bottom was composed of evil-smelling soft mud containing much rotten vegetable matter. The deterioration of water quality in the northern and southern zones of the lake may be attributed to heavy loading of pollutants from rivers and channels, degradation of *phumdis*, inflow of fertilizers and pesticides from the surrounding agricultural fields and poor flushing of water.

Proliferation of *Phumdis*: Due to heavy inflow of nutrients inside lake and changes in the water regime, *phumdis*, have profusely proliferated in the lake during the last two decades. Overall area of *phumdis* in the lake has increased from 116.4 sq. km to 134.6 sq. km during 1989-2002 (Trisal and Manihar, 2004; LDA and WISA, 2004). The high concentration of nutrients like N, P, K, makes the lake ecosystem more fertile and accelerates growth of *phumdis*. Proliferation is further enhanced by uncheck loading of nutrients and practice of the *athaphum* fishing in the lake by the local communities. LDA and WISA (2004) reported that *phumdis* in the central zone of the lake have increased at an annual rate of 5.7% and substantial increase to the tune of 18.96% occurred during 1999-2002, which can be attributed to the enhancement of aquaculture activities using *phumdis*. In the Northern and Southern Zones, area under *phumdis* has decreased mainly due to their extraction for *athaphum* purposes. This is more pronounced in northern zone as compared to southern zone. Due to the proliferation of *phumdis* and utilization of lake area for fish farming and agricultural purposes, open water area of the lake is decreasing. Changes in Loktak lake area during 1989 and 2002 is presented in Figure 1.5.

Table 1.2
Mineral composition (% dry wt.), percentage of organic carbon, percentage of organic matter and pH of bottom sediments in Loktak lake, Manipur

Parameter	*Zones*					*Mean*	*sd*
	Northern	*Western*	*Middle*	*Eastern*	*Southern*		
N	1.4	1.0	1.2	1.1	1.5	1.24	0.21
P	0.11	0.05	0.08	0.07	0.12	0.09	0.03
K	0.79	0.56	0.67	0.71	0.75	0.70	0.09
Ca	0.72	0.64	0.72	0.6	0.56	0.65	0.07
Mg	0.24	0.22	0.29	0.18	0.18	0.22	0.05
OC	7.1	4.4	4.5	6.7	7.5	6.04	1.5
OM	12.2	8.7	7.8	11.5	12.9	10.6	2.2
pH	4.9	5.1	4.9	5.3	4.8	5.0	0.2

(Source: LDA and WISA)

Table 1.3
Mineral nutrient composition (% of dry wt.) of different components of *Phumdi*. N=7

Sample	*N*			*P*			*K*		
	Mean (%)	*Range (%)*	*sd*	*Mean (%)*	*Range (%)*	*sd (%)*	*Mean (%)*	*Range*	*sd*
Live tissue of Macrophytes	1.4	0.8-2.1	0.41	0.18	0.09-0.35	0.08	0.91	0.48-1.4	0.3
Litter	1.1	0.5-1.5	0.31	0.13	0.06-0.19	0.04	0.76	0.42-1.2	0.24
Soil	1.2	0.7-1.7	0.38	0.11	0.07-0.16	0.03	0.72	0.45-1.1	0.24

(Source: LDA and WISA)

Table 1.4
Mineral nutrient composition (% dry wt) of weeds and macrophytes of *phumdis*

Sl. No.	*Plant Species*	*Local Name*	*Mireral constituen*		
			N	*P*	*K*
1	*Saccharum munja*	Khoimom	1.40	0.157	1.03
2	*Cyperus brevifolius*	Chumthang	1.20	0.121	0.79
3	*Phragmites karka*	Tou	1.10	0.108	0.78
4	*Zizania latifolia*	Ishing Kambong	1.40	0.123	0.90
5	*Oenanthe javanica*	Komprek	1.30	0.169	0.95
6	*Echinochloa stagnina*	Hoop	1.14	0.111	0.99
7	*Hedychium coronarium*	Loklei	1.30	0.161	1.12
8	*Brachiaria mutica*	Parangrass	1.40	0.194	0.95
9	*Vallisneria spirallis*	Lairenchak	1.00	0.181	0.91
10	*Polygonum barbatum*	Yelang	1.50	0.221	1.33
11	*Capillipedium* sp.	Wanamanbi	1.30	0.101	0.85
12	*Salvinia natans*	Kangkup	1.90	0.243	1.27
13	*Hydrilla zeylanica*	Charang kokphabi	2.20	0.311	1.72
14	*Hydrilla verticillata*	Charang	1.80	1.134	1.10
15	*Potamogeton crispus*	—	2.00	0.140	1.20

(Source: LDA and WISA)

Loss of Biodiversity: Loss of biodiversity is global issue and mass extinctions o plants and animals could have a severe impact on the living standards of the poores people on the planet. Biodiversity is shorthand for biological diversity or the variabilit of living organisms and the ecological complexes of which they are part. It is the tota variety of genetic strains, species and ecosystems. This diversity is a wonder and a deligh but also a great responsibility. Currently there is much concern over the increasing impac of our human actions on biodiversity. There are widespread calls for political action t halt the loss of species and protect the living world around us.

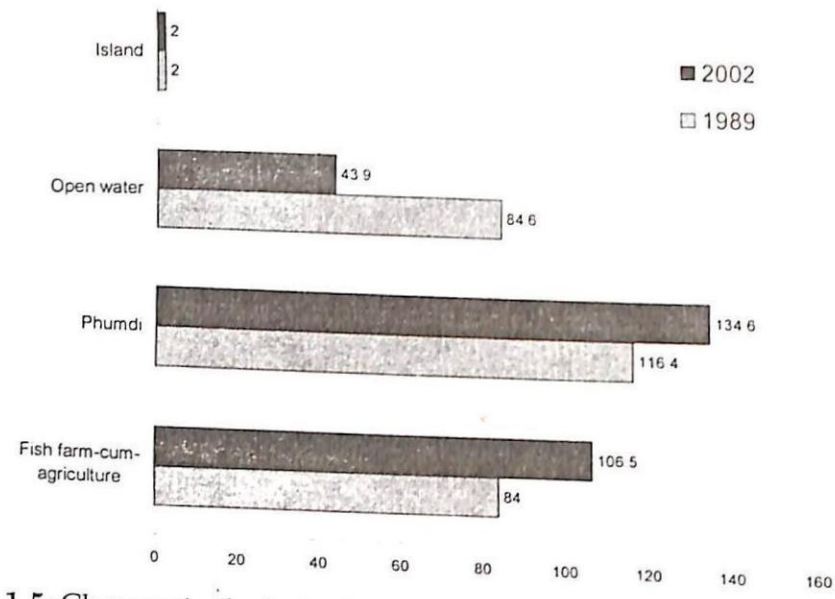


Figure 1.5: Changes in the Loktak lake area during 1989 and 2002 in sq. km (Trisal and Manihar 2004)

Due to pollution and other changes in the ecological characteristics of the Loktak lake ecosystem and also due to various human activities many desired species are already disappeared and many are on the verge of extinction from the lake. Sanjit *et al.* (2005) remarked that *phumdi* proliferation threatens the habitat of most water fowls, including dabbling and diving ducks. The diversity and population of migratory birds and fishes has declined during the last few decades due to poaching, over-exploitation and changes in ecological characteristics of the wetland. LDA and WISA (2004) reported that several plant species including *Cymbopogon nadus, Erianthus arundinaceus, Erianthus procerus, Imperata cylindrica*, which earlier were found abundantly, have now limited distribution in the lake. *Carex cruciata*, the preferred food plant of Sangai, which was earlier a dominant species in Keibul Lamjao National Park has now become extremely rare. The habitat of Sangai deer in KLNP is also threatened due to thinning of *phumdis* and poaching. Similarly, indigenous fish species are fighting a loosing battle against the exotic carps. Indiscriminate

fishing practices without strict imposition on mesh size, especially during breeding season leads to further decline in the diversity and production of fishes in the lake. LDA and WISA (2004) reported 12 fish species earlier reported by the workers were not observed in their recent studies. The populations of migratory and resident waterfowl have declined during the last few decades.

Conservation of Loktak Lake

From the foregoing account, it is clear that the lake plays an important role in the ecological and economic security of the state. However, at present the condition of the lake has reached a critical stage from the hydrological and ecological angles and if proper conservation measures are not taken, the lake is likely to deteriorate further. Before a conservation strategy is adopted it would be essential to examine the current state of the environment in the Loktak area and review current policies, including their administrative, technical and managerial aspects.

The Government of Manipur is greatly concerned about the deteriorating conditions of the lake. During 1986 the Loktak Development Authority (LDA) was constituted by the state Government to check deterioration of Loktak lake and to bring improvement in the areas of power generation, fisheries, tourism and siltation control etc. LDA has been involved for more than a decade in the management of the lake (Manihar, 1999). Recently, the Government of Manipur has notified the Manipur Loktak Lake (Protection) Act, 2006 and Loktak Lake (Protection) Rules, 2008, which would improve functioning of the authority by reorganizing and bringing legislative basis for lake management. However, for proper conservation and management of the lake, it is essential to have a basic understanding of the structure and functioning of the lake's ecosystem along with its watershed area. Some of the information required in detail for sustainable management of the lake are furnished below:

- Characteristics of the catchment area including a study of the geology, geomorphology, soil characteristics, soil erosion status and land use pattern;
- Hydrological characteristics in terms of water inflow-outflow and net water balance;
- Quantification of silt load and rate of siltation in the lake;
- Quantification of pollutant load from point sources and non-point sources;
- Assessment of water quality;
- Nutrient budgeting;
- Role of *Phumdis* and aquatic weeds and measures for their control;
- Waterborne diseases and health aspect;
- Socioeconomic studies.

For the proper long term management of the lake's ecosystem, it is imperative to undertake an integrated systematic study of the above aspects. However, some of the threats, which demand immediate attention, are as follows.

1. **Control of land reclamation and other encroachments**: One of the main factors contributing to the deterioration of lake ecosystem comes from the pressure of the human settlements along the shores and within the lake itself. With the growth of the population, the pressure on the lake and its surrounding as potential settlement areas, has increased. A number of villagers have come up in the Floating hutment on the *phumdis*. Encroachments in the lake area should be checked and proper rehabilitations may be arranged if required. Proper demarcation of lake boundary is necessary.

2. **Catchment area treatment**: Afforestation is a practically effective means of reducing soil erosion. It would be of great help, if the afforestation programme is accelerated and positive steps to control grazing on the slopes, which are prone to soil erosion, are taken up. An extensive social forestry programme will effectively check the pressures on denudation of the available forest cover. This would ultimately help to retain vegetal cover and stop nutrient- rich runoff from such areas. Check dams, peripheral bunding, water harvesting structures etc. may be constructed to control soil erosion.

3. **Flushing and increase in water circulation**: Proper flushing and circulation of water may be maintained by operating the Ithai barrage base on an appropriate policy. Proper water management plan may be developed for the lake, which is quite essential for the restoration of Loktak lake ecosystem.

4. **Treatment of sewage**: In many countries the major pollution problem is associated with the discharge of untreated municipal wastewaters. Loktak lake also receives untreated municipal and domestic sewage from the Imphal and Bishenpur areas. An improved sanitation and waste disposal mechanism needs to be initiated. Treatment of waste water may be given to the most polluted rivers like Nambul, Nambol, Moirang etc. For the islands and the *Phum* Hut dwellers, a proper effluent disposal system may be designed and built.

5. ***Phumdis* and weeds control**: Effective measures may be taken up to control the menacing growth and proliferation of *phumdis* and aquatic weeds. Both manual and mechanical methods may be employed for deweeding. Inflow of nutrients and practice of *athaphum* fishing may be reduced in the lake.

6. **Enhancement of fish diversity and yield:** The fish diversity and yield may be enhanced through restocking by operation of hatcheries, strengthening of traditional fish farms, promotion of improved harvesting and post-harvesting structures and implementation of pen/cage culture. The water quality needs to be improved by increasing water circulation and reducing the inflow of pollutants.

7. **Habitat improvement of Keibul Lamjao National Park (KLNP)**: The population of the highly endangered brow antlered deer, *Cervus eldi eldi* locally known as *Sangai*, is threatened due to the changes in habitat characteristic of KLNP. A long term management plan has to be developed integrating the hydrological, ecological and socio-economic aspects in order to conserve this highly endangered specie and its habitat.

8. **Awareness and education programmes**: In conservation and management of any lake, participation of local communities is quite necessary. In fact no conservation programme is successful without cooperation of communities. Therefore, proper awareness and education programmes may be given to the local communities.

9. **Monitoring of lake environment:** A meaningful interpretation of the causes and mechanisms of deterioration in the lake is only possible, if periodic surveys of different ecological aspects are carried out. This emphasizes the need to monitor the lake's environment on a regular basis. Base line data may be collected systematically for planning and management of the lake. Further, monitoring of lake ecosystem would also assess the efficacy of control measures put into operation for the conservation of the lake.

Conclusion

From the above discussion it is clear that Loktak lake has rich bioresources and plays very important role in the ecological and economic security of the people of Manipur. However, the lake is experiencing severe environmental stress and serious habitat degradation especially in the northern and southern zones of the lake due to various anthropogenic activities. The consequences of increasing nutrient load are apparent, through deterioration of water quality characteristics and symptoms of eutrophication with prolific growth of aquatic weeds and *phumdis*. Direct discharge of untreated human wastes from the *phum hut* dwellers and settlements in and around the lake has further aggravated the nature and extent of eutrophication. Proliferation of *phumdis*, siltation and human encroachments have combined with natural processes to reduce the area of open water within the lake. At present, the condition of the lake has reached a critical stage from the ecological angles and if proper conservation measures are not taken, the lake is likely to deteriorate further. However, establishment of a Lake Development Authority and notification of the Manipur Loktak Lake (Protection) Act, 2006 may be considered as major steps taken by the state government towards promoting sustainable management of the lake.

The various measures proposed for the conservation of the lake include afforrestation of the catchment area, control of land reclamation and other encroachments, flushing and increase in water circulation, treatment of sewage with improved sanitation and waste disposal programme, control of *phumdis* and aquatic weeds, enhancement of fish diversity

Mitre, Vishnu, Prasad, K. V. and Guha, P. K. 1986. Technical report by members of multidisciplinary survey of the Loktak Lake submitted to the Government of Manipur in 1981.

Munawar, M. 1970. Limnological studies on freshwater ponds of Hydarabad, India. II. The biocoenose. Distribution of unicellular and colonial phytoplankton in polluted and unpolluted environments. *Hydrobiologia.*, 36: 105 - 128.

Ningombam, B. and Bordoloi, S. 2007. Amphibian fauna of Loktak, Manipur, India with ten new records for the state. *Zoos Print Journal*, 22(5): 2688 - 2690.

Romi Singh, T. 2002. Loktak Lake fisheries and the role of Phumdis. In *Management of Phumdis in Loktak Lake*, (eds Trisal, C.L. and Manihar, Th.), Wetlands International South Asia and Loktak Development Authority Publication, pp. 22 - 23.

Sanjit, L., Bhatt, D. and Sharma, R.K. 2005. Habitat heterogeneity of the Loktak lake, Manipur. *Current Science*, 88 (7): 1027 - 1028.

Schindler, D.W. 1974. Eutrophication and recovery in experimental lakes: Implication for Lake Management. *Science*, 184: 897 - 899.

Sharma, B.K. 2007. Notes on rare and interesting rotifers (Rotifera: Eurotatoria) from Loktak lake, Manipur – a Ramsar site. *Zoos Print Journal*, 22(9): 2816 - 2820.

Shyamjai Singh S. 2002. Vegetatioin and Phumdi of Keibul Lamjao National Park. In: C. L. Trisal & Th. Manihar (Eds.), *Management of Phumdis in Loktak Lake*, Wetlands International South Asia and Loktak Development Authority Publication: 29 - 36.

Shyamananda, R.K. 1991. Study of nutrient enrichment in Loktak lake with reference to biological indices. Ph.D. Thesis , Manipur University.

Singh, Th. M. 1999. The role of LDA in the management of Loktak Wetland. In: R.K. R. Singh & H.P. Sharma (Eds.) *Wetlands of Manipur* (Vol. 1), 53 - 60.

Tombi Singh, H. 1992. Study of wetlands ecosystem of Manipur valley from management perspectives of fish, wildlife and environment. *Final Technical Report*, Department of Science Technology and Environment, Government of Manipur.

Tombi Singh, H. and Shyamananda Singh, R.K. 1994. *Ramsar Sites of India, Loktak Lake, Manipur*. World Wide Fund for Nature and Natural Resources, New Delhi, 69 pp.

Trisal, C.L. and Manihar, Th. 2002a. Management of Phumdi in the Loktak Lake. *Loktak: Newsletter*, 2: 1 - 5.

Trisal, C.L. and Manihar, Th. 2002b. Management of phumdis in the Loktak lake. In *Management of Phumdis in Loktak Lake*, (eds Trisal, C.L. and Manihar, Th.), Wetlands International South Asia and Loktak Development Authority Publication, pp. 1 - 6.

Trisal, C.L. and Manihar, Th. 2004. *Loktak - The atlas of Loktak*. Wetlands International and Loktak Development Authority, New Delhi.

Trivedy, R.K. and Goyal, P.K. 1986. *Chemical and biological methods for water pollution studies*. Environmental Publication, Karad, 248 pp.

2

Current Status and Fisheries Enhancement of Rudrasagar Lake in Tripura

—*S. Munilkumar*, A. Paul* and *A. Dey*

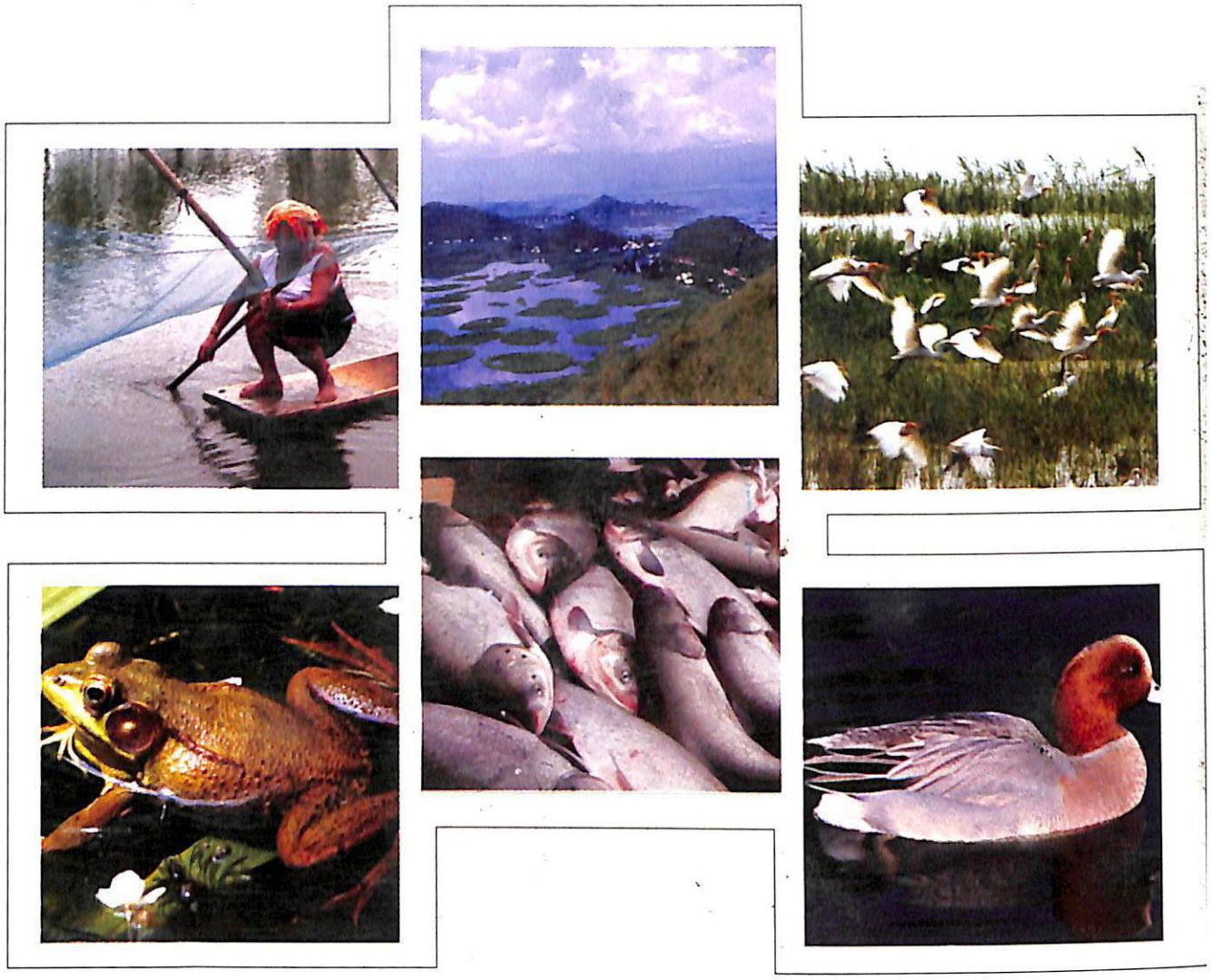
[The Rudrasagar lake is a Ramsar site located in Tripura, a northeastern state of India. It has always been one of the famous tourist spots in the state. Responsibility of managing the lake lies with the state fisheries department. The lake had been leased out to a fishermen's cooperative society. The society generates revenues through issuing of rights for fishing in the lake, cultivation of surrounding areas and running of tourist boats. The lake itself is in the process of autogenic succession and various factors like increasing silt loading due to deforestation, expansion of agricultural land and intensive farming, and settlements forever increasing human population, are exerting enormous pressure on the lake ecosystem. Unless some urgent management measures are taken up, the lake, which has lot of socioeconomic importance, faces uncertain future. In this chapter, the current status of the lake has been discussed along with some issues related with fisheries development in the lake.

Key words: Rudrasagar, Tripura, ecology, water quality, fisheries.]

Introduction

Tripura, one of the northeastern states of India, is situated between latitude 22°56′ and 24°32′ N and longitude 90°12′ and 90°21′ E. The drainage systems are Khowai, Dhalai, Manu, Jari and Longai rivers in the north, Gumti and Howra rivers in the east, the tidal rivers of Fenny and Muhuri in the south east, mixing the Bay of Bengal through Bangladesh. The Gumti is the largest river flowing from east to west direction. Temperature ranges between 35-40° C during summer and 10-15° C during winter, with 70-85% humidity

**College of Fisheries, Central Agricultural University, Lembucherra, Tripura West - 799 210.*
Present address: *Central Institute of Fisheries Education, Versova, Mumbai - 400 061 (India).*



Rs.2,500/-

ISBN 978-81-8370-187-7

9 788183 701877

AKANSHA PUBLISHING HOUSE

4649-B/21, Ansari Road, Darya Ganj, New Delhi-110 002 (INDIA)

Tele/Fax : 011-23263193 E-mail : ektabooks@yahoo.com

www.akanshapublishinghouse.com