CHAPTER II

Review of literature

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Studies on lakes have been made since a very long time as water is a vital resource for all kinds of living organisms. It is a medium for life processes, and source of nutrients and oxygen to the atmosphere. The global water cycle disruption is the fundamental cause of human disturbance. Changes in land use/cover and enhanced green house warming are recognized as critical factors governing future availability of fresh water. Lake ecosystems are linked to other ecosystems in the lithosphere and this linkage depends entirely on drainage basin. A number of ecosystems such as marshy land and lake interact with each other based on drainage basin in relation to its biochemistry and metabolism forming 'ecocomplexes'.

Geohydro-ecology

Monitoring of the drainage basin and its interaction with land use components is very much important for understanding the functional aspects of a lake or any aquatic body. Rawson (1939) gave a constructed diagram to display the multitude of factors that interact with lake. Aquatic ecologists have a rich history, including landscape perspective and theories about lakes. The landscapes and their its geology provide critical insights into differences among lake types that led to trophic classification (Wetzel 1983). Klinger and Erickson (1997) have undertaken the coupling of the terrestrial and marine ecosystem. Kratz *et al.* (1997) provided an intriguing demonstration within the regional flow regime which can affect physical, biological and chemical properties of lakes. Lake ecosystems are

intensively coupled with and dependent on their geological and morphological situation, on the climatic factors during their development, on the state and type of drainage area, and on the amount of sediments and nutrients washed into the waters. Vegetation composition, structure and its association in the drainage basin has been an important attribute for the management of an aquatic ecosystem. The role of forests as filter for the nutrients and sediments has been well explained by Edward (1988). Anderson and Hobba (1959) concluded that vegetation exploitation increases floods from the watershed and the peak discharge decreases as the forest regrows. The studies on the hydro-ecological characteristics including the slope, land use practices and the vegetation composition are important to identify the threats that pose detrimental effect on the aquatic water bodies and their longevity. The work undertaken by Bren and Turner (1979) and Waring *et al.* (1981) gave an insight account on soil losses from the system along with overland flow. The partitioning of the precipitation into various pathways is important in hydrological cycles and it has been well explained by Kimmins (1973). Reports on sediment flow to the aquatic water bodies are available (Milliman and Meade 1983). Brooks and Peter (1995) have taken up the integrated watershed management approach. The biomass and productivity potential of the temperate forest (Rodin and Bazilevich 1967), ecosystem productivity (Binkley and Arthur 1983) and age pattern of trees and occurrence of opportunistic species due to environmental conditions (Wilson 1991) are well documented.

There has been a growing interest among the common people, planners and researchers about the importance of understanding physical,

chemical and biological attributes on functioning of drainage in view of the proper management strategies for catchment areas (Sharma *et al.* 1998). The factors leading to depletion of the mountain ecosystem need corrective measures through identification of various resources, their utilization pattern, consequences and quantification of the extent of the problems through scientific planning and measuring the nature, extent and characteristics of resources depletion (Sharma and Dixon 1995). A multidisciplinary integrated approach towards watershed management was tried in Kali river watershed of the central Himalaya (Burman 1991). The rate and volume of river sediment delivered to wetlands depend partly on the erodibility of the upland basin and in part on the magnitude and frequency of precipitation and there is several fold acceleration in the runoff if the watershed is disturbed (Ambasht 1996, 1998). Gupta (1983) has estimated the total annual flow of water from the Himalaya to the plain. The Himalayan mountains having poor forest cover, steep slopes and human related activities contributes a huge amount of runoff water and sediment load in the rivers, streams and lakes of Indian subcontinent. The importance of ground vegetation in protecting the top soil removal has been well stated by Melkania and Singh (1989) and Ambasht (1996). The species composition, forest structure, regeneration and the biomass production have been studied by numerous workers (Ralhan *et al.* 1982; Negi *et al.* 1983; Saxena and Singh 1982; Singh and Singh 1984; Saxena *et al.*1984; Sukhla and Ramakrishnan 1984; Khan and Tripathi 1987; Singh and Singh 1987; Rawat and Singh 1988; Sundriyal and Bisht 1988) in the central Himalaya. Similar work has also been undertaken in the Sikkim Himalaya by Sundriyal *et al.* (1994) and Sundriyal and Sharma

(1996). Investigations on the forested watershed dealing with ecological aspect with overland flow, nutrient loss and throughfall precipitation have been done by Pandey *et al.* (1983), Pathak (1983) and Singh *et al.* (1983). The hydrology of a high altitude forest in the central Himalaya has been studied by Negi *et al.* (1998). Bio-geochemical studies in lesser Himalayan lakes have been carried out by some workers (Das *et.al.* 1995, 1998; Singh and Das 1995).

Ecological impacts are quiet apparent in the watershed level due to utilization of natural resources and their integration with socio-economic demands which revealed the stresses on the resources (Sharma *et al.* 1992, 1998). The sediment accumulation through ^{210}pb method was studied by Das and Singh (1994) and in Kumaon lakes by Das *et al.* (1994). Natural resource management using watershed approach in the Mamlay watershed of South Sikkim provided a new dimension of management in the hills (Sharma *et al.* 1992). Sundriyal and Sharma (1996) emphasized the need of identifying the optimal level of forest resources for sustainability. Extensive works on the hydrology on watershed approach in the Mamlay watershed of South Sikkim has been undertaken by Rai and Sharma (1998a, 1998b).

Limnology

Lakes are classified as tropical, subtropical, temperate, sub polar and polar lakes (Forel 1892; Yoshimura (1936). Hutchinson (1957) developed detailed classification systems for the origin of lakes. Extensive studies on the water quality of closed basin (Plass 1975; Tundisi and Saijo 1997) are well documented. The biogeochemistry of a cirque lake has been well

studied by Michael *et al.* (1997). European lakes are classified into different trophic classes in relation to the planktonic biomass (Vollenweider 1968) and comprehensive study of the dystrophic ecosystem has been carried out (Schalles 1989; Schalles and Shure 1989). The inland aquatic ecosystems comprise less than 1% of the earth surface, but often are among the most productive areas. Many of these water bodies have undergone dramatic change which is beneficial to man for short term but in the long run it has been detrimental in various ways and has reversed effects (Likens 1975). The phytoplankton community is the most widely distributed primary producers on our planet. The potential habitat for the phytoplankton covers 70% of the earth's surface and has maximum vertical extent of ca. 200 m. Nevertheless, oceans contribute only 30 to 50% of the global primary production (Koblentz-Mischke *et al.* 1970; Parsons *et al.* 1984). The model for the eutrophication with reversible and irreservible change has been given by Carpenter *et al.* (1999). A major challenge of ecology is to determine the degree to which primary producers are controlled by consumers or resources that are available in the system (Carpenter and Kitchell 1992; Strong 1992; Michael *et al.* 1997; Vanni and Findlay 1990; Vanni and Layni 1997). The food chain has strong linkages with trophic status (Newman and Shalles 1990).

Indian civilization is closely linked with rivers, lakes and ponds. Some of the large lakes and man-made reservoirs of India listed in the 'Wetlands of India Directory' has been published by the Ministry of Environment and Forest (1990). History of the studies on the aquatic life in India can be traced back to 19th century when survey on fish fauna was

made (McClelland 1839; Hamilton 1822). The survey on water quality related with its habitat characteristic and their relationship was discussed earlier by Prasad (1916). The Yale North Indian strengthened the foundation for detailed limnological works (Hutchinson 1933, 1937). The work on limnology took a momentum after the independence but the coupling of the terrestrial and aquatic ecosystems for the lake studies has been only fragmentary. The watershed approach of the studies has not yet become familiar because of the fragmentary and sectoral work done by the various workers. The landscape ecology has not been considered for the lake ecosystem studies, however, huge work has been undertaken on sectoral basis considering the lake and the forest. The linkage part between these two sectors has been missing in various lake studies.

In India the extensive studies on water quality of a closed basin has been done by many workers (Zutshi *et al.* 1972; Kaul 1977; Zutshi and Khan 1977; Zutshi *et al.* 1980; Gopal *et al.* 1981; Purohit and Singh 1981; Rao *et al.* 1982; Pant *et al.* 1985; Trisal 1987; Ishaq and Kaul 1988; Gopal *et al.* 1988; Kaul 1989; Lakher *et al.* 1990; Khuble 1992; Gopal and Sharma 1994; Joshi and Sundriyal 1995; Kundangar and Sarwar 1997; Jana 1998). Comparative studies on lakes and reservoirs of India with those in other tropical countries are reported by Serruya and Pollingher (1983). The lake ecosystem with emphasis on Himalyan lakes has been studied by Zutshi (1985). Recently, Jana (1998) has summarized the limnological data for about 60 lakes and reservoirs of India. The aquatic habitats and their biota have been extensively studied since early 19th century, and interest has grown rapidly in recent years due to rising demand for water and fish, and the need for managing the water quality.

Venugopalan *et al.* (1998) has stated the eutrophication processes of lake and fish kill by aquatic birds. The work on biology and population ecology was undertaken by a number of workers (Jana 1973; Murungan and Venkataraman 1977; Jana *et al.* 1980). The aquatic productivity in the fresh water was studied by Sreenivasan (1964) along with limnology and physicochemical parameters and also aquatic biodiversity in number of lakes. Phytoplankton (Zafar 1966; Munawar 1970, 1974; Kaul 1977; Sharma 1980; Pant and Joshi 1987; Mahajan 1989; Sarkar and Jana1995) and zooplankton (Sharma and Pant 1979,1984; Pant *et al.* 1985; Yusuf 1989; and Arunachalam *et al.* 1997) of Indian lakes are well studied.

Transistional zones/environment

Marshy or swampy areas are neither considered fully as aquatic nor terrestrial, and possesses characteristics of both the environmental set up and are often stated as wetlands. The dual properties of wetlands are interesting and researchers are showing increasing interest on their study as they also constitute rich biological diversity. They are universal in occurrence and cover 7 to 8 million km^2 area which is quite less but due to biological productivity they have great ecological and economic importance (Ambasht 1998). Wetlands play critical role in maintaining and improving water quality, mitigating floods, recharging aquifers and providing habitat for fish and wildlife. Historical losses of the wetlands have been large and the remaining areas, even protected from conversion to other land uses, are often subjected to serious development related pressures. Deforestation in surrounding watersheds and impoundments by dams or construction of dikes, alter sediment loads and flooding regimes

(Petts 1984). Mitsch and Gosselink (1993) have studied some marshy lands, which developed into peatlands through various processes. They have given 26 list of common names of different kinds of wetlands. Peatlands exist throughout the world, but particularly in northern temperate and boreal latitudes are common feature of the glaciated landscapes (Curtis 1959; Larsen 1982) and covers about 1% of the earth's surface, or about 150 million hectares, mostly in the former Soviet Union, Canada, and the United States (Moore and Bellamy 1973). Peatlands have developed in northern latitudes around the world since the retreats of Pollen trapped in peat throughout the development of peatlands provides a record of climatic and vegetational change on a worldwide basis. Post glacial archeological information has been uncovered from accumulated peat. People have been found buried and preserved intact, for 2,000 years in European bogs (Godwin 1981). Extensive areas of bogs and fens occur in Scandinavia, Eastern Europe, West Siberia, Alaska, Labrador, Canada and the north-central United States. Canada and Soviet Union have 1 million km^2 out of the total 5 million km^2 of peatland of the world (Moore and Bellamy 1974). Bogs and fens have been well studied and described on a worldwide basis and have been documented by Sjors (1961), Reader and Steward (1972) and Mitsch *et al.* (1994).

In India 32,000 ha of peatland are reported (Bord na Mona 1984) but no detail study has been attempted except the listing of peat forming locations by Scott (1989). A few studies on vegetational history with pollen analysis of some marshy land in India has been undertaken by Sharma (1985) and Sharma and Singh (1974).

Godwin (1978) classified peatlands into two categories of which

one is 'fens' which developed under the influence of mineral rich, aerated ground water dominated by grass like plants mostly sedges and developed into coniferous swamps, and the other is 'bog' which are acid peatlands, poor in minerals and raised above the influence of ground water by the accumulation of sudden anaerobic peat. Development of the bog has long been well understood several decades earlier (Frolik 1941, Dansereau and Segadas-Vianna 1952, Godwin *et al.* 1957, Gorham 1957, Heinselman 1963, 1970, Clymo 1983). Crum (1988) provides an excellent history of the study of bogs in the United Kingdom from a historical and archeological viewpoint. The bog climax hypothesis is well studied by the fossil records and stratigraphic peat evidence by Klinger *et al.* (1990). A study on the successional pattern of the vegetation, which includes the classic hydrosere succession has been done in the western countries by a number of workers (Clements 1916, Frolik 1941, Gates 1942, Conway 1949; Whitford 1949; Kratz and DeWitt 1986). The bog succession through terrestrialization and the paludification has been well explained by Klinger (1996a) in southeast Alaska. The limnology of the wetland (Richardson *et al.* 1978, Schalles 1989) and coupling of soil and vegetation (Klinger 1996b; Christopher and Richardson 1997) are available. The nutrient dynamics of the peatland are important in lake ecosystem (Moore and Bellamy 1974; Forrest and Smith 1975; Kadlec 1976; Davis *et al.* 1978, 1983; Prentki *et al.* 1978; van der Valk *et al.* 1978; Mitsch and Goselink 1993; Proctor 1995). The relationship between primary production and peat accumulation has been explained by several workers (Reader and Steward 1972; Bradbury and Grace 1983; Forrest and Smith 1975; Reader 1978) and particularly the ecology of the

Sphagnum moss by Clymo and Hayward (1982).

Biotic pressure

Water bodies especially the lakes are major attractions for tourists. For recreation all over the world, there are thousands of picnic spots on the margins of lakes where large number of tourists enjoy. Tourism on account of wetlands brings millions of dollars. The pilgrimage and the sacred sites in mountains frequently draw the interest of the trekkers and tourist seeking colorful sights and interesting experiences, not only the beauty of these sites but also the festivals and the biodiversity associated with them are the major tourist attractions (Bernbaum 1997). The environmental impact assessment of the Himalayan belt with special reference to disturbance due to human pressure has been well dealt by Ahmad (1993). With the rapid growth in human population, increase in industrial activity and consequent demand of water, the water bodies both lentic and lotic are becoming increasingly polluted by domestic wastes and agricultural runoff (Gopal and Zutshi 1998). The limnological study gains new impetus with growing realization that large-scale human alteration of landscapes has widespread negative implications for the well being of aquatic ecosystems (Naiman *et al.* 1995). Changes in land use/cover due to increasing human and livestock population and economic development in the mountain regions are becoming central issue of concern in the perspective of global environmental change. Indiscriminate clearing of forest and resource extraction have led to a great loss of biodiversity and depletion of forest resources, thus affecting stream flow regimes (Hamilton and King 1983, 1988). Hamilton and Bruijnzeel (1997)

have analyzed the mountains as the integrated system with biotic pressure. Rai and Sundriyal (1997) has given the positive and negative impact of tourism in the Sikkim state.

Limnological research in Sikkim

Although there are 150 lakes all over the state only preliminary and fragmentary reports on the lakes of Sikkim Himalaya are available (Bhasin 1984; Roy and Thapa 1998a). Tamang (1994) has dealt fish fauna on lotic water bodies of Sikkim. A preliminary attempt on limnological work on Khecheopalri lake has been done by Roy and Thapa (1996, 1998b). Their work is confined to lake nutrient dynamics and listing of few species only. No attempt has been made to understand the lake on a holistic approach considering its support system. The state is still virgin with respect to indepth research in terms of hydro-ecology. Therefore this study was planned to understand the functional roles of watershed uplands, drainage basin and land use practices on the longevity of a sacred lake in west Sikkim ■