Chapter 1
General Introduction

River ecosystems are central elements in the biosphere and form important natural corridors for the flows of energy, matter and species (Malanson, 1993). They are often hot-spots of species richness and thus key elements in the regulation and maintenance of landscape biodiversity (Naiman et al., 1993). Their string-like shape and dendritic drainage pattern mean they are effectively interspersed into the landscape despite their small total area (Nilsson and Jansson, 1995).

Rivers throughout the world have acted as the cradles of civilization. One of the first major human civilizations was nurtured along the river Nile 5000 thousand years ago in the Middle East. The ancient human beings living along river valleys of Euphrates and Tigris, practiced cultivation through irrigation for the first time. It can also be mentioned that the disappearance of river valley civilizations have been partially attributed to changing course of rivers. Due to easy availability of water, human settlements usually developed on or near the river bank which during the course of time became important towns and cities. Water since then has been used for drinking, irrigation, bathing and recreational purposes. Industries too developed near the river banks because of two reasons: the river water could be used for running industries and industrial effluents could be discharged into the river. Eventually, the river began to receive the sewage of the townships with the spurt in population (James and Elizabeth, 1996; Perry and Venderklein, 1996). All these anthropogenic activities have created severe pressure on the natural regeneration capacities of rivers resulting in pollution, habitat degradation and
biodiversity loss. These conditions necessitated studies on rivers with special reference to pollution and the measures to control it. The world literature on scientific studies on river pollution probably dates back to 1847 from rivers Thames and Mersey (Unni, 2003). The industrial revolution and its subsequent effects on rivers was very crucial in Britain and some of the rivers remained as drains for several years until the Royal British Commission recommended the treatment of sewage (Unni, 2003).

The developed and fast developing economies of the world are currently experiencing very extensive problem of water quality not only from the perspective of purification needs for human consumption but also in relation to the recreational use of fresh water either directly by bathing and boating or indirectly via fisheries. Thus declining water quality also constitutes a conservation threat (Malcolm, 1992).

Adequate supply of safe water and basic sanitation are the foundations of health. Water pollution because of poor sanitation is probably responsible for 80% of the morbidity and mortality in the developing countries. It is estimated that over 13 million children die each year in the developing countries and nearly 1/3rd of these deaths are due to diarrheal diseases associated with biologically polluted water. Prevention of such diseases depends on the improvement of the water quality by provision of adequate sanitation facilities and proper waste disposal sites besides personal hygiene (Bewtra and Biswas, 1993).

Thus it can be said that urbanization and industrialization are making the rivers unsuitable not only for the human kind but also for the diverse group of organisms in the river as a result of the degradation of their habitat and ultimately the complete extinction of some species.
Broadly speaking rivers in India are of four kinds (Hosetti and Kumar, 2002).

They are:

1. The Himalayan rivers
2. The rivers of Central India and the Deccan
3. The Coastal rivers
4. The rivers flowing into the interior drainage.

The Himalayan rivers are generally snow fed and continue to flow throughout the year. In their mountain courses they pass through deep gorges. The rivers of Central and the Deccan are generally rain fed and their volume of water fluctuates considerably throughout the year. Coastal streams especially in the west have limited catchment areas. Most of the streams of interior drainage basin are of ephemeral character. They drain towards the individual basin such as salt lakes and have no outlet to sea.

Based on the size of their catchment area the rivers are classified into four categories.

1. Rivers of 20,000 km$^2$ catchment area and above constitute the major group and are 14 in number.
2. Rivers between 2,000 and 20,000 km$^2$ catchment areas constitute medium group and are 44 in number.
3. Rivers with catchment area below 2,000 km$^2$ belonging to minor group are 55 in number.
4. The desert rivers

According to surveys carried on selected stretches of important rivers it has been found that most of the Indian rivers are grossly polluted (Sharma and Kaur, 1997). It is estimated that about 1200 million litre of waste water is released into Ganga from about
27 major cities situated on its banks. At Varanasi it receives the largest amount of biological and chemical filth. About 60 million litre of untreated sewage are dumped into it everyday besides the ashes of about 40,000 human bodies, and about 10,000 incompletely burnt dead human and dead animal bodies (Agarwal et al., 1976). The main sources of pollution of Ganga at Kanpur in U.P. are jute, chemical, metal and surgical industries, tanneries, textile mills and a great bulk of domestic sewage of highly organic nature (Saxena et al., 1996). According to the Central Board for Prevention and Control of Water Pollution (CBPCWP), the biochemical oxygen demand in Ganga has reached upto 9.7 mg l⁻¹ as against the prescribed acceptable limit of 3 mg l⁻¹ (Sharma and Kaur, 1997).

A study conducted by Bhargava (1985) on river Yamuna revealed that water quality of Yamuna was degraded downstream of Delhi, Agra and Mathura. Large scale encroachment along the river embankment along with industrial complexes have been responsible for making the Yamuna water unfit even for irrigation.

Besides Ganga and Yamuna all other major rivers of India such as Gomti (near Lucknow), Damodar (between Bakaro and Panchet, Bihar), Hooghly (Calcutta), Sone (Dalminagar, Bihar), Godavari (Andhra Pradesh), Cauvery (Tamil Nadu), Periyar (Kerala), Mahanadi and Katjori rivers (Orissa) have become giant sewers for the country’s urban population (Sharma and Kaur, 1997).

Despite vigorous efforts, riverine pollution levels have not been reduced substantially (Dudgeon, 1992). Lean et al., (1990) described Indian rivers as open sewers carrying untreated wastes from urban and rural areas to the sea. Of some 3119 Indian towns and cities, only 217 have partial or complete sewage treatment facilities (Mahajan,
Only 12 out of 132 industrial plants discharging directly into the river are said to have waste treatment plants in working order. Some cities along the river like Varanasi lack sewage treatment facilities completely.

In contrast to substantially large volume of data available on the rivers from other regions of India, the north east Indian rivers have not been studied in any detail for their water quality, biodiversity and pollution except for some sporadic studies on different aspects of the ecology of hill streams of Meghalaya (Ao et al., 1984; Gupta and Michael, 1983; 1992; Gupta, 1994, 1995), limnological studies of rivers Haora in Tripura (Bhattacharya and Saha, 1997) and Barak (Rout and Das, 2002; Das, 2002). However, like most of the other rivers of the Northeast, the rivers and streams of Arunachal Pradesh lying in the Indian eastern Himalayan region also remain poorly investigated as far as their ecology is concerned.

Arunachal Pradesh falls under Brahmaputra river system constituted by 10 major river basins viz., Tawang, Kameng, Dikrong, Subansiri, Siang, Sisseri, Dibang, Tirap-Dihing, Lohit and Tisa (Figure 1.1). Among the various river systems in Arunachal Pradesh, River Dikrong and its tributaries is one of the major drainage systems in Papum Pare district (Figure 1.2) of Arunachal Pradesh and is also a major source of usable water. Dikrong river is named after confluence of two main rivers-Pachin and Pare at a place called Doimukh (126m asl) (Figure 1.3). The total length of R. Dikrong is 145 km from its tributary at remotest point to the confluence with Brahmaputra river, out of which its length within Arunachal Pradesh is 113 km and rest 32 km is in Assam. The total catchment area of the river is 1525 km², of which 1250 km² falls in Arunachal Pradesh and the rest 275 km² falls in Assam. In the catchment of Dikrong river light
Figure 1.3. Sampling stations across Dikrong river system
textured unstable soils with the prevalent practice of jhum cultivation makes the entire catchment susceptible to soil erosion and runoff losses. In every monsoon Dikrong carries tremendous amounts of silt, gravel, small boulder and causes flood in some parts of the catchment. This indicates serious threat to soil resources (Arunachalam et al., 1998). Besides the above, various other anthropogenic activities like deforestation in the catchment areas, quarrying of boulders and cobbles, washing vehicles, bathing and washing utensils, defecation along the river bank besides urban runoff especially during monsoon might have lead to tremendous pressure on the Dikrong river which is likely to alter its physico-chemical and biological characteristics both in terms of its water and sediment properties. Such a perturbation might affect the Dikrong river in terms of habitat loss for the aquatic organisms comprising microorganisms like bacteria and fungi, phyto- and zooplankton, periphyton, micro and macro-invertebrate communities, fishes and ultimately the local people who are dependent on this river for their livelihood. The magnitude of such stress conditions can be assessed only after a thorough ecological study and based on the results obtained various management aspects can be taken into consideration so as to prevent its further degradation. Thus considering the importance of R. Dikrong in the life of this area and the swiftness and increasing extent of human-induced environmental damage in addition to the paucity of data on wetland ecology per se, the present study proposes to investigate the ecology of this lotic system, which constitutes one of the major drainage systems in Arunachal Pradesh.

A stream or a river cannot be easily separated from its catchment. Rivers are connected to all parts of their catchments by the movement of water. They are elongated ecosystems carrying water and dissolved and particulate nutrients, organic matter, plants,
microbes and animals downhill. Sometimes they overflow flooding surrounding land and exchanging materials with the surrounding floodplain (Closs et al., 2004). The influence of terrestrial, allochthonous carbon sources from the watershed is important in the benthic river ecosystems (Essington and Carpenter, 2000). According to Davidea et al. (2003) the nature of the spatial variability must be considered to ensure that the full range of soil, landscape, and associated wetness conditions are described. Since the ecological state and performance of an aquatic ecosystem is intrinsically linked with its catchment both structurally and functionally, it is important to know the factors which regulate or control the flow and ecology of aquatic ecosystems. In this regard, three subsections have been selected for the present study i.e., river bank, river bed and river line.

River bank comprises the upland area of the riverine wetland. The nutrients and various pollutants get transported to the lowland areas through erosion during rainy season. Nutrients leave the river bank area through stream flow, subsurface flow, deep seepage i.e. leaching, loss through volatile gases, microbial activities and the harvest of plant and animal products (Lowrance et al., 1985).

River bed is the riparian ecosystem, which in general extends outward from the river or stream channel, include the limits of flooding, and travel into the canopy of streamside vegetation (Sedell et al., 1991). Riparian zones are integrally connected with rivers such that water-borne materials can pass freely into and out of them. Manci (1989) defines the term riparian ecosystem as landscapes adjacent to drainage ways of floodplains that exhibit vegetation, soil, and hydrologic mosaics along topographic and moisture gradients that are distinct from the predominant landscape surface types. Functionally, riparian zones can be defined as 3-dimensional zones of interaction
between terrestrial and aquatic systems (Sedell et al., 1991). In such areas, groundwater table remains near or above the soil for most of the growing season and the dominant vegetation is adopted to wet environments (Zoltai, 1980). Local climate is clearly an important contributing factor (Williams and Feltmate, 1992). The river bed acts as corridors which interact continuously with the surrounding watershed. This area is disturbed both by increased runoff from upland areas which increase stream flow and more directly by runoff and erosion originating on side slopes directly upslope from the riparian system (Books et al., 1998) and it functions in at least two wetland capacities, viz., sediment entrapment and flood water storage (Stolt et al., 2001). Riparian zones are also a source of litter to the streams and rivers they border and the litter inputs to streams in riparian zones aids seed dispersal and primary production in stream ecosystems (Xiong and Nilsson, 1997).

River line consists of the thalweg. It signifies the line of greatest slope along the bottom of a valley i.e. a line drawn through the lowest points of a valley in its downward slope. It thus marks the natural direction of a watercourse. It usually extends about 25m from the river bed. In river line the input of nutrients occurs from two sources- autochthonous source from the sediment itself and allochthonous source from the soil of the upland area or the catchment. The substrate in the river line consists primarily of cobbles, pebbles, gravel and sand besides large boulders especially in the upstream areas.
Diagrammatic illustration showing the three subsections (river bank, river bed and river line) of a watershed

Arranged along elevational gradients river banks often exchange water and dissolved particulate matters through runoff and ground water discharge phenomenon to the lowland area. During the passage through the river bank these substances become part of the complex biogeochemical processes within the riverine wetland, which may lead to chemical transformation with important consequences for the ecological functioning of the whole system (Van Der Peijl and Verhoeven, 2000). So, actions in the catchment area may strongly affect the productivity, nutrient cycling and hence the biodiversity in the lowland areas comprising the aquatic ecosystem in the form of river, lake, floodplain etc.

Thus spatial variability is important to consider when assessing the environmental and ecological functions of a riverine wetland. Many of these functions, such as floodwater storage, traps for sediment, and sinks for various non-point source pollutants are difficult to measure directly. In lieu of direct measurements, soil and landscape properties can be recorded and then related to the potential of the wetland to function in
one or more of these capacities (Maltby, 1987; Federal Interagency Committee for Wetland Delineation, 1989; Kentula et al., 1992). According to Lal (1998), since fluvial processes are governed by watershed characteristics (e.g., slope gradient, length, vegetation cover, soil type and management), controlling erosion and minimizing risk of water pollution require an understanding of hydrologic processes at the watershed scale.

So far a holistic study comprising the structures and function of the riverine ecosystem including the whole watershed has not been done in India as well as in Arunachal Pradesh. Therefore the present study was undertaken with the following objectives:

1. Evaluation of water quality of river Dikrong in the stretch extending from upstream of Sagalee to Karsinghsa.
2. Enumeration and guild composition of macrophytes, phytoplankton, and periphyton.
3. Enumeration and guild composition of zooplankton and benthic macro invertebrate community.
4. Estimation of phytoplanktonic productivity and periphytonic biomass.
5. Study of biomass, productivity and nutrient (N and P) concentrations of macrophytes.
6. Analysis of physico-chemical properties of the river sediment.
7. Analysis of microbiological properties of the river sediment.

All the above objectives would be conducted along a stress gradient imposed by human land use across the river belt. These objectives were based on the hypothesis that no part of a watershed should be considered alone as all the parts are linked (Mishra, 2001). To manage a system one needs to consider all parts as equal and at the relationships of one field to another (Mishra, 2001). The management strategy of
watersheds is constrained by the lack of appropriate baseline data on natural resources in relation to all aspects i.e. biophysical (soil, terrain, vegetation, climate, drainage), socio-economic (farm size, land tenure, education, health, access to market, credit facilities, availability of inputs) and culture. Once the baseline is established the impact of land use on natural resources including the aquatic systems like lakes and rivers can be quantified and accordingly suitable management practices can be prescribed.

The data pertaining to the above objectives were collected from field surveys and laboratory experiments. In order to explore the status of river Dikrong the investigation was carried out through the characterization of water, sediment and soil to establish some remedial measures. The present thesis is an attempt to ensure information concerning the riverine ecosystem and its surrounding landscape and the likely impact of the different land use alternatives on the structural and functional values of the riverine ecosystem lying in the north eastern region of Arunachal Pradesh. The present study, therefore, represents a base line data on the ecology of the Dikrong river system in relation to various ecological attributes of catchment areas in the foothills of Indian Eastern Himalayan region in Arunachal Pradesh.