Rivers, watersheds and aquatic ecosystems are the biological engines of the planet.

World Commission on Dams (2000)

All life depends on water. Terrestrial as well as aquatic biodiversity is dependent on water networks and their flow characteristics. Inland waters and freshwater biodiversity constitute a valuable natural resource in economic, cultural, aesthetic, scientific and educational terms. The goods and services provided by freshwater ecosystems include (i) water supply: for drinking, cooking, washing and other household uses; for manufacturing, thermoelectric power generation and other industrial uses; for irrigation of crops, parks, golf courses, etc., for aquaculture, (ii) supply of goods other than water: fish, waterfowl, clams, mussels, other shellfish, crayfish, and (iii) non-extractive benefits as maintenance of biodiversity, flood control, transportation, recreational swimming, boating etc., pollution dilution and water quality protection, hydroelectric generation, bird and wildlife habitat, enhanced property values (Postal and carpenter, 1997; Poff et al., 2002). However, of all the world's global ecosystems, freshwater ecosystems may well be the most endangered ecosystems in the world. Declines in biodiversity are far greater in freshwaters than in the most affected terrestrial ecosystems (Sala et al., 2000) and if trends in human demands for water remain unaltered and species losses continue at current rates, the opportunity to conserve much of the remaining biodiversity in freshwater will vanish before the United Nations' ‘Water for Life’ decade ends in 2015. The main reason which makes freshwater habitats and the biodiversity that they support especially vulnerable to human activities and environmental change is the disproportionate richness of inland waters as a habitat for plants and animals. Over 10,000 fish species live in freshwater (Lundberg et al., 2000); which is approximately 40% of global fish diversity and one quarter of global vertebrate diversity. When amphibians, aquatic
reptiles (crocodiles and turtles) and mammals (otters, river dolphins and platypus) are added to this freshwater fish total, it becomes clear that as much as one third of all vertebrate species are confined to freshwater. Yet surface freshwater habitats contain only around 0.01% of the world’s water and cover only about 0.8% of the earth’s surface (Gleick, 1996).

A stream is a body of water that carries rock particles and dissolved ions and flows down slope along a clearly defined path, called a channel. Thus, streams may vary in width from a few centimeters to several kilometers. Streams are integrated flowing systems that create and maintain aquatic habitats within the structure of their flow as well as on and below their wetted boundaries. Flowing freshwater environments are called lotic (lotus, from lavo, to wash) for obvious reasons of unidirectional water movement along a slope in response to gravity. The unidirectional movement of water is a fundamental property of lotic ecosystems (Wetzel, 2001). Streams are open systems characterized by a high level of heterogeneity across a range of spatio-temporal scales (Ward, 1989). Four dimensions are recognized: (i) longitudinal dimension: along the direction of flow from source to estuary, (ii) lateral dimension: the system composed of the main channel and floodplain, (iii) vertical dimension: the interactions between river water and groundwater in the surrounding area, and (iv) temporal dimension: processes such as succession and rejuvenation. Longitudinally rivers are divided into three zones: headwaters, transfer and deposition zones (Schumm, 1977).

Streams and rivers are the arteries of the landscape, integrating the impacts of change in atmospheric and terrestrial systems and delivering these to the coast. En-route geomorphological processes create dynamic and diverse habitats, both in-stream and in riparian and floodplain environments (Petts and Amoros, 1996). The dynamics of channel change have led to conflict with human resource development with the outcome that many river and riparian environments have been significantly modified and damaged (Brookes and Shields, 1996). Responses to change in driving variables (runoff regime and sediment loads) have become dampened or prevented through river maintenance (Sear et al., 1995), while in other circumstances, land use and land management changes, coupled to more efficient drainage networks may have increased system sensitivity to environmental change (Newson and Leeks, 1987; Robinson, 1990). Flowing waters or lotic systems are not simply conduits for water, plant nutrients and organic matter obtained from land and conveyed downstream to
nourish lakes and wetlands. Nor are they flowing lakes. Rather, they are complete ecosystems intimately coupled with their drainage basins. Lotic systems reflect the climate, as well as geomorphology and land use of their drainage basins. Catchment and stream characteristics help structure stream communities and determine their productivity. The stream biota, in turn, has a major impact on the processing of autochthonously and allochthonously produced organic matter and consequently, on the release rate, timing of release, and form of organic matter and plant nutrients exported to the receiving lakes or wetlands. Streams are characterized by a continual downstream movement of water, dissolved substances, and suspended particles. These components are derived primarily from the drainage basin or watershed. Thus the hydrological, chemical and biological characteristics of a stream reflect the climate, geology and vegetational cover of the drainage basin (Hynes, 1970; Oglesby et al., 1972; Whitton, 1975; Likens and Bormann, 1995).

In every respect, the valley rules the stream.

H.B.N. Hynes (1975)

Rivers are being increasingly investigated from a landscape perspective, both as landscapes in their own right (Wiens, 1989; Ward, 1998; Robinson et al., 2002) and as ecosystems that are strongly influenced by their surroundings at multiple scales (Schlosser, 1991; Allan et al., 1997; Fausch et al., 2002; Townsend et al., 2003). River ecologists have long recognized that rivers and streams are influenced by the landscapes through which they flow (Hynes 1975; Vannote et al., 1980). However, a landscape perspective of rivers continues to evolve, owing both to the emergence of landscape ecology as a field of study (Wiens 1989; Turner et al., 2001) and to an increased focus on catchment-scale studies by freshwater ecologists. Landscape ecology places particular emphasis on habitat heterogeneity, connectivity, and scale, all of which have received considerable attention in running waters (Allan, 1995). However, most of the earlier work has been conducted at small spatial scales, often within stream reaches of a few hundred meters and their immediate surroundings; less consideration has been given to the importance of larger spatial units. Our current understanding of rivers, as with other ecosystems, increasingly incorporates a conceptual framework of spatially nested controlling factors in which climate, geology, and topography at large scales influence the geomorphic processes that shape channels at intermediate scales and thereby create and maintain habitat important to the biota at smaller scales (Allen and Starr 1982; Frissell et al., 1986;
Snelder and Biggs, 2002). Recognizing that rivers are complex mosaics of habitat types and environmental gradients, characterized by high connectivity and spatial complexity, riverine landscapes increasingly are viewed as “riverscapes” (Schlosser, 1991; Fausch et al., 2002; Ward et al., 2002), a unit that is amenable to study over a wide range of scales from a braided river and its valley (Tockner et al., 2002) to small habitat patches (Palmer et al., 2000). The study of rivers in an ecosystem perspective has been recognized as the most interdisciplinary among the areas of aquatic ecology. As Hauer and Lamberti (2007) put it that: “…no other area of aquatic ecology requires a more interdisciplinary approach than stream ecology. Geology, geomorphology, fluid mechanics, hydrology, biogeochemistry, nutrient dynamics, microbiology, botany, invertebrate zoology, fish biology, food web analysis, bioproduction, and biomonitoring are but a few of the disciplines from which stream ecology draws…. “.

During the past several decades, river ecosystem concepts have been developed to describe the functioning and structure of natural, undisturbed rivers (Lorenz et al., 1997). Many descriptive studies of biological communities in small streams (Minshall, 1981; Cummins et al., 1995) and more holistic concepts recognized that stream biota are influenced by the surrounding landscape (Vannote et al., 1980; Allan et al., 1997). The development of the River Continuum Concept (RCC) by Vannote et al. (1980) has been recognized as an important step in river ecology, as it was the first attempt to describe both the structural and functional characteristics of stream communities along the entire length of a river. This concept was developed specifically in reference to naturally undisturbed river ecosystems in North America. The RCC argues that the biotic stream community adapts its structural and functional characteristics to the abiotic environment, which presents a continuous gradient, from headwater to river mouth and is expressed by the source and distribution of organic matter and macroinvertebrate functional feeding groups.

The all-important feature of river ecosystems for the biota they contain and the ecosystem processes that occur within them is that they flow in one direction, by gravity, from source to sea. This theory (Statzner and Higler, 1986) distinguishes a zonation pattern of benthic fauna in which the distinct changes in species assemblage are often linked to transition in stream hydraulics. Stream hydraulics is determined by the geomorphological and hydrological characteristics of the river, such as flow velocity, depth, substrate roughness and surface slope. These determine local
conditions which in turn influence local community structures and ecosystem processes (Petts and Calow, 1996).

The four-dimensional concept presented by Ward (1989) introduced the temporal scale. Upstream-downstream interactions constitute the longitudinal dimension, as expressed by the longitudinal gradient or the RCC. The lateral dimension includes interactions between the channel and riparian/floodplain systems. Significant interactions also occur between the channel and contiguous groundwater, the vertical dimension through the hyporheic zone (sub-benthic habitat of interstitial spaces between substrate particles in the stream bed). The fourth dimension, time, provides the temporal scale. Lotic ecosystems have developed in response to dynamic patterns and processes occurring along these four dimensions.

Disturbance defined by Stanford and Ward (1983) as “any stochastic event which forces normal system environmental conditions substantially away from the mean”, has been regarded as playing a central role in determining the structure of stream communities (Stanford and Ward, 1983; Reice, 1985; Robinson and Rushforth, 1987; Resh et al., 1988; Palmer et al., 1992; Lake, 2000; Matthaei and Townsend, 2000). It also has important practical implications for the maintenance of biodiversity, of which species richness is the most basic component (Townsend and Scarsbrook, 1997). It appears that intermediate level of disturbance induced by the flooding regime may lead to higher levels of alpha and beta diversity (Ward, 1998). However, according to Death (2002), there appears to be no widely accepted model that can be used to predict a link between diversity and disturbance, nor is there much understanding of the mechanisms behind that relationship.

Given these insights in stream ecology as highlighted above a need was felt to start work in this direction in the valley of Kashmir, of which water is arguably the most important resource. The present study is hoped to be at least a starting point in this direction. Kashmir valley, paradise on earth, lies between 33° 20’ and 34° 54’N latitudes and 73° 55’ and 75° 35’E longitudes and covers an area of 15,948 km². Topographically, it is a deep elliptical bowl-shaped valley bounded by the lofty mountains of the Pir-Panjal Range in the South and South-West and the Greater Himalayan Range in the North and East, with 64% of the total area being mountainous. The valley is an asymmetrical fertile basin, stretching from South-East to North-Westerly direction. Its diagonal length (from South-East to North-West corner) is 187km, while the breadth varies considerably, being 115.6km along the
latitude of Srinagar (Kaul, 1977). The altitude of the valley floor at Srinagar is 1,585 m a.s.l. and the highest peak among its surrounding mountains is that of the Kolahoi or ‘Gwashibror’ with a height of 5,420 m. Traversing the valley is the River Jhelum and its tributaries. The Jhelum (also called Vitasta/Vyeth) has been and continues to be the key element of the ecosystem of Kashmir. Kashmir is indeed the gift of the Jhelum. It is born of it, made up of the material brought down by its numerous tributaries; and is united with it through every fibre of its being (Raza et al., 1978).

The Jhelum and a host of streams that drain the bordering mountainous slopes together constitute the drainage network of Kashmir valley. The right bank tributaries to River Jhelum include: (i) Sandran (ii) Bring (iii) Arapat (iv) Liddar (v) Arapal (vi) Harvan (vii) Sind (viii) Erin (ix) Madhumati (x) Pohru and (xi) Viji-Dakil and the left bank tributaries include (xii) Vishav (xiii) Rembiara-Sadara (xiv) Romshi (xv) Doodhganga-Shaliganga (xvi) Sukhnag-Ferozpura and (xvii) Ningal (Pandit, 2002).

Kashmir Himalaya, which is well known for its freshwater resources viz., streams, rivers, lakes, wetlands, springs etc. the world over, has of late seen a deterioration of its precious water resources. For long, studies have been focused on the lakes and wetlands with only a few studies on lotic systems. In view of the paucity of knowledge there is an urgent need to conduct rigorous studies on lotic ecosystems using the state of the art knowledge of river ecology and allied sciences.

The present study, therefore, in an ecosystem perspective, has been conducted on “Doodhganga Stream” which is one of the principal tributaries to the river Jhelum in the Valley of Kashmir. The conceptual model which was followed in the present study focuses on the links which connect streams with their catchments (Fig.1.1). The model emphasizes that the watershed (drainage basin) and reach scale factors influence the conditions in streams which in turn influence the life histories and biotic interactions of organisms living in them and thus on long term basis these factors together shape the biotic communities in streams.
1.1. AIMS AND OBJECTIVES OF THE STUDY

The main aims and objectives of the present study on Doodhganga stream were:

1. To characterize the general drainage basin and the riparian corridor of the stream.
2. To work out the hydrology and geomorphology of the stream.
3. To work out the physico-chemical limnology of the stream.
4. To work out the composition, dynamics, longitudinal zonation and productivity of periphyton and their use as bioindicators.
5. To work out the macroinvertebrate composition, dynamics, longitudinal zonation, functional feeding groups in relation to the River Continuum Concept (RCC) and their use as bioindicators.
6. To understand how the stream physical, chemical and biological aspects reflect the characteristics of the drainage basin in the spirit that “in every respect the stream reflects the valley (drainage basin)”. 

Figure 1.1. Conceptual model of watershed influences on aquatic habitats and biota (Karr, 1991)