Chapter 1

General Introduction
1.1. Introduction

Ecology is a new and exceedingly complex field of study, even though its concept was recognized by the Apostles in their use of the phrase ‘all flesh is grass’. Basically it is a quantitative science and is defined as the study of interrelationships among organisms and the interrelationships of organisms with their non-living environments. The environment includes all physical and biological variables affecting a population, including interactions between the individuals of a population and between individuals of different species. Ecology is usually considering as a branch of biology due to its complex relationship with physiology, population genetics, evolutionary biology but it is also an integration of the biological sciences with the earth sciences such as Oceanography and Geology and is a unifying concept of how life exists on our planet (Poole, 1974).

Aquatic ecology is a multidisciplinary science with no clear boundaries among the many contributing sciences. And it is, in some ways, more complex than terrestrial ecology, because most other systems that have well-defined boundaries, within which community-ecosystem interactions occur while stream and rivers are highly integrated with the adjacent landscape and are influenced by processes within the riparian corridor and the basin as a whole (Cowx and Welcomme, 1998). Moreover, in aquatic ecosystem both communities and environmental units tend to be in a permanent state of turbulent flux (Poole, 1974). Comprehensive assessment of aquatic ecosystems starts with an evaluation of habitat quality (Plafkin et al.1989). In its broadest sense, the term habitat defines where a species lives without specifying resource availability or use (Cowx and Welcomme, 1998). Habitat diversity is a more useful term than that of ecosystem diversity since habitats are easy to envisage. Furthermore, habitats often
have clear boundaries. So habitats have been termed as “template for ecology” (Southwood, 1977).

Well over a decades ago, the fishery and natural resource agencies began adopting a habitat-based approach to impact assessment and resource inventory, and habitat now forms the basis of species conservation and management, mitigation, planning and environmental regulation. In comparison to population-based management, habitat has the advantages of being relatively stable through time and habitat is easily defined in intuitive physical terms and provide a tangle resource for negotiations and decision making. However, the validity of habitat-based management rests on a precise definition of what constitutes a species habitat, and accurate quantification of habitat quality (Bain and Hughes, 1996). Physical habitat or abiotic variables are believed to influence both the occurrence and biomass of fishes in stream systems, but these relations are not well understood for most species (Hubert and Rahel, 1989). The physical environment selected by fish depends mainly on geological, morphological and hydrological processes that influence riparian vegetation and form a mosaic of stream channel and floodplain habitats (Keim and Skaugset, 2002). The potential capacity of a stream reach or stream segment to support a rich fish community depends on the habitat complexity. Fish species composition, abundance and age class structure of a specific population are determined by the organization, diversity and structure of the physical stream habitat (Cowx and Welcomme, 1998).

The biotic diversity and natural characteristic of fish communities are directly related to the variety and extent of natural habitats within a river basin. Consequently, a stream ecosystem has to have a complex habitat structure to maintain a healthy and diverse fish community (Cowx and Welcomme, 1998). Habitat is the principal determinant of biological potential of a stream and, as such, can be used to predict
biological conditions, particularly the presence and abundance of fish (Gorman and Karr 1978; Plafkin et al. 1989; Rankin 1989). On this basis the Conservation International (CI) developed the Rapid Assessment Programme (RAP) to provide information necessary to develop a rational conservation management strategy for a particular area. In a review by WWF, IUCN and UNEP on ways of conserving genetic diversity of freshwater fish it was recommended that the best way to conserve species diversity is to conserve habitats (Naiman, 1991).

The convention on Biological Diversity was negotiated before the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. Over 175 countries are now part of this convention which aims at to conserve biodiversity through its sustainable and equitable use. Signatory countries have indicated that they are aware of the general lack of information regarding biological diversity and have agreed to enhance scientific and technological studies to provide the basic knowledge required to implement biodiversity conservation strategies.

On the basis of habitat the biodiversity measures have been divided into alpha diversity (within-habitat), beta diversity (between habitat) and gamma diversity (Landscape diversity). Alpha diversity deals with the species interaction within a habitat (Whittaker, 1960, 1967) while beta diversity deals with the species interactions between habitat or community (Whittaker, 1960). Gamma diversity or landscape diversity is the most complex type of diversity measure and was defined as the mosaic of habitats over larger scales often hundreds of km (Whittaker, 1960; Cody 1986).

There are many reasons why humans should be concerned with biodiversity conservation. Organisms provide a wealth of resources and ecological services that benefit humans. Biotic resources include food, building materials, firewood and medicines. Many organisms bring significant pleasure and humans also have a moral
and ethical responsibility to care for the environment and the variety of life it supports (Osborne, 2000). An estimation of the socio-economic benefits accruing from biological diversity at United States revealed that about 4.5% of the GDP of the nation (approximately 87 billion US dollar per year) originates from the collection and catching of wild species (Keating, 1993). Even if this is the condition in U.S.A what will be the benefit of biodiversity conservation accrued in a biodiversity hotspot like India?

Scientists estimate that over the next 25 years more than a million species of plants and animals will become extinct (Wilson, 1988; Ehrlich and Wilson, 1991; Soule, 1991). The ever-increasing demand for resources in terms of land area (agriculture, urbanization, industry, Leisure) materials (food, construction materials) and energy from an ever-increasing population and the attendant array of harmful effects (pollution, degradation, fragmentation and disappearance of habitats) constitute the greatest threats to the integrity of ecosystems and, consequently, to biodiversity.

National Research Council outlined the five important and widespread human impacts on biodiversity and placed habitat loss and degradation as the prime factors responsible for biodiversity decline. On this basis Solbrig (1991) opined that in order to ensure the maximum quantity and quality of renewable resources for ourselves and our descendants, we must learn to use resources sustainably.

Habitat based approach has following applications in wet land ecosystem studies (1) for the proper understanding and management of human impact on fish diversity (2) to study the relationship between habitat variables and species assemblage structure (3) to quantify the extent of ecosystem degradation (4) to develop the Habitat Suitability Index (HSI) models of individual species (5) to classify the river reaches
based on their physical conditions and instream habitat features (6) to study the habitat quality and biotic integrity of the ecosystems.

1.1 Habitat concept

Fish in rivers depend on undamaged interactive pathways along four dimensions, i.e. longitudinal, lateral, vertical and temporal. The longitudinal pathway refers to the migration of fishes that are very essential for reproduction and rearing of larvae and young fish. The presence of barriers will definitely affect the species composition of fish populations both above and below. This barrier - effect view of the way in which fish communities are distributed in river ecosystems relates to the effect of longitudinal pathways and is connected to the habitat-centered view.

The lateral dimension suggests that the interactions between riparian vegetation and the river channel provide suitable habitats such as inshore zones, connected backwaters and the various types of stagnant water bodies. These habitats serve not only as preferred feeding and refuge areas but also as spawning areas, depending on the fish species.

The vertical dimension refers to riverine groundwater interactions and concerns mainly fish species that bury their eggs in gravel depressions. Habitat requirements of eggs and embryos during incubation in substrate interstices are different from those of fish living in the open water. To ensure the development of the embryo, sufficient water must flow at sufficient depth through the gravel as to supply the eggs and embryo with oxygen and carry away metabolic wastes. Hydrological processes in the groundwater-river exchange play an important role for successful reproduction of lithophilic fish.

In addition to the above three pathways of interactions, the fish community structure is also significantly influenced by the local habitat conditions itself. Fish species
composition, abundance and age class structure of a specific population are determined by the diversity and structure of the physical stream habitat which is contributed by the channel geomorphology, substrate, instream cover and riparian zone conditions.

1.1.1. Channel geomorphology

Based on the landscape, the valley through which the river passing was classified into the following types

Colluvial: Landslides from adjacent hill slopes deliver sediment and organic matter and usually the riverbank is ‘V’ shaped

Alluvial: The sediment is transported only by stream flow and usually the bank is an overhanging type.

Bedrock type: The bedrock valley has little soil and the river bank is mainly formed of bedrock.

A channel reach is a channel segment with relatively repetitions and homogenous sequence of physical processes and habitat types (eg. Homogenous slope, habitat, channel type and riparian features). A river system can be divided into three zones (1) Erosion zone (2) sediment transfer zone and (3) deposition zone.

In erosion zone channel slope is relatively steep and deposition of sediment, if it occurs is localized. The eroding nature of the channel ensures that the substrate particle size is large (cobbles and boulders) and, occasionally the river may be eroded to the bedrock. The steep channel slope and coarse substrate may produce turbulent flow, in which the river reaches may be bedrock, cascade, step pool or pool-riffle type. The sediment transfer zone is a region in which river gradient is reduced so that water and sediment are transported with little net loss or gain. Substrate particle size is dominated by sand and gravel and flow is relatively smooth and unbroken. Usually
the channel reaches in the sediment transfer zone is either pool-riffle, braided, plane
bed type or regime type.

The deposition zone is where the river deposits its sediment load, typically as it
approaches the sea and develops a delta or an estuary. The substrate is dominated by
fine silt and the reach is usually a regime type. Based on the physical parameters such
as channel pattern, channel confinement, gradient, streambed and bank materials the
stream reaches may be classified into following categories (Anon, 2000).

Cascade reach

Cascade reach is characteristic of steepest alluvial channel. A few small pools may be
present but majority of flowing water tumble over and around boulders and large
woody debris.

Pool-riffle reach

The reach characterized by the alternative riffles and pools and is very prevalent type
of reach in alluvial valley of low to moderate gradient. The reach is most commonly
associated with low to midsize streams.

Braided reach

This reach is characterized by numerous grave and sand bars scattered throughout the
channel. This habitat is a sign of water scarcity and degradation. No fish species like
to stay in this habitat.

Regime reach

This reach is very common in low gradient meandering channels (downstreams) with
predominantly sandy substrata. The reach is characterized by deeper areas with very
low or negligible flow rates.

Step-pool reach
Step-pool reach is rare and found only in the upstream reaches. This habitat is formed due to the accumulation of boulders and logs that forms a series of steps alternating with pools containing finer substrata.

**Plane bed reach**

This reach is characterized by long relatively straight channels of uniform depth. Due to the low diversity of channel geographical units no common fish species is available from this reach.

**Bedrock reach**

This reach exhibits little or no alluvial bed material or valley fill and are generally confined by valley walls and lack flood plains.

Plate 1.1 depicts the 7 different types of channel reaches in riverine ecosystems, while the common fish species available in various channel reaches of Kerala rivers are shown in Plate 1.2 to 1.6.

All the 7 types of channel reaches were formed of numerous channel geographical units (CGU) or microhabitats and the percentage occurrence of each type of microhabitat have significant influence on the distribution and abundance of fishes in the respective reaches (Lachavanne and Juge, 1997). The microhabitat for an individual fish is the site where the fish is located at any point in time. The channel geographical units are of the following types.

1. **Fast water**
   1.1. **Turbulant**
      1.1.1. Falls
      1.1.2. Cascade
      1.1.3. Rapids
      1.1.4. Riffle
1.1.5. Chute

1.2. Non turbulent

1.2.1. Sheet

1.2.2. Run

2. Slow water

2.1. Scour pools

2.1.1. Eddy pools

2.1.2. Trench pools

2.1.3. Mid-channel pools

2.1.4. Convergence

2.1.5. Lateral pools

2.1.6. Plunge pools

2.2. Dammed pools

2.2.1. Debris

2.2.2. Landslide

2.2.3. Backwater

2.2.4. Abandoned channel

**Instream cover**

Cover is defined as the structured material (Boulders, logs or stump), channel features (ledges, vegetation) and water features (turbulence or depth) in the wetted channel or within 1m above the water surface that provides hiding, resting or feeding places for fish. The various cover types are of the following.

1. **Turbulence;** It is defined as cover when the water velocity in a stream at a given point varies erratically in magnitude and direction and disrupts reaches with laminar flow.
2. **Woody log**: All the woody debris more than 1 cm of diameter must be recorded along with its length. The woody logs/debris less than 10cm is classified as small woody debris while the woody logs larger than 10cm are classified as large woody debris.

3. **Vegetation**: The vegetation seen in the stream and also overhanging the stream may be calculated and the dominant species may be noted. The vegetation may be classified as emergent, floating, submerged and overhanging.

4. **Depth**: Depending on water transparency provides surface concealment for fish.

5. **Boulder**: Stream substrate particles with diameter more than 256mm provides cover when they create a turbulent white water surface layer, scour out pool or overhang the stream.

6. **Undercut bank**: Stream bank where the base is cut away by the water and overhangs the part of the stream.

**Substrate**

Substrate refers to the bottom material of the water body and it is almost always documented in habitat studies because of the following reasons:

1. The substrate determines the roughness of the stream which influences channel hydraulics.

2. Substrate provides micro conditions needed by many fish species (for spawning).

3. Substrate provides clue to local and water shed influences on stream habitat quality.

Based on the particle size the substrate may be classified into 6 types which are illustrated in Table 1.1.

**Quality of substrate**
The quality of the substrate is determined by delineating the embedness of the substrate. Embedness is a substrate attribute reflecting the degree to which larger particles (boulders, cobble, and gravels) are covered by fines (sand, silt, and clay). Table 1.2 shows the criteria to determine quality of substrate based on the embedness level.

**Riparian zone**: The vegetation on land surface on land adjacent to the normal high waterline of the stream, extending to the portion of land that influenced by the presence of adjacent ponded or channeled water. Based on the water retention capacity, the riparian zone was classified into

- **Hydroriparian**: The soil/substrate is rarely/briefly dry and wet riparian plant dominate vegetation
- **Mesoriparian**: The soil/substrate is dry seasonally
- **Xeroriparian**: The soil/substrate is wet less than one month a year

1.2. Stream classification

A classification of river is an organization of data on stream features into discreet combinations. It has long been a goal of individuals working with rivers to define and understand the processes that influence the pattern and character of river systems. The differences in river systems, as well as their similarities under diverse settings, pose a real challenge for study. One axiom associated with rivers is that what initially appears complex is even more so upon further investigation. Underlying these complexities is an assortment of interrelated variables that determine the dimension, pattern, and profile of the river system. Stream pattern morphology is directly influenced by eight major variables including channel width, depth, velocity, discharge, channel slope, roughness of the channel materials, sediment load, and sediment size (Leopold et al. 1964). Because stream morphology is the product of this
integrative process, the variables that are measurable should be used as stream
classification criteria.

Obivously a classification scheme risks oversimplification of a very complex system.

While the classification of river systems based on channel morphology is essential to
achieve the following objectives

1. Predict a river's behavior from its appearance

2. Develop specific hydraulic and sediment relations for a given morphological
channel type and state

3. Provide a mechanism to extrapolate site-specific data collected on a given stream
reach to those of similar character

4. Provide a consistent and reproducible frame of reference of communication for
those working with river systems in a variety of professional disciplines

The effect to classify streams is not new. Davis (1899) first divided streams into three
classes based on relative stage of adjustment: youthful, mature and old age.

Additional river classification systems based on qualitative and descriptive
demarcations were subsequently developed by Melton (1936) and Matthews (1956).

Simpson and Wolman (1957) divided the streams into straight, meandering and
braided types. Schumm (1963) classified the river stretches based on channel
stability (stable, eroding or depositing) and mode of sediment transport (mixed load,
suspended load and bedload). Culbertson et al. (1967) utilized depositional features,
vegetation, braiding patterns, sinuosity, meander scrolls, bank heights, levee
formation and flood plain types. Thornbury (1969) classified the river stretches as
antecedent, superposed, consequent and subsequent based on valley types. Khan
(1971) developed a quantitative classification for sand-bed streams based on
sinuosity, slope and channel pattern. To cover a wide range of stream morphologies, a
Descriptive classification scheme was developed for Canadian rivers by Kellerhals et al. (1972, 1976), Galay et al. (1973) and Mollard (1973). Schumm (1977) developed a classification system based on sediment transport, channel stability and some physical properties of the river stretches. Based on the physical properties of the river stretches, Bloxam and Blodgett (1978) described four channel types such as braided, braided point-bar, sandbar, and equi-width point bar. Church and Rood (1983) developed a classification system for alluvial river channels. Rosgen (1994) developed a classification system based on sinuosity, entrenchment ratio, w/d ratio, slope and type of dominant substratum in the river reaches after field observation of hundreds of rivers of various sizes in all the climatic regions of North America.

Although fish community analyses have used numerous approaches, analytical procedures for habitat data are still relatively new. Approaches to habitat analysis have involved using habitat indices (Fajen and Wehnes 1982; Plafkin et al. 1989; Rankin 1989; Petersen 1992; Wang et al. 1998; Goldstein et al. 1999), Habitat quantification models (Terrel et al. 1982, Nestler et al. 1989; Baker and Coon 1997), examination of habitat gradients (Schlosser 1982) or analysis of habitat preference (Rosenzweig 1981; Nelson et al. 1992). All these analysis are composed of various measures called metrics that are designed to rate the streams physical environment. The metrics rate the various aspects of the environment in several categories; channel geomorphology, Riparian zone, substrate, instream cover and biology (Stauffer and Goldstein, 1997)

1.3. Habitat indices
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1.3. Habitat indices
Indices that characterize habitat are important for proper interpretation of biological survey results (Plafkin et al., 1989) by providing an environmental context. Moreover, the habitat indices can serve as tools for rapid appraisals of habitat quality before an
extensive biological survey is undertaken and the use of habitat indices allows sampling of sites that have comparable habitat quality (Stauffer and Goldstein, 1997).

1.3.1. Habitat quality (HQ) scoring

Habitat quality scoring are composed of various measures called metrics that are designed to rate the stream’s physical environment. The metrics rate the various aspects of the environment in several categories: channel geomorphology, riparian zone, substrate and instream cover and biology. The sum of the ratings of all the metrics produces the total index score. The correlation of habitat index score with fish community statistics is a means of evaluating the effectiveness of the habitat indices for particular sites or geographic areas because the relative composition of a fish community is a sensitive indicator of direct and indirect stresses on the entire aquatic ecosystem (Fausch et al. 1990; Karr 1991). Gorman and Karr (1978) correlated stream habitat diversity with fish species diversity in selected streams in Indiana and Panama and suggested that fish community characteristics for a particular segment of a stream were determined by the complexity of habitats present in the area.

1.3.2. Biotic integrity

The physical, chemical and biological integrity of nation’s water resources can best be assessed by evaluating the degree to which waters provide the beneficial uses. Important uses as defined by society may include water supply, recreational and other uses as well as the preservation of future options for the use of the resource. Pollution may induce alteration in the chemical, physical, biological and radiological integrity of water. The environmental quality monitoring in the streams based on the development of thresholds and criteria levels for specific contaminants have the following drawbacks:

1. It is not accounting the naturally occurring geographic variation of contaminants
2. Not considering the subtle effect or how it affects the aquatic fauna and flora (e.g., reproduction, growth)

3. It misses many of the man induced perturbations such as flow alterations, habitat degradation, heated effluents and uses of power generation, etc.

In short, criteria that emphasize chemical attributes of water are unsuccessful as surrogates for measuring biotic integrity (Karr and Dudley, 1981). Since an ability to sustain a balanced biotic community is one of the best indicators of the potential for beneficial use.

Biological communities reflect water shed conditions since they are sensitive to changes in a wide array of environmental factors. Many groups of organisms have been proposed as indicators of environmental quality. Wisconsin natural resource department of United States pioneered the development of bioassessment and biomonitoring techniques based on benthic micro invertebrate community data during 1970's (Hilsenhoff 1977). Micro invertebrates and diatoms have been widely used in monitoring because of the availability of a theoretical substructure that allows an integrated ecological approach (Cummins 1974; Vannote et al.1980). However, use of diatoms or invertebrates as monitoring targets has the following major deficiencies.

1. They require specialized taxonomic expertise

2. It is difficult and time consuming to sample, sort and identify micro invertebrates and diatoms

3. Background life history information is often lacking for many species of microinvertebrates and diatoms

4. The results obtained by using diatoms and invertebrates are difficult to translate into values meaningful to the general public.
The procedure to use fish populations in bioassessment programme were first described by Dr. James Karr during 1980 to assess biotic integrity and environmental quality in small streams in Indiana and Illinois (Karr 1981, Karr et al. 1986).

Fishes, have numerous advantages as indicator organisms for biological monitoring programs. These advantages include

1. Life history information is extensive for most fish species
2. Fish communities generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores) and include foods of both aquatic and terrestrial origin. Their position at the top of the aquatic food web in relation to diatoms and invertebrates also helps provide an integrative view of the watershed environment.
3. Fish are relatively easy to identify. Technicians require relatively little training. Indeed, most samples can be sorted and identified at the field site itself, with release of study organisms after processing
4. The general public can relate to statements about conditions of the fish community.
5. Both acute toxicity (missing taxa) and stress effects (depressed growth and reproductive success) can be evaluated. Careful examination of the recruitment and growth dynamics among years can help to pinpoint periods of unusual stress.
6. Fish are typically present, even in the smallest streams and in all but the most polluted waters.
1.3.2.1. Index of Biotic Integrity (IBI) scoring

Index of Biotic integrity is a biological criterion. But its integration with the habitat indices are very essential to understand the community structure prevailing at different reaches of the river system. Karr and Dudley (1981) defined biotic integrity as 'a balanced, integrated adaptive community of organisms having a species composition, diversity and functional organization natural habitats of that region. Although the specific attributes and expectations of the original version of IBI apply only to Indiana and Illinois, the general principles underlying the IBI concept applied to many streams throughout the North America. Biologists and managers in other states of U.S.A and Canadian provinces found the IBI to be a useful assessment and evaluation tool and modified the IBI to fit the physical and biological characteristics of streams in their areas (Miller et al. 1988, Fausch et al. 1990). One of the most thorough modifications of the IBI has been done by the Division of Water quality and Monitoring and Assessment of the Ohio Environmental Protection Agency (Ohio EPA, 1988). The Ohio EPA developed several versions of the IBI based on hundreds of fish community, habitat and water quality samples from a wide variety of Ohio streams and rivers. The Ohio Environmental Protection Agency uses the IBI extensively and IBI scores have been incorporated in to Ohio water quality standards.

In the present study, a pioneer attempt had been done to introduce the concept of Index of Biotic Integrity (IBI) scores to six major river systems of Kerala. The criteria used for IBI scoring mainly derived from the Wisconsin version of the Ohio EPA (Lyons, 1992) with suitable modifications compatible to the ecological conditions prevailing in the river systems of Kerala.
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1.3.3. Habitat Suitability Index models

Most habitat models are based on co-variation between environmental variables and habitat use in the wild (Rosenfeld, 2003). Stream habitats are strongly hierarchical and habitat associations can be modeled at a variety of spatial scales. Usually three fundamental types of predictive models can be used to define habitat requirements from correlative data; distributional or macro habitat models, which predict the presence or absence of species at large spatial scales (e.g., within different drainage basins); capacity models (multiple regression), which predict density or population size when a taxon is present (usually at the reach or channel unit scale) and microhabitat models, which predict habitat associations at a fine spatial scale (e.g., water velocities and depths selected by different species). Bioenergetic habitat models for stream fishes have recently been emerged as an additional class of habitat model. These models differ fundamentally from other model types in that they are inherently mechanistic (i.e., their predictions are based on explicit biological mechanisms rather than observational data).

Habitat suitability index models have a wide range of applications. To conserve the extreme fish germplasm resources and endemism, declaration of aquatic sanctuaries and mitigating anthropogenic activities, development of habitat suitability index (HSI) models are very essential. With the help of this information, the species can be conserved in their natural habitats by way of maintaining the critical habitat parameters at threshold levels. These models are also vital in deciding the factors governing endemism. Habitat Suitability Index models are widely employed as an efficient tool for the conservation and management of the stock of indigenous fishes (Hubert and Rahel, 1989). These models are also useful either in simulating the required habitat in other regions of the same river or demarcating identical habitats.
where the species can be transplanted. Habitat Suitability Index (HSI) models will give some technical guidelines for stream restoration and management activities. The monitoring and maintenance of the critical parameters deciding the distribution and abundance of endangered species will help to maintain the physical, chemical and biological integrity of the river system and in effect reduce the ecosystem degradation. With this view the U.S Fish and wildlife service has developed a series of Habitat suitability index (HSI) models to describe and quantify habitat influences on the abundance of particular species (Terrell, 1984), which found its immense application for fish species conservation programmes.

A combined analysis of diversity indices (Shannon-Weiner diversity index, Simpson index, Pecoleou’s evenness index, Margalef’s index) and Index of Biotic Integrity (IBI) scoring with habitat variables will unfold the extent of ecosystem degradation undergone in a water body. The diversity indices and the index of biotic integrity (IBI) scores so arrived at will give a summary picture of the biological potential of an area which is the net product of physico-chemical and biological conditions prevailing in the study area. According to Plaffkin et al. (1989) habitat is a principal determinant of biological potential and can be used as a general predictor of biological conditions or there are links between the diversity of species (biological diversity) and the way ecosystem functions (Osborne, 2000). According to Mac Aurther (1972) and Cody (1975), diversity of habitat is the major factor determining the pattern of species diversity in an area, which is supported by the Krebs postulations. Krebs (1985) revealed that the more heterogeneous and complex the physical environment, the more complex the plant and animal communities and in a healthy ecosystem where the interaction between habitat variables and species diversity are more the abundance of each species is the product of same integer while overcrowding or degeneration of
any of the species occurs due to some habitat alterations. Portt et al. (1986) experimentally proved that reduction of the complexity of aquatic ecosystem drastically reduces establishment of large specimens. Schloesser (1982) and Lachvanne and Juge (1997) opined that habitat degradation may lead to the modification of trophic structure, reduction in the reproductive potential of the population leading to greater variability and smaller number of specimens in a population. So quantification of the extent of relationship between habitat variables and fish species descriptions such as diversity indices, fish abundance and index of biotic integrity (IBI) scoring are the ideal methods to quantify the ecosystem degradation brought about in a river system.

Studies on community level is rather very common in temperate systems (Ross, 1986), while tropical fish communities especially of the South Asia, are thoroughly under investigated (Wikramanayake and Moyle, 1989). Due to its immense applications in natural resource conservation in western countries like U.S.A., Canada and many European countries, habitat ecology had become the major component of biological research. But investigations on the fishes of the fluvial systems in Kerala or India are mostly limited to mere descriptions on taxonomy or distributions and in few cases, their biology, if the species are commercially important (Arun, 1997). The next level of understanding of fishes, ie, from species level to community/ assemblage level, sheds ample insight into the structure and functioning of fish communities in natural systems. The present study is a pioneer attempt in this line to assess the impact of human intervention in the habitat and biotic integrity of six major river systems of Kerala, which would be useful in impressing upon the seriousness of habitat degradation and biotic devastation thus enabling the concerned to adopt relevant conservation and management steps to conserve the resources. An attempt was also
made to study the biology of an endemic fish species *Puntius carnaticus* (Jerdon, 1849), which would be a better substitute for grass carp in aquaculture basket of our country. So it is hoped that the results of the present study will open new vistas for the conservation of threatened freshwater fishes, demarcation and declaration of aquatic sanctuaries, and overall, for developing better management and restoration measures for the lotic ecosystems of the country.

Against this background the present study was undertaken with the following objectives

1. To study the physical (channel geomorphology and riparian zone) and chemical conditions and instream habitat (instream cover and substrates) in six major river systems of Kerala
2. Based on some physical ratios (sinuosity, entrenchment ratio, w/d ratio, slope) and dominant substrates classify the river stretches up to Rosgen’s II level.
3. To study the biotic integrity and habitat quality (HQ) in six major river systems of Kerala
4. To study the biodiversity status of six major river systems in Kerala
5. To quantify the extent of ecosystem degradation due to increased human intervention and suggest mitigation measures
6. To develop the Habitat Suitability Index (HSI) models of 10 endemic and endangered freshwater fishes endemic to the streams of Western Ghats
7. To study the food and feeding, reproductive Biology, length-weight relationship and condition factor, age and growth and population dynamics of *P. carnaticus* for evaluating the suitability of the species for aquaculture.

The results of the present study are organized under 2 sections comprising a total of 13 chapters. The first section consists of 6 chapters, dealing with the habitat
structure and habitat-species relationships in six major river systems of Kerala. While the results of life history traits of \textit{P.carnaticus} are presented under section 2. The first chapter under section 1 is the general introduction and review of literature wherein a general outline on the necessity of habitat inventory, rationale and the present scenario of habitat ecology are clearly illustrated. Materials and methods employed to comply the objective of the study are adequately explained in chapter 2. Location wise instream habitat and physico-chemical conditions at selected reaches in six major river systems of Kerala are presented in chapter 3. Besides, the channel classification, habitat quality (HQ) scoring and Index of Biotic Integrity (IBI) scoring of the selected locations are also given in this chapter. The fish diversity of six major river systems based on the diversity indices such as Shannon-Weiner diversity index, Simpson index, Pieolou’s evenness index and Margalef’s index are summarized in Chapter 4. While Chapter 5 embodies the results of quantification of extent of ecosystem degradation undergone in six major river systems of Kerala. The results of Habitat Suitability Index (HSI) models developed for 10 threatened and endemic freshwater fishes of Kerala are presented in chapter 6. The salient features of \textit{P.carnaticus} along with its systematic position are described in chapter 7 under section 2. The results of qualitative and quantitative aspects of food composition in relation to sex, size and season, seasonal variation in feeding intensity as well as gastro-somatic index are presented in chapter VIII. In chapter IX, an attempt is made to investigate the maturation and spawning of \textit{P. carnaticus} using different methods. Length-weight relationship of males, females and indeterminates was established by the general linear equation and are presented in chapter X. While chapter XI deals with the age and growth studies in \textit{P.carnaticus}. Population dynamics of \textit{P.carnaticus} are
presented in chapter XII. Chapter XIII gives a summary of the thesis together with relevant recommendations on the basis of the results of the present study which would be useful for the conservation of the unique fish diversity richness in the river systems of Kerala. This chapter is followed by a list of references cited and appendices.
Plate 1.1 Seven different types of channel reaches in riverine ecosystems

- Step-pool reach
- Plane bed reach
- Regime reach
- Pool riffle reach
- Bedrock reach
- Braided reach
- Cascade reach
Plate 1.2 Common fishes seen in Cascade reaches of Kerala rivers

*Garra mullya* (Sykes, 1841)

*Salmostoma acinaces* (Valenciennes, 1842)

*Barilius bakeri* Day, 1865

*Tor putitora* (Hamilton - Buchanan, 1822)
Plate 1.3 Common fishes seen in Pool-riffle reaches of Kerala rivers

Osteocheilichthys nashi (Day, 1868)  Chela dadidurjori (Menon, 1952)

Gonoprototerpus dubius (Day, 1867)  Puntius conchonius (Ham-Buch)

Neolissochilus wynadensis (Day, 1873)

Silurus wynadentensis Day, 1876
Plate 1.4 Common fishes seen in Regime reaches of Kerala rivers

Gonoproktopterus curmuca (Ham-Buch, 1807)  
Pristolepis marginata Jerdon, 1848

Channa micropeltes (Cuvier, 1831)

Channa marulius (Ham-Buch, 1822)

Anabas testudineus (Bloch, 1795)  
Horabagrus brachysoma (Gunther, 1864)
Plate 1.5 Common fishes seen in Step-pool reaches of Kerala rivers

Nemacheilus triangularis Day, 1865

Garrra mullya (Sykes, 1841)

Basrilius gatensis (Valenciennes, 1844)

Bhavana australis (Jerdon, 1849)
Plate 1.6 Common fishes seen in bedrock reaches of Kerala rivers

*Crossocheilus periyarensis* Menon & Jacob (1996)

*Lepidopygopsis typus* Raj, 1941

*Gonoprotoperus micropogon periyarensis* Raj 1941

*Osteochilichthys longidorsalis* Petiyagoda & Kottlet, 1994