FISH HABITATS AND SPECIES ASSEMBLAGE IN THE SELECTED RIVERS OF KERALA AND INVESTIGATION ON LIFE HISTORY TRAITS OF *PUNTIUS CARNATICUS* (JERDON, 1849)

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Dedicated to my beloved parents

DECLARATION

I,Manojkumar T.G., do hereby declare that the thesis entitled **"Fish habitats and species assemblage in the selected rivers of Kerala and investigation on life history traits of *Puntius carnaticus*(Jerdon,1849)"** is a genuine record of research work carried out by me under the guidance of **Dr.B.Madhusoodana Kurup,** Professor, School of Industrial Fisheries,Cochin University of Science and Technology ,Kochi -16 and no part of the work has previously formed the basis for the award of any Degree, Associateship and Fellowship or any other similar title or recognition of any University or institution.

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CERTIFICATE

This is to certify that the thesis entitled **"Fish habitats and species assemblage in the selected rivers of Kerala and investigation on life history traits of *Puntius carnaticus*(Jerdon,1849)"** is an authentic record of research work carried out by **Sri.Manojkumar T.G.** under my guidance and supervision in the School of Industrial Fisheries, Cochin University of Science and Technology in partial fulfillment of the requirements for the degree of Doctor of Philosophy and no part thereof has been submitted for any other degree.

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Contents

Section I

Fish habitat and species assemblage in the selected rivers of Kerala

	Page
Chapter 1.General Introduction	**1**
Chapter 2.Materials and methods	**24**
Chapter 3.Habitat quality and index of biotic integrity in six major river systems of Kerala	**34**
Chapter 4.Fish diversity vis-à-vis altitude in the major River basins of Kerala	**58**
Chapter 5.On the extent of degradation of fish habitats In the major river systems of Kerala and Management plans for fish germplasm conservation	**75**
Chapter 6.Habitat Suitability Index(HSI) models of selected endangered and endemic fish species of Kerala	**96**

Section II

Life history traits and resource characteristics of *Puntius carnaticus*(Jerdon,1849)

Chapter 7. Systematics of *Puntius carnaticus*(Jerdon,1849)	**127**
Chapter 8. Food and Feeding	**132**
Chapter 9. Maturation and Spawning	**148**
Chapter 10. Length- Weight relationship and Condition factor	**176**
Chapter 11.Age and Growth	**187**
Chapter 12.Population Dynamics	**199**
Chapter 13.Summary and Recommendations	**216**
References	**234**
Publications	**293**

Section I

Fish habitat and species assemblage in the selected rivers of Kerala

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.

1.1Habitat 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. Cinvergence

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. **Turbulance;** 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 I 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 (foe 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

Xeroriaprian: 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 determines 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.

Obiviously 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 effort 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 definitions were subsequently developed by Melton (1936) and Matthews (1956). Leopold 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 Mollrd(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 Brice and Blodgett(1978)described four channel types such as braided , braided point-bar, wide-bend point bar 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

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 descriptive classification scheme was developed for Canadian rivers by Kellerhals *et al.* (1972, 1976), Galay *et al.*(1973) and Mollrd(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 Brice and Blodgett(1978)described four channel types such as braided , braided point-bar, wide-bend point bar 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.

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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 suble effect or how it affects the aquatic fauna and flora (eg. 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. Back ground 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 Ilinois (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 Ilinois , 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.

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 Ilinois , 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.

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 (eg., 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.(eg. 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 (ie., 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 helps 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 (Shanon-Weiner diversity index,Simpson index,Pieoleou'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 Aurthur(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.Schliosser (1982) and Lachvanne and Juge(1997) opined that habitat degradation may leads 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 in to 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 *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 *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 *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 *P.carnaticus*. Population dynamics of *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.

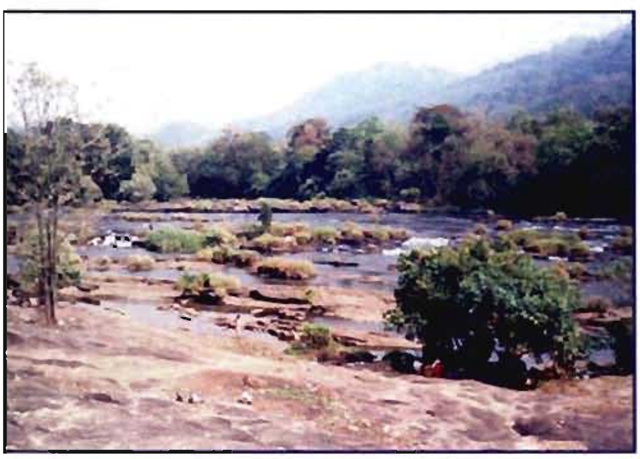
Plate 1.1 Seven different types of channel reaches in riverine ecosysystems

Step-pool reach

Plane bed reach

Regime reach

Pool riffle reach



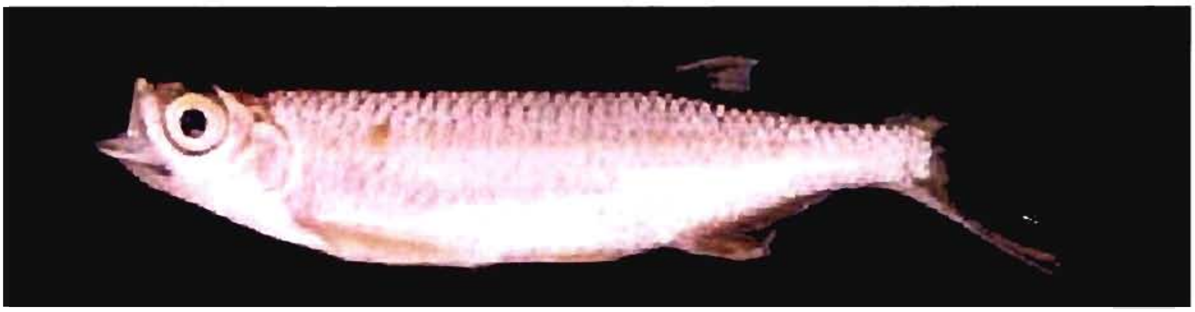
Bedrock reach

Braided reach

Cascade reach

Plate 1.2 Common fishes seen in Cascade reaches of Kerala rivers

Garra mullya **(Sykes,1841)**

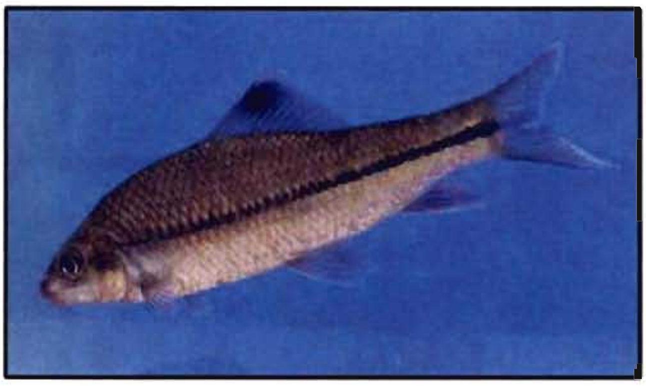


Salmostoma acinaces **(Valenciennes,1842)**

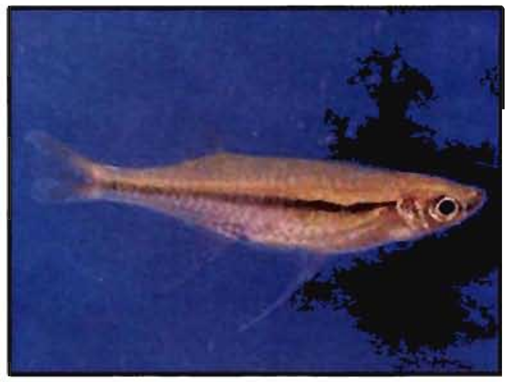
Barilius bakeri **Day,1865**

Tor putitora **(Hamilton - Buchanan,1822)**

Plate 1.3 Common fishes seen in Pool-riffle reaches of Kerala rivers



Osteocheilichthys nashi (Day,1868)

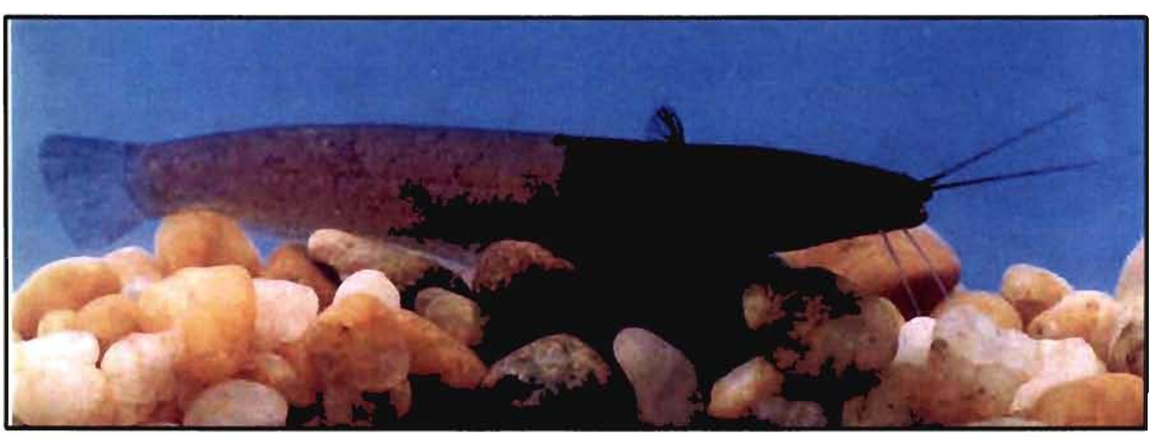


Chela dadidurjori(Menon,1952)

Gonoproktopterus dubius (Day, 1867)

Puntius conchonius (Ham-Buch)

Neolissochilus wynaadensis (Day, 1873)

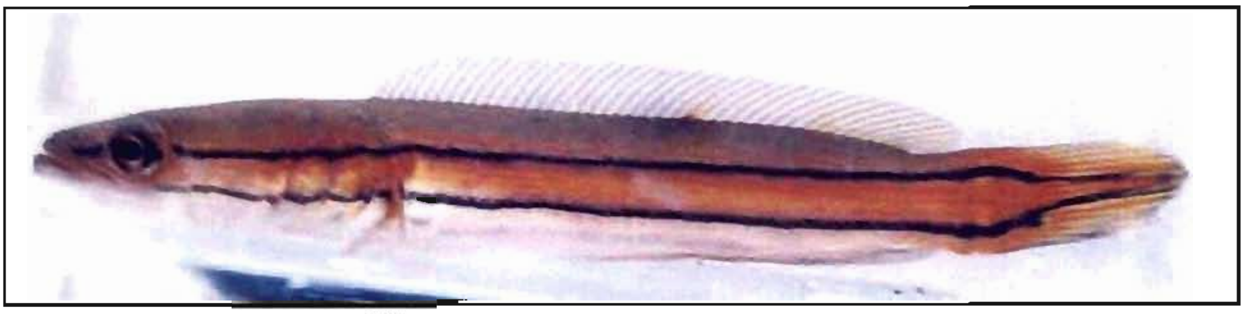


Silurus wynaadensis Day, 1876

Plate 1.4 Common fishes seen in Regime reaches of Kerala rivers

Gonoproktopterus curmuca (Ham-Buch, 1807)

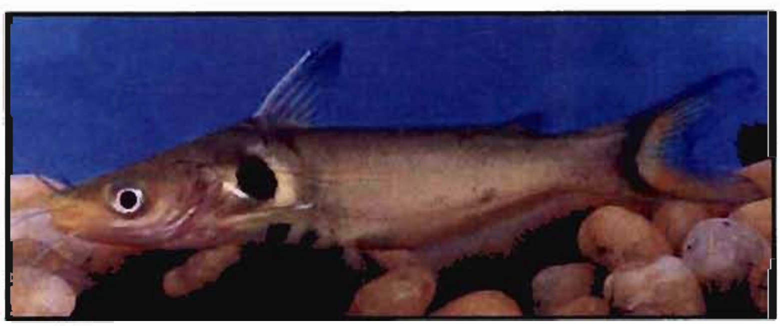
Pristolepis marginata Jerdon,1848



Channa micropeltes (Cuvier, 1831)

Channa marulius(Ham-Buch, 1822)

Anabas testudineus (Bloch,1795)



Horabagrus brachysoma(Gunther, 1864)

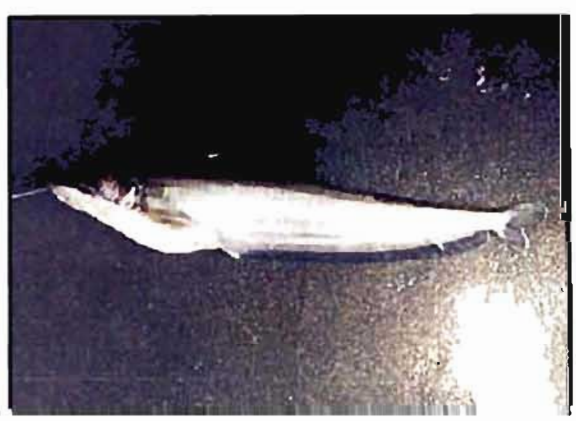


Plate 1.5 Common fishes seen in Step-pool reaches of Kerala rivers

*Nemacheilus triangularis*Day, 1865

Garrra mullya (Sykes, 1841)

Basrilius gatensis (Valenciennes,1844)

Bhavania australis (Jerdon, 1849)

Plate 1.6 Common fishes seen in bedrock reaches of Kerala rivers

Crossocheilus periyarensis Menon & Jacob (1996)

Lepidopygopsis typus Raj, 1941 b

Gonoproktopterus micropogon periyarensis Raj 1941 a

Osteochilichthys longidorsalis Petiyagoda & Kottlet,1994

Chapter 2

Materials and methods

2.1. Description of the study area

Detailed habitat inventory and species assemblage studies were conducted during January 2001 to January 2004 at a total of 91 locations of six river systems viz.Periyar ,Chalakudy,Kabbini,Kallada,Pamba and Bharathapuzha river systems giving due representation to all the seven types of channel reaches. The itirinary of river systems where detailed habitat and species inventory were conducted are given in Table 2.1.

Kabbini river passes through the neighbouring Karnataka state and drains into Bay of Bengal. 15 locations encompassing between 721-946m MSL were investigated. In Kabbini river system, the sampling stations were located between 11^0 30' 59N in the downstream and $76^0$02'06 E in the upstream, which also accommodates I, II and III order streams.

In Bharathapuzha river system, 27 locations were studied including the main stretch, tributaries such as Gayathripuzha, Kunthipuzha, Kanjirapuzha and Chitturpuzha and some I order streams above Malampuzha, Mangalam dam and Meen vallam region. All the locations were embarked between 18.4-1001m MSL. In the main river stretch II, III and IVth order streams between $10^0$45'00N and $76^0$38'85E in the upstream and $10^0$45'11N and $76^0$16'49E in the down stream were studied. In Gaythripuzha the II order river stretch between $10^0$35'21N and $76^0$30'22E in the upstream and $10^0$82'46N and $76^0$39'25E in the downstream were investigated. In Kunthipuzha I and II order streams in between $11^0$08'37N and $76^0$26'35E in the upstream and $10^0$59'23N and $76^0$16'49E in the downstream were surveyed. In Kanjirapuzha I order stream between $10^0$58'09N and $76^0$32'59E in the upstream and $10^0$58'27N and $76^0$29'54E in the down stream were studied. In chitturpuzha III order river stretch between $10^0$41'28N and $76^0$44'33E in the upstream and $10^0$43'21N and $76^0$34'16E in the downstream were surveyed.

In Kallada river system a total of 11 locations were studied including the main stretch, tributaries such as Kulathupuzha, Kazhuthuruty Ar and Chenturuny Ar. All the locations were between 20.3 to 641m MSL. In the main river stretch III order streams between $8^0$56'02' and $77^0$05'53E in the upstream and $8^0$59'12N and $77^0$01'14E in the downstream were studied. In Kulathupuzha I and II order streams between $8^0$8048'29N and $77^0$7'18E in the upstream and $8^0$56'11N and $77^0$04'11E in the down stream were surveyed. In Kazhuthuruty river I and II order streams in between $8^0$58'58N and $77^0$09'18 E in the upstream and $8^0$57'54 N and $77^0$05'26 E in the downstream were surveyed. Only a single location (8048'29N and 77007'18E) were studied in Chenturuny river, which is, a I order tributary of Kallada river system.

In Pamba river system a total of 15 locations were surveyed including the main river stretch, tributaries such as Kakkiyar, Kochupamba and Azhutha. In the main river stretch III and IV^{th} order streams between $9^0$24'49N and $76^0$52'33E in the upstream and $9^0$19'53N and $76^0$40'35E in the downstream were investigated. In Kakkiyar I and II order streams between $9^0$16'22N and $77^0$09'11E in the upstream and $9^0$20'25 N and $76^0$56'30 E in the downstream were studied. In Pamba II order streams between $9^0$24'50N and $77^0$04'18E in the upstream and $9^0$24'31N and $77^0$01'28E in the downstream were observed. In Azhutha II order streams between $9^0$25'54N and $76^0$56'23 E in the downstream were surveyed.

Chalakudy river flows in the Western direction and drains into the Arabian sea at the northern end of the Cochin Backwaters. A total of 20 locations encompassing between 40- 996.4m. MSL were studied which include the main river stretch and major tributaries such as Sholayar, Parambikulam and Karrapara. In the main river stretch locations between 10^{0}22'45N and 76^{0}40'0E in the upstream and 10^{0}17'32N and 76^{0}34'66N in the down stream having only third order streams were studied. In the Karappara tributary I and II order streams between 10^{0}26'13N and 76^{0}35'19E in the upstream and 10^{0}23'46N and 76^{0}43'0 E in the down stream were surveyed. In Sholayar, locations between 10^{0}18'62N and 76^{0}52'20E in the upstream and 10^{0}23'10N and 76^{0}39'43E in the down stream having both I and II order streams were investigated. In Parambikulam, tributary locations in the I and II order streams between 10^{0}27'27N and 76^{0}39'43E in the upstream and 10^{0}23'10N and 76^{0}39'43E in the downstream were surveyed.

Periyar river system is flowing in the Western direction and drains into the Arabian sea through Cochin Backwaters. Habitat inventory and species assemblage studies in this river system were conducted at 29 selected locations in the middle and high plains located between 20 – 1540m.MSL. Sampling sites were located in the main river stretch and also in two tributaries such as Neriyamangalampuzha and Pooyamkuttypuzha. The main river stretch located between 9^{0}18'40N and 77^{0}17'22E in the upstream and 10^{0}2'51N and 76^{0}48'15 E in the downstream which embark I, II.III and IVth order streams were investigated. In Pooyamkuttypuzha II and III order streams between10^{0}07'30N and 76050'10E in the upstream and 9^{0}58'39N and 77^{0}03'28E in the downstream were surveyed. In Neriyamangalampuzha the II order river stretch between

$10^0 05'7N$ and $77^0 03'42E$ in the upstream and $10^0 02'51N$ and $76^0 48'15E$ in the downstream were investigated.

2.2. Instream habitat and physical conditions

The site selection for habitat inventory was based on physical features such as channel pattern, channel confinement, gradient, streambed and bank bed materials (Anon, 2000). Maximum length of each reach was 10 times the average channel width. For habitat analysis, each site was divided into six equally spaced transect with 4 equally spaced sampling points on each transect (Hubert and Rahel, 1989). These procedures yielded at each site 24 measurements on nature of microhabitats, instream cover, substrate, flow velocity and lux, 12 measurements for riparian and bank features, 6 measurements for w/d ratio, entrenchment ratio and slope and one measurement each for sinuosity, dissolved oxygen, pH, TDS, conductivity and hardness.

The physical and chemical parameters of the river at each sampling point, reach descriptions such as sinuosity, entrenchment ratio, width/depth ratio, mean channel width, mean channel depth, slope, nature of riparian zone, substrate, instream cover and nature of microhabitats were studied based on Hubert and Rahel(1989),Edds(1998)and Anon(2000). Geographical Position of the selected zones was recorded using hand held GPS while altitude was measured using electronic altimeter. The dissolved oxygen and pH were measured using Eutech cyberscan DO100 dissolved oxygen meter and pH meter respectively. Light intensity on the surface water was measured from all the four sampling points on each transect using TES 1332 digital lux meter. Flow velocity was measured with a water current meter at 0.5m of the water depth at three equally spaced points across each transect.Temperature was measured using thermometer while total hardness and alkalinity were estimated following APHA (1992).

2.3. Fish sampling regime

For analyzing the species assemblage structure, sampling of fishes was at all stations selected for habitat inventory. Samples were collected during 8:00-18:00 h and 20:00-06:00 h. using monofilament and multifilament gillnets of different mesh sizes (32,34,64,78 and 100mm), cast net (mesh size: 16 and 22mm) and hand/scoop nets (mesh size: 6and 8mm). The fishing effort was made uniform at all the sampling locations. The fishes were identified following Day (1878; 1889), Jayaram (1981) and Talwar and Jhingran (1991). Required specimens for laboratory examination were preserved in 10% formalin while the rest of the fishes were released back into the system without any damage.

2.4. Stream classification

The river reaches identified for habitat study were classified upto Rosgen' II level following Rosgen(1994)(Table 2.2& 2.3).

2.5. Habitat quality scoring

The habitat quality scoring of the selected locations in Periyar river was done based on Lyons (1992). But to suite with the environmental conditions prevailing in Western Ghats streams, the fifth rating item such as BB ratio in the original habitat quality scoring system was replaced by sinuosity and w/d ratio. Appropriate changes were also incorporated in the qualitative evaluation of the habitat quality scoring. The metrics used for habitat quality scoring and scoring criteria were shown in Table 2.4.The qualitative evaluation of habitat quality scoring is shown in Table 2.5.

2.6. Index of Biotic Integrity scoring

Species richness

This metric is a common measure of biological diversity that generally decline with environmental degradation (Karr, 1981). The original metric of Karr (1981), total number of species was modified to number of native species in the Wisconsin version (Lyons, 1992). The number of native species used is a measure of biological diversity that typically decreases with increased degradation (Noss, 1990).

Species composition

In the present study the three metrics, number of darter species and number of sunfish species were replaced by number of loach species, sucker species and number of water coloumn species. Lyons (1992) suggested these substitutes and they are common substitutes when IBI is modified for using outside the United States (Hughes and Oberdorff, 1999), Ganasan and Hughes (1998) also used the modification for central Indian rivers and included both large and small benthic species in this metric, for accommodating both darter and sucker substitute metrics. Both these two metrics are strongly responsive to change in water quality and habitat structure like siltation, turbidity, reduced oxygen content and toxic chemical (Oberdorff and Hughes, 1992). Water column species are medium sized, midwater species, which tend to occur in pools or other areas of slow moving water. They are active swimmers that typically feed on a variety of invertebrates or other fishes (Lyons, 1992; Ganasan and Hughes, 1998). The metrics such as percent sucker, percent intolerant species and percent tolerant individuals were retained as such. Suckers are large bentic species that generally live in pools or runs, although a few species are common in riffles. Some species are intolerant of environmental degradation, whereas others are tolerant (Lyons, 1992). The metric, number of intolerant species was retained as it declines with environmental degradation (Karr 1981, Lyons, 1992).

Trophic composition

The three metrics namely percentage omnivore, percentage top carnivore and percentage insectivore were retained as such while percentage of simple lithophilous spawners were replaced by percent herbivore species. This herbivore metric as proposed by Ganasan and Hughes (1998) is significant in tropical and subtropical rivers where such species are vital trophic components, a view supported by Hughes and Oberdorff(1999). Moreover herbivores being sensitive to physical and chemical alteration in habitat are indicative of primary production status in the site.

Fish abundance and condition correlation factors

The metrics such as number of fishes per 300m sampled (excluding tolerant species) and percent with deformities, eroded fins, lesions, or tumors were retained. Total number of individuals is a gross measure of fish production and is lowest in highly disturbed systems (Lyons, 1992). The metric percent of fish with anomalies has been an important indicator of highly degraded zones in the rivers (Karr et al. 1986; Hughes and Gammon, 1987; Ganasan and Hughes, 1998). The number of individual fish with skeletal or scale deformities, heavily frayed or eroded fins, open skin leis ions, or tumors, that are apparent from an external examination were only considered in the anomaly category. Fish with heavy parasite burdens were not included in this category unless the parasites have caused deformities or lesions. Also fish with anomalies that are only visible after dissection were not included.

Calculation of IBI metrics:

The scoring criteria was developed (Table 2.6) as per the methods of Lyons (1992). The maximum values obtained for the metric 'total number of native species, number of loach species, number of sucker species, number of midwater species, number of intolerant species, percent omnivores, percent insectivores, percent top carnivores, percent herbivores and number of individuals per $300m^2$ are indicators of the least disturbed condition. Maximum values for the metric % tolerant, %omnivores and %individuals with anomalies or disease are indicators of highly altered habitat conditions.

The qualitative evaluation of the IBI scores (Table 2.7) were done following Lyons (1992) and Karr et al. (1986) with a slight modification based on the ecological conditions prevailing in the Western ghat streams.

2.7. Calculation of Diversity indices:

Once the identification is confirmed the number of specimens belonged to each species from each location were enumerated and used for calculating biodiversity indices such as Shanon-Weiner index, Simpson index, Margalef's index and Pieleou's evenness index using the statistical software Primer V5(Plymouth Routines in Multivariate Ecological Research, Clarke and Warwick,2001).The diversity indices so calculated for each location were further compared using two way ANOVA (Schender and Cohran, 1967) to confirm whether there is any significant variation in diversity at same altitudes in different river systems and also between different altitudes in same river system.

1. Shanon-Weiner (Shanon and Weaver, 1949), diversity index was used to emphasize species richness

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1. Shanon-Weiner (Shanon and Weaver, 1949), diversity index was used to emphasize species richness

H' = -sigma pi loge (pi) where pi is the proportion of the total count arising from the ith species. The natural logaritham is used for biological interpretation.

2. Margalef's index was used to measure the number of species present for a given number of individuals.

d=(S-1) Log N, where S is the total number of species and N the total number of individuals

2. Simpson index 1-λ is a equitability or evenness index, its largest value correspond to the equal abundance of all the species present in the ecosystem. This index has the natural interpretation as the probability that any two individuals chosen at random, are from the same species.

$1- \lambda = 1- (\varepsilon pi^2)$ where pi is the proportion of the total count(or biomass) arising from the ith species

3. Evenness of the community was calculated using Pielou's evenness index(Pielou,1984)

$J' = H'/H'_{max} = H'/\log S$ where H'_{max} is the maximum possible value of Shannon diversity and S is the total number of species

2.8. Relationship between habitat variables and species assemblage structure:

Shanon-Weiner diversity index, fish abundance and index of biotic integrity were the fish community descriptions used to calculate the relationship between habitat variables and species assemblage structure.

In the case of instream habitat and physical conditions Principal Component Analysis (PCA) was used to reduce the number of variables in the data set (Primer V5). For rivers having more number of sampling points the number of PCA axes were fixed to ten while rivers having comparatively less number of representative zones number of PCA axes were reduced to seven. In each axes the parameter showing the highest value was selected for further multiple regression analysis.

To find out the extent of relationship between fish population and habitat conditions multiple regression analyses was performed between selected instream habitat and physical condition variables with Shanon-Weiner diversity index, fish abundance and index of biotic integrity scores. Regressions were considered significant if the corresponding P-values did not exceed 0.05.

2.9. Habitat Suitability Index models:

Physical and instream habitat measurements and population estimates at each site were pooled for statistical analysis using Statistical Package for Social Sciences (SPSS for Windows) software. All the variables having significant (P_<0.05) correlation with the species abundance were further analyzed by simple regression to study the effect of each variable on the occurrence of individual species. Multiple regression models so developed were used in explaining the combined effect of the crucial factors responsible for the endemism of ten critically endangered species studied.

Table 2.1.Itinerary of river systems surveyed for habitat and species inventory details

Name of the river system	Number of surveys conducted	Seasons surveyed
Kabbini	Eight	Covered all seasons
Bharathapuzha	Six	Covered all seasons
Kallada	Five	Covered all seasons
Pamba	Four	Covered all seasons
Chalakudy	Six	Covered all seasons
Periyar	Ten	Covered all seasons

Table 2.2.Criteria for Rosgen's level -I stream reach classification

Stream type	Entrenchment ratio	W/D ratio	Sinuosity	Slope	Description
Aa+	<1.4	<12	1.0-1.1	>0.1	Headwater
A	<1.4	<12	1.0-1.2	0.04-0.1	Headwater
B	1.4-2.2	>12	>1.2	0.02-0.039	Intermediate
C	>2.2	>12	>1.4	<0.02	Meandering
D	N/a	>40	N/a	<0.04	Braided
DA	>4.0	<40	variable	<0.005	Braided
E	>2.2	<12	>1.5	<0.02	Meandering
F	<1.4	>12	>1.4	<0.02	Entrenched
G	<1.4	<12	>1.2	0.02-0.039	Gully

Table 2.3.Criteria for Rosgen's level-II stream reach classification

Stream type	Slope range		Channel material				
		Bedrock	Boulder	Cobble	Gravel	Sand	Silt or Clay
A	>0.1	A1a+	A2a+	A3a+	A4a+	A5a+	A6a+
	0.04-0.099	A1	A2	A3a+	A4	A5	A6a+
B	0.04-0.099	B1a	B2a	B3a	B4a	B5a	B6a
	0.02-0.039	B1	B2a	B3	B4a	B5	B6a
	<0.02	B1c	B2c	B3c	B4c	B5c	B6c
C	0.02-0.39	C1b	C2b	C3b	C4b	C5b	C6b
	0.001-0.02	C1b	C2	C3b	C4b	C5	C6
	<0.001	C1c	C2c	C3c	C4c	C5c	C6c
D	0.02-0.39	n/a	n/a	D3b	D4b	D5b	D6b
	0.001-0.02	n/a	n/a	D3b	D4	D5	D6
	<0.001	n/a	n/a	n/a	D4c	D5c	D6c
DA	<0.005	n/a	n/a	n/a	DA4	DA5	DA6
E	0.02-0.39	n/a	n/a	E3b	E4b	E5b	E6b
	<0.02	n/a	n/a	E3	E4b	E5	E6
F	0.02-0.39	F1b	F2b	F3b	F4b	F5b	F6b
	<0.02	F1	F2	F3	F4b	F5b	F6
G	0.02-0.39	G1	G2	G3	G4	G5	G6
	<0.02	G1c	G2c	G3c	G4c	G5c	G6c

Table 2.4.The metrics used and the scoring criteria used for habitat quality scoring at selected locations in Periyar river

Rating item	excellent	Good	Fair	Poor
Bank erosion,failure and bank prtection	No significant bank erosion,failure.>/-90% of bank protected by plants of stable rock 12	Limited amount of bank erosion, failure. 80% of bank protected by plants or stable rock 8	Intermediate amount of bank erosion, failure.60% of bank protected by plants or stable rock 4	Extensive amount of bank erosion, failure.,/-50% of bank protected by plants or stable rock 0
Main channel bedrock substrate(%of area)	100-65% of the bottom material covered by bedrock 25	56-45% of the bottom material covered by bedrock 16	45-25% of the bottom material coverd by bedrock 8	25-5% of the bottom material covered by bedrock 0
Available cover for adult game fish	100-50% cover(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank) 25	49-25% cover(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank) 16	24-15% cover(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank) 8	15-0% cover(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank) 0
Average maximum Talweg depth(4 deepest depths)	>/-10m 25	5-9.9m 16	3-4.9m 8	<3m 0
Sinuosity	1 12	1.01-1.2 8	1.2-1.4 4	>1.4 0
W/D ratio	</-12 6	13-18 4	19-24 2	>/-25 0

Table 2.5.Qualitative evaluation of Habitat Quality(HQ) scoring

100-75	Excellent	
74-50	Good	
49-25	Fair	
24-0	Poor	

Table 2.6.Scoring criteria used for the 10 metrics and 2 correction factors used to calculate the IBI score at selecte locations in Periyar river

Species richness and composition metrics	Stream width	Scores based on the number	Scores based on the number	Scores based on the number	
		10	5	0	
Total number of native species	2.5-6.1.	>6	3 - 6	<3	
	6.2-12.1	>10	6 - 10	<6	
	>/-12.2	>14	9 - 14	<9	
Number of loach species	2.5-6.1	>1	1	0	
	6.2-12.1	>1	1	0	
	>/-12.2	>1	1	0	
Number of sucker species	2.5-6.1	>1	1	0	
	6.2-12.1	>1	1	0	
	>/-12.2	>1	1	0	
Number of midwater species	2.5-6.1	1	0	0	
	6.2-12.1	2	1	0	
	>/-12.2	>2	1 - 2	0	
Number of intolerant species	2.5-6.1	1	0	0	
	6.2-12.1	>1	1	0	
	>/-12.2	>2	1 - 2	0	
Scores	10	7	5	2	0
Number of tolerant species	0-19	20	21-49	50	51-100
Trophic metrics					
Percent hervivores	100-76	75	74-51	50	49-0
Percent insectivores	100-61	60	59-31	30	29-0
percent topcarnivores	100-15	14	13-8	7	6 - 0
Percent omnivores	0-19	20	21-39	40	41-100
Fish abundance and condition correlation fctors					
Number of individuals per $300m^2$	If <50 fish,substract 10 from overall IBI score				
Percent fishes with anomalies	If>/-4 percent , substract 10 from overall IBI score				

Table 2.7.Qualitative evaluation of IBI score

100-60	Excellent
59-40	Good
39-25	Fair
24-10	Poor
<10	Very poor

Chapter 3

Habitat quality and index of biotic integrity in six major river systems of Kerala

3.1. Introduction

The most distinctive effect of increasing human activity around the globe is steady reduction of environmental diversity. In the case of fluvial ecosystems, one of the most important factors responsible for the sharp decline in biodiversity has been channelization combined with wetland degradation. Throughout the world, the morphology of river systems has been dramatically altered by human action. The changes have been induced directly by dams and reservoirs and channelization, and indirectly by land-use developments through out the drainage basins.

The first question to answer in analyzing the relations between land-water ecotones and fish diversity seems to be: what are the factors, which stimulate the increase in biodiversity of the ecosystems? It can be answered by two components1) the nature of the ecosystem (Mac Arthur and Wilson, 1967; Magurran, 1988) and and its latitudinal position (Pianka, 1983). Among all aquatic habitats, rivers, due to their spatial and temporal heterogeneity, are most appropriate ecosystems for the analysis of the relationship between fish biodiversity and environmental properties. The four fundamental components which determine the productivity of any riverine habitats are: 1) the flow regime 2) water quality 3) the physical nature of the floodplain and 4) energy budget of the system. Habitat evaluation methods must attempt to quantify the interaction and relative importance of these four components (Cowx and Welcomme, 1998).

Much of the freshwater aquatic sciences have aimed at assessing waterways and their communities to provide some index of their health and functionality. Initially, the main problem was to improve degraded water quality to a point where aquatic life could be restored to systems. Later it was realized that degradation had not only occurred in the quality of water but in the structure of the environment itself, and many recent models have been aimed at defining the role of the form of river systems on the processes that make them work as viable ecosystems (Cowx and Welcomme, 1997). A fluvial hydrosystem comprises of the river channel, riparian zone, floodplain and alluvial aquifer. It can be considered as a four dimensional system being influenced not only by longitudinal processes, but also by lateral and vertical fluxes, and strong temporal changes. These models provide the basic guide as to what types of intervention are needed to rehabilitate systems (Cowx and Welcomme, 1997).

While analyzing the data from different rivers, Zalewski and Naiman(1985) concluded that abiotic factors are of primary importance in regulating fish communities. According to Lachavanne and Juge(1997), along with temperature, salinity, current speed, dissolved oxygen, pressure, light and available food and the physical and ecological factors also play a substantial role in the dispersal of fishes. The presence of quality habitat is a critical factor in the health and diversity of the biological community.

Many studies indicate that the pattern of distribution for many fishes is the result of both local-habitat conditions and larger scale biotic and abiotic processes (Rabeni and Sowa, 1996; Dunham *et al.*1997; Schrank *et al.*2001). The physical characteristics of the local stream reaches have significant influence on the variation in fish density (Rabeni and Sowa 1996; Watson and Hillman 1997). On the other hand, large-scale watershed or landscape features such as stream size, basin area, spatial geometry and stream temperature as well as biotic factors such as the presence of non native species and degree of isolation from other populations also have substantial role in the distribution and abundance of fish species (Bozek and Hubert 1992; Fausch *et al.*1994; Riemann and

McIntyre 1995; Dunham *et al.*1997, Osborne and Wiley, 1992; Dunham and Rieman 1999). Based on the study in the streams at Minnesota region of United States Talmage *et al.* (1999) reported that factors such as impervious cover, water chemistry, water temperature, geomorphology, substrate, instream habitat and migration barriers have significant influence on the fish community composition in these streams.

Comprehensive assessment of aquatic systems starts with an evaluation of habitat quality. The habitat quality can be determined by various aspects of the riverine environment in several categories:channel geographical units,riparian zone, substrate and instream cover and biology(Stauffer and Goldstein,1997).The sum of all these parameters will decide the complexity of aquatic system. According to Cowx and Welcomme(1997) and Stauffer and Goldstein(1997), areas with the greatest intensity of habitat complexity will support the maximum biological diversity. Habitat data have a significant role in biocriteria interpretation because the physical habitat of a stream has a major influence on the presence and abundance of fish and may therefore overshadow or confound the identification of other factors affecting the biotic integrity of fish communities (Muhar and Jungwirth, 1998). Thus, quantification and interpretation of stream habitat are an important aspect of biocriteria development.

In the present study, a pioneer attempt is made to evaluate the influence of various habitat components such as the nature of microhabitats, instream cover, substrates, riparian zone and water quality parameters to the fish species assemblage structure in six major river systems of Kerala. Based on the river morphology, the river systems were classified up to Rosgen's II level. The objective of the integration of this classification system in the present fish habitat survey is to determine the potential of the stream reach, current state, and a variety of hydraulic and sediment relations that can be utilized for habitat and biological interpretations.

An attempt was also made to develop location wise index of biotic integrity (IBI) scoring and habitat quality (HQ) scoring in each river system by which one can rapidly assess the health of a local water resource. Moreover, it would evaluate the effect of habitat quality on the biotic integrity of the river system and will provide adequate information on the physical and biological components of the ecosystem.

3.2. Materials and methods

Materials and method used the study is illustrated in chapter 2. (Please refer chapter 2)

3.3. Results

3.3.1. Kabbini river system

Kabbini is one of the east flowing rivers in Kerala, endowed with a wide range of fish diversity and endemism. The river has a total length 56.6km in Kerala with a basin of 1920km^2. The origin of the river is from Thondarmudimalai having an elevation of 1500m from the MSL. The important tributaries of the river are Mananthavady, Panamaram, Bavelipuzha and Noolpuzha. In the present study detailed habitat inventory surveys were conducted at 15 selected locations giving representation to various habitats of Kabbini river system. The locations where detailed habitat inventory surveys were conducted in Kabbini river system are shown in Plate 3.1. The overall physical, chemical and biological habitat structure of Kabbini river system is given below:

3.3.1.2. Physical habitat structure

In Kabbini river system instream cover was dominated by overhanging vegetation (59.6%) followed by depth (24.8%). All the other types of instream cover together constituted only 15.6% (Fig.3.1.) .Among substrates gravels (38.4%) and fines (18.6%) together constituted 57% of the river bed while the contribution of bedrock, rock, boulders and cobbles were 13.5%,4.8%,12.1%,and 12.5% respectively(Fig.3.7). Sinuosity of the river system varied from 1-2.6(SD=0.58) while stream gradient ranged from 0.001-0.1(SD=0.03). Mean entrenchment ratio and w/d ratios were1.33 (SD=0.87) and 8.17(SD=7.78) respectively (Table 3.1). Heterogeneity of channel geomorphic units was comparatively less and was dominated by run (39.6%) followed by lateral pool (18.8%) (Fig.3.13). Mean flow velocity was 0.3m/s (SD=0.23). Riparian zone having 26.1% shrub cover, 58.6% tree cover while 15.3% of the riparian zone was without any vegetation. Habitat quality score varied from 14(Sugandagiri and Tariyod) to 56(Palvelicham) with a mean value of 33.4(SD=19.7) (Fig.3.19).The habitat quality score at various locations selected for habitat inventory in Kabbini river system are shown in Table 3.1

3.3.1.3. Species assemblage structure

Fifty four species representing 14 families were collected from the total 15 locations selected from habitat inventory surveys in Kabbini river system which accounts for100% of the total species so far reported from Kabbini river system. The total number of species and the location wise species abundance at various locations of Kabbini river system is depicted in Table 3.7. Cyprinids were the most common family with 24 species, representing 83.3% of the total number of individuals reported from Kabbini river system followed by Balitoridae and Bagridae with 6 species each. The classification of different species identified from Kabbini river system under 10metrics used for IBI scoring is shown in Table 3.13. Of the total 50 species reported from this river system during the present study, suckers contributed to 10%, loaches 14% and midwater species 12%. Suckers were collected from 80% of the sampling locations while loaches and midwater species from 40% and 73% locations respectively. Intolerant fish species and tolerant fish species respectively formed 24% and 14% of the fish fauna. Intolerant fish species showed their occurrence at 93% of the selected locations while tolerant fish species were reported only from 67% of the locations studied. Among the different trophic groups, omnivores were dominating (46.3%) followed by herbivores (22.6%), insectivores (17.3%) and carnivores (13.8%). Omnivores were reported from 96.4% of the total locations surveyed while herbivores, insectivores and carnivores shown their occurrence at 78.6%, 71.4% and 53.6% of the total locations surveyed. Index of biotic integrity ranged from 5(Aranagiri II) to 65(Kuruvadeep) with a mean of 38.4(SD=18.8) (Fig.3.20).The location wise index of biotic integrity at the selected locations of Kabbini river system is shown from Table 3.19.

The range of water quality parameters at selected locations of Kabbini river system is shown in Table 3.25.A few typical channel reaches identified from Kabbini river system is shown in plate 3.2.

3.3.2. Bharathapuzha river system

Bharathapuzha, one of the largest rivers in Kerala, has a total length of 209km and has a total basin area of 6186km^2 shared by both Kerala and Tamilnadu states. The origin of the river is from Anamalai hills with an elevation of 1964m.The main tributaries of the river are Gayathripuzha,Kunthipuzha, Chitturpuzha, Kalpathipuzha and Thuthapuzha. Detailed habitat inventory surveys were carried out at 28 selected locations of Bharathapuzha river system. The locations where detailed habitat inventory surveys were conducted in Bharathapuzha river system are shown in Plate 3.3. The overall physical, chemical and biological habitat structure of Bharathapuzha river system is given below:

3.3.2.1. Physical habitat structure

In Bharathapuzha river system, instream habitats varied among sites. While considering the entire river stretch, depth was the dominant instream cover (38.68%) (SD=15.86) followed by overhanging vegetation (18.9%), emergent vegetation (17.5%) and turbulence (12.1%) (Fig.3.1). Riverbed was dominated by bedrock (28.6%) followed by cobbles (19.5%), gravels (17.85%), fines (16.57%), boulders (13.2%) and rock (4.2%) (Fig.3.8). Among physical conditions, sinuosity varied between 1-1.63(SD=0.14) and stream gradient ranged between 0.001-0.25 (SD=0.06). Mean entrenchment ratio and w/d ratios were 1.46(SD=0.9) and16.42 (SD=19.3) respectively (Table 3.2).Midchannel pools (23.3%) were the dominant channel geomorphic unit followed by run (18.35). glide (12.3%) and landslide (9.6%) (Fig.3.14). Mean flow velocity was comparatively less with 0.31m/s(SD=0.35). Riparian vegetation was comparatively less and 29.4% of the riparian zone was without any vegetation while 26.2% having shrub cover and 44.4% of the riparian zone was covered with trees. Habitat quality score varied from 14(Churiode) to 63(Pambadi east) and the mean habitat quality score was 39.6(SD=12.1) (Fig.3.19).The habitat quality scores at various locations selected for habitat inventory in Kabbini river system are shown in Table 3.2.

3.3.2.2. Species assemblage structure

Fifty eight fish species representing 23 families were collected from this river system, which formed 92% of the fish species reported from this river basin. The total number of fish species and the location wise fish species abundance at various locations selected for habitat inventory in Bharathapuzha river system is given in Table 3.7.Cyprinids were the most common family (represented by 25 species) and constituted approximately 64.35% of the total number of individuals collected. Balitoridae and Bagridae, the next most common families, were each represented by 5 and 3 species respectively. The classification of different species identified from Bharathapuzha river system under 10 metrics used for IBI scoring is shown in Table 3.14. Of the 58 species reported in the present study, 8.6% were suckers, 10.3% were loaches and 6.9% were midwater species. Among the 28 locations surveyed, suckers were found in 57% of the locations surveyed while representation of loaches and midwater species were observed only from 25% and 32% locations respectively. Tolerant and intolerant species formed 13.8% and 17.2%respectively of the total number of species reported from Bharathapuzha river system. Intolerants have representation at 60.7% of the total locations surveyed while tolerant species were reported from 50% of the locations surveyed. Among the different trophic groups, omnivores dominated (50%) followed by herbivores (18.2%) insectivores (16.9%) and carnivores (14.9%) in the order of their dominance. Omnivores were collected from 85.7% of the total number of locations surveyed. While herbivores, insectivores and carnivores showed their presence at 75%, 67.9% and 53.6% respectively of the total number of locations surveyed. Index of Biotic Integrity scores ranged from 0(Velampattapuzha) to 60(Yakkara) and the mean IBI score was 21.7(SD=13.7) (Fig.3.20), which indicated that the biotic integrity of Bharathapuzha river system is very poor.The location wise index of biotic integrity at the selected locations of Bharathapuzha river system is presented in Tables 3.20.

The range of water quality parameters at selected locations of Bharathapuzha river system is depicted in Table 3.26. Some typical channel reaches identified from Bharathapuzha river system is shown in Plate 3.4.

3.3.3. Kallada river system

Kallada river system has a total length of 121 km covering a basin area of 1699km^2. The origin of the river is from Karimalai at an elevation of 1524m MSL. The river has three tributaries

1. Kulathupuzha
2. Chendurni
3. Kalathuruthi

Detailed habitat inventory surveys were conducted at 11 selected locations of Kallada river system (Plate 3.5). The overall physical, chemical and biological habitat structure of Kallada river system is given below:

3.3.3.1. Physical habitat structure

While comparing Kallada river system with other river systems, habitat heterogeneity is very less. Overhanging vegetation (35.2%), depth (25.7%) and turbulence (21.9%) together contributed to 82.8% of the total instream cover in this reach (Fig.3.3). Gravels (30.2%) and fines (10.2%) together contributed to 40.4% of the riverbed, which indicate high degree of bank erosion and embedness. While the contribution of bedrock, rock, boulders and cobbles were only 21.9%, 7.1%, 11.3% and 19.4% respectively (Fig.3.9).

Sinuosity ranged between 1-1.4(SD=0.15) and slope ranged from 0.001-0.1(SD=0.037). While mean entrenchment ratio and w/d ratios were 1.25(SD=0.5) and 5.9(SD=4.94) respectively (Table 3.3). Three microhabitats such as midchannel pools (28.6%), run (25.5%) and riffles (24.3%) together contributed to 78.4% of the total river reach in this river system (Fig.3.15). The remaining river reach was contributed by plunge pool (9.9%), cascade (7.9%), falls (3.4%) and rapids (0.39%) respectively. Flow velocity was comparatively high especially in the upper reaches and the mean flow velocity was 0.48m/s (SD=0.78).Riparian zone having 17.9% shrub cover, 62.6% tree cover while 19.5% of the riparian zone was without any vegetation. Habitat quality score varied from 12 (Ariyankavu) to 70(Meenmutty) with a mean value of 40(SD=16.5)(Fig.3.19).The habitat quality scores at various locations selected for habitat inventory in Kallada river system is presented in Tables 3.3.

3.3.3.2. Species assemblage structure

23 fish species belonging to 8 families were collected from the 11 locations surveyed at Kallada river system which formed 53.7% of the total species so far reported from Kallada river system. The total number of species and the location wise species abundance at different locations selected for habitat inventory in Kallada river system is shown in Table 3.9. Family Cyprinidae represented 14 species and constituted 93.3% of the total individuals collected from this river system. All the other families were represented by 1 species each. Table 3.15 shows the classification of different species identified from Kallada river system under 10 metrics used for IBI scoring. Of the total 23 fish species, suckers represented 11.9%, loaches 17.4% and midwater species by 21.7%. Suckers were collected from 82% of the locations studied while loaches and midwater species have representation only at 36.4% and 45.5% locations. Intolerant fish species formed 26.1% of the total fish fauna and were collected from all the locations

surveyed while tolerant species formed 30.4% of the fish fauna and were collected only from 63.3% of the locations. Omnivores (50.4%) were the dominant trophic groups in this river system followed by insectivores (22.8%), herbivores (19.6%) and carnivores (7.2%). Omnivores and insectivores were present in all the locations surveyed while herbivores and carnivores were identified only from 90.9% and 36.4% of the total number of locations surveyed. Index of biotic integrity ranged from 15(Chenturuny) to 45(Meenmutty and Chenkali) with a mean of 27.3(SD=10.5) (Fig.3.20).Index of biotic integrity score at selected locations in Kallada river system are presented in Table3.21.

The range of water quality parameters at selected locations of Kallada river system is given in Table 3.27. Some typical channel reaches identified from Kallada river system is shown in Plate 3.6.

3.3.4. Pamba river system

Pamba river system has a total length of 176km with a basin area of 2235km^2. The origin of the river is from Pulachimalai having an elevation of 1650m.The major tributaries of the river are Kakkiyar, Kochupamba , Azhutha and Kallar. Detailed habitat inventory surveys were conducted at 15 selected locations of Pamba river system. The locations where detailed habitat inventory surveys were conducted in Pamba river system are shown in Plate 3.7. The overall physical, chemical and biological habitat structure of Pamba river system are given below:

3.3.4.1. Physical habitat structure

In Pamba river system, instream cover did not show much oddity. Among the three dominant types of instream cover depth alone contributed to 48.8% followed by turbulence (22.3%) and overhanging vegetation (16.8%) (Fig.3.4). In the riverbed, bedrock was dominating (24.8%) followed by fines (19%) and gravels (16.8%). While the other types of substrates such as cobbles, boulders and rock together contributed only 39.5 %(Fig.3.10).

Sinuosity varied between 1-1.3 (SD=0.15) and channel gradient varied from 0.001-0.1(SD=0.04). The mean entrenchment ratio and w/d ratios were 1.21(SD=0.28) and 7.13(SD=5.61) respectively (Table 3.4). Heterogeneity of channel geomorphic units was comparatively less and midchannel pools (45.5%), rapids (19.8%) and run (18.8%) together contributed to 84.1% of the total river reach (Fig.3.16).The remaining 15.9% of the river reach was contributed by plane bed (4%), riffle(3.9%), chute(2.7%), falls(1.5%),trench pool(1.4%), lateral pool(1.3%), cascade(0.6%) and glide(0.4%) respectively. Mean flow velocity was 0.38m/s (SD=0.3). Riparian zone having 66% tree cover, 13% shrub cover while 20.25% of the riparian zone was without any vegetation. Habitat quality score varied from 20(Pamba and Moozhiyar II) to 66(Kakkad Ar II) with a mean value of 41.9(SD=15.4)(Fig.3.19). The habitat quality scores at various locations selected for habitat inventory in Pamba river system is presented in Table 3.4.

3.3.4.2. Species assemblage structure

Thirty species belonging to 13 families were collected from 15 locations selected for habitat inventory in Pamba river system, which constituted 57.4 % of the total species reported from this river. The total number of species and the location wise species abundance at different locations selected for habitat inventory is shown in Table 3.10. Cyprinids were the most common group with 21 species and represented 89.8% of the total number of individuals collected from this river system followed by Balitoridae and Bagridae with 2 and 3 species respectively. Classification of different species identified from Bharathapuzha river system under 10 metrics used for IBI scoring is given in Table 3.16. Suckers, loaches and midwater species represented 7%, 7% and 13% respectively of the total fish fauna of Kabbini river system. Of the total 15 locations surveyed, suckers and midwater species were collected from 67% locations while loaches were observed only from 7% locations. Intolerant species formed 27% of the total fish fauna and were collected from all the locations studied. While tolerant fish species contributed to 17% of the fauna and collected only from 53% locations. Among the different trophic groups, insectivore was the dominant group (42.5%) followed by omnivore (34.7%), carnivore (14.2%) and herbivores (8.5%) in the order of their dominance. Presence of omnivores were reported from all the locations while insectivores, herbivores and carnivores were reported from 93.3%, 73.3% and 33.3% locations respectively among the total number of locations surveyed. Index of biotic integrity ranged from 17(Nilakkalthodu) to 50(Peruthenaruvi) with a mean value of 34.2(SD=9.7)(Fig.3.20). Index of biotic integrity score at selected locations in Pamba river system is shown in Table 3.22.

The range of water quality parameters at selected locations of Pamba river system is presented in Table 3.28. A few typical channel reaches identified from Pamba river system is shown in plate 3.8.

3.3.5. Chalakudy river system

Chalakudy, one of the biodiversity rich rivers in Kerala has a total length of 130km and has a total basin area of 1704 km^2 shared by both Kerala and Tamilnadu. The origin of the river is from Anamalai with an elevation of 1250m.MSL.As part of the present study detailed habitat inventory surveys were conducted at 20 selected locations of Chalakudy river system (Plate 3.9). The overall physical, chemical and biological habitat structure of Chalakudy river system is given below:

3.3.5.1. Physical habitat structure

Instream habitat and physical conditions were highly heterogenic in Chalakudy river system, which are very ideal for supporting rich fish diversity. Depth (38.1%) was the dominant instream cover followed by overhanging vegetation (26.8%), emergent vegetation (8.5%), turbulence (7.1%), large woody debris (4.8%), undercut bank (4.3%) and overhanging stream boulders (4.2%)(Fig.3.5). On an average bedrock constituted 47.8% of the riverbed followed by fines (14.9%), boulders (12.9%), rock (12.6%), gravels (8.9%) and cobbles (2.8%) (Fig.3.11).

Among physical conditions, sinuosity varied between 1-1.5(SD=0.15) and stream gradient varied from 0.001-0.1 (SD=0.03). While the mean entrenchment ratio and w/d ratios were 1.23 (SD=0.27) and 9.59 (SD=9.74) respectively (Table3.5). Channel geomorphic units are highly heterogenic dominated by midchannel pools (30.5%), riffle (17.9%), run (16.9%), rapids(13.7%) and pocket water pools(9.9%)(Fig.3.17).Mean flow velocity was 0.25m/s(SD=0.23). Riparian zone having 87.65% tree cover and 7.6% shrub cover while only 4.75% of the riparian zone was endowed with bare ground. Habitat quality score in Chalakudy river system varied from 24(Malakkapara) to 75(Vallakayam) with a mean of 57(SD=17.5) (Fig.3.19). The habitat quality scores at various locations selected for habitat inventory in Chalakudy river system is presented in Table 3.5.

3.3.5.2. Species assemblage structure

Fourty fish species under 16 families were collected and identified from the locations selected for habitat inventory in Chalakudy river system, which formed 58.2% of the fish species reported so far from this river. The total number of species and the location wise species abundance at different locations selected for habitat inventory is shown in Table 3.11. Cyprinids were the most common family represented by 21 species and formed 93.7% of the total number of individuals collected. Bagrids appeared as the next common family represented by 4 species followed by Cichlids with two species. Table 3.17 shows the classification of different species identified from Chalakudy river system under 10 metrics used for IBI scoring. Of the total 40 species, suckers represented 7.5%, loaches 5% and midwater species 22.5%. Suckers showed their representation at 95% locations studied while loaches and midwater species were collected from 40% and 80% locations respectively. Intolerant species and tolerant species form 27.5% and 12.5% respectively of the total fish fauna. Intolerant species have representation at all the locations, while tolerant fish species were collected only from 65% of the sampling locations. Among the different trophic groups identified 48.8% of the species were omnivores, 28.2% was insectivore and the remaining 23% was represented by herbivores (15%) and carnivores (8%) respectively. Of the total 20 locations surveyed omnivores and herbivores were present at all the locations while detritivores and carnivores were collected respectively from 95% and 60% of total locations surveyed. Index of biotic integrity scores ranged from 25(at Malakkapara) to 64(at Kuriarkuutty) with a mean of 44.1(SD=9.5) (Fig.3.20). The index of biotic integrity at various locations selected for habitat inventory in Chalakudy river system is given in Table 3.23.

The range of water quality parameters at selected locations of Chalakudy river system is presented in Table 3.29. Few typical channel reaches identified from Chalakudy river system is shown in plate 3.10.

3.3.6. Periyar river system

Periyar river, the largest river system in Kerala, is identified as one of the biodiversity rich river system in Kerala. It spreads in two states-Idukki and Ernakulam. During its course, the river is passing through Periyar tiger reserve, one of the world's most fascinating natural wildlife reserves spreading across 777sqkm. The Periyar Lake –stream system consists of 74 km of long streams that drain into the lake and 26 km^2 of Lake System within the Periyar tiger reserve of the southern Western Ghats. The lake is formed by the construction of a dam across the streams, Mullayar and Periyar in 1895.The river Mullayar originates at an altitude of 1780MSL, has a total length of 31km and joins the southern tip of the lake. The Periyar stream joins the eastern tip of the lake from the southern direction, originating at an altitude of 1593m MSL, has a length of 43km. Further down a number of small tributaries join the main stream before it drains to the Idukki reservoir, the technological aspiration of Kerala. Tributaries Muthirapuzha and Perinankutty join the main stream before the river reach at Perinjankutty and Kallar. The river then takes a turn to the North west direction and reaches the legendary Bhoothathankettu believed to be constructed by demons, as per the local folklore. The reservoir at Bhoothathankettu is the main source of irrigation under the Periyar valley irrigation project.

Before reaching the legendary reservoir, the river passes by the hydel projects at Sengulam, Neriyamangalam and Panniyar. The Idamalayar tributary joins the main river here. At the downstream the river bifurcates into the Marthanda Varma and the Mangalapuzha branch. The former drains out to the backwaters of the Lakshadeep sea and the latter joins the 'Chalakudy' river. Mathanda Varma branch further bifurcates into two- The Eloor branch and Edamala branch. Eloor branch runs in between a cluster of industries on both banks termed as the industrial hub of Kerala. As part of the present study detailed habitat inventory surveys were conducted at 29 selected locations of Periyar river system (Plate 3.11). The overall physical, chemical and biological habitat structure of Periyar river system is given below:

3.3.6.1. Physical habitat structure

In Periyar river system, among the various habitat variables, the instream cover was dominated by depth (40.8%) followed by turbulence (31.4%). The percentage occurrence of different types of instream cover in Periyar river system was shown in Fig.3.6. On an average bedrock formed 45.5%of the river bed followed by boulders (14.6%), cobbles (14.5%), gravels (12.6%), rock (6.6%) and fines (6.2%) (Fig.3.12).

Among the physical conditions sinuosity varied from 1-1.4(SD=0.12) and stream gradient ranged from 0.01-0.15 (SD=0.03). Mean entrenchment ratio and w/d ratios were1.39 (SD=0.03) and 5.1(SD=3.6) respectively (Table 3.6). Midchannel pools contributed to 24% of the total river reach followed by run (19.8%), riffles (15.5%) and cascade (11%) (Fig.3.18). Mean flow velocity was 0.49m/s(SD=0.35) and the riparian zone having 22.9% shrub cover, 55.2% tree cover while 21.8% of the riparian zone was without any vegetation. Habitat quality score varied from 10(Kuntrapuzha) to 77(Purakkallu) with a mean value of 49.1(SD=20.6) (Fig.3.19). The habitat quality scores at various locations selected for habitat inventory in Periyar river system is presented in Table 3.6.

3.3.6.2. Species assemblage structure

Fourty six fish species representing14 families were collected from the 30 locations surveyed in Periyar river system, which formed 60.5% of the total species so far collected from Periyar river system. The total number of species and the location wise species abundance at different locations selected for habitat inventory is shown in Table 3.12.Cyprinids dominated the catch with 21 species forming 91.3% of the total individuals collected followed by Balitoridae and Cichlidae with 8 and 3 species respectively. Table 3.18 shows the classification of different species identified from Periyar river system under 10 metrics used for IBI scoring. Of the total 46 species reported during the present study, 8.7% were suckers, 17.4% were loaches and 15.2% were midwater species. Suckers showed their distribution in 75.9% locations, loaches in 62.1% locations and midwater species in 41.4% locations selected for the study. Tolerant and intolerant fish species respectively constituted 13% and 29% of the fish fauna. Distribution of tolerant fish species were identified from only 27.6% locations while intolerant fish species showed their distribution at all selected locations. Among the different trophic groups omnivores contributed to 56.2% of the total species collected followed by insectivores (20.9%), herbivores (18.6%) and carnivores (4.3%). Among the 29 locations surveyed omnivores was collected from all the locations. While distribution of herbivores and insectivores were recorded only from 80% of the total locations while carnivores were confined to only up to 20% of the total locations surveyed. Index of biotic integrity score varied from 0 (Kuntrapuzha) to 52(Thandamankuthu) with a mean value of 34.1(SD=11.8)(Fig.3.20). The index of biotic integrity at various locations selected for habitat inventory in Periyar river system is presented in Table 3.24.

The range of water quality parameters at selected locations of Periyar river system is given in Table 3.30. Few typical channel reaches identified from Periyar river system is shown in Plate 3.12.

3.4. Discussion

In Kabbini river system the low hetrogenity of channel geomorphic units and high embedness of sand and silt on the river bed are the major threats to fish diversity. The increased proportion of bare ground in the riparian zone is the major reason for the low heterogeneity of channel geomorphic units and high embedness of sand and silt on the river bed. Due to the conversion of riparian zone to agricultural lands, large number of trees and shrubs were removed which in turn resulted the increased proportion of bare ground in the riparian zone.Williams *et al.*(1997) reported that roots of trees in the riparian zone held the soil particles together and improves the bank stability.57% of the river bed in Kabbini river system was formed of gravels and fines , which manifests the high degree of bank erosion and embedness due to the conversion of the catchment areas of the river into agricultural lands. The present finding strongly corrobrates the view of Judy *et al.* (1984) who opined that silt, which is often associated with agricultural land use, could be one of the most important factors reducing the availability of usable fish habitat.

In Bharthapuzha river system, the increased proportion of sand and silt in the river bed, comparatively less pool-riffle type channel geomorphic unit in the river reach and increased number of check dams across the river were identified as the major fish diversity threats. The result of the present study revealed that the low contribution of bigger substrates like bed-rock, rock and boulders when compared to smaller substrates reduce the fish diversity and this finding is in full compliance with that of Talmage *et al.*(1999) who reported that percentage sand within the reach was negatively correlated with IBI scores in streams in the Twin cities metropolitan area of Minnesota. He further added that when there was a paucity of bigger substrates there was limited habitat for fish. The present study revealed that the sparse and sporadic occurrence of pool-riffle habitats in the Bharathapuzha river system have a negative effect on the fish diversity which is corroborating with the findings of Talmage *et al.* (1999) who opined that streams with greater percentages of riffles often had higher IBI scores. Presence of 9.6% of landslide among channel geomorphic units was due to the presence of numerous check dams constructed across the main river stretch. According to Hynes (1970), waterfalls and dams act as migration barriers for fishes, which will reduce the species abundance and the consequent decrease in IBI scores. Dams affect fish communities by altering stream geomorphology, substrate composition and stream flow. Moreover, siltation behind dams may alter the substrate composition within the pool, causing the pool-habitat even more homogenous. Goldstein *et al.* (1999) reported that dams form pools, decrease stream flow variability, and can result in a shift from lotic to lentic species. According to Talmage *et al.* (1999) water in small urban impoundments gains heat because the surface area got exposed to the sun is always higher.

Due to the low habitat quality in Bharathapuzha river system, the percentage contribution of top carnivores, herbivores and the coloumn feeding fishes together with the total number of species was less. Conversely, the number of carnivores was found high. This finding strongly supports the view of Karr (1981) who opined that when the habitat quality decreases the proportion of omnivores increases while the number of species, the percent contribution of top carnivores and herbivores will decrease. The low level of water column or midwater species in Bharathapuzha river system are fully supporting the view of Hughes and Oberdorff (1999) who supported that that the density of water column or midwater species declines with urban development but particularly with sedimentation, turbidity, decreased dissolved oxygen and warming .Due to the low habitat quality, the mean index of biotic integrity in Bharathapuzha river system was only 21.7, which is very low when compared to that of the streams at Washinton region of United states, where it varied from 24 to 57(Lyons,1992).

The high degree of bank erosion and embedness were identified as the major reasons for the low microhabitat diversity, which has a major role in the low fish diversity in Kallada river system. This finding is highly corroborating with that of Lachvanne and Juge(1997) who reported that due to human intervention, the river systems become more homozygous which will drastically reduces the faunastic diversity.

The mean index of biotic integrity in Kallada river system (27.3) was very less when compared to other river systems such as Chalakudy (44.1) and Pamba(34.2) river systems. Among the 10 metrics which determines the index of biotic integrity, the low number of native species and the high percentage occurrence of tolerant species negatively affected the IBI score of Kabbini river system. Similar finding was reported by Noss(1990) who observed that number of native species declined with increased habitat degradation. Similarly high percentage occurrence of tolerant species in the community structure in the Kabbini river is corollary to the view of Ganasan and Hughes (1998) who reported that tolerant species are the last to disappear following a disturbance and the first to reappear as the system begins to recover.

In Pamba river system, the highly degraded condition of the riparian zone has significant impact on the low heterogeneity of microhabitats and high embedness of fishes and gravels on the river bed. Talmage *et al.* (2002) while studying the relation of instream habitat and physical conditions to fish communities of agricultural streams in the Northern Midwest of United States revealed that the most effective restoration efforts for Midwestern agricultural streams are those that focus on the riparian corridor because riparian restoration addresses instream habitat and physical conditions at multiple scales. When compared to other river systems such as Bharathapuzha and Kallada the habitat quality score was little high in Pamba river system(41.9) which also manifested in the high mean index of biotic integrity score (34.2) in the Pamba river system.

In Chalakudy river system, the instream habitat and physical conditions are comparatively good when compared to other river systems. The present finding is corroborating with the findings of Krebs (1985) who opined that within certain spatial and functional limits, the more heterogeneous and complex the physical environment, the more complex the flora and fauna and higher the species diversity. When compared to other river systems, the distribution of pools and riffles were maximum in Chalakudy river system. According to Cowx and Welcomme(1998), reaches having alternating pools and riffles supports the maximum fish diversity in lotic ecosystems. Riparian zone in Chalakudy river system has high tree cover (87.65%) and shrub cover (7.6%) and the contribution of bare ground was very less (4.75%). The presence of high percentage of tree cover and shrub cover reduces the bank erosion and thereby the embedness on the riverbed. The present finding is in compliance with that of Talmage *et al.* (2002) who reported that vegetation on the riparian zone provide fish communities with cover, temperature stabilization, a food source, and reduced fine sediment.Mean habitat quality score of Chalakudy river is far higher than the other five river systems in Kerala. Due to the good habitat quality the resulting index of biotic integrity score was also highest in Chalakudy river system.

In periyar river system, the increasing bare ground contribution in the riparian zone was found responsible for reducing the heterogeneity of instream cover, which was found as the major treat to fish diversity. During the study period, the river bed was dominated by bigger materials like bedrock, rock and boulders. But due to the increasing human intervention into the riparian zone there is every possibility for the dominance of silt on the river bed in the near future.

Periyar river system showed the second highest habitat quality score after Chalakudy river, among the six major river systems in Kerala. Eventhough the average index of biotic integrity score is only 34.1, except in some few locations, all other locations are having an IBI score above 40 and coming under 'good' category.

The results of the present study revealed that, among the six major river systems in Kerala, the best habitat quality was shown by Chalakudy river system followed by Periyar, Kabbini, Pamba, Kallada and Bhrathapuzha river systems, In the case of index of biotic integrity scoring, Chalakudy river system showed the highest followed by Kabbini, Pamba, Periyar Kallada and Bharthapuzha river systems. It would thus appear that the physical, chemical and biological integrity in Bharathapuzha and Kallada river systems were undergoing drastic reduction due to increasing habitat alteration interventions. The extent of ecosystem degradation undergone by these six major river systems of Kerala and appropriate management plans relevant for various river restoration programmes are discussed in the subsequent chapters.

Table 3.1. Habitat quality(HQ) scoring at slected locations of Kabbini river

	Sugandagiri		Begur		Kunnambatta		Kuruvadeep	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Intermediate	4	Limited	8	Limited	8	Extensive	0
Main channel bedrock substrate(%of area)	0	0	13.7	0	0	0	60	16
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	11.1	0	27.45	16	11.1	0	37	16
Average maximum Talweg depth(4 deepest depths)(m)	1.8	0	4.5	8	1.8	0	6	16
Sinuosity	1.1	4	1	6	1.1	4	1.1	4
W/D ratio	7.4	6	7.8	6	7.4	6	31.3	0
Overall HQ score		14		44		18		52

Table 3.1(continued) Habitat quality(HQ) scoring at slected locations of Kabbini river

	Palvelicham		Achoor		Begur I		Begur II	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Extensive	0	Extensive	0	Limited	8	Limited	0
Main channel bedrock substrate(%of area)	60	16	0	0	0	0	0	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	34	16	5	0	60	25	72.5	25
Average maximum Talweg depth(4 deepest depths)(m)	6	16	7	16	3.9	8	4	8
Sinuosity	1	6	1	6	1	6	1	6
W/D ratio	20.8	2	3.9	6	5.64	6	6.1	6
Overall HQ score		56		28		53		45

Table 3.1.(continued)Habitat quality(HQ) scoring at slected locations of Kabbini river

	Thariyod		Aranagiri I		Aranagiri II		Aranagiri	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Extensive	0	Extensive	0	Extensive	0	Limited	8
Main channel bedrock substrate(%of area)	20	0	8.1	0	0	0	20.5	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	23	8	42.2	16	14	0	31.1	16
Average maximum Talweg depth(4 deepest depths)(m)	1.6	0	1.3	0	16	25	1.04	0
Sinuosity	2.1	0	1.2	2	1.2	2	1.5	0
W/D ratio	3.8	6	4.75	6	0.51	6	6.18	6
Overall HQ score		14		24		33		30

Table 3.1.(continued) Habitat quality(HQ) scoring at slected locations of Kabbini river

	Ponkuzhy		Noolpuzha		Muthanga	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Limited	8	Extensive	0	Extensive	0
Main channel bedrock substrate(%of area)	20	0	0	0	0	0

Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	46.5	16	26	16	37	16
Average maximum Talweg depth(4 deepest depths)(m)	4.5	8	2.5	0	3	8
Sinuosity	2.1	0	2.6	0	2.5	0
W/D ratio	6.3	6	6.3	6	8.25	6
Overall HQ score		38		22		30

Table 3.2.Habitat quality(HQ) scoring at slected locations of Bharathapuzha river

	Cheruthuruthy		Kanakkanoor		Thonikadavu		Cheerakuzhi	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Limited	8	Intermediate	4	Extensive	0	Extensive	0
Main channel bedrock substrate(%of area)	0	0	10	0	90	25	10	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	0	0	20	8	6.4	0	13	0
Average maximum Talweg depth(4 deepest depths)(m)	3	8	4	8	4	8	5	16
Sinuosity	1	6	1	6	1	6	1	6
W/D ratio	83.3	0	20	2	17.1	4	15.1	4
Overall HQ score		22		28		43		26

Table 3.2.(continued) Habitat quality(HQ) scoring at slected locations of Bharathapuzha river

	Meenvallam I		Cheerakuzhi II		Pambadi east		Manarkkad	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Intermediate	4	Extensive	0	Extensive	0	Limited	8
Main channel bedrock substrate(%of area)	0	0	93	25	94	25	3	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	28	16	3	0	20	16	3	0
Average maximum Talweg depth(4 deepest depths)(m)	13.3	25	7	16	5	16	4	8
Sinuosity	1.2	4	1	6	1	6	1	6
W/D ratio	0.85	6	15.1	4	44	0	15.5	4
Overall HQ score		55		51		63		18

Table 3.2.(continued) Habitat quality(HQ) scoring at slected locations of Bharathapuzha river

	Mudappallur		Yakkara		Churiode		Kalpathi	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank prtection	Extensive	0	Nosignificant ba	12	Intermediate	4	Extensive	0
Main channel bedrock substrate(%of area)	75	25	25	8	0	0	87	25
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	11.8	0	42	16	19	8	12.3	0
Average maximum Talweg depth(4 deepest depths)(m)	6.8	16	2.78	0	1.5	0	2.5	0
Sinuosity	1	6	1	6	1.63	0	1	6
W/D ratio	13.4	4	54	0	23.7	2	11	6
Overall HQ score		51		42		14		37

Table 3.2.(continued) Habitat quality(HQ) scoring at slected locations of Bharathapuzha river

	Pezhumkara		Choorapara		Chittur		Kavarakundu	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Extensive	0	Extensive	0	Extensive	0	Intermediate	4
Main channel bedrock substrate(%of area)	70	25	40	8	94	25	10	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	50	16	20	8	21.7	8	24	8
Average maximum Talweg depth(4 deepest depths)(m)	4	8	10	16	8.5	16	25	25
Sinuosity	1	6	1.3	2	1	6	1.1	4
W/D ratio	43.8	0	3	6	13.1	4	0.48	6
Overall HQ score		55		40		59		47

Table 3.2.(continued) Habitat quality(HQ) scoring at slected locations of Bharathapuzha river

	Velampattapuzha		Kanjirapuzha		Karimala		Thippilikayam	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Intermediate	4	Limited	8	Extensive	0	Extensive	0
Main channel bedrock substrate(%of area)	0	0	0	0	0	0	0	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	16	8	19.5	8	22	8	25	16
Average maximum Talweg depth(4 deepest depths)(m)	2.5	0	2	0	2.5	0	11	25
Sinuosity	1	6	1.15	4	1	6	1.1	4
W/D ratio	6	6	15	4	4	6	1.72	6
Overall HQ score		24		24		20		51

Table 3.2.(continued) Habitat quality(HQ) scoring at slected locations of Bharathapuzha river

	Thodunnampara		Meenvallam I		Atla		Puchappara	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Extensive	0	Extensive	0	Extensive	0	Limited	8
Main channel bedrock substrate(%of area)	15	0	0	0	12	0	0	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	12.8	16	27	16	18.6	8	23	16
Average maximum Talweg depth(4 deepest depths)(m)	4	8	18	25	12.7	25	1.5	0
Sinuosity	1.1	8	1.3	2	1.2	4	1	6
W/D ratio	2.6	6	0.56	6	2.3	6	21.2	2
Overall HQ score		38		49		43		32

Table 3.2.(continued) Habitat quality(HQ) scoring at slected locations of Bharathapuzha river

	Cheriyawalakkad I		Karingathodu		Cheriyawalakkad II		Syrendri	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Intermediate	4	Extensive	0	Limited	8	Extensive	0
Main channel bedrock substrate(%of area)	0	0	0	0	0	0	0	0

Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	16	8	49	16	13	0	6	0
Average maximum Talweg depth(4 deepest depths)(m)	5	16	25	25	3	8	25	25
Sinuosity	1	6	1.1	4	1	6	1.2	4
W/D ratio	6.08	6	0.77	6	9.1	6	3	6
Overall HQ score		40		49		28		35

Table 3.3.Habitat quality scoring at slected locations of Kallada river

	Urukunnu		Ottakkal		Meenmutty	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Extensive	0	Extensive	0	Limited	8
Main channel bedrock substrate(%of area)	24	0	19	0	17	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	8.2	0	13.4	0	44.6	25
Average maximum Talweg depth(4 deepest depths)(m)	3.5	8	25	25	10	25
Sinuosity	1.38	2	1	6	1	6
W/D ratio	17.1	4	4	6	7.5	6
Overall HQ score		14		38		70

Table 3.3.(continued)Habitat quality scoring at slected locations of Kallada river

	Dali		MSL		Chenkali		Kazhuthuruty	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Extensive	0	Limited	8	No significant bank	12	Extensive	0
Main channel bedrock substrate(%of area)	28	8	0	0	0	0	0	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	13	0	14	0	22	8	32	16
Average maximum Talweg depth(4 deepest depths)(m)	10	25	15	25	5.2	16	3	8
Sinuosity	1	6	1.05	4	1.4	2	1	6
W/D ratio	3.98	6	1.3	6	6.4	6	6.8	6
Overall HQ score		45		35		36		36

Table 3.3.(continued) Habitat quality scoring at slected locations of Kallada river

	Ariyankavu		Palaruvi II		Palaruvi I		Chenthuruny	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Extensive	0	Extensive	0	Extensive	0	Extensive	0
Main channel bedrock substrate(%of area)	0	0	43	8	56	16	0	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	7	0	44	16	44	16	33	8
Average maximum Talweg depth(4 deepest depths)(m)	1.2	0	50	25	15	25	4	8

Sinuosity	1.1	6	1.1	4	1.2	4	1	6
W/D ratio	5.58	6	0.23	6	0.85	6	11.25	6
Overall HQ score		12		59		67		28

Table 3.4. Habitat quality scoring at slected locations of Pamba river

	Thottapuzhassery		Tiruvillapra		Perunthenaruvi		Azhutha	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Intermediate	4	No significant bank erosion	12	Extensive amount o	0	Limited	8
Main channel bedrock substrate(%of area)	0	0	0	0	98	25	10	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	7	0	13.4	0	15	8	13.1	0
Average maximum Talweg depth(4 deepest depths)(m)	10.08	25	7	16	30	16	21	25
Sinuosity	1	6	1	6	1	6	1.2	4
W/D ratio	7.74	6	7.3	6	7.8	6	2.5	6
Overall HQ score		**41**		**40**		**61**		**43**

Table 3.4.(continued) Habitat quality scoring at slected locations of Pamba river

	Angamoozhi		Nilakkalthodu		Attathodu		Kakkad Ar I	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Extensive	0	Extensive	0	Limited amount of b	8	Intermediate	4
Main channel bedrock substrate(%of area)	2	0	0	0	0	0	59	16
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	16.5	8	45	16	12	0	12	0
Average maximum Talweg depth(4 deepest depths)(m)	10	25	1.3	0	20	25	14	25
Sinuosity	1.2	4	1	6	1.3	2	1	6
W/D ratio	3.2	6	10.77	6	2.25	6	2.6	6
Overall HQ score		**43**		**28**		**33**		**57**

Table 3.4.(continued) Habitat quality scoring at slected locations of Pamba river

	Kakkad Ar II		Pamba		Moozhiyar I		Moozhiyar II	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Intermediate	4	Limited	8	Limited	8	Limited	8
Main channel bedrock substrate(%of area)	76	25	8	0	0	0	57	16
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	3	0	13	0	5	0	12	0
Average maximum Talweg depth(4 deepest depths)(m)	17	25	2.5	0	2	0	14.7	25
Sinuosity	1	6	1	6	1	6	1.2	4
W/D ratio	2.2	6	7.9	6	22	2	3.2	6
Overall HQ score		**66**		**20**		**20**		**59**

Table 3.4.(continued) Habitat quality scoring at slected locations of Pamba river

	Kakki I		Kakki II		Kochupamba	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Extensive	0	Extensive	0	Limited	8

Main channel bedrock substrate(%of area)	0	0	0	0	45	16
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	9	0	14	0	27	16
Average maximum Talweg depth(4 deepest depths)(m)	21	25	17.5	25	2	0
Sinuosity	1.3	2	1.33	2	1	6
W/D ratio	0.9	6	0.68	6	9.25	6
Overall HQ score		**33**		**33**		**52**

Table 3.5. Habitat quality scoring at slected locations of Chalakudy river

	Vettilappara		Athirappally I		Athirappally II		Vazhachal	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	No significant b	12	Limited	8	Intermediate	4	No significant b	12
Main channel bedrock substrate(%of area)	95.97	25	50	16	73.5	25	48	16
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	12.7	0	16.7	8	18.4	8	15	8
Average maximum Talweg depth(4 deepest depths)(m)	6.9	16	4	8	50	25	4.5	8
Sinuosity	1	6	1	6	1	6	1	6
W/D ratio	20.5	2	21.8	2	2.6	6	28.1	0
Overall HQ score		61		48		74		50

Table 3.5.(continued) Habitat quality scoring at slected locations of Chalakudy river

	Karappara		Orukomban I		Sholayar		Orukomban II	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Intermediate	4	Limited	8	Intermediate	4	Extensive	0
Main channel bedrock substrate(%of area)	16.2	0	20	0	78	25	45	16
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	22	8	33.7	16	19	8	34.1	16
Average maximum Talweg depth(4 deepest depths)(m)	17.2	25	7.3	16	3.5	8	6.5	16
Sinuosity	1	6	1	6	1	6	1.1	4
W/D ratio	2.4	6	7.1	6	8	6	11.3	6
Overall HQ score		49		52		57		58

Table 3.5.(continued) Habitat quality scoring at slected locations of Chalakudy river

	Kuriarkutty		Puliyala		Thekkadiyar		Thekkadiyar II	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	No significant b	12	Limited	8	Extensive	0	Extensive	0
Main channel bedrock substrate(%of area)	77	25	69.7	25	58.9	16	0	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	15	8	5.9	0	21.4	8	50	25

Average maximum Talweg depth(4 deepest depths)(m)	4	8	20	25	5	16	5.75	16
Sinuosity	1	6	1	6	1	6	1.5	0
W/D ratio	21.8	2	3.6	6	6.1	6	2.26	6
Overall HQ score		61		70		52		47

Table 3.5.(continued) Habitat quality scoring at slected locations of Chalakudy river

	Thekkadiyar III		Orukomban		Malakkapara		Vallakayam	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Extensive	0	Limited	8	Limited	8	Limited	8
Main channel bedrock substrate(%of area)	59.7	16	50	16	0	0	60	16
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	21.4	8	25	16	0.8	0	25	16
Average maximum Talweg depth(4 deepest depths)(m)	5	16	9.3	16	3.25	8	45	25
Sinuosity	1	6	1.1	4	1.4	2	1.1	4
W/D ratio	6.1	6	6.3	6	8.3	6	0.5	6
Overall HQ score		52		66		24		75

Table 3.5.(continued) Habitat quality scoring at slected locations of Chalakudy river

	Anakkallankayam		Padikutty		Karappara river		Vetti Ar	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Extensive	0	Extensive	0	Intermediate	4	Intermediate	4
Main channel bedrock substrate(%of area)	63	16	77	25	8.5	0	7	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant while water boulders,overhanging stream boulders, undercut bank)	24.3	16	15	8	32.8	16	52	25
Average maximum Talweg depth(4 deepest depths)(m)	31.6	25	15	25	15.5	25	5	16
Sinuosity	1.2	4	1	6	1.3	2	1.15	4
W/D ratio	0.79	6	2.8	6	3.1	6	5.65	6
Overall HQ score		66		70		53		55

Table 3.6. Habitat quality scoring at slected locations of Periyar river

Habitat quality score	Bhoothathankettu		Neriyamangalam		Pooyamkutty		Purakallu	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	intermediate	4	Limited	8	Limited	8	Limited	8
Main channel bedrock substrate(%of area)	0	0	0	0	35	8	92.5	25
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant while water boulders,overhanging stream boulders, undercut bank)	40.5	16	5.2	0	4.1	0	26.3	16
Average maximum Talweg depth(4 deepest depths)(m)	15	25	6	16	8	16	9	16
Sinuosity	1.1	4	1.1	4	1	6	1	6
W/D ratio	5.7	6	10.8	6	10.9	6	2.1	6
Overall HQ score		55		34		44		77

Table 3.6.(continued) Habitat quality scoring at slected locations of Periyar river

Habitat quality score	Thandamankuttu		Neendapara		Magappara		Pidippara	

Metrics	Quantification	HQ score	Quantification	HQ score	Quantification	HQ score	Quantification	HQ score
Bank erosion,failure and bank protection	No significant b	12	Extensive	0	Extensive	0	Extensive	0
Main channel bedrock substrate(%of area)	87.5	25	5	0	20	0	50	16
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	6.2	0	9	0	19	8	12.4	0
Average maximum Talweg depth(4 deepest depths)(m)	6	16	4	8	30	25	7	16
Sinuosity	1	6	1	6	1.2	4	1.07	4
W/D ratio	9.6	6	2.3	12	1.5	6	5.7	6
Overall HQ score		65		26		43		42

Table 3.6.(continued) Habitat quality scoring at slected locations of Periyar river

Habitat quality score	Thannimmodu		Panniarkutty		Mukkan		Nallathanni	
Metrics	Quantification	HQ score	Quantification	HQ score	Quantification	HQ score	Quantification	HQ score
Bank erosion,failure and bank protection	Extensive	0	Extensive	0	intermediate	4	Extensive	0
Main channel bedrock substrate(%of area)	0	0	10	0	82	25	0	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	9.9	0	29	16	7	0	13	0
Average maximum Talweg depth(4 deepest depths)(m)	5	16	6	16	22	25	3.5	8
Sinuosity	1.3	2	1.1	4	1	6	1	6
W/D ratio	3	6	4.3	6	2.1	6	10.6	6
Overall HQ score		24		42		66		20

Table 3.6.(continued) Habitat quality scoring at slected locations of Periyar river

Habitat quality score	Kunchithanni		Mandrappara		Choorrapara		Ummikuppanthodu	
Metrics	Quantification	HQ score	Quantification	HQ score	Quantification	HQ score	Quantification	HQ score
Bank erosion,failure and bank protection	Extensive	0	Extensive	0	Extensive	0	Extensive	0
Main channel bedrock substrate(%of area)	62	16	23	0	84	25	45.2	16
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	17	8	32	16	15	8	43.2	16
Average maximum Talweg depth(4 deepest depths)(m)	7	16	5	16	5	16	2.8	0
Sinuosity	1	6	1	6	1	6	1.4	2
W/D ratio	10.4	6	6.75	6	3.2	6	3.23	6
Overall HQ score		52		44		61		38

Table 3.6.(continued) Habitat quality scoring at slected locations of Periyar river

Habitat quality score	Thannikudy I		Anakkallankayam		Pulikkayam		Mlappara station	
Metrics	Quantification	HQ score	Quantification	HQ score	Quantification	HQ score	Quantification	HQ score
Bank erosion,failure and bank protection	Intermediate	4	Extensive	0	Limited	8	Limited	8
Main channel bedrock substrate(%of area)	39	8	75.3	25	90.25	25	64.5	16

Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	14.3	0	13.9	0	13	0	14.1	0
Average maximum Talweg depth(4 deepest depths)(m)	5.85	16	10	25	23	25	6	16
Sinuosity	1	6	1	6	1	6	1.1	4
W/D ratio	10.9	6	4.06	6	2.43	6	10.8	6
Overall HQ score		40		62		70		50

Table 3.6.(continued) Habitat quality scoring at slected locations of Periyar river

Habitat quality score	Thannikudy II		Pillakayam		Nadathottam		Moolavaiga	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	intermediate	4	Limited	8	Intermediate	4	Intermediate	4
Main channel bedrock substrate(%of area)	85	25	38.1	8	65.2	25	0	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	26.3	16	26.5	16	6.1	0	11.5	0
Average maximum Talweg depth(4 deepest depths)(m)	20	25	20	25	15	25	10	25
Sinuosity	1	6	1.1	4	1.4	2	1.2	4
W/D ratio	2.14	6	1.8	6	2.9	6	3.35	6
Overall HQ score		82		66		62		39

Table 3.6.(continued) Habitat quality scoring at slected locations of Periyar river

Habitat quality score	Kundamkallu		Mukkar		Chembakavallithodu		Kattamadithodu II	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Intermediate	4	Limited	8	intermediate	4	Extensive	0
Main channel bedrock substrate(%of area)	15	0	0	0	0	0	0	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	26.5	16	47	16	56	25	35	16
Average maximum Talweg depth(4 deepest depths)(m)	8	16	2.5	0	12	25	14	16
Sinuosity	1.5	0	1.18	4	1.3	2	1.66	0
W/D ratio	3.7	6	7.6	6	0.92	6	0.7	6
Overall HQ score		42		34		62		38

Table 3.6.(continued) Habitat quality scoring at slected locations of Periyar river

Habitat quality score	Kattamadithodu I		Kuntrapuzhaza	
Metrics	**Quantification**	**HQ score**	**Quantification**	**HQ score**
Bank erosion,failure and bank protection	Extensive	0	Extensive	0
Main channel bedrock substrate(%of area)	0	0	0	0
Available cover for adult game fish(turbulance,woody debris,vegetation, turbulant white water boulders,overhanging stream boulders, undercut bank)	16.5	8	0	0
Average maximum Talweg depth(4 deepest depths)(m)	9	16	4.2	0
Sinuosity	1	6	1.1	4
W/D ratio	0.7	6	1.6	6
Overall HQ score		36		10

Table 3.7.Fish species collected from different locations of Kabbini river system

		SU	BE	KU	KR	PA	AC	BE	BE II	TA	AR I	AR II	AR	PO	NO	MU
Cyprinidae	**Rasborinae**															
A.melettinus					X											
B.bakeri					X			X	X		X	X		X	X	
B.gatensis				X	X		X	X	X					X	X	
D.malabaricus				X	X	X		X	X					X	X	
R.daniconius		X					X						X	X	X	
Aplocheilidae																
Aplocheilus lineatus					X			X	X							
Cyprinidae	**Cyprininae**															
Puntius carnaticus			X		X			X	X					X	X	
C.reba					X											
Kantaka brevidorsalis									X					X		
H.dubius			X	X			X	X	X					X		
O.nashii			X	X					X					X	X	
P.chola														X		
P.conchonius				X	X	X	X		X					X		
P.fasciatus		X	X	X	X		X	X	X		X		X	X	X	
P.filamentosus					X											
P.parrah					X											
P.sarana subnasutus					X											
P.ticto			X		X				X					X		
P.vittatus					X			X	X							
N.wynaadensis											X	X	X			
T.putitora									X					X		
Nandidae																
Chanda nama					X											
Cyprinidae	**Gariinae**															
G.g.stenorhynchus			X			X		X	X					X		
G.mcclellandi					X	X		X	X					X		
G.mullya			X	X	X	X		X	X	X		X		X	X	
Gobiidae	**Gobiinae**															
G.giuris														X	X	
Sisoridae																
G.lonah			X		X				X							
Glyptothorax annandalei														X		
Heteropneustidae																
H.fossilis					X											
Cyprinidae	**Cobitidae**															
L.thermalis					X									X	X	
Bagridae																
M.armatus			X	X	X			X	X					X	X	
M.bleekeri				X												
M.cavasius														X	X	
M.gulio														X		
M.malabaricus				X												
Mystus punctatus					X											
Belontidae	**Macropodinae**															
Macropodus cupanus					X											
Mastacembelidae																
Mastacembeles armatus			X		X			X	X							
Channidae																
C.marulius					X											
C.striatus					X											
Balitoridae	**Balitorinae**															
N.guentheri		X														
N.monilis														X		
N.semiarmatus					X											

N.triangularis		X			X		X									
B.australis		X			X							X		X		
Nemacheilus denisoni dayi						X										
Notopteridae																
Notopterus notopterus					X	X										
Siluridae																
Ompok malabaricus								X	X							
S.wynaadensis												X				
Ambassidae																
Parambassis thomassi					X	X								X		
Pseudambassis ranga						X										
Cyprinidae	**Cultrinae**															
Salmostoma boopis					X			X	X					X		
Salmostoma sardinella														X	X	

Su - Sugandagiri
BE I - Begur I
KU - Kunnambatta
KR - Kuruvadeep
PA - Palvelicham
AC - Achoor
BE - Begur
BE II - Begur II
TA - Thariod
AR I - Aranagiri I
AR II - Aranagiri II
AR - Aranagiri
PO - Ponkuzhi
NO - Noolpuzha
MU - Muthanga

Table 3.8.Fish species collected from different locations of Bharathapuzha river system

Ambassidae	Subfamily	CH	KA	TH	CE	ME	CE I	PA	MA	MU	YA	CU	KA	PE	CO	CI	KA	VE	KN	KR	TI	TO	ME II	AT	PU	CH	KI	CH	SY
Ambassis gymnocephalus		X			X																								
Parambassis thomassi		X	X								X			X		X													
P.dayi		X							X		X																		
Cyprinidae	**Rasborinae**																												
Amblypharyngodon microlepis		X																											
Barilius bakeri									X																				
Barilius gatensis						X			X			X					X								X				X
Barilius bendelesis		X																											
Barilius canarensis																	X		X					X					
D.aequiipinnatus					X							X					X					X		X					
D.malabaricus					X	X	X			X	X			X															
Rasbora daniconius		X			X							X			X							X							
Cyprinidae	**Cyprininae**																												
Catla catla			X																										
Puntius bovanicus			X													X													
Puntius chloa									X		X									X									
Puntius dorsalis					X																								
Puntius fasciatus									X						X		X					X	X	X					
Puntius filamentosus		X	X	X	X	X	X		X		X	X	X	X		X			X										
Puntius parrah			X	X							X				X	X													
Puntius sarana subnasutus					X						X		X																
Puntius ticto		X			X	X					X	X		X															
Tor khudree																	X												
Puntius amphibious		X			X						X																		
Gonoproktopterus curmuca			X						X		X				X				X										
Channidae																													
Channa marulius											X																		
Channa striatus			X																										
Clupeidae	**Pellonuline**																												
Dayella malabarica				X																									
Cichilidae																													
Etroplus maculatus		X	X	X	X		X	X	X		X			X		X													
Etroplus suratensis			X				X	X																					
Oreochromis mossambicus			X										X																
Sisoridae																													
Glyptothorax annandalei																													X
Glyptothorax madraspatnam									X																				

Gobidae	**Gobiinae**																												
Glossogobius giuris															X														
Cyprinidae	**Garrinae**																												
Garra menoni																													
Garra mullya			X	X		X	X	X	X	X	X	X					X	X	X	X	X	X							
Garra hugi																													X
Heteropneustidae																													
Heteropneustes fossilis													X																
Balitoridae	**Balitorinae**																												
Homoloptera pillai																													
Nemacheilus triangularis									X								X								X				
Nemacheilus guentheri																						X							
Nemacheilus remadevi																													X
Hemirhampidae																													
Hemirhamphus limbatus								X																					
Cobitidae																													
Lepidocephalus thermalis																									X				
Bagridae																													
Mystus armatus						X									X	X													
Mystus bleekeri											X																		
Mystus cavasius		X							X				X																
Belontidae	**Macropodinae**																												
Macropodus cupanus									X																				
Mastacembelidae																													
Mastacembeles armatus			X						X																				
Notopteridae																													
Notopterus notopterus											X																		
Siluridae																													
Ompok bimaculatus									X																				
Pristolepidanae																													
Pristolepis marginata									X		X				X														
Cyprinidae	**Cultrinae**																												
Salmostoma acinaces									X																				
Salmostoma boopis			X													X													
Tetradontidae																													
Tetraodon travancoricus					X				X																				
Siluridae																													
Wallago attu											X																		
Belonidae																													

Xenatodon cancila			X	X	X				X			X				X													
Anabantidae																													
Anabas testudineus			X																										
Aplocheidae																													
Aplocheilus lineatus		X																											
Balitoridae																													
Bhavania australis																	X			X				X					

CH-Cheruthuruthy
KA-Kanakkanoor
TH-Thonikadavu
CE-Cheerakuzhi
ME I-Meenvallam I
CE II-Cheerakuzhi I
PA-Pambadi east
MA-Manarkkad
MU-Mudappallur
YA-Yakkara
CU-Churiode
KA-Kalpathi
PE-Pezhumkara
CO-Choorapara
CI-Chittur

KA-Kavarakundu
VE-Velampatapuzha
KN-Kanjirapuzha
KR-Karimala
TI-Tippilikayam
TO-Tonikadavu
ME II-Meenvallam II
AT-Atla
PU-Puchappara
CE-Cheriyawalakkad I
KI-Karingathodu
CE II-Cheriyawalakkad II
SY-Synendri

Table 3.9.Fish species collected from different locations of Kallada river syster

		UR	OT	ME	DA	MS	CH	KA	AR	PA I	PA II	CE
Cyprinadae	**Rasborinae**											
B.bakeri			X	X		X	X	X				
B.gatensis							X		X	X	X	
D.malabaricus		X	X	X	X		X		X			
R.daniconius												
Channidae												
C.micropeltes										X		
Gobiidae	**Gobiinae**											
G.giuris		X										
Cyprinadae	**Garrinae**											
G.mullya				X	X	X	X	X	X	X	X	X
Cyprinidae	**Cyprininae**											
H.curmuca			X	X	X		X					X
H.thomassi			X	X								
Cobitidae												
Lepidocephalus thermalis												
N.guentheri									X			
N.triangularis							X			X	X	
Cyprinidae	**Cyprininae**											
O.bakeri			X									
P.amphibius												
P.arulius							X					
P.fasciatus				X	X		X			X	X	
P.filamentosus		X	X	X	X		X		X		X	
T.khudree				X	X		X		X			X
P.ticto												
Ambassidae	**Rasborinae**											
Parambassis thomassi				X								
Belonidae												
X.cancila			X					X	X		X	
Balitoridae												
B.australis										X	X	
Cichlidae												
Oreochromis mossambicus								X				

UR-Urukunnu
OT-Ottakkal
ME-Meenmutty
DA-Dali
MS-MSL
CH-Chenkali
KA-Kazhuthuruty
AR-Ariyankavu
PA I-Palaruvi I
PAII-Palaruvi II
CE-Chenthuruny

Table 3.10.Fish species collected from different locations of Pamba river system

		TH	TI	PE	AZ	AN	NI	AT	KA I	KA II	PA	MO I	MO	KK I	KK II	KO
Cyprinidae	**Rasborinae**															
B.bakeri		X		X	X	X		X	X	X	X	X	X	X	X	X
B.gatensis		X		X	X	X	X	X	X	X						X
D.aequipinnatus							X									
D.malabaricus				X	X	X		X	X		X	X	X		X	X
R.daniconius																
Bagridae																
Batasio travancoria							X									
Horabagrus brachysoma			X													
Mystus armatus		X	X				X	X		X						
Channidae																
Channa marulius			X													
Cyprinidae	**Cultrinae**															
Chela fasciata						X										
Salmostoma acinaces		X				X		X	X	X	X					X
Cichilidae																
Etroplus maculatus			X													
Cyprinidae	**Garrinae**															
G.mullya				X	X	X	X	X	X		X					X
G.surendranathanii					X	X										X
Cyprinidae	**Cyprininae**															
H.curmuca				X		X	X	X			X			X	X	
P.amphibius		X			X					X						
P.chola			X													
P.fasciatus		X				X	X			X					X	
P.filamentosus		X	X	X	X	X	X	X	X	X	X					X
P.sarana subnasutus		X	X							X						
P.ticto																X
T.khudree														X	X	X
Heteropneustidae																
H.fossilis																
Mastacembelidae																
Mastacembeles armatus		X	X				X			X						
Balitoridae	**Balitorinae**															
N.guentheri		X	X				X	X		X						
N.triangularis				X												
Nandidae																
Nandus nandus			X													
Pristolepidinae																
P.marginata			X													
Poecilidae																
Poecilia sp.		X		X			X		X	X	X					
Siluridae																
Wallago attu			X													
Ambassidae																
Parambassis thomassi			X													

TH-Thottapuzhssery
TI-Tiruvillapra
PE-Peruthenaruvi
AN-angamoozhi
AZ-Azhutha
NI-Nilakkalthodu
AT-Attathodu

KA I-Kakkad Ar I
KA II-Kakkad Ar II
PA-Pamba
MO I-Moozhiyar I
MO II-Moozhiyar II
KK I-Kakki I
KK II-Kakki II
KO-Kochupamba

Table 3.11.Fish species collected from different locations of Chalakudy river system

		VE	AT I	AT II	VA	KA	OR	SH	OR II	KU	PU	TH I	TH	TH II	OR	MA	VL	AN	PA	KR	VE
Aplocheidae	**Rasborinae**																				
A.lineatus															X						
Cyprinidae	**Rasborinae**																				
B.bakeri		X			X	X		X		X	X				X		X		X		X
B.bendelesis					X		X			X											
B.camarensis				X		X	X	X	X	X	X				X				X	X	X
B.gatensis		X	X	X	X	X	X	X	X	X	X				X		X	X	X	X	X
D.aequipinnatus										X										X	
Esomus dandricus	Cyprinidae																				
Danio malabaricus		X	X	X	X	X	X	X	X	X	X				X						
R.daniconius	Cyprinidae	X																X			
Bagridae																					
B.travancoria											X										
Clarridae																					
C.dussumieri																		X	X		
Cichilidae																					
E.maculatus		X			X																
E.suratensis		X			X																
Sisoridae																					
G.annandalei																			X		
Cyprinidae	**Garrinae**																				
G.mullya		X	X	X	X	X	X	X	X	X	X										
G.surendranathanii						X		X	X	X	X				X		X		X	X	
Gobiidae	**Gobiinae**																				
Glossogobius giuris		X																			
Sicyopterus griseus		X																			
Cyprinidae																					
H.curmuca															X						
H.kolus						X	X	X		X	X	X	X	X	X				X		
O.longidorsalis	Cyprinidae			X	X		X	X		X	X				X						
P.amphibius	Cyprinidae		X																		
P.chola	Cyprinidae				X																
P.denisonii	Cyprinidae	X	X																		
P.fasciatus	Cyprinidae	X		X	X	X		X			X								X		
P.filamentosus	Cyprinidae	X	X		X	X				X					X				X	X	
P.jerdoni	Cyprinidae			X	X										X						

T.khudree	Cyprinidae		X	X	X	X	X	X	X	X	X										
Heterpneustidae																					
H.fossilis																		X			
Bagridae																					
Horabagrus nigricollaris		X																			
Horabagrus brachysoma		X																			
Cobitidae																					
L.thermalis		X													X			X	X		
Bagridae																					
M.armatus		X	X		X																
M.cavasius		X								X	X										X
Balitoridae																					
N.triangularis		X	X		X					X								X			
Cichlidae																					
O.mossambicus															X						
Pristolepidinae																					
P.marginata		X			X		X				X				X						
Ambassidae																					
P.thomassi							X			X											
Cyprinidae	**Cultrinae**																				
S.boopis		X			X																
Belonidae																					
Xenetodon cancila			X																		

VE-Vettilappara	OR I-Orukomban I	TH I-Thekkadiyar I	VL-Vallakayam
AT I-Athirappally I	SH-Sholayar	TH-Thekkadiyar	AN-Anakkayam
AT II-Athirappally II	OR II-Orukomban II	TH II-Thekkadiyar II	PA-Padikutty
VA-Vazhachal	KU-Kuriarkutty	OR-Orukomban	KR-Karappara river
KA-Karappara	PU-Puliyala	MA-Malakkapara	VE-Vetti Ar

Table 3.12.Fish species collected from different locations of Periyar river system

	Sub family	BH	NE	PO	PU	TH	NE	MA	PI	TN	PA	MU	NA	KN	MA	CH	UM	TK	AN	PU	ML	TK I			MO	KU	MU	CE	KM II	KM I	KR
Aplocheilidae																															
A.blochii		X											X																		
A.lineatus									X																						
A.melittinus																															
Balitoridae	**Balitorinae**																														
B.australis			X		X			X			X																				
L.thermalis								X		X	X										X										
N. menoni																											X			X	
N.denisonii																												X			
N.guentheri																												X	X		
N.keralensis																														X	
N.triangularis						X	X					X			X	X			X		X	X									
T.jonesi				X		X													X												
Cyprinidae	**Rasborinae**																														
Barilius.gatensis					X			X			X	X	X		X	X		X	X	X											
B. bakeri		X		X					X		X								X	X	X	X				X	X	X			
Danio malabaricus		X	X	X	X						X	X	X	X	X	X		X		X	X					X	X	X	X		
R.daniconius		X	X					X	X	X	X						X														
Clariidae																															
C.dussumieri						X																									
Cyprinidae	**Cyprininae**																														
C.periyarensis																	X				X				X						
H. micropogon periyarensis																					X										
H.curmuca																		X	X						X	X					
H.thomassi						X																									
L.typus																			X	X	X				X	X					
Labeo nigrescens				X																											
O.longidorsalis					X																										
P.denisonii				X	X																										
P.fasciatus			X	X		X	X	X		X	X		X	X	X	X	X	X	X	X											
P.filamentosus		X	X	X			X		X																						
P.ophicephalus																	X								X		X	X	X		
P.vittatus								X																							
T.khudree		X		X	X	X			X			X			X	X		X	X	X	X	X			X	X					
Nandidae																															
Chanda nama		X																													
Channidae																															
Channa micropeltes		X	X																												
Cichlidae																															
E.maculatus			X	X			X																								

E.suratensis																															
O.mossambicus								X			X																				
Cyprinidae	**Gariinae**																														
G. surendranathanii																															
G.hugi																											X	X	X		
G.mullya		X			X	X		X	X	X		X	X		X	X		X	X	X	X	X			X	X					
G.periyarensis																		X	X	X	X	X									
Heteropneustidae																															
H.fossilis						X																									
Bagridae																															
M.armatus		X				X																									
Belontidae	**Macropodinae**																														
M.cupanus			X					X																							
Siluridae																															
Ompok malabaricus																									X						
Wallago attu							X																								
Pristolepidinae																															
P.marginata		X	X	X																											
Poecillidae																															
Pocelia sp.											X																				
Belonidae																															
X.cancila		X																													

BH-Bhoothathankettu
NE-Neriyamangalam
PO-Pooyamkutty
PU-Purakkallu
TH-Thandamankuthu
NE-Neendapara
MA-Mangappara
PI-Pindippara
TN-Tannimoodu
PA-Panniarkutty
MU-Mukkan
NA-Nallathanni
KU-Kunchithanni
MA-Mandrappara
CH-Choorappara

UM-Ummikuppanthodu
TK-Tannikudy
AN-Anakkallankayam
PU-Pulikkayam
ML-Mlappara
TK I-Tannikudy I
PL-Pillakayam
NA-Nadathottam
MO-Moolavaiga
KU-Kundamkallu
MK-Mukkar
CE-Chembkavalli
KA II-Kattamadithodu II
KA I-Kattamadithodu I
KU-Kuntrapuzha

Table 3.13.Classification of different species identified from Kabbini under 10 metrics used for IBI scoring

Species	NAT	LO	SU	INTS	MWS	TP	HE	OM	IN	TC
A.melettinus	Y								I	
B.bakeri	Y			Y					I	
B.gatensis	Y			Y					I	
D.malabaricus	Y			Y					I	
R.daniconius	Y					Y		O		
Aplocheilus lineatus	Y								I	
Puntius carnaticus	Y							O		
Cirrhinus reba	Y				Y			O		
Kantaka brevidorsalis	Y			Y	Y			O		
H.dubius	Y			Y	Y			O		
O.nashii	Y			Y	Y			O		
P.chola	Y							O		
P.conchonius	Y							O		
P.fasciatus	Y							O		
P.filamentosus	Y							O		
P.parrah	Y							O		
P.sarana subnasutus	Y				Y			O		
P.ticto	Y							O		
P.vittatus	Y							O		
N.wynaadensis	Y			Y	Y			O		
T.putitora	Y			Y				O		
Chanda nama	Y									TC
G.g.stenorhynchus	Y		Y				H			
G.mcclellandi	Y		Y				H			
G.mullya	Y		Y				H			
G.giuris	Y					Y				TC
G.lonah	Y		Y	Y			H			
Glyptothorax annandalei	Y		Y	Y			H			
H.fossilis	Y									TC
L.thermalis	Y	Y						O		
M.armatus	Y					Y				C
M.bleekeri	Y									C
M.cavasius	Y									C
M.gulio	Y									C
M.malabaricus	Y									C
Mystus punctatus	Y									C
Macropodus cupanus	Y							O		
Mastacembeles armatus	Y					Y				TC
C.marulius	Y									TC
C.striatus	Y					Y				TC
N.guentheri	Y	Y						O		
N.monilis	Y	Y						O		
N.semiarmatus	Y	Y						O		
N.triangularis	Y	Y						O		
B.australis	Y		Y	Y			H			
Nemacheilus denisonii dayi	Y	Y		Y				O		
Notopterus notopterus	Y									TC
Ompok malabaricus	Y									TC
S.wynaadensis	Y									C
Parambassis thomassi	Y									TC
Pseudambassis ranga	Y									TC
Salmostoma boopis	Y			Y					I	
Salmostoma sardinella	Y			Y					I	

Table 3.14.Classification of different species identified from Bharathapuzha river under 10 metrics used for IBI scoring

Species	NAT	LO	SU	INTS	MWS	TP	HE	OM	IN	TC
Ambassis gymnocephalus	Y									TC
Parambassis thomassi	Y									TC

P.dayi	Y									TC
Amblypharyngodon microlepis	Y									C
Barilius bakeri	Y			Y					I	
Barilius gatensis	Y			Y					I	
Barilius bendelesis	Y			Y					I	
Barilius canarensis	Y			Y					I	
D.aequipinnatus	Y			Y					I	
D.malabaricus	Y			Y					I	
Rasbora daniconius	Y					Y		O		
Catla catla	Y							O		
Puntius bovanicus	Y			Y				O		
Puntius chloa	Y			Y				O		
Puntius dorsalis	Y							O		
Puntius fasciatus	Y							O		
P.filamentosus	Y							O		
Puntius parrah	Y							O		
Puntius sarana subnasutus	Y				Y			O		
Puntius ticto	Y							O		
Tor khudree	Y							O		
Puntius amphibius	Y							O		
Gonoproktopterus curmuca	Y				Y			O		
Channa marulius	Y									TC
Channa striatus	Y					Y				TC
Dayella malabarica	Y						H			
Etroplus maculatus	Y							O		
Etroplus suratensis	Y							O		
Oreochromis mossambicus	Y					Y		O		
Glyptothorax annendalei	Y						H			
Glyptothorax madraspatnam	Y						H			
Glossogobius giuris	Y					Y				TC
Garra menoni	Y		Y				H			
Garra mullya	Y		Y				H			
Garra hugi	Y		Y				H			
Heteropneustes fossilis	Y					Y				TC
Homoleptera pillai	Y		Y				H			
Nemacheilus triangularis	Y	Y						O		
Nemacheilus guentheri	Y	Y						O		
Mesonemacheilus remadevi	Y	Y					H			
Hemirhamphus limbatus	Y							O		
Lepidocephalus thermalis	Y							O		
Mystus armatus	Y					Y				C
Mystus bleekeri	Y									C
Mystus cavasius	Y									C
Macropodus cupanus	Y							O		
Mastacembeles armatus	Y					Y				TC
Notopterus notopterus	Y									TC
Ompok bimaculatus	Y					Y				TC
Pristolepis marginata	Y				Y			O		
Salmostoma acinaces	Y								I	
Salmostoma boopis	Y								I	
Tetraodon travancoricus	Y									TC
Wallago attu	Y					Y				TC
Xenentodon cancila	Y									TC
Anabas testudineus	Y					Y				C
Aplocheilus lineatus	Y								I	
Bhavania australis	Y		Y				H			

Table 3.15.Classification of different species identified from Kallada river under 10 metrics used for IBI scoring

Species	NAT	LO	SU	INTS	MWS	TP	HE	OM	IN	TC
B.bakeri	Y			Y					I	
B.gatensis	Y			Y					I	

D.malabaricus	Y			Y					I	
R.daniconius	Y					Y		O		
C.micropeltes	Y									TC
G.giuris	Y					Y				TC
G.mullya	Y		Y				H			
H.curmuca	Y				Y			O		
H.thomassi	Y			Y	Y			O		
Lepidocephalus thermalis	Y	Y					H			
N.guentheri	Y	Y						O		
N.triangularis	Y	Y						O		
O.bakeri	Y			Y				O		
P.amphibius	Y							O		
P.arulius	Y			Y				O		
P.fasciatus	Y							O		
P.filamentosus	Y							O		
T.khudree	Y			Y				O		
P.ticto	Y							O		
Parambassis thomassi	Y									TC
X.cancila	Y									TC
B.australis	Y			Y			H			
Oreochromis mossambicus						Y		O		

Table 3.16.Classification of different species identified from Pamba river under 10 metrics used for IBI scoring

	NAT	LO	SU	INTS	MWS	TP	HE	OM	IN	TC
B.bakeri	Y			Y					I	
B.gatensis	Y			Y					I	
D.aequipinnatus	Y			Y					I	
D.malabaricus	Y			Y					I	
R.daniconius	Y					Y		O		
Batasio travancoria	Y									C
H.brachysoma	Y									C
Mystus armatus	Y									C
Channa marulius	Y								I	
Chela fasciata	Y								I	
Salmostoma acinaces	Y			Y					I	
E.maculates	Y							O		
G.mullya	Y		Y				H			
G.surendranathanii	Y		Y	Y			H			
H.curmuca	Y				Y			O		
P.amphibius	Y							O		
P.chola	Y			Y				O		
P.fasciatus	Y							O		
P.filamentosus	Y							O		
P.sarana subnasutus	Y				Y			O		
P.ticto	Y							O		
T.khudree	Y			Y				O		
H.fossilis	Y					Y				TC
Mastacembeles armatus	Y					Y				TC
N.guentheri	Y	Y						O		
N.nandus	Y									TC
N.triangularis	Y	Y						O		
P.marginata	Y				Y			O		
Poecilia sp.	Y							O		
Wallago attu	Y					Y				TC
P.thomassi	Y									TC

Table 3.17.Classification of different species identified from Chalakudy river under 10 metrics used for IBI scoring

	NAT	LO	SU	INTS	MWS	TP	HE	OM	IN	TC
A.lineatus	Y								I	
B.bakeri	Y			Y					I	
B.bendelesis	Y			Y					I	

P.carnaticus	Y			Y					I	
B.gatensis	Y			Y					I	
D.aequipinnatus	Y			Y					I	
Esomus dandricus	Y					Y			I	
Danio malabaricus	Y			Y					I	
R.daniconius	Y					Y		O		
B.travancoria	Y									C
C.dussumieri	Y					Y				TC
E.maculatus	Y							O		
E.suratensis	Y							O		
G.annandalei	Y		Y	Y			H			
G.mullya	Y		Y				H			
G.surendranathanii	Y		Y	Y			H			
Glossogobius giuris	Y		Y							TC
Sicyopterus griseus	Y		Y				H			
H.curmuca	Y				Y			O		
H.kolus	Y				Y			O		
O.longidorsalis	Y			Y	Y			O		
P.amphibius	Y							O		
P.chola	Y							O		
P.denisonii	Y							O		
P.fasciatus	Y							O		
P.filamentosus	Y							O		
P.jerdoni	Y				Y			O		
T.khudree	Y			Y				O		
H.fossilis	Y					Y				TC
Horabagrus nigricollaris	Y				Y					C
Horabagrus brachysoma	Y				Y					C
L.thermalis	Y	Y						O		
M.armatus	Y					Y				C
M.cavasius	Y									C
N.triangularis	Y	Y						O		
O.mossambicus						Y		O		
P.marginata	Y				Y			O		
P.thomassi	Y									TC
S.boopis	Y			Y					I	
Xenentodon cancila	Y									TC

Table 3.18.Classification of different species identified from Periyar river under 10 metrics used for IBI scoring

Species	NAT	LO	SU	INTS	MWS	TP	HE	OM	IN	TC
A.blochii	Y								I	
A.lineatus	Y								I	
A.melittinus	Y								I	
B.australis	Y		Y	Y			H			
L.thermalis	Y	Y						O		
N. menoni	Y	Y		Y			H			
N.denisonii	Y	Y		Y				O		
N.guentheri	Y	Y						O		
N.keralensis	Y	Y		Y				O		
N.triangularis	Y	Y						O		
T.jonesi	Y		Y	Y			H			
B.gatensis	Y			Y					I	
Barilius bakeri	Y			Y					I	
Danio malabaricus	Y			Y					I	
R.daniconius	Y					Y		O		
C.dussumieri	Y					Y				TC
Crossocheilus periyarensis	Y			Y				O		
H. micropogon periyarensis	Y			Y	Y			O		
H.curmuca	Y				Y			O		
H.thomassi	Y			Y	Y			O		

L.typus	Y			Y				O		
L.nigriscens	Y			Y	Y			O		
O.longidorsalis	Y			Y	Y			O		
P.denisonii	Y			Y				O		
P.fasciatus	Y							O		
P.filamentosus	Y							O		
P.ophicephalus	Y			Y				O		
P.vittatus	Y							O		
T.khudree	Y			Y				O		
Chanda nama	Y									TC
Channa micropeltes	Y							O		
E.maculatus	Y							O		
E.suratensis	Y							O		
O.mossambicus	Y					Y		O		
G. surendranathanii	Y		Y	Y			H			
G.hugi	Y		Y	Y			H			
G.mullya	Y		Y				H			
G.periyarensis	Y		Y	Y			H			
H.fossilis	Y									TC
M.armatus	Y									C
M.cupanus	Y							O		
Ompok malabaricus	Y					Y				TC
Wallago attu	Y					Y				TC
P.marginata	Y				Y			O		
Pocelia sp.	Y							O		
Xenentodon cancila	Y									TC

NAT-Native species
LO-Loaches
SU-Suckers

INTS-Intolerant species
MWS-Midwater species
TP-Tolerant individuals

HE-Herbivores
OM-Omnivores
IN-Insectivores

TC-Total carnivores
C - Carnivores

Table 3.19.Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Kabbini river

Metrics	**SU**	**IBI score**	**BE**	**IBI score**	**KU**	**IBI score**	**KUR**	**IBI score**
Total number of native pecies	5	0	15	10	10	5	29	10
Number of loach species	2	10	0	0	0	0	4	10
Number of sucker species	1	5	3	10	1	5	3	10
Number of intolerant species	1	5	4	10	4	10	7	10
Number of midwater species	0	0	2	5	2	5	2	5
Number of tolerant species	11.6	10	7.8	10	1.3	10	3.8	10
Trophic metrics								
Percent hervivores	20	0	20	0	10	0	12.1	0
Percent omnivores	80	0	26.7	5	40	2	45.5	0
Percent insectivores	0	0	33.3	5	20	0	12.1	0
percent topcamivores	0	0	13.3	7	0	0	17.2	10
Fish abundance and condition correlation fctors								
Number of individuals per 300m	69	-	129	-	79	-	208	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		30		62		37		65

SU-Sugandagiri
KU-Kunnambatta
BE-Begur
KUR-Kuruvadeep

Table 3.19.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Kabbini river

Metrics	**PAL**	**IBI score**	**AC**	**IBI score**	**BE I**	**IBI score**	**BE II**	**IBI score**
Total number of native pecies	10	5	6	0	10	5	21	10
Number of loach species	2	10	1	5	0	0	0	0
Number of sucker species	3	10	0	0	3	10	4	10
Number of intolerant species	2	5	3	10	3	10	10	10
Number of midwater species	0	0	1	5	3	10	4	10
Number of tolerant species	0	10	6.3	10	0	10	3.8	10
Trophic metrics								
Percent hervivores	30	0	0	0	30	0	18.2	0
Percent omnivores	30	5	83.3	0	50	0	45.5	0
Percent insectivores	10	0	16.7	0	0	0	22.7	0
percent topcarnivores	30	10	0	0	10	5	9.5	5
Fish abundance and condition correlation fctors								
Number of individuals per 300m	33	-10	32	-10	128	-	105	
Percent fishes with anomalies	0	0	0	-	0	-	0	-
Overall IBI score		45		20		50		55

PAL-Palvelicham
BE-Begur I
AC-Achoor
BE II-Begur II

Table 3.19.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Kabbini river

Metrics	**TA**	**IBI score**	**AR I**	**IBI score**	**AR II**	**IBI score**	**AR**	**IBI score**
Total number of native pecies	1	0	3	0	3	0	7	5
Number of loach species	0	0	0	0	0	0	0	0
Number of sucker species	1	5	0	0	0	0	3	10
Number of intolerant species	0	0	2	5	1	5	5	10
Number of midwater species	0	0	1	5	1	5	1	5
Number of tolerant species	0	10	0	10	21.1	5	0	10
Trophic metrics								
Percent hervivores	100	10	0	0	0	0	50	0
Percent omnivores	0	0	66.6	0	100	0	16.7	10
Percent insectivores	0	0	33.4	5	0	0	16.7	0
percent topcamivores	0	0	0	0	0	0	14.3	7
Fish abundance and condition correlation fctors								
Number of individuals per 300m	2	-10	19	-10	32	-10	34	-10
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		15		15		5		47

TA-Tariyod
AR II-Aranagiri II
AR I-Aranagiri I
AR-Aranagiri

Table 3.19.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Kabbini river

Metrics	PO	IBI score	NO	IBI score	MU	IBI score
Total number of native pecies	29	10	13	5	6	0
Number of loach species	2	10	1	5	0	0
Number of sucker species	6	10	1	5	1	5
Number of intolerant species	14	10	5	10	1	5
Number of midwater species	4	10	2	5	0	0
Number of tolerant species	4.6	10	3	10	22.6	5
Trophic metrics						
Percent hervivores	23.3	0	7.7	0	20	0
Percent omnivores	36.7	0	38.5	5	40	2
Percent insectivores	20	0	23.1	0	40	5
percent topcarnivores	3.4	0	7.7	0	0	0
Fish abundance and condition correlation fctors						
Number of individuals per 300m	172	-	135	-	62	-
Percent fishes with anomalies	2.3	-	0	-	0	-
Overall IBI score		60		45		22

PO-Ponkuzhy MU-Muthanga
NO-Noolpuzha

Table 3.20.Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Bharathapuzha river

Metrics	CH	IBI score	KA	IBI score	TH	IBI score	CE	IBI score
Total number of native pecies	13	5	15	10	6	0	13	5
Number of loach species	0	0	0	0	0	0	0	0
Number of sucker species	0	0	1	5	0	0	0	0
Number of intolerant species	1	5	2	10	0	0	0	0
Number of midwater species	0	0	2	5	0	0	1	5
Number of tolerant species	22.2	5	8	10	0	10	7.6	10
Trophic metrics								
Percent hervivores	0	0	14.3	0	16.7	0	0	0
Percent omnivores	38	5	57.1	0	66.7	0	58.3	0
Percent insectivores	15.4	0	0	0	0	0	16.79	0
percent topcarnivores	23.1	10	28.6	10	16.7	10	25	10
Fish abundance and condition correlation fctors								
Number of individuals per 300m	72	-	33	-10	25	-10	79	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		30		40		10		30

CH-Cheruthuruthy TH-Thonikadavu
KA-Kanakkanoor CE-Cheerakuzhi

Table 3.20.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Bharathapuzha river

Metrics	ME I	IBI score	CE	IBI score	PA	IBI score	MA	IBI score
Total number of native pecies	6	0	5	0	10	5	19	10
Number of loach species	0	0	0	0	1	5	0	0
Number of sucker species	1	5	1	5	1	5	2	10
Number of intolerant species	2	5	1	5	0	0	5	10
Number of midwater species	0	0	0	0	1	5	2	5
Number of tolerant species	4	10	0	10	12	10	4.3	10
Trophic metrics								
Percent hervivores	16.6	0	20	0	10	0	10.5	0
Percent omnivores	33.3	0	60	0	40	2	42.1	0
Percent insectivores	33.3	5	20	0	0	0	15.8	0
percent topcarnivores	0	0	0	0	50	10	21.1	10
Fish abundance and condition correlation fctors								
Number of individuals per 300m	25	-10	19	-10	25	-10	69	-
Percent fishes with anomalies	0	-	0	-	0	0	0	-
Overall IBI score		10		10		32		55

ME I-Meenvallam I PA-Pambadi east
CE II-Cheerakuzhi I MA-Manarkkad

Table 3.20.(continued)Percentage contribution of different metric groups,IBI scores obtained

by different metrics and overall IBI at selected locations of Bharathapuzha river

Metrics	MU	IBI score	YA	IBI score	CH	IBI score	KA	IBI score
Total number of native pecies	4	0	16	10	8	0	6	0
Number of loach species	0	0	0	0	0	0	0	0
Number of sucker species	1	5	1	5	0	0	0	0
Number of intolerant species	1	5	2	5	0	0	0	0
Number of midwater species	0	0	3	10	1	5	1	5
Number of tolerant species	0	0	2.7	10	15.7	10	7	10
Trophic metrics								
Percent hervivores	25	0	6.25	0	0	0	14.3	0
Percent omnivores	25	5	62.5	0	71.4	0	57.1	0
Percent insectivores	25	0	6.25	0	0	0	14.3	0
percent topcarnivores	25	10	25	10	12.5	5	28.6	10
Fish abundance and condition correlation fctors								
Number of individuals per 300m	56	-	112	-	19	-10	56	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		25		50		5		25

MU-Mudappallur CU-Churiode
YA-Yakkara KA-Kalpathi

Table 3.20.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Bharathapuzha river

Metrics	PE	IBI score	CO	IBI score	CH	IBI score	KV	IBI score
Total number of native pecies	6	0	7	0	8	0	8	0
Number of loach species	0	0	0	0	0	0	1	5
Number of sucker species	0	0	1	5	0	0	1	5
Number of intolerant species	0	0	2	2	0	0	5	10
Number of midwater species	0	0	0	0	0	0	0	0
Number of tolerant species	0	10	12.2	10	6.7	10	0	10
Trophic metrics								
Percent hervivores	0	0	14.3	0	0	0	25	0
Percent omnivores	50	0	42.9	0	62.5	0	37.5	0
Percent insectivores	16.7	0	28.6	0	0	0	37.5	5
percent topcarnivores	16.6	10	14.3	7	25	10	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	17	-10	41	-10	30	-10	117	-
Percent fishes with anomalies	0		0	0	0	-	0	-
Overall IBI score		10		14		10		35

PE-Pezhumkara CI-Chittur
CO-Choorapara KV-Kavarakundu

Table 3.20.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Bharathapuzha river

Metrics	VE	IBI score	KN	IBI score	KR	IBI score	TH	IBI score
Total number of native pecies	1	0	4	0	3	0	1	0
Number of loach species	0	0	0	0	0	0	0	0
Number of sucker species	1	5	1	5	1	5	1	5
Number of intolerant species	0	0	1	5	2	5	0	0
Number of midwater species	0	0	1	5	0	0	0	0
Number of tolerant species	0	0	0	10	0	10	0	10
Trophic metrics								
Percent hervivores	100	10	25	0	66.6	0	100	10
Percent omnivores	0	0	50	0	33.3	0	0	0
Percent insectivores	0	0	25	0	0	0	0	0
percent topcarnivores	0	0	0	0	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	24	-10	28	-10	12	-10	24	-10
Percent fishes with anomalies	0	-	0	0	0	-	0	0
Overall IBI score		5		15		20		15

VE-Velampatapuzha KR-Karimala
KN-Kanjirapuzha TI-Tippilikayam

Table 3.20.(continued)Percentage contribution of different metric groups,IBI scores obtained

by different metrics and overall IBI at selected locations of Bharathapuzha river

Metrics	TO	IBI score	ME II	IBI score	AT	IBI score	PU	IBI score
Total number of native pecies	6	0	1	0	4	0	4	0
Number of loach species	0	0	0	0	0	0	2	10
Number of sucker species	1	5	0	0	0	0	0	0
Number of intolerant species	2	5	0	0	3	10	2	5
Number of midwater species	0	0	0	0	1	5	0	0
Number of tolerant species	1.5	10	0	10	0	10	3.4	10
Trophic metrics								
Percent hervivores	50	0	0	0	25	0	0	0
Percent omnivores	33.3	0	100	0	25	0	75	0
Percent insectivores	16.6	0	0	0	50	5	25	0
percent topcarnivores	0	0	0	0	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	131	-	3	-10	14	-10	29	-10
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		20		0		20		5

TO-Thodunnampara AT-Atla
ME II-Meenvallam II PU-Puchappara

Table 3.20.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Bharathapuzha river

Metrics	SY	IBI score	KN	IBI score	CH I	IBI score	CH II	IBI score
Total number of native pecies	4	0	2	0	5	0	2	0
Number of loach species	1	5	1	5	1	5	1	5
Number of sucker species	2	10	0	0	2	10	0	0
Number of intolerant species	4	10	2	5	4	10	2	5
Number of midwater species	0	0	0	0	0	0	0	0
Number of tolerant species	0	10	0	10	6.7	10	0	0
Trophic metrics								
Percent hervivores	50	0	50	0	60	0	50	0
Percent omnivores	25	5	0	0	20	5	0	0
Percent insectivores	25	0	50	5	0	0	50	5
percent topcarnivores	0	0	0	0	20	10	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	21	-10	15	-10	15	-10	9	-10
Percent fishes with anomalies	0	0	0	-	0	-	0	-
Overall IBI score		30		15		40		5

CE-Cheriyawalakkad I CE II-Cheriyawalakkad II
KI-Karingathodu SY-Synendri

Table 3.21.Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Kallada river

Metrics	UR	IBI score	OT	IBI score	ME	IBI score	DA	IBI score
Total number of native pecies	4	0	7	0	9	5	6	0
Number of loach species	0	0	0	0	0	0	0	0
Number of sucker species	0	0	0	0	1	5	1	5
Number of intolerant species	1	5	4	10	4	10	2	5
Number of midwater species	0	0	2	5	2	5	1	5
Number of tolerant species	5.5	10	8.2	10	0	10	0	10
Trophic metrics								
Percent hervivores	0	0	0	0	11.1	0	16.7	0
Percent omnivores	25	5	71.4	0	55.6	5	66.7	0
Percent insectivores	25	0	28.6	0	22.2	0	16.7	0
percent topcarnivores	25	10	0	0	11.1	5	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	18	-10	62	-	92	-	106	-
Percent fishes with anomalies	0		0	-	0	-	0	-
Overall IBI score		**20**		**25**		**45**		**25**

UR-Urukunnu ME-Meenmutty
OT-Ottakkal DA-Dali

Table 3.21.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Kallada river

Metrics	MSL	IBI score	CH	IBI score	KA	IBI score	AR	IBI score
Total number of native pecies	3	0	10	5	4	0	7	5
Number of loach species	0	0	1	5	0	0	1	5
Number of sucker species	1	5	1	5	1	5	1	5
Number of intolerant species	1	5	5	10	1	5	3	10
Number of midwater species	0	0	1	5	0	0	0	0
Number of tolerant species	3.5	10	0	10	76.1	0	28	5
Trophic metrics								
Percent hervivores	16.7	0	10	0	25	0	14.3	0
Percent omnivores	66.7	0	60	0	25	5	57.1	0
Percent insectivores	16.7	0	30	5	50	5	28.6	0
percent topcarnivores	0	0	0	0	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	115	-	137	-	71	-	102	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		20		45		20		25

MS-MSL KA-Kazhuthuruty
CH-Chenkali AR-Ariyankavu

Table 3.21.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Kallada river

Metrics	PA II	IBI score	PA I	IBI score	CH	IBI score
Total number of native pecies	7	5	8	0	3	0
Number of loach species	2	10	3	10	0	0
Number of sucker species	1	5	1	5	1	5
Number of intolerant species	2	10	2	5	1	5
Number of midwater species	0	0	0	0	1	5
Number of tolerant species	9.9	10	14.3	10	0	10
Trophic metrics						
Percent hervivores	28.6	0	25	0	33.3	0
Percent omnivores	57	0	50	0	66.6	0
Percent insectivores	14.3	0	12.5	0	0	0
percent topcarnivores	0	0	12.5	0	0	0
Fish abundance and condition correlation fctors						
Number of individuals per 300m	121	-	28	-10	19	-10
Percent fishes with anomalies	0	-	0	-	0	0
Overall IBI score		40		20		15

PA I-Palaruvi I CE-Chenthuruny
PAII-Palaruvi II

Table 3.22.Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Pamba river

Metrics	TH	IBI score	TI	IBI score	PE	IBI score	AZ	IBI score	AN	IBI score
Total number of native pecies	10	5	13	5	9	5	8	5	10	5
Number of loach species	0	0	0	0	2	10	0	0	0	0
Number of sucker species	0	0	0	0	1	5	1	10	2	10
Number of intolerant species	3	10	1	5	3	10	4	10	6	10
Number of midwater species	1	5	3	10	1	5	0	0	1	5
Number of tolerant species	14	10	20	7	5	10	0	10	0	10
Trophic metrics										
Percent hervivores	0	0	7.7	0	11.1	0	25	0	20	0
Percent omnivores	50	0	30.8	0	55.6	0	37.5	5	30	5
Percent insectivores	30	5	0	0	33.3	5	37.5	5	50	5
percent topcarnivores	10	5	46.2	10	0	0			0	0
Fish abundance and condition correlation fctors										
Number of individuals per 300m	119	-	115	-	108		53	-	38	-10
Percent fishes with anomalies	3	-	4	-10	0		0	-	0	
Total IBI score		40		27		50		45		40

TH-Thottapuzhssery AN-Angamoozhi
TI-Tiruvillapra AZ-Azhutha
PE-Peruthenaruvi

Table 3.22.(continued)Percentage contribution of different metric groups,IBI scores obtained

by different metrics and overall IBI at selected locations of Pamba river

Metrics	NI	IBI score	AT	IBI score	KA I	IBI score	KA II	IBI score	PA	IBI score
Total number of native pecies	10	5	8	5	7	0	10	5	7	0
Number of loach species	0	0	0	0	0	0	0	0	0	0
Number of sucker species	1	5	1	5	1	5	0	0	1	5
Number of intolerant species	2	5	4	10	4	10	3	10	3	10
Number of midwater species	1	0	1	5	0	0	1	5	1	5
Number of tolerant species	23	5	8	10	1	10	20	7	32.3	0
Trophic metrics										
Percent hervivores	20	0	12.5	0	14.3	0	0	0	11.1	0
Percent omnivores	40	2	28	5	28.6	5	50	0	42.9	0
Percent insectivores	20	0	50	5	57.1	5	30	2	42.9	5
percent topcarnivores	10	5	12.5	5	0	0	10	5	0	0
Fish abundance and condition correlation fctors										
Number of individuals per 300m	38	-10	38	-10	80	-	87	-	65	-
Percent fishes with anomalies	0	-	-	-	0	-	0	-	0	-
Total IBI score		17		40		45		34		25

NI-Nilakkalthodu KA II-Kakkad Ar II
AT-Attathodu PA-Pamba
KA I-Kakkad Ar I

Table 3.22.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Pamba river

Metrics	MO I	IBI score	MO II	IBI score	KK I	IBI score	KK II	IBI score	KO	IBI score
Total number of native pecies	8	0	4	0	3	0	5	0	9	5
Number of loach species	0	0	0	0	0	0	0	0	0	0
Number of sucker species	1	5	1	5	0	0	0	0	2	10
Number of intolerant species	5	10	2	5	2	5	3	10		10
Number of midwater species	0	0	0	0	1	5	1	5		0
Number of tolerant species	0	10	0	10	0	10	0	10		10
Trophic metrics										
Percent hervivores	12.5	0	25	0	0	0	0	0	22.2	0
Percent omnivores	25	5	25	5	66.7	0	60	0	33.3	5
Percent insectivores	62.5	10	50	5	33.3	5	40	5	44.4	5
percent topcarnivores	0	0	0	0	0	0	0	0	0	0
Fish abundance and condition correlation fctors										
Number of individuals per 300m	54	-	49	-10	54	-	112	-	40	-10
Percent fishes with anomalies	0	-	0	0	1	-	0.5	-	0	0
Total IBI score		40		20		25		30		35

MO I-Moozhiyar I KK II-Kakki II
MO II-Moozhiyar II KO-Kochupamba
KK I-Kakki I

Table 3.23.Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Chalakudy river

Metrics	VE	IBI score	AT	IBI score	AT	IBI score	VA	IBI score
Total number of native pecies	20	10	11	5	11	5	18	10
Number of loach species	2	10	1	5	0	0	1	5
Number of sucker species	1	5	1	5	1	5	1	5
Number of intolerant species	5	10	4	10	6	10	8	10
Number of midwater species	3	10	0	0	3	10	2	5
Number of tolerant species	6.8	10	12.5	10	2	10	7.3	10
Trophic metrics								
Percent hervivores	14.3	0	9.1	0	11.1	0	11.8	0
Percent omnivores	42.9	0	54.5	0	66.7	0	55.6	0
Percent insectivores	19	0	22.2	0	22.2	0	29.4	5
percent topcarnivores	5	0	9.1	5	0	0	5.9	2
Fish abundance and condition correlation fctors								
Number of individuals per 300m	146	-	125	-	101	-	151	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		55		40		40		52

VE-Vettilappara AT II-Athirappally II

AT I-Athirappally I VA-Vazhachal

Table 3.23.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Chalakudy river

Metrics	KA	IBI score	OR I	IBI score	OR	IBI score	SH	IBI score
Total number of native pecies	10	5	12	5	11	5	10	5
Number of loach species	0	0	0	0	1	5	0	0
Number of sucker species	2	10	1	5	2	10	2	10
Number of intolerant species	6	10	7	10	7	10	7	10
Number of midwater species	1	5	4	10	3	10	3	10
Number of tolerant species	0	10	1.6	10	2.1	10	0	10
Trophic metrics								
Percent hervivores	20	0	7.7	0	18.2	0	20	0
Percent omnivores	50	0	46.2	0	63.6	0	50	0
Percent insectivores	30	2	23.1	0	9.1	0	30	0
percent topcarnivores	0	0	15.4	10	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	64	-	64	-	61	-	151	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		42		50		50		45

KA-Karappara SH-Sholayar
OR I-Orukomban I OR II-Orukomban II

Table 3.23.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Chalakudy river

Metrics	KU	IBI score	PU	IBI score	TH	IBI score	TH II	IBI score
Total number of native pecies	15	10	13	5	5	0	8	0
Number of loach species	1	5	0	0	0	0	0	0
Number of sucker species	2	10	2	10	0	0	1	5
Number of intolerant species	9	10	7	10	4	10	3	10
Number of midwater species	3	10	4	10	1	5	1	5
Number of tolerant species	0	10	0	10	14.2	10	0	10
Trophic metrics								
Percent hervivores	13.3	0	23.1	0	0	0	12.5	0
Percent omnivores	40	2	46.2	0	60	0	62.5	0
Percent insectivores	33.3	5	23.1	0	40	5	12.5	0
percent topcarnivores	6.7	2	0	0	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	157	-	116	-	126	-	126	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		64		45		30		30

TH II-Thekkadiyar I
PU-Puliyala TH-Thekkadiyar

Table 3.23.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Chalakudy river

Metrics	TE II	IBI score	OR II	IBI score	MAL	IBI score	VAL	IBI score
Total number of native pecies	12	5	18	10	5	0	6	0
Number of loach species	1	5	1	5	0	0	0	0
Number of sucker species	1	5	2	10	1	5	2	10
Number of intolerant species	5	10	8	10	2	5	5	10
Number of midwater species	1	5	5	10	1	5	0	0
Number of tolerant species	7.4	10	1.9	10	7.1	10	0	10
Trophic metrics								
Percent hervivores	8.3	0	11.8	0	20	0	33.3	0
Percent omnivores	50	0	58.8	0	60	0	16.7	10
Percent insectivores	33.3	5	29.4	2	20	0	50	5
percent topcarnivores	0	0	0	0	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	94	-	206	-	56	-	53	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		45		57		25		45

TH III-Thekkadiyar II MA-Malakkapara

OR-Orukomban VL-Vallakayam

Table 3.23.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Chalakudy river

Metrics	ANA	IBI score	PAD	IBI score	KAR	IBI score	VET	IBI score
Total number of native pecies	8	0	14	5	9	5	8	0
Number of loach species	1	5	1	5	0	0	0	0
Number of sucker species	1	5	3	10	2	10	1	5
Number of intolerant species	2	5	7	10	5	10	4	10
Number of midwater species	0	0	2	5	1	5	0	0
Number of tolerant species	11.7	10	5.5	10	5.2	10	0	10
Trophic metrics								
Percent hervivores	12.5	0	7.1	0	22.2	0	12.5	0
Percent omnivores	37.5	5	50	0	44.4	0	37.5	5
Percent insectivores	25	0	21.4	0	33.3	5	37.5	5
percent topcarnivores	25	10	0	0	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	60	-	109	-	96	-	73	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		40		45		45		35

AN-Anakkayam
PA-Padikutty VE-Vetti Ar
KR-Karappara river

Table 3.24.Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Periyar river

Metrics	BH	IBI score	NE	IBI score	PO	IBI score	PU	IBI score
Total number of native pecies	11	5	9	5	10	5	8	0
Number of loach species	0	0	0	0	1	5	0	0
Number of sucker species	1	5	0	0	1	5	2	10
Number of intolerant species	11	10	9	10	8	10	8	10
Number of midwater species	1	5	1	5	1	5	0	0
Number of tolerant species	0	10	16	10	0	10	0	10
Trophic metrics								
Percent herbivores	9.1	0	0	0	20	0	25	0
Percent omnivores	36.4	5	66.7	0	60	0	37.5	5
Percent insectivores	18.2	0	22.2	0	20	0	37.5	5
percent topcarnivores	27.3	10	11.1	5	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	63	-	68	-	76	-	54	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		50		35		40		40

BH-Bhoothathankettu PO-Pooyamkutty
NE-Neriyamangalam PU-Purakallu

Table 3.24.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Periyar river

Metrics	TH	IBI score	NE	IBI score	MA	IBI score	PI	IBI score
Total number of native pecies	10	5	5	0	8	0	6	0
Number of loach species	3	10	1	5	1	5	0	0
Number of sucker species	1	5	0	0	1	5	1	5
Number of intolerant species	4	10	5	10	6	10	3	10
Number of midwater species	1	5	1	5	0	0	0	0
Number of tolerant species	30	5	3.7	10	22.1	5	3.8	10
Trophic metrics								
Percent herbivores	20	0	0	0	11.1	0	16.7	0
Percent omnivores	40	2	80	0	88.8	0	50	0
Percent insectivores	10	0	0	0	0	0	33.3	5
percent topcarnivores	20	10	20	10	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	98	-	27	-10	77	-	78	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		52		30		25		30

TH-Thandamankuthu MA-Mangappara

NE-Neendapara		PI-Pindippara

Table 3.24.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Periyar river

Metrics	TN	IBI score	PA	IBI score	MU	IBI score	NL	IBI score
Total number of native pecies	5	0	6	0	6	0	4	0
Number of loach species	1	5	1	5	1	5	0	0
Number of sucker species	1	5	0	0	2	10	1	5
Number of intolerant species	4	10	6	10	6	10	4	10
Number of midwater species	0	0	0	0	0	0	0	0
Number of tolerant species	6.3	10	11.1	0	0	10	0	10
Trophic metrics								
Percent herbivores	20	0	0	0	33.3	0	25	0
Percent omnivores	60	0	57.1	0	33.3	5	25	5
Percent insectivores	20	0	42.9	5	33.3	5	50	5
percent topcarnivores	0	0	0	0	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	80	-	63	-	56	-	11	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		30		20		45		35

TN-Thannimoodu MU-Mukkan
PA-Panniarkutty NL-Nallathanni

Table 3.24.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Periyar river

Metrics	KU	IBI score	MN	IBI score	CO	IBI score	UM	IBI score
Total number of native pecies	3	0	6	0	6	0	3	0
Number of loach species	0	0	1	5	1	5	0	0
Number of sucker species	0	0	1	5	1	5	0	0
Number of intolerant species	1	5	6	10	6	10	3	10
Number of midwater species	0	0	0	0	0	0	0	0
Number of tolerant species	0	10	0	10	0	10	17	10
Trophic metrics								
Percent herbivores	0	0	16.6	0	13.7	0	0	0
Percent omnivores	33.3	5	50	0	83.3	0	100	0
Percent insectivores	66.6	10	16.6	0	0	0	0	0
percent topcarnivores	0	0	0	0	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	58	-	53	-	62	-	43	-10
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		30		30		30		10

KU-Kunchithanni CO-Choorapara
MN-Mandrappara UM-Ummikuppanthodu

Table 3.24.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Periyar river

Metrics	TA	IBI score	AN	IBI score	TE	IBI score	ML	IBI score
Total number of native pecies	8	0	9	5	8	0	9	5
Number of loach species	1	5	1	5	0	0	2	10
Number of sucker species	2	10	2	10	2	10	2	10
Number of intolerant species	8	10	9	10	8	10	9	10
Number of midwater species	1	5	1	5	0	0	1	5
Number of tolerant species	0	10	0	10	0	10	0	10
Trophic metrics								
Percent herbivores	37.5	0	37.5	0	25	0	22.2	0
Percent omnivores	50	0	37.5	5	37.5	5	55.6	0
Percent insectivores	12.5	0	25	0	37.5	5	22.2	0
percent topcarnivores	0	0	0	0	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	95	-	284	-	54	-	104	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		40		50		40		50

TA-Thannikudy TE-Thekkudukumpara

AN-Anakkallankayam ML-Mlappara

Table 3.24.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Periyar river

Metrics	TNA	IBI score	PL	IBI score	NA	IBI score	MO	IBI score
Total number of native pecies	8	0	9	5	9	5	6	0
Number of loach species	0	0	1	5	1	5	1	5
Number of sucker species	2	10	1	5	2	10	1	5
Number of intolerant species	8	10	8	10	9	10	6	10
Number of midwater species	1	5	2	5	1	5	0	0
Number of tolerant species	0	10	0	10	0	10	0	10
Trophic metrics								
Percent herbivores	25	0	33.3	0	37.5	0	33.3	0
Percent omnivores	50	0	44.4	0	37.5	5	33.3	5
Percent insectivores	25	0	22.2	0	25	0	33.3	5
percent topcarnivores	0	0	0	0	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	103	-	132	-	284	-	94	-
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		35		40		50		40

TNA-Thannikudy NA-Nadathottam
PL-Pillakayam MO-Moolavaiga

Table 3.24.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Periyar river

Metrics	KU	IBI score	MK	IBI score	CE	IBI score	KM II	IBI score
Total number of native pecies	6	0	6	0	6	5	2	0
Number of loach species	0	0	1	5	2	10	1	5
Number of sucker species	1	5	1	5	1	5	1	5
Number of intolerant species	5	10	6	10	6	10	2	5
Number of midwater species	1	5	0	0	0	0	0	0
Number of tolerant species	0	10	0	10	0	10	0	10
Trophic metrics								
Percent herbivores	28.6	0	33.3	0	50	0	100	10
Percent omnivores	42.9	0	33.3	5	16.7	10	0	0
Percent insectivores	28.6	0	33.3	5	33.3	5	0	0
percent topcarnivores	0	0	0	0	0	0	0	0
Fish abundance and condition correlation fctors								
Number of individuals per 300m	87	-	94	-	33	-10	7	-10
Percent fishes with anomalies	0	-	0	-	0	-	0	-
Overall IBI score		30		40		45		25

KU-Kundamkallu CE-Chembakavallithodu
MK-Mukkar KM II-Kattamadithodu II

Table 3.24.(continued)Percentage contribution of different metric groups,IBI scores obtained by different metrics and overall IBI at selected locations of Periyar river

Metrics	KM I	IBI score	KU	IBI score
Total number of native pecies	4	0	0	0
Number of loach species	1	5	0	0
Number of sucker species	1	5	0	0
Number of intolerant species	4	10	0	0
Number of midwater species	0	0	0	0
Number of tolerant species	0	10	0	0
Trophic metrics				
Percent herbivores	50	0	0	0
Percent omnivores	25	5	0	0
Percent insectivores	25	0	0	0
percent topcarnivores	0	0	0	0
Fish abundance and condition correlation fctors				
Number of individuals per 300m	15	-10	0	0
Percent fishes with anomalies	0	-	0	0
Overall IBI score		25		0

KM I-Kattamadithodu I
KU-Kunthrapuzha

Table 3.25.Rang eof water quality parameters at selected locations of Kabbini river system

	Air temperature	Water temperature	pH	DO	Total hardness	Total alkalinity	Flow velocity
Kunnambatta	29.3-32.8	26.1-32	7.4-7.6	6.28-6.7	14-22	8-10	0.11-0.2
Aranagiri I	20.8-28	19.1-27	7.3-7.5	7-7.6	8-12	3-6	0.221-0.24
Aranagiri II	20.6-26	19.5-25.8	7-7.3	6.7-7.3	10-16	5-8	0.305-0.318
Sugandagiri	22.9-30.2	20.3-28.2	7.2-7.6	6.9-7.2	10-14	6-10	0.239-0.246
Begur	25.4-31.8	24.2-29.8	7.6-8	7.2-7.5	14-20	10-14	0.16-0.167
Aranagiri	21.9-26.2	19-25.1	7.2-7.3	7.5-8	7-10	2-4	0.531-0.556
Begur I	26.2-30.9	21.3-28.7	7.4-7.7	7.1-7.5	12-16	6-10	0.24-0.261
Begur II	27-31.7	24.5 - 28.8	7.2-7.5	7.3-7.6	14-22	7-12	0.88-0.903
Muthanga	25.8-29.9	19.8-26.5	7.5-7.8	7.4-7.8	10-18	10-16	0.054-0.068
Noolpuzha	27.6-30.4	20-25.9	7.4-7.8	7.5-7.9	10-14	6-10	0
Ponkuzhy	20.5-27.2	18.2-25	7.6-7.9	7.9-8.3	12-18	5-8	0.44-0.47
Kurvadeep	27.9-32.2	23.2-27.6	7.5-7.8	7.7-8	16-24	8-14	0.47-0.482
Palvelicham	26.9-32	23.2-27.1	7.5-7.8	7.5-7.8	10-20	3-8	0.49-0.503
Achoor	22-31.1	19.4-25.6	7.3-7.6	5.98-6.3	16-24	6-10	0.32-0.361
Thariod	25.6-29.1	19-24.9	7.3-7.5	7.1-7.5	18-22	4-8	0

Table 3.26.Rang eof water quality parameters at selected locations of Bharathapuzha river system

	Air temperature	Water temperature	pH	Dissolved ox	Total hardness	Total alkalinity	Flow velocity
Karingathodu	21.3-22.8	19.4-21.2	7.8-8.3	5.62-5.83	23-26	4-8	0.437-0.442
Cheriya walakkad II	25.2-28	21.5-22.4	7.6-8.1	5.95-6.26	22-28	4-8	0
Puchapara	25.1-27	21.7-22.5	7.7-8.2	5.74-5.98	18-24	4-10	0.371-0.385
Karimala	26.2-28.7	22.8-24.2	6.9-7.3	5.24-5.47	22-28	4-10	0.982-1.03
Cheriya walakkad I	24.1-26.4	21.4-22.8	7.9-8.2	6.34-6.78	24-28	3-8	0.108-0.112
Kavarakundu	26.4-28.7	23.6-25.2	7.9-8.3	4.28-5.92	10-14	2-8	0.14-0.162
Cheerakuzhi	31.8-35	27.4-31	7-7.5	4.54-5.28	12-18	4-10	0.78-0.89
Cheruthuruthy	27-33.5	27.9-30.4	7.5-7.9	4.62-5.89	14-20	5-12	0.294-0.286
Thippilikayam	28-31.2	25.4-27.2	7.2-7.7	4.85-5.64	16-22	4-6	0.79-0.85
Choorapara	27.4-29.8	26.3-28	7.1-7.5	4.93-5.48	26-32	4-8	0.34-0.39
Meen vallam	27.5-32.4	24.6-25.7	7.3-7.6	5.24-5.75	18-24	4-10	0.28-0.34
Velanputupuzha	28.2-29.5	25.5-26.9	7.8-8.3	4.86-5.42	14-20	4-8	0.95-1.128
Thodunnempara	26.5-27.8	24.3-25.8	7.4-7.8	4.46-5.42	15-18	4-10	0.98-1.07
Syneadri	22.6-24.2	19.5-21.6	7.7-8.2	6.12-6.64	22-28	2-6	0.298-0.315
Meen vallam	24.2-25.8	23.4-26.5	7.6-8	4.77-5.24	22-28	4-8	0.298-0.326
Cherakuzhi	28.6-32.7	24.2-29.5	7.8-8.3	4.52-5.21	28-34	3-8	0
Karakkannoor	26-31.3	24-29.4	7-7.6	4.95-5.24	24-28	3-6	0
Manarkkad	26.1-32.8	22-28.4	7.2-7.7	6.24-6.51	16-22	2-6	0.32-0.38
Chittur	26.7-31.8	21.6-26.4	7.7-8.2	4.81-5.34	110-154	16-24	0
Pezhunkara	26.4-31.9	21.9-24.5	6.8-7.4	4.48-4.59	54-72	8-12	0
Mudappallur	27.9-32.4	22.9-26.7	6.7-7.4	4.81-5.32	20-28	20-28	0
Kanjirappuzha	25.1-29.8	19.6-22.1	7-7.5	5.18-5.47	8-14	8-16	0.15-0.23
Pambadi East	28.5-32.6	25.8-28.7	7.9-8.9	5.06-5.32	56-76	56-82	0
Thonikadavu	25.9-31.8	23.1-26.2	7.2-7.7	46.5-5.08	34-48	26-44	0
Churiode	27.6-31.4	22.2-25.4	6.7-7.3	4.71-4.92	8-14	8-14	0.48-0.54
Kalpathi	30.4-32.6	24.6-25.7	7.5-8.1	4.98-5.36	44-58	6-12	0
Yakkara	31.4-33.5	25.8-27.7	7.2-7.9	4.88-5.29	14-26	3-6	0

Table 3.27.Rang eof water quality parameters at selected locations of Kallada river system

	Air temperature	Water temperature	pH	Dissolved ox	Total hardness	Total alkalinity	Flow velocity
Palaruvi I	27-30	24.2-26.3	7.4-7.7	4.78-6	8-12	4-6	0.48-0.493
Ottakkal	30-33.7	27-28.9	6.8-7.4	4.92-5.6	18-24	5-10	0.174-0.183
Palaruvi II	31.5-32.3	23-25.5	7.5-7.8	4.85-5.64	10-16	6-10	0.22-0.241
Meenmutty	27-30	27.2-28.5	7-7.4	5.56-6.31	18-24	6-10	0
Chenkili	25.7-27.8	22.1-23.4	7.4-7.9	4.76-5.38	8-14	4-8	0.37-0.424
Chenthuruny	27-30.2	24.2-25.8	7-7.6	4.86-5.41	8-12	3-6	0.923-2.8
Urukunnu	32-38	27.6-32	7.2-7.8	4.69-5.28	14-20	4-6	0.174-0.192
Dali	27-29.2	27.5-28.4	7.4-8	5-5.91	8-16	4-12	0.38-0.435
Kazhuturuty	30-32.5	27.5-28.9	7.4-7.6	5.08-5.88	8-12	2-6	0.291-0.308
Ariyankavu	29.5-31	27-29.1	6.3-7.2	4.78-5.16	6-12	2-8	0.13-0.162
MSL	30.8-32.5	27.3-32.5	7.5-8	5-5.62	6-10	6-12	0.3-0.341

Table 3.28.Rang eof water quality parameters at selected locations of Pamba river system

	Air temperature	Water temperature	pH	Dissolved ox	Total hardness	Total alkalinity	Flow velocity
Kakkad Ar. I	30-32.7	27.2-31	7.5-8	5.42-5.83	24-36	4-8	0.12-0.135
Azhutha	26-31	23-25.8	7.2-7.7	5.9-6.47	8-14	2-6	0.7-0.724
Kakkad Ar. II	31-37.5	27.6-34	7.3-7.6	5.66-5.91	26-32	6-12	0.108-0.116
Tiruvillapra	31.2-33	27.8-30.5	6.7-7.3	5.7-6.96	44-66	10-18	0.11-0.121
Thatapuzhassery	27-31	25.5-29.7	7.3-7.8	5.48-7.6	46-62	12-22	0.08-0.14
Moozhiyar	26-30.2	25.5-27.4	7-7.3	6.01-6.46	16-28	2-6	0.271-0.293
Kochupamba	21-28.2	19.4-22.8	6.6-7.2	5.93-6.21	8-14	2-8	0.108-0.127
Perunthenaruvi	25.6-32.4	23.2-25.4	7-7.6	6.3-6.6	8-18	2-4	1.01-1.33
pamba	25.8-30.9	22.3-25.2	7.4-7.9	6.34-6.58	6-12	2-4	0.54-0.56
Attathodu	24.5-29.8	24-26.5	7.2-7.5	6.32-6.45	16-24	6-10	0.57-0.582
Nilakkalthodu	25-28.6	23.3-25.8	7.2-7.6	5.81-6.22	18-26	4-8	0.52-0.64
Angamoozhi	28.5-31.4	25.5-27.4	7-7.4	5.93-6.34	8-14	6-14	0.44-0.471

Table 3.29.Rang eof water quality parameters at selected locations of Chalakudy river system

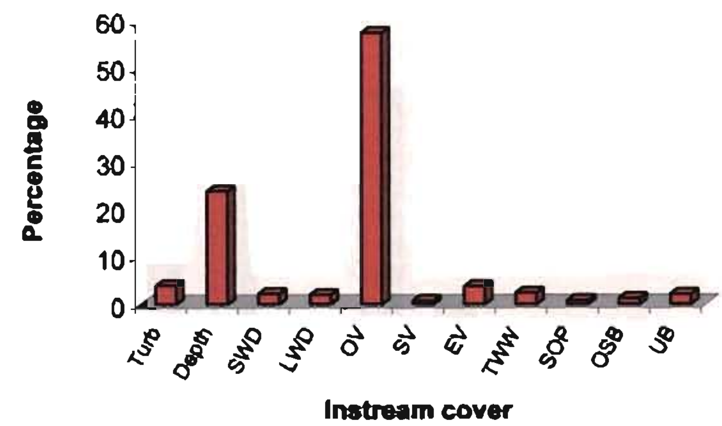
	Air temperature	Water temperature	pH	Dissolved ox	Total hardness	Total alkalinity	Flow velocity
Anakkayam I	25 -30	22.4-23.5	7-7.3	7.5-7.93	15-22	4-8	0.634-0.641
Orukomban	26-30.5	24.2-26	7.6-8.9	6.33-6.5	24-33	4-6	0.437-0.441
Thekkadiyar	29.3-31.2	24.7-27.5	6.9-7.5	7.1-7.38	24-28	4-8	0.136-0.15
Vallakayam	26.8-29.5	23-25.2	6.1-7.3	7.8-8.14	18-24	6-12	0.437-0.452
Orukomban I	30.2-33.5	23-26	7.3-7.7	5.11-5.62	16-20	4-10	0.136-0.148
Orukomban II	31.2-31.8	23.7-27.9	7.3-7.9	5.7-5.8	18-20	4-8	0.169-0.172
Thekkadiyar	30.8-31.9	24.2-27	6.7-7.3	4.76-5.33	52-75	5-10	0
Vettilapara	31.3 -32.4	25.9-26.7	7.6-8.1	7.1-7.42	12-18	6-10	0.66-0.672
Vazhachal	31.9-34.7	23.2-26	7.7-8.2	7.1-7.3	14-20	6-14	0.24-0.32
Athirappally	29.8-31.5	24-26.2	7.6-8.4	7.81-7.93	10-16	6-14	0.5-0.54
Sholayar	30.5-31.9	25.7-29	7-7.4	5.6-5.82	20-28	4-8	0
Athirappally	28.5-30.8	23.5-26.4	7.7-8.4	7.5-7.6	10-16	6-12	0.7-0.73
Kuriarkutty	32-32.8	26.5-29	7.6-8.1	5.11-5.26	28-35	6-14	0.12-0.17
Padikutty	28.1-30.6	24-27.2	7.7-8.5	6.2-6.41	24-37	4-8	0.138-0.146
Karapara river	28.7-30.3	23-25.8	7.7-8.2	6.24-6.35	22-28	4-10	0.21-0.27
Puliyala	32.7-33.2	25.5-27.4	7.4-7.9	6.41-6.65	36-42	3-6	0.29-0.315
Thekkadiyar	29-30.2	27.4-29	7.3-7.6	4.59-5.6	22-25	3-8	0.108-0.125
Vetti Ar.	27.5-28.6	24.5-26.7	7-7.5	4.51-5.53	24-28	4-10	0
Karappara	31.5-37.4	26.6-28	7.1-7.6	4.66-5.73	26-32	4-12	0
Malakkapara	30.6-31.4	24-26.8	7.6-8.2	5.19-5.56	14-18	4-8	0

Table 3.30.Rang eof water quality parameters at selected locations of Periyar river system

	Air temperature	Water temperature	pH	DO	Total hardness	Total alkalinity	Flow velocity
Nadathottam	30.2-33.4	25.7-30	8.2-8.9	7.12-7.63	8-14	2-4	0.31-0.35
Thannikudy A	27.4-29.6	22.1-27.3	7.9-8.5	6.86-7.17	23-30	3-8	0.53-0.582
Mandrappara	28.6-20.8	25.4-27.9	7.5-7.8	5.93-6.59	8-16	2-6	0.45-0.48
Ummikuppanthodu	25.4-26.8	21.6-25.1	7.8-8.2	5.46-5.82	8-12	4-8	0.18-0.22
Mukkan	31.6-38	29.4-33.5	7.9-8.2	5.63-6.02	22-28	2-6	0.28-0.34
Anakkallankayam	28.9-31.9	27.4-28.7	8.4-8.8	6.98-7.35	8-14	2-6	0.45-0.48
Pulikkkayam	28.2-30.6	26.6-27.8	7.8-8	6.41-6.8	9-12	2-6	0.41-0.47
Thandamankuthu	29.8-32	25.9-27.6	7.4-7.7	6.53-7.08	6-10	2-4	0.89-0.94
Purakkallu	30.6-35	31.5-33.7	8.4-8.6	6.95-7.34	6-10	2-4	1.18-1.42
Bhoothathankettu	27.4-29.7	25.2-26.7	7.8-8	7.18-7.34	17-22	5-16	0.66-0.69
Thannimoodu	30.5-32.2	28.2-30.1	7.8-8	4.75-5.08	26-33	4-10	0
Mangappara	29.4-30.7	28.2-34.5	7-7.3	6.25-6.59	12-17	2-6	0
Pindippara	30.2-32.1	28.1-29.6	6.7-6.9	6.37-6.75	8-15	2-4	0.76-0.83
Pillakayam	26.5-27.7	24.7-27.8	8-8.4	6.08-6.54	10-16	2-8	0.38-0.47
Thannikudy B	29.4-31.5	27.4-29.5	8.4-8.7	6.79-7.12	8-14	3-6	0.64-0.72
Mlappara	22.4-23.6	23.4-26.7	7.9-8.3	6.35-6.72	8-11	2-6	0.22-0.27
Pooyamkutty	34.2-35.7	28.4-34.2	8.4-8.8	5.9-6.3	22-26	3-8	0.43-0.49
Choorappara	29.2-31.4	25.8-28.5	7.5-7.8	6.2-6.5	24-32	3-8	0.287-0.325

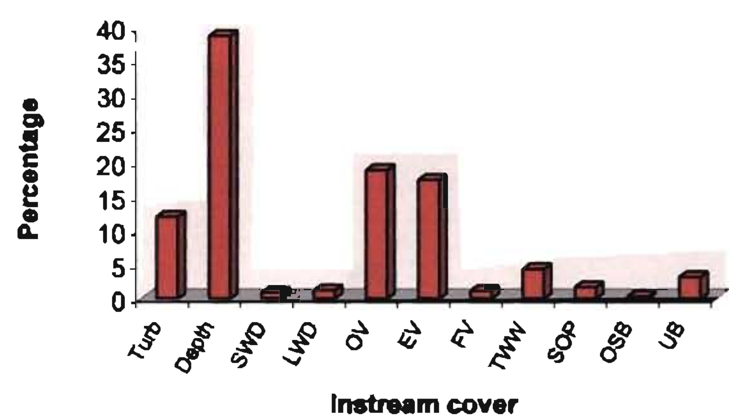
Nallathanni	25.5-26.7	22.4-23.7	7.4-7.7	7.8-8.1	3-5	2-5	0.75-0.81
Kuntrapuzha	18.5-21.6	17.6-19.8	7-7.2	7.08-7.41	3-7	4-8	0.74-0.82
Panniarkutty	31.4-36.8	27.4-29.6	6.5-6.8	7.34-7.65	10-18	2-6	0.94-1.03
Neriyamangalam	27.4-33.8	25.1-26.7	7.8-8.1	7.08-7.34	16-23	4-10	0.085-0.14
Neendapara	35.2-36.9	27.5-29.6	6.9-7.2	7.45-7.68	10-16	2-6	0
Chembakavalli	20.4-22.8	14.6-16.2	7.3-7.5	7.1-7.63	8-12	2-6	0.54-0.67
Kattamadithodu II	12.9-14.2	14.7-16	7.5-7.6	6.89-7.32	8-10	2-4	0.42-0.53
Mukkar	22.4-24.3	17.8-18.9	7.7-7.9	6.32-6.51	9-14	2-6	0
Kundamkallu	22-23.2	19-20.2	7.7-7.9	6.92-7.33	9-12	2-6	0.42-0.53
Kattamadithodu I	20.4-21.8	14.7-16	7.8-7.9	6.85-7.31	8-10	2	0.32-0.37
Moolavaiga	11.7-13.2	17.1-18.3	7.4-7.7	6.21-6.48	8-14	3-8	0

Fig.3.1.Instream cover composition in Kabbini river system



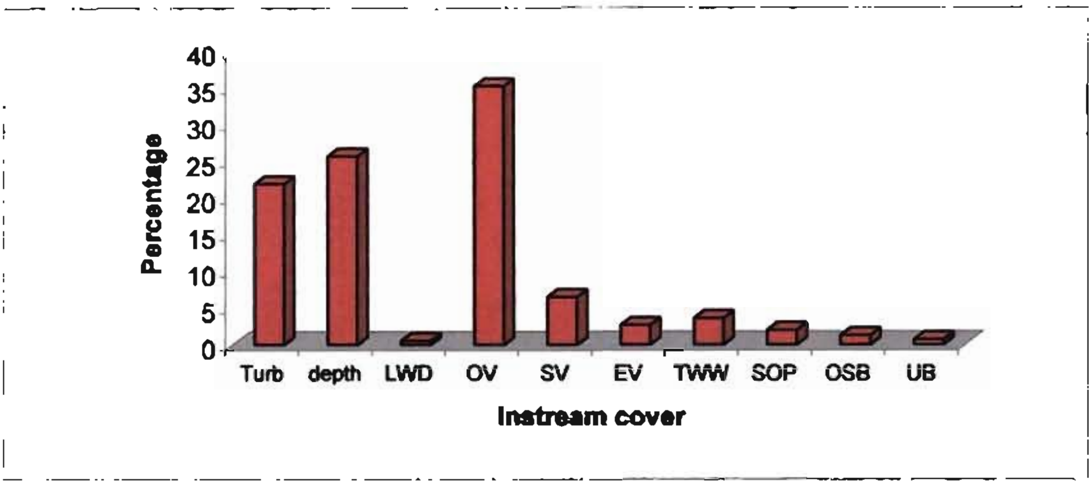
Turb-Turbulance
SWD-Small woody debris
LWD-Large woody debris
OV-Overhanging vegetation
SV-Submerged vegetation
EV-Emergant vegetation
TWW-Turbulant white water boulders
SOP-Scour out pools
OSB-Overhanging stream boulders
UB-Undercut bank

Fig.3.2.Instream cover composition in Bharathapuzha river system



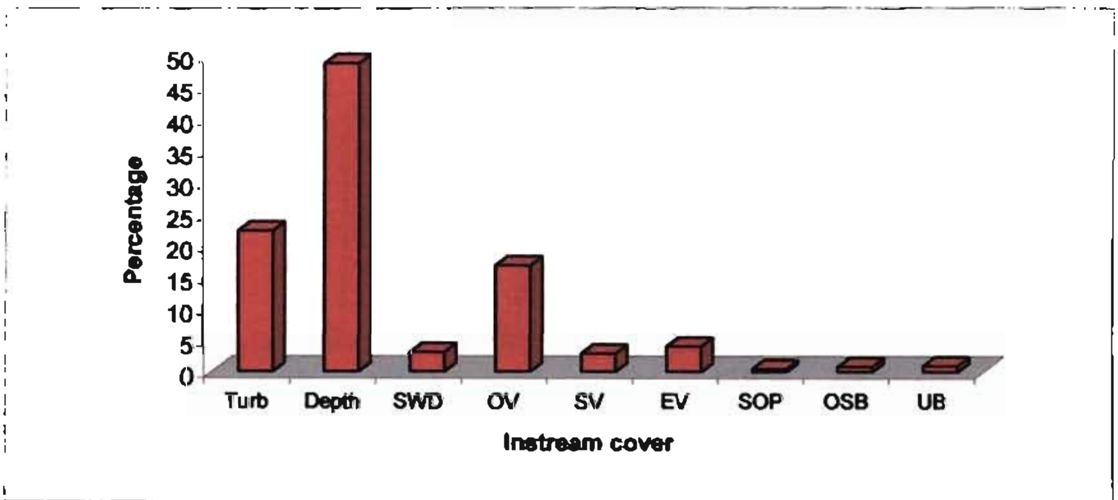
Turb-Turbulance
SWD-Small woody debris
LWD-Large woody debris
OV-Overhanging vegetation
EV-Emergant vegetation
FV-Floating vegetation
TWW-Turbulant white water boulders
SOP-Scour out pools
OSB-Overhanging stream boulders
UB-Undercut bank

Fig.3.3.Instream cover composition in Kallada river system



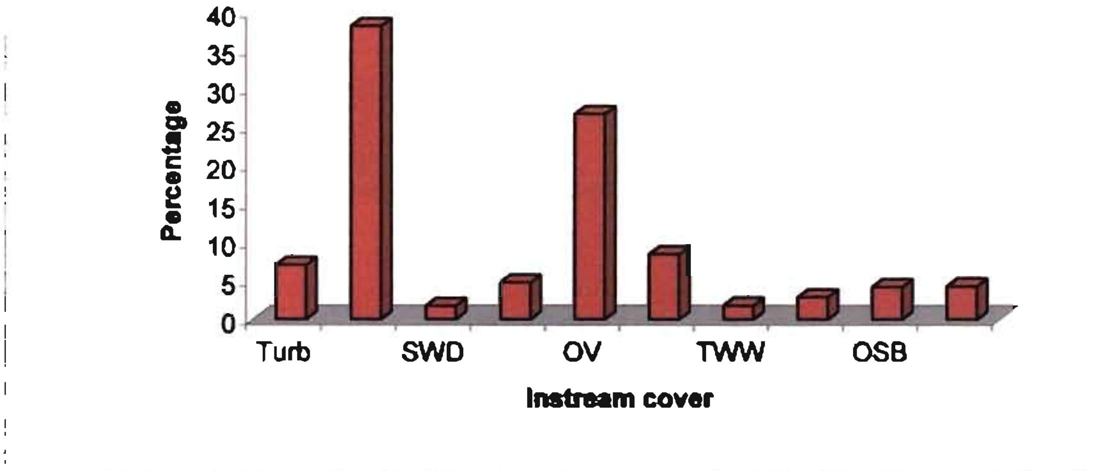
Turb-Turbulance
LWD-Large woody debris
OV-Overhanging vegetation
SV-Submerged vegetation
EV-Emergant vegetation
TWW-Turbulant white water boulders
SOP-Scour out pools
OSB-Overhanging stream boulders
UB-Undercut bank

Fig.3.4.Instream cover composition in Pamba river system



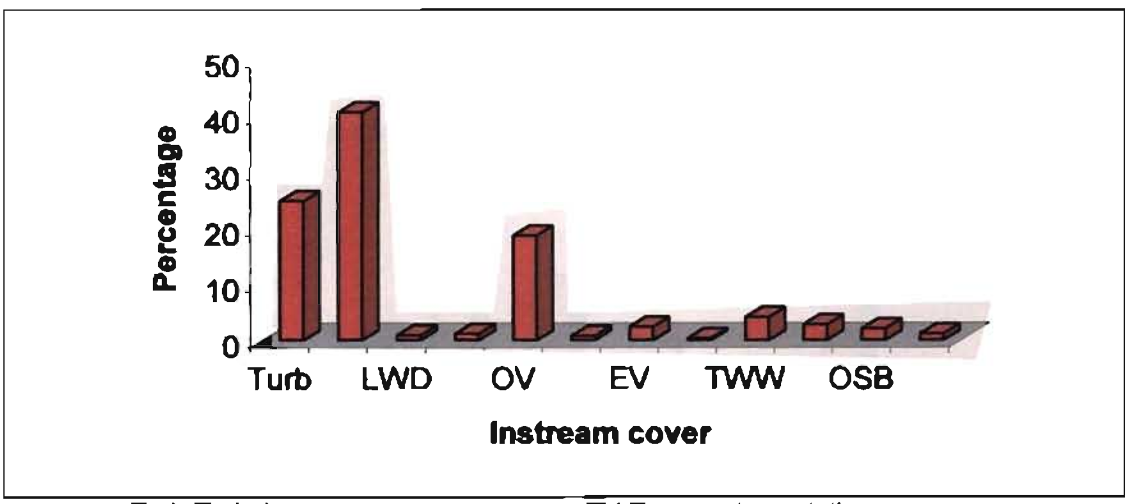
Turb-Turbulance
SWD-Small woody debris
OV-Overhanging vegetation
SV-Submerged vegetation
EV-Emergant vegetation
SOP-Scour out pools
OSB-Overhanging stream boulders
UB-Undercut bank

Fig.3.5.Instream cover composition in Chalakudy river system



Turb-Turbulance
SWD-Small woody debris
LWD-Large woody debris
OV-Overhanging vegetation
EV-Emergant vegetation
TWW-Turbulant white water boulders
SOP-Scour out pools
OSB-Overhanging stream boulders
UB-Undercut bank

Fig.3.6.Instream cover composition in Periyar river system



Turb-Turbulance
SWD-Small woody debris
LWD-Large woody debris
OV-Overhanging vegetation
SV-Submerged vegetation
EV-Emergant vegetation
FV-Floating vegetation
TWW-Turbulant white water boulders
SOP-Scour out pools
OSB-Overhanging stream boulders
UB-Undercut bank

Fig.3.7.Substrate composition in Kabbini river system

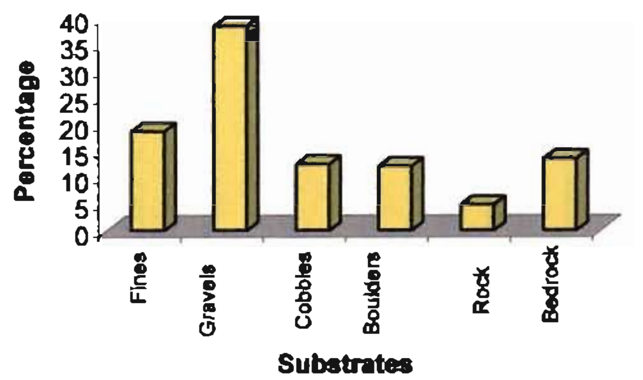


Fig.3.8.Substrate composition in Bharathapuzha river system

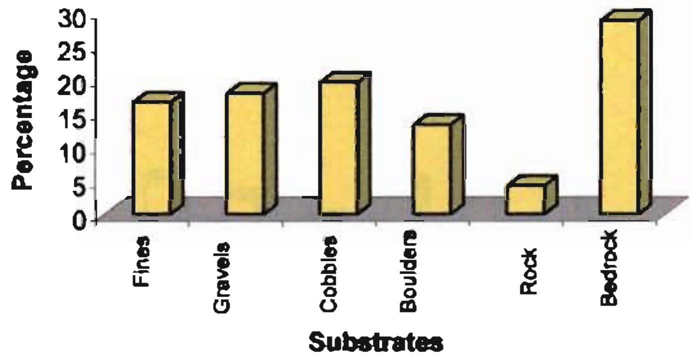


Fig.3.9.Substrate composition in Kallada river system

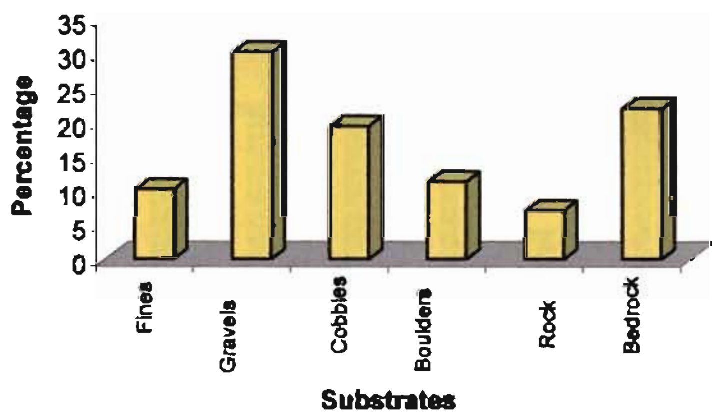


Fig.3.10.Substrate composition in Pamba river system

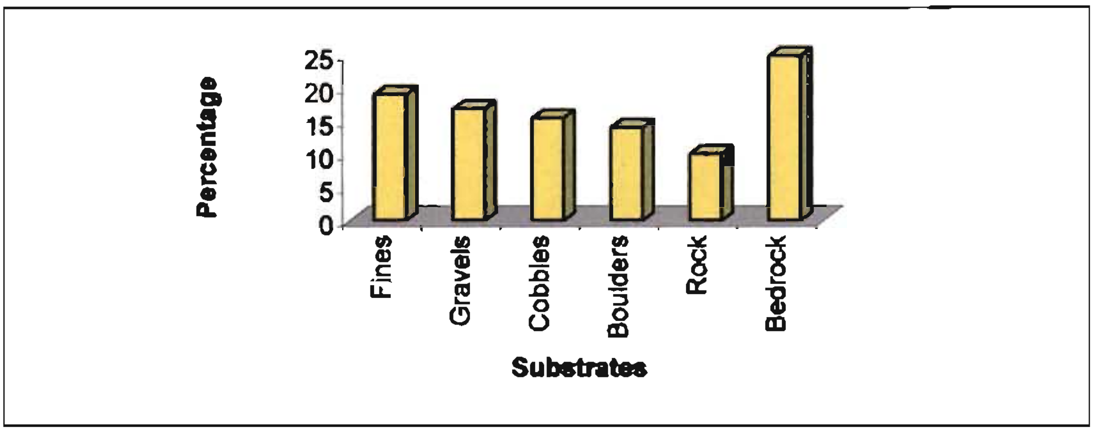


Fig.3.11.Substrate composition in Chalakudy river system

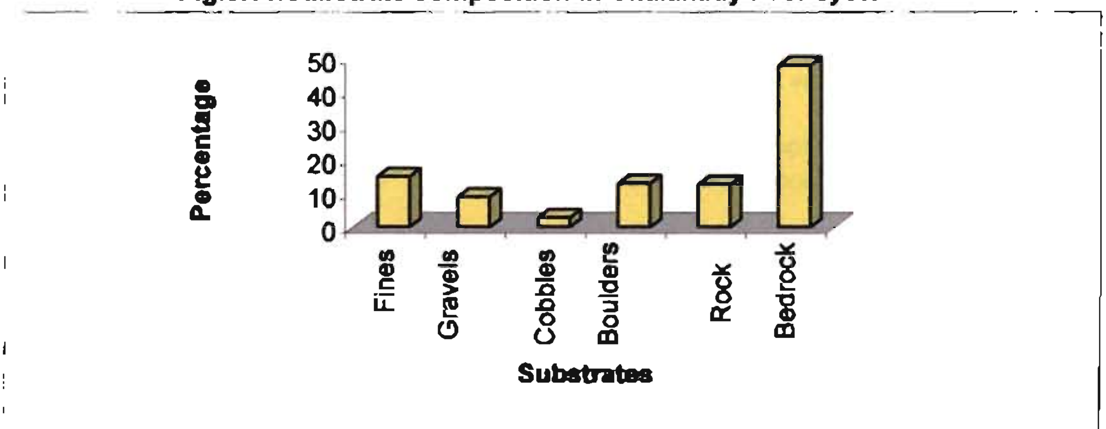


Fig.3.12.Substrate composition in Periyar river system

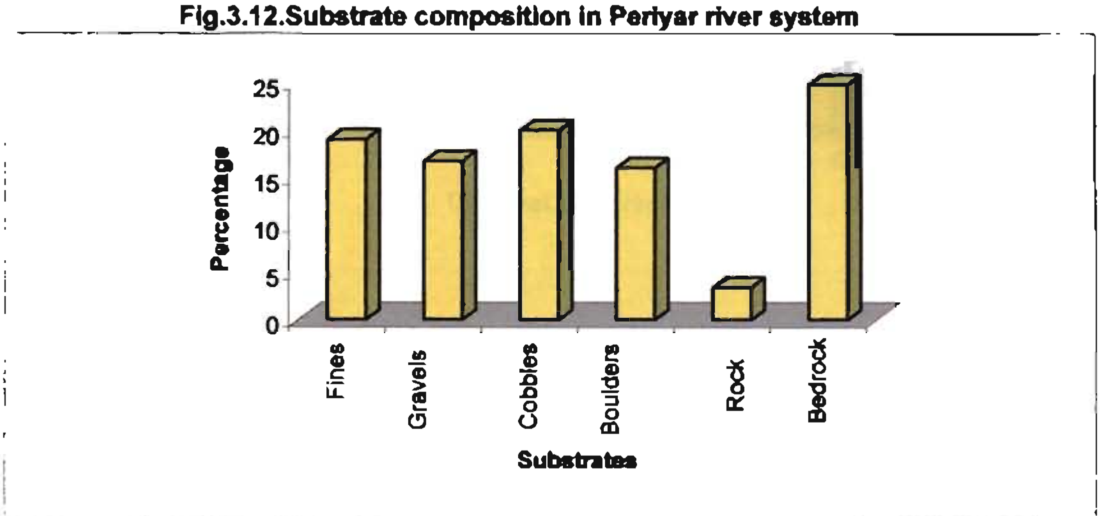
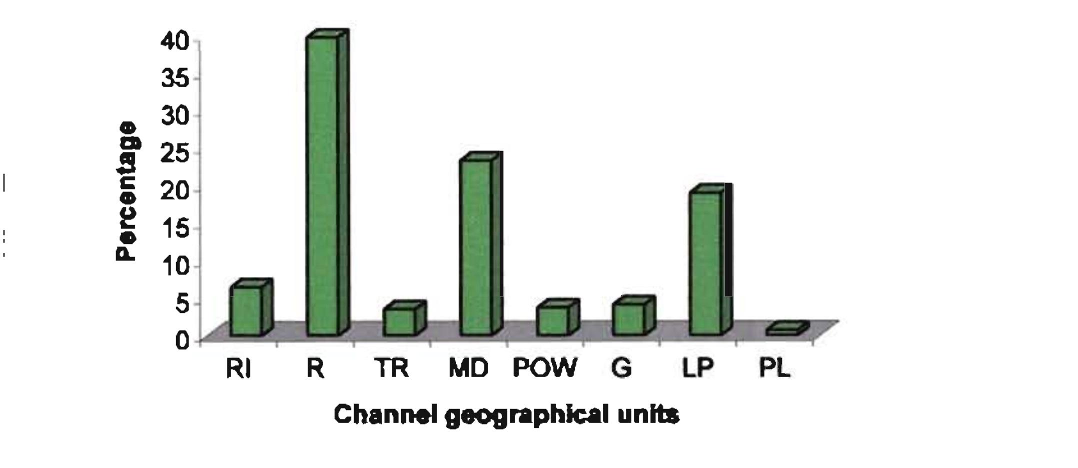
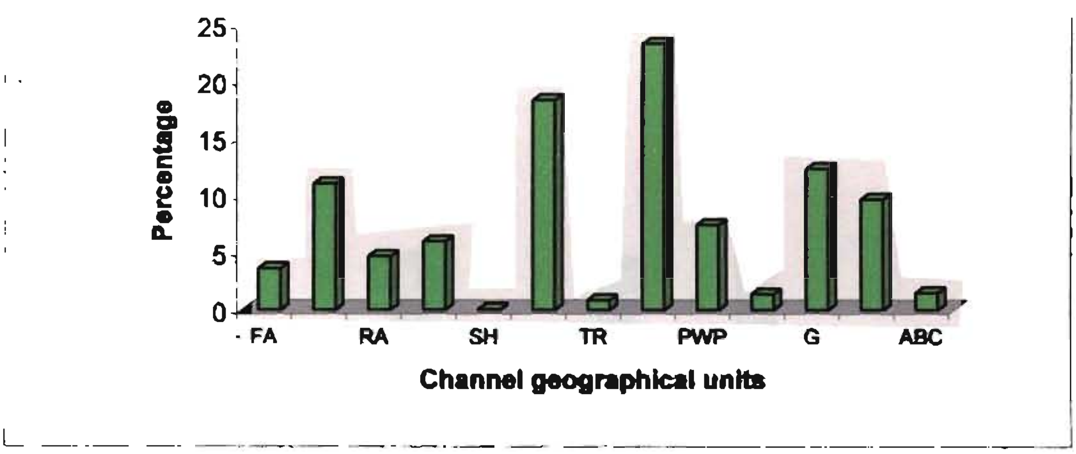


Fig.3.13.Channel geographical units composition in Kabbini river system



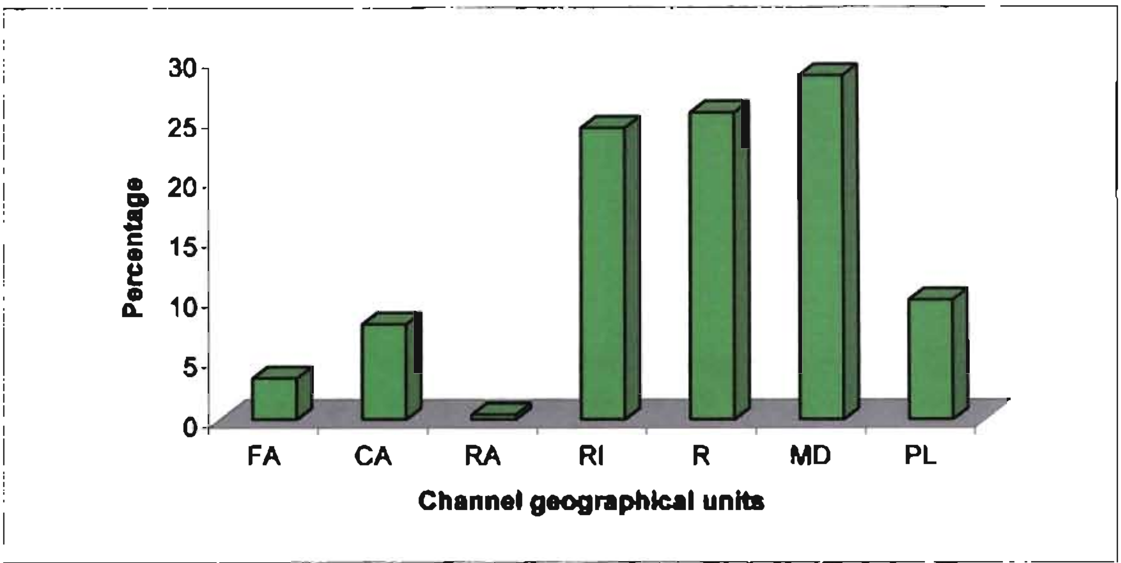
RI-Riffle
R-Run
TR-Trench pool
MD-Midchannel pool
POW-Pocket water pool
G-Glide
LP-Lateral pool
PL-Plunge pool

Fig.3.14.Channel geographical units composition in Bharathapuzha river system



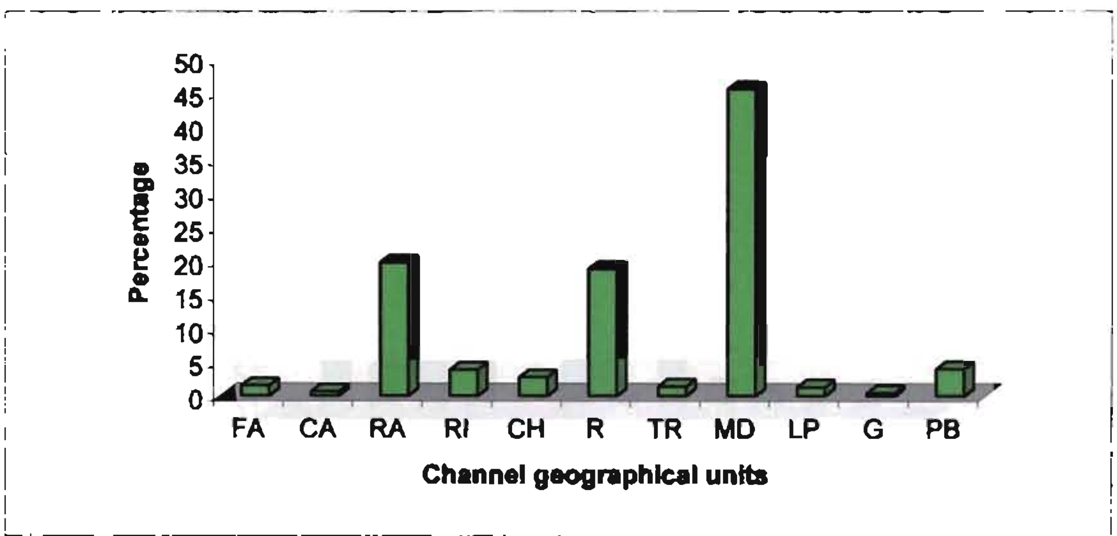
FA-Falls
CA-Cascade
RA-Rapids
RI-Riffle
SH-Sheet
R-Run
TR-Trench pool
MD-Midchannel pool
PWP-Pocket water pools
PB-Plane bed
G-Glide
LS-Lateral scour pools
ABC-Abondoned channel

Fig.3.15.Channel geographical units composition in Kallada river system



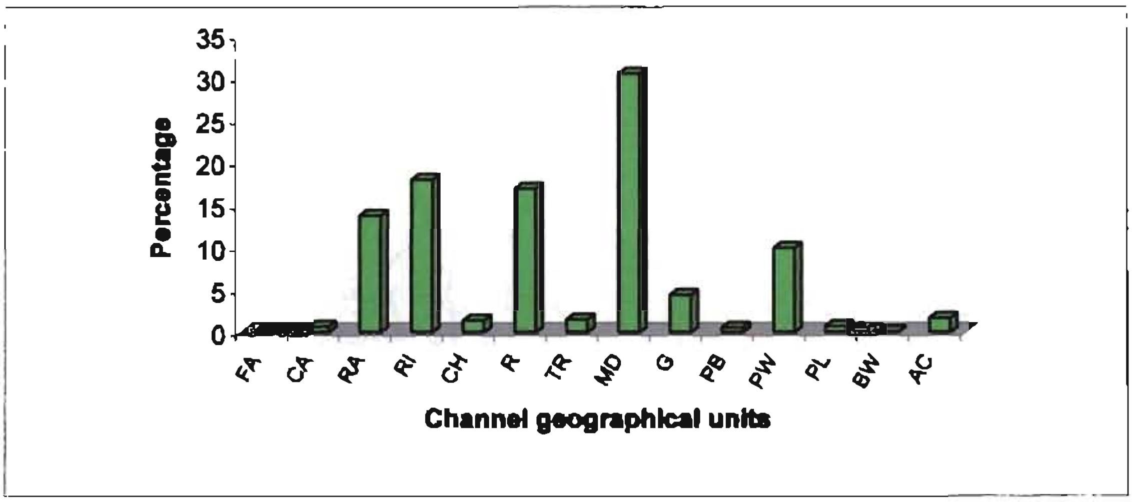
FA-Falls
CA-Cascade
RA-Rapids
RI-Riffle
R-Run
MD-Midchannel pool
PL-Plunge pool

Fig.3.16.Channel geographical units composition in Pamba river system



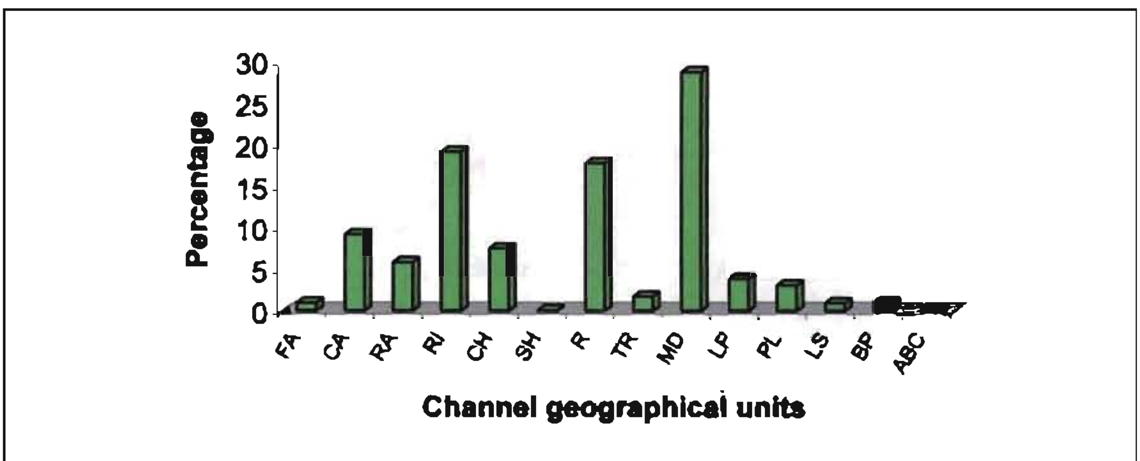
FA-Falls
CA-Cascade
RA-Rapids
RI-Riffle
CH-Chute
R-Run
TR-Trench pool
MD-Midchannel pool
LP-Lateral pool
G-Glide
PB-Plane bed

Fig.3.17.Channel geographical units composition in Chalakudy river system



FA-Falls
CA-Cascade
RA-Rapids
RI-Riffle
CH-Chute
R-Run
TR-Trench pool
MD-Midchannel pool
G-Glide
PB-Plane bed
PW-Pocket water pools
PL-Plunge pool
BW-Back water pools
AC-Abondoned channel

Fig.3.18.Channel geographical units composition in Periyar river system



FA-Falls
CA-Cascade
RA-Rapids
CH-Chute
SH-Sheet
R-Run
TR-Trench pool
MD-Midchannel pool
LP-Lateral pool
LS-Land slide
BP-Backwater pool
ABC-Abandoned channel

Plate 3.1 Kabbini river system - Detailed habitat inventory locations

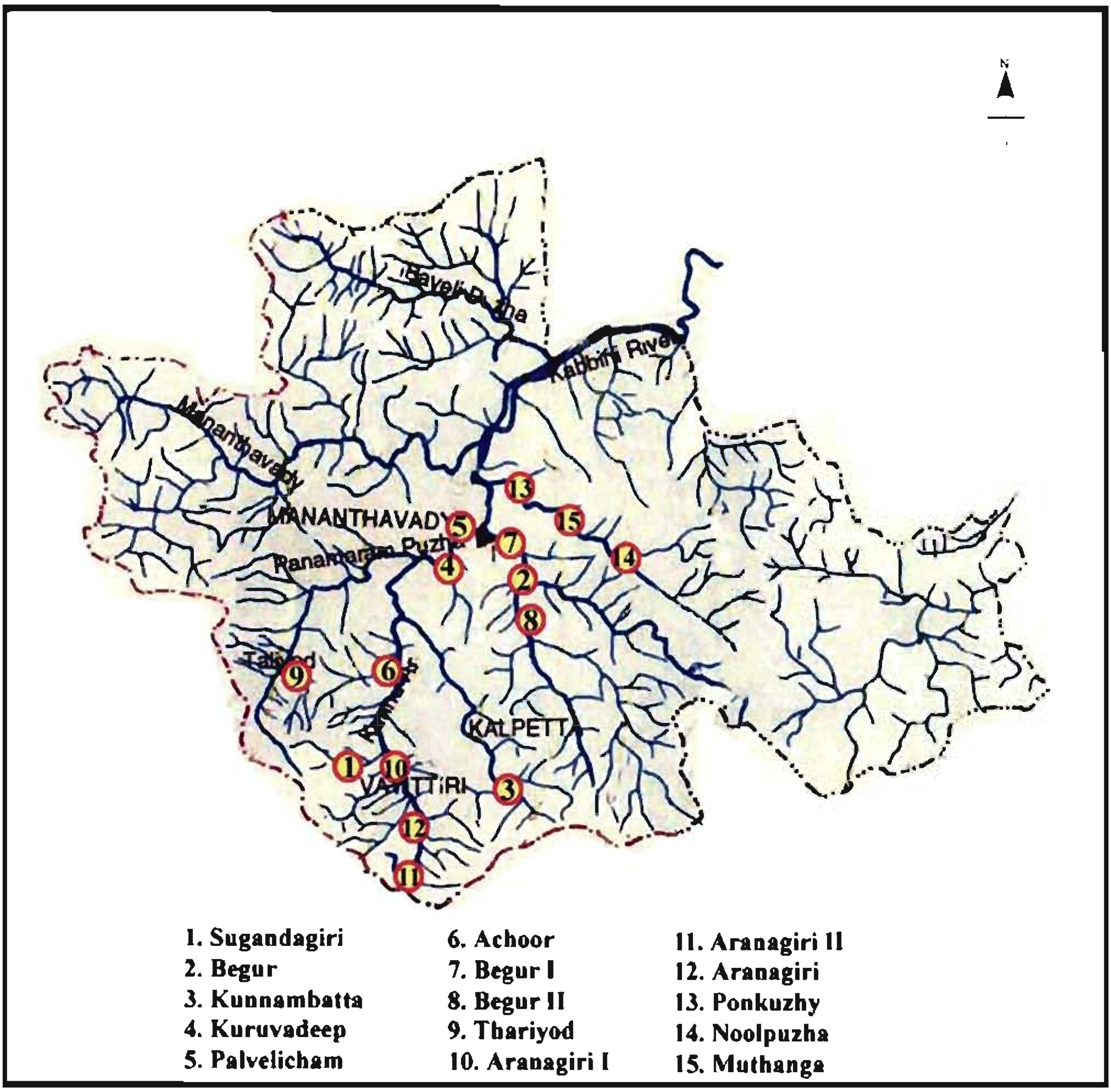


Plate 3.2 Few typical channel reaches from Kabbini river system

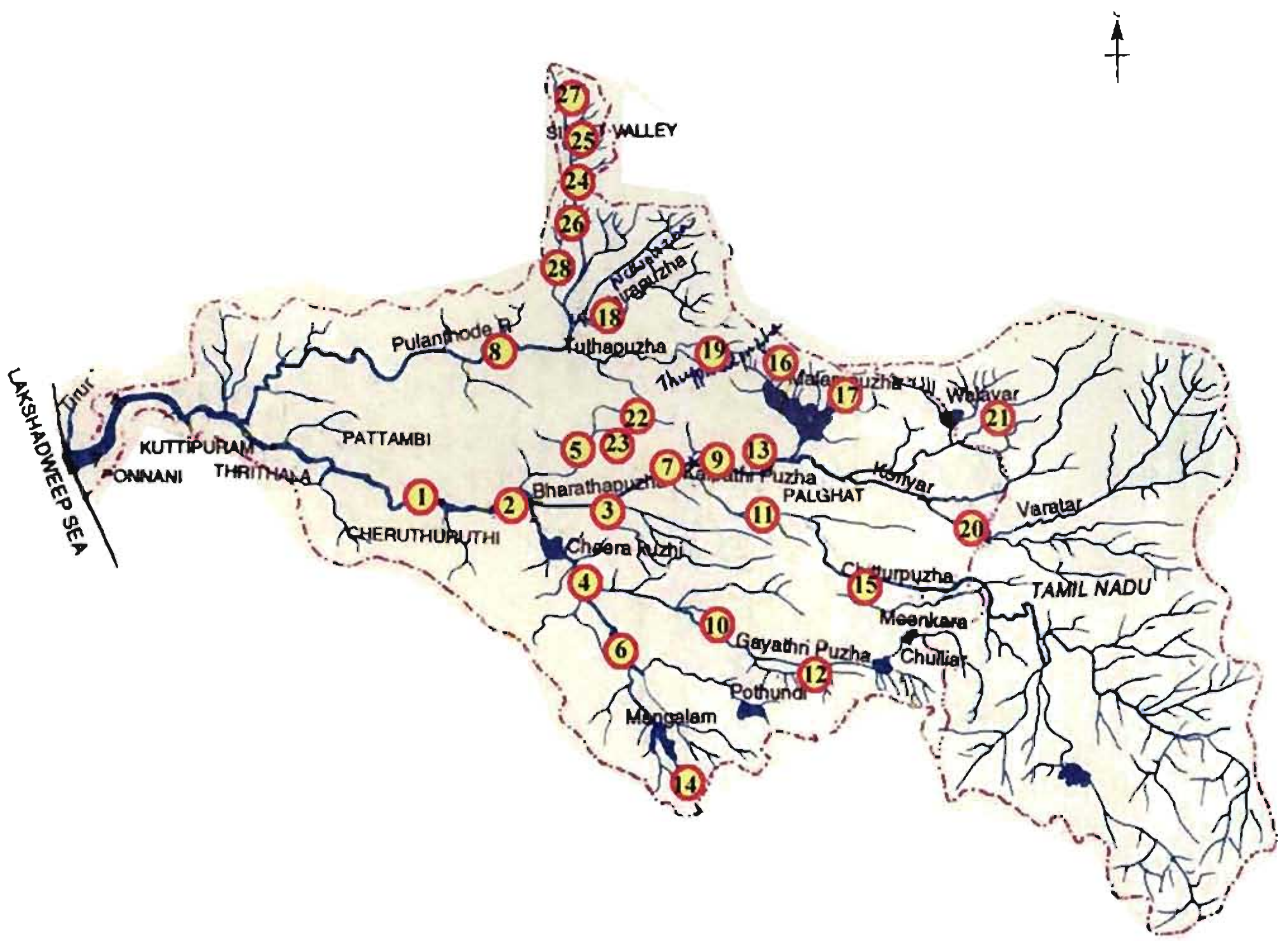
Braided reach

Regime reach

Bedrock reach

Pool-riffle reach

Plate 3.3 Bharathapuzha river system - Detailed habitat inventory locations



1. Cheruthuruthy
2. Kanakkannor
3. Thonikadavu
4. Cheerakuzhi I
5. Meenvallam
6. Cheerakuzhi II
7. Pambadi East
8. Mannarkad
9. Mudappallur
10. Yakkara
11. Churiodu
12. Kalpathi
13. Pezhumkara
14. Choorapara
15. Chittoor
16. Kavarakundu
17. Velampattapuzha
18. Kanjirapuzha
19. Karimala
20. Thippillikayam
21. Thodunnampara
22. Meenvallam II
23. Atla
24. Puchapara
25. Cheriyavalakad I
26. Karingathodu
27. Cheriyavalakad II
28. Synendri

Plate 3.4 Few typical channel reaches from Bharathapuzha river system

Cascade reach

Bedrock reach

Plain bed reach

Pool-riffle reach

Plate 3.5 Kallada river system-Detailed habitat inventory locations

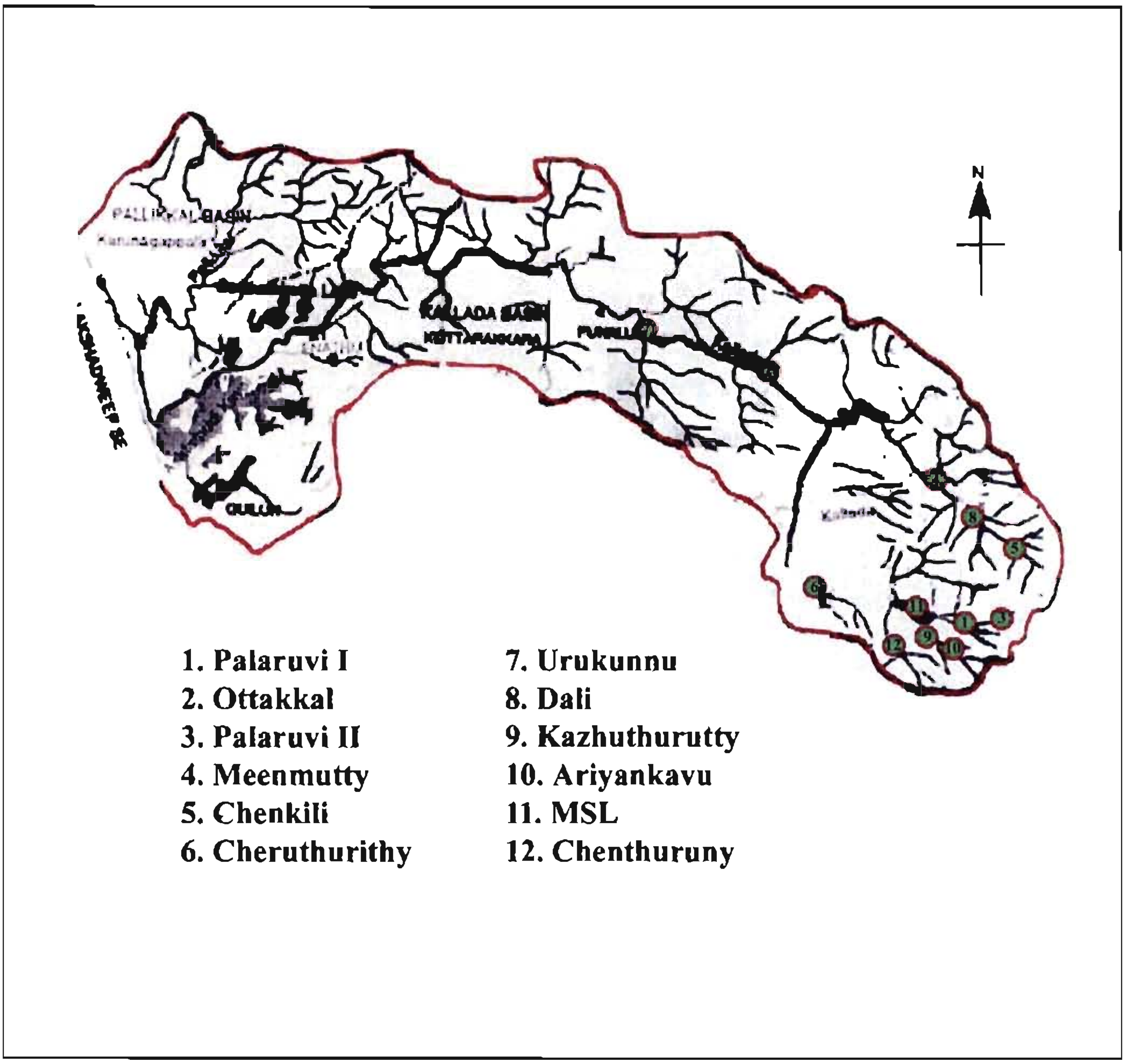
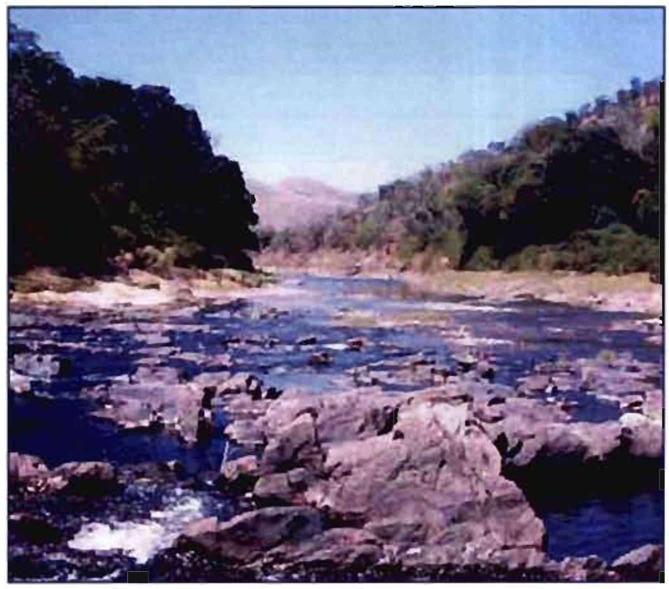


Plate 3.6 Few typical channel reaches from Kallada river system

Step-pool reach

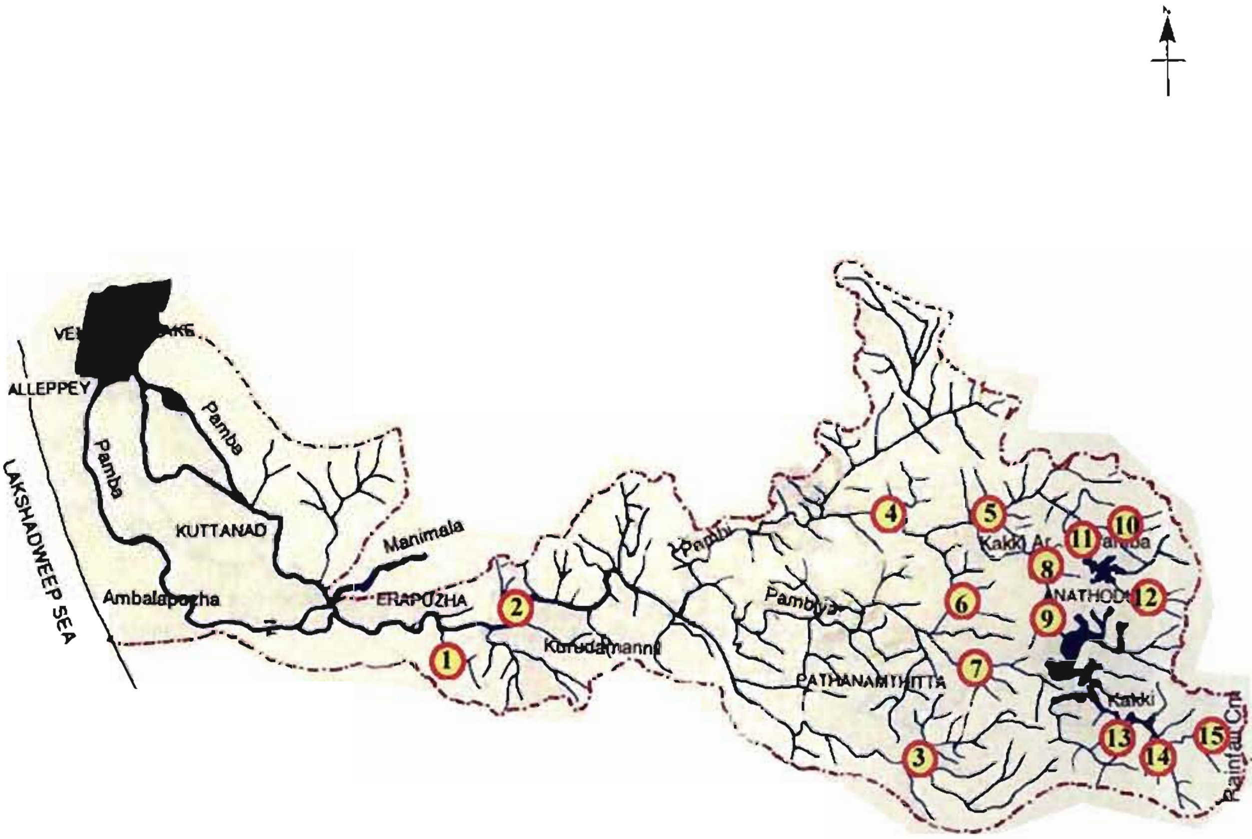


Pool-riffle reach

Braided reach

Bedrock reach

Plate 3.7 Pamba river system - Detailed habitat inventory locations



1. Thottapuzhassery	6. Nilakkalthodu	11. Moozhiyar I
2. Thiruvillapra	7. Attathodu	12. Moozhiyar II
3. Perunthenaruvi	8. Kakkad Ar I	13. Kakki I
4. Azhutha	9. Kakkad Ar II	14. Kakki II
5. Angamoozhi	10. Pamba	15. Kochupamba

Plate 3.8 Few typical channel reaches from Pamba river system

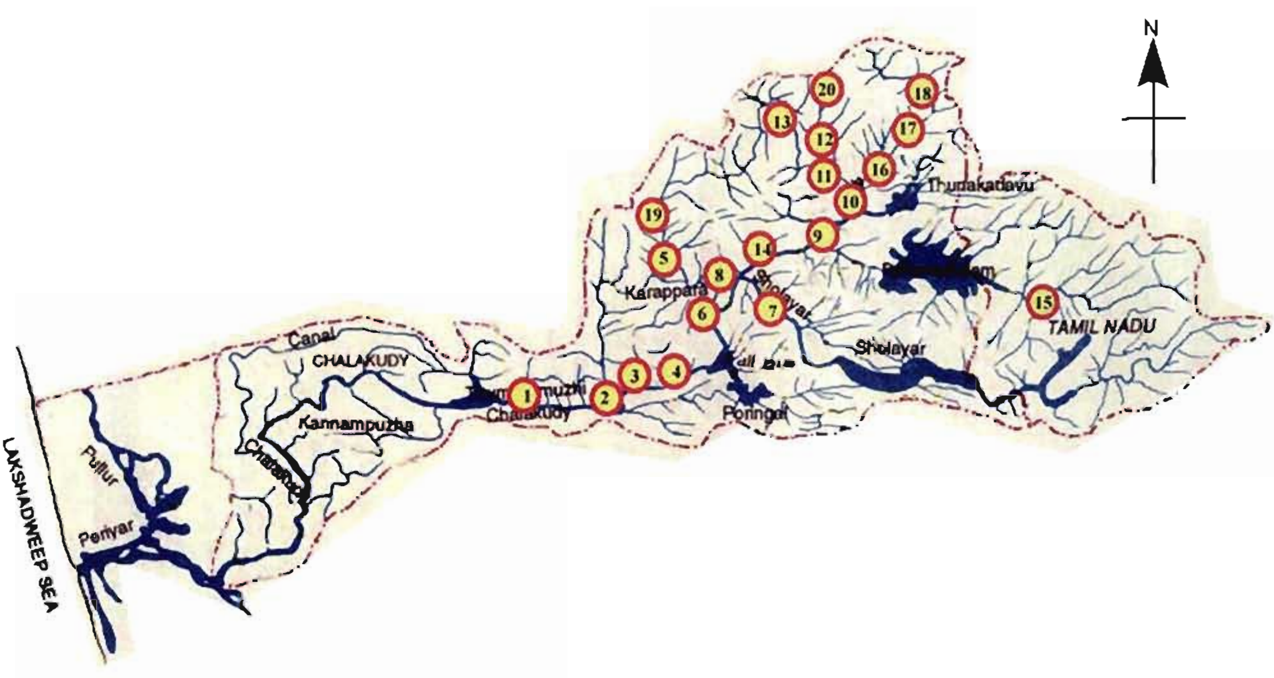
Pool-riffle reach

Cascade reach

Braided reach

Bedrock reach

Plate 3.9 Chalakkudy river system - Detailed habitat inventory locations

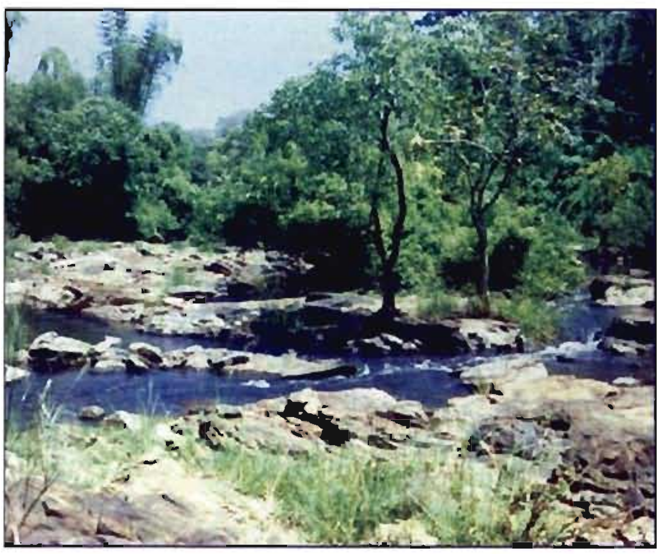


1. Vettilappara	11. Thekkadiyar I
2. Athirappally I	12. Thekkadiyar II
3. Athirappally II	13. Thekkadiyar III
4. Vazhachal	14. Orukomban
5. Karappara	15. Malakkappara
6. Orukomban I	16. Vallakayam
7. Sholayar	17. Anakkayam
8. Orukomban II	18. Padikkutty
9. Kuriarkutty	19. Karappara river
10. Puliyala	20. Vettiyar

Plate 3.10 Few typical channel reaches from Chalakudy river system

Plane bed reach

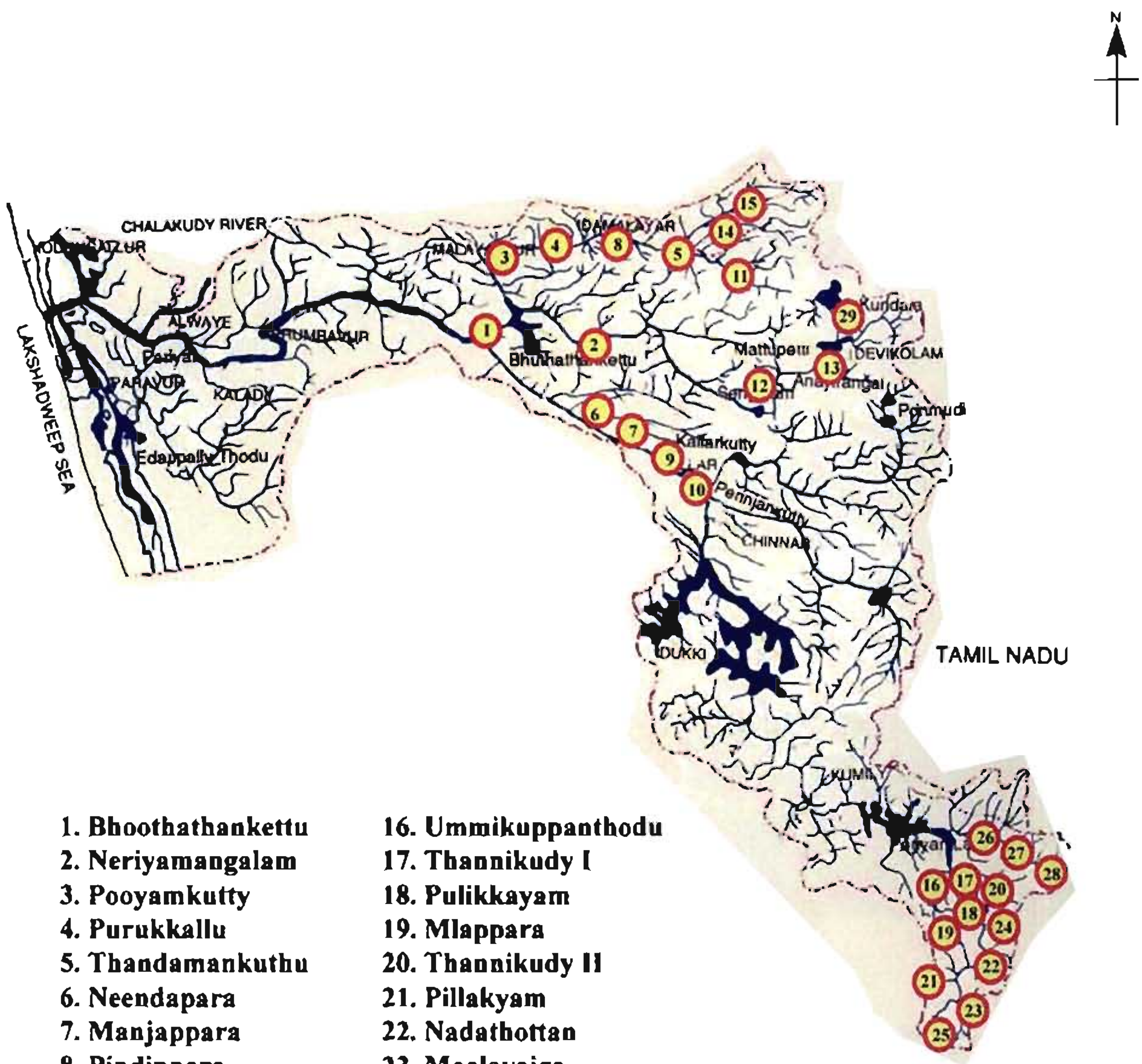
Regime reach



Braided reach

Bedrock reach

Plate 3. 11 Periyar river system - Detailed habitat inventory locations



1. Bhoothathankettu
2. Neriyamangalam
3. Pooyamkutty
4. Purukkallu
5. Thandamankuthu
6. Neendapara
7. Manjappara
8. Pindippara
9. Thannimoodu
10. Panniarkutty
11. Mukkan
12. Nallathanni
13. Kunchithanni
14. Mandrappara
15. Choorappara
16. Ummikuppanthodu
17. Thannikudy I
18. Pulikkayam
19. Mlappara
20. Thannikudy II
21. Pillakyam
22. Nadathottan
23. Moolavaiga
24. Kundamkallu
25. Mukkar
26. Chembakavallithodu
27. Kattamadithodu II
28. Kattamadithodu I
29. Kunthrapuzha

Plate 3.12 Few typical channel reaches from Periyar river system

Plane bed reach

Bedrock reach

Pool-riffle reach

Cascade reach

Chapter 4

Fish diversity vis-à-vis altitude in the major river basins of Kerala

4.1. Introduction

The convention on biodiversity signed by 156 countries at the Earth summit in June 1992 in Rio de Janeiro defined biological diversity as the variability among living organisms from all source including interalia, terrestrial, marine and other aquatic ecosystems and ecological complexes of which they are a part; this includes diversity within species and of ecosystems(Lachavanne and Juge,1997). The challenges thrown down to humanity by the loss of biodiversity and the hazards which the reduction in the number of species could pose to future generations have been discussed by numerous authors (Brown,1981; Ehrlich and Ehrlich,1981; Ramade,1981;Ehrlich,1984; Wilson,1985,1989;Clark and Munn,1986;Soule,1986;Wolf,1987;Ojeda and Mares,1989; Reid and Miller,1989;Mc Neely *et al.*, 1990; Myers,1990;Groombrodge,1992;Barbault,1994). These challenges are at the centre of the line of research currently being pursued in the context of the international collaborative research programme IUBS-SCOPE-UNESCO-MAB 'Diversitas'(Solbrig,1991b) and are one of the key issues of the UNESCO-MAB programme. 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).

A most disturbing observation in recent decades is the acceleration of species extinction due to impairment of natural habitats and pollution (Soule, 1986; Wilson and Peter, 1988; Ulfstrand, 1992). 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 human 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 (Lachavanne and juge,1997).Database from the well-known vertebrate groups, plants and extent of habitat destruction showed that over the next 25 years more than one million species will become extinct(Wilson,1988;Ehrlich and Wilson,1991;Soule,1991). On this basis IUCN/UNEP/WWF (1991) reminded that the threat of extinction to human population had become worsen and for the sustenance of human beings conservation of nature and biodiversity is mandatory.

In the case of fluvial ecosystems, one of the most important factors responsible for the sharp decline in biodiversity has been channelization combined with wetland degradation. This is due to the reduction of water retention in the catchment, reduction of flow variation and loss of habitats resulting in increased abiotic stress (Ward and Stanford, 1989).

The Western Ghats, one of the 21-biodiversity hotspots of India, is unique for its high rate of endemism (Gadgil, 1996; Pascal, 1996). The Kerala region of Western Ghats is encompassing an area of 20,000sq. km from where 41 west flowing and 3 east flowing rivers are originated, many of them drain mainly through forested catchments and empty into Arabian Sea and Bay of Bengal respectively. These rivers support a rich and diverse fish fauna comprising of 170species, which represent many rare and endemic species (Kurup, 2002). Data base on fish biodiversity is very essential as a decision making tool for conservation and management of fish germplasm, declaration of part of rivers as aquatic sanctuaries, protection and preservation of endangered species and mitigation of anthropogenic activities, etc., so as to fulfill the obligation on the part of India under convention on biological diversity. Fish germplasm inventory of the rivers of Kerala is still partial and are being continued. Among them, the notable studies are those of Day (1865, 1878, 1889), Pillay (1929), John (1936), Hora and Law (1941), Menon (1952), Silas (1951a,1951b), Jayram (1981,1999), Remadevi and Indira (1986), Petiyagoda and Kottelat(1994), Easa and Shaji (1996),Zacharias *et al.*(1996), Menon and Jacob(1996), Arun(1997), Manimekhalan and Das(1998), Ajtithkumar *et al.*(1999) and Kurup(1992, 2002). However, hitherto no attempt was made to bring out the extent of diversity and influence of altitude on fish diversity in the streams and rivers of Western Ghats.Against this background, an attempt was made in this direction on the basis of four diversity indices such as Shanon-Weiner diversity index (Shanon and Weiner 1949),Simpson index,Margalef's index and Pieolu,s index calculated from different altitudes of six major river systems viz;Kabbini,Bharathapuzha, Chalakudy, Periyar,Pamba and Kallada in Kerala, which form 34% of the total riverine area of the state.

4.2. Materials and methods

Materials and method used for in the study are illustrated in chapter 2.

4.3. Results

While comparing the fish biodiversity at different altitude ranges (given as MSL) in 6 major river systems of Kerala it was observed that species diversity showed an inverse relationship with altitude (Table 4.1-4.6). In Bharathapuzha river system, between altitudes of 0-1200m, the Shanon- Weiner diversity index (H') varied from 0.67-1.59 (Table 4.1) and the highest average of 1.59 was observed at 0-200m height while the same showed a reduction (0.67) from 1000-1200m. Locationwise study (Table 4.7) showed highest diversity of 2.373 at Kanakkanoor having an elevation of 39.4m from the mean sea level while diversity was nil at Velampattapuzha and Tippilikayam situated at an altitude of 212m and 477m respectively. Simpson diversity index (D') was calculated for all the stations which fluctuated between 0.4-0.74(Table 4.1) .The maximum value (0.74) was recorded between 600-800m followed by 0-200m(0.73) while the lowest diversity of 0.4 was registered at 1000-1200m range. Location wise analysis (Table 4.7) showed highest value (0.9) for Simpson index at Kanakkanoor and lowest '0' diversity at meenvallam I (ele.589m),Velampattapuzha(ele.212m) and Thippilikayam(477m).The species richness (d) was highest in the 0-200m stretch(1.76) while the lowest richness of 0.58 was recorded in the river stretch located between 800-1000m range(Table 4.1). Highest location wise richness registered at Kanakkanoor (4) followed by Pambadi east (3.11). While 0 richness was registered at MeenvallamI, Velampattapuzha and Thippilikayam(Table 4.7).Pielou's eveness measured ranged between 0.45-0.86(Table 3.1).The highest value was registered between 600-800m while the lowest(0.45) between 400-600m. Highest location wise evenness of 0.96 was observed at Atla(ele.607m) while it was 0 at Meenvallam I,Velampattapuzha and Thippilikayam(Table 4.7).

In Periyar river system, an inverse relationship was observed between fish diversity and altitude. However, at the upstream reaches between 1000-1200m, the fish diversity showed an unusually increasing trend. Between altitudes 0-1600m the Shanon-Weiner diversity index (H') varied from 0.3-1.87(Table 4.2) with the highest average diversity index of 1.87 between 0-200m followed by 1000-1200m(1.77) and 400-600m heights (1.68). The fish diversity was very low in between 1400-1600m range. Location wise diversity was highest at Bhoothathankettu (2.03) having an elevation of 20m from the mean sea level. While fish diversity was 0 at Kunthrapuzha (ele.1540m), the highest altitude surveyed in this river system (Table 4.8). Simpson (D') diversity index also showed an inverse relationship between fish diversity and altitude. The maximum diversity of 0.82 was registered at 0-200m range while it was lowest (0.24) at 1400-1600m stretch of this river system(Table 4.2).Location wise diversity(D')was maximum at Anakkallankayam(0.87) having an elevation of 1040m from the mean sea level while the diversity(D') was 0 at Kuntrapuzha(Table 4.8).Species richness or Margalef's index ranged between 0.26-1.91 and the maximum fish species richness was observed at 0-200m range and the lowest at 1400-1600m range(Table 4.2). Location wise species richness was maximum at Bhoothathankettu (2.41) and lowest at Kuntrapuzh(0)(Table 4.8).Species evenness which expressed in terms of Pieolu's index was ranged between 0.43-0.83 . Maximum evenness or equal abundance (0.83) of all the species present were registered at 400-600m stretch while it declined to 0.43 at 1400-1600m stretch (Table 4.2). Location wise evenness was highest (0.93) at Anakkallankayam and lowest (0) at Kuntrapuzha(Table 4.8).

The Chalakudy river system, with an altitude range of 0-1000m, the Shanon-weiner diversity index (H') ranged between 1.59-2.43(Table 4.3). Highest average diversity of 2.43 was found at 200-400m height followed by 0-200m (2.13), in contrast, it was comparatively low at 600-800m (1.59). Location wise diversity was maximum at Orukomban I (2.58) and lowest at Thekkadiyar II (1.4) (Table 4.9). Diversity measure on the basis of Simpson index also revealed more or less similar trend as shown by Shanon-Weiner diversity index. The Simpson diversity index (D') was ranged between 0.81-

0.88(Table 4.3) and the maximum diversity (0.88) was observed in the river stretch located between 200-400m and lowest (0.81) at 800-1000m stretches. Location wise diversity (D') was at the peak (0.88) at Orukomban I ,Karappara and Vazhachal and lowest at Thekkadiyar (0.72)(Table 4.9). Species richness was between 1.27-3.00(Table 4.3) and the maximum (3.00) was registered at locations between 0-200m and the lowest at 600-800m.range.Locationwise observation revealed that the highest richness (3.4) was registered at Vettilappara and Athirappally I having an elevation of 40m and 87m respectively from the mean sea level. On the contrary, the lowest richness (1.24) was registered at Malakkapara having an elevation of 743m from the mean sea level (Table 4.9). Species evenness ranged between 0.8-0.91 and was highest (0.91) at 600-800m stretch and lowest (0.8) at river stretch located between 200-400m.Locationwise species evenness was highest at Malakkapara(0.91) while it was lowest at Thekkadiyar and Sholayar(0.7)(Table 4.9) .

The Kallada river system, which is located between an altitude of 0-800m, the Shanon-Weiner diversity ranged from 1.01-1.16(Table 4.4).Fish diversity was highest between 200-400 m (1.16) while the diversity showed almost similar trend in the height of 0-200m and 400-600m ranges (1.13&1.12respectively). In the upstream regions, a decreasing trend in fish diversity was quite discernible. At 600-800m height, the diversity index declined to 1.01. Location wise diversity (H') was highest (1.89) at Meenmuty having an elevation of 89m from the mean sea level while the lowest diversity (0.33) was recorded at MSL (ele.194m) (Table 4.10). On the contrary, Simpson index (D') was highest (0.7) at 600-800m stretch and lowest (0.54) at 0-200m stretches. (Table 4.4). Location wise diversity (D') was highest (0.83) at Meenmutty and lowest (0.15) at MSL (Table 4.10).

Species richness which indicated on the basis of Margalef's index was in the range 0.68-1.45(Table 4.4). Maximum species richness (1.45) was recorded at 400-600m while lowest richness (0.68) was recorded from 600-800m. Location wise species richness was highest (1.77) at Meenmutty while the lowest richness (0.42) was registered at MSL (Table 4.10). Species evenness ranged between 0.66-0.92(Table 4.4) with a peak in between 600-800m and lowest at 0-200m. Location wise study revealed that the evenness of species was maximum (0.92) at Chenturuny(ele.641m) and Dali (ele.115.5m) and lowest (0.3) at MSL(Table 4.10)

In Kabbini river system, the surveyed locations falls in the range 600-1000m height and the fish diversity (H') varied from 1.42-1.63(Table 4.5). Highest average diversity of 1.63 was observed at 600-800m height. Further increase of altitude brought about a reduction in the diversity. At 800-1000m altitude, the diversity reduced to 1.42.Locationwise diversity analysis revealed that maximum value for Shanon-Weiner diversity index (2.47) was registered at Begur I having an elevation of 783m from the mean sea level while the diversity was 0 at Thariyod (ele.796.5m)(Table 4.11).Species diversity measured based on Simpson index revealed that there is not much variation in diversity in the two altitude ranges and the highest value (0.71) was recorded at 800-1000m stretch and the lowest (0.69) at 600-800m stretch(Table 4.5). Location wise diversity (D') was maximum (0.86) at Noolpuzha(ele.946m) and Ponkuzhy(ele.914.8m) while diversity was nil at Thariyod (Table 4.11). Species richness showed not much variation in both the stretches and was 1.88-1.89 (Table 4.5) between an altitude range of 600-1000m.Locationwise, highest richness of 3.1 was registered at Kuruvadeep(ele.769m). While no species richness was observed at Thariyod(Table 4.11) Species evenness ranged between 0.71 to 0.78(Table

4.5) and the highest evenness was observed in 800-1000m of the river system. Location wise, highest evenness of 0.89 was registered at Ponkuzhy while no evenness was registered at Thariyod (Table 3.11).

In Pamba river system, the Shanon-Weiner diversity index varied from 1.08 to 1.85(Table 4.6) in between an altitude of 0-1000m and the highest diversity of 1.85 was recorded in between 400-600m altitude ranges. While the lowest diversity of 1.08 was recorded in the river stretch located in between 600-800m altitudes. Locationwise, highest diversity (H') of 1.99 was recorded at Kakkad Ar II having an elevation of 300.3m from the mean sea level and the lowest diversity of 0.91 was registered at Kakki I (Table 4.12). Diversity analysed based on Simpson index was highest at 200-400m (0.82) while it was lowest (0.78) at 400-600m (Table 4.6). Location wise, maximum diversity of 0.92 was registered at Kakki I having an elevation of 824m from the mean sea level while the lowest diversity of 0.65 was registered at Angamoozhi having an elevation of 133m from the mean sea level (Table 4.12). Fish species richness ranged between 1.11-1.74(Table 4.6) in the altitude range of 0-1000m and the maximum richness was registered in between 0-200m while it was lowest (1.11) in the 600-800m of the river system. Location wise analysis revealed that highest richness (2.47) was registered at Nilakkalthodu while it was lowest (1.09) at Azhutha(Table 4.12). Equality of species abundance measured based on Pielou's evenness index varied between 0.74-0.91(Table 3.6) with highest evenness in 400-600m and the lowest in 800-1000m. While comparing different locations, highest evenness of 0.91 was registered from Kakkad Ar I (ele.257m), Moozhiyar I (ele.413.9m) and Attathodu (ele.145.8m)while it was only 0.64 at Kakki I(Table 4.12).

Table 4.13 and 4.14 show the result of analysis of variance of Shanon-Weiner diversity index and Simpson diversity index at different altitudes in six river systems of Kerala. The results showed that there is significant difference in fish diversity at the same altitude in the different river systems studied. Difference was also significant in fish diversity between different altitudes of the same river system ($P<0.01$).

Table 4.15 shows the result of analysis of variance of species richness at different altitudes in six river systems of Kerala. There is significant difference in fish species richness at the same altitude in the different river systems studied, and also significant difference in species richness was also observed between different altitudes of the same river system ($P<0.05$).

Table 4.16 shows the result of analysis of variance of species evenness at different altitudes in six river systems of Kerala. There is significant difference in fish species evenness at the same altitude in the different river systems studied, and also significant difference in species evenness was observed between different altitudes of the same river system ($P<0.01$).

Fig.4.1-4.4 depicts the fish diversity based on four diversity indices at different altitude ranges in six major river systems of Kerala.

4.4. Discussion

The results of the present study revealed that altitude has a very significant influence in the qualitative and quantitative fish diversity in six major river systems of Kerala. The fish diversity studied on the basis of Shanon-weiner (H') and Simpson (D') indices revealed that even though some minor variations occur with the suitability and complexity of habitats, the altitude showed an inverse relationship with fish diversity.

The present finding is in compliance with that of Dukes *et al.* (2000) who compared the fish diversity in the second, third and fourth order streams of Cullowhee creek in United states on the basis of Shanon-Weiner and Simpson diversity indices and reported that the fish diversity increasesd with the increase of stream order. Lachavanne and juge (1997) reported that the decline in abiotic stress and increase in habitat heterogeneity towards downstream is mainly due to the increasing space in land-water ecotones by transmission of the riparian zone into floodplain and also added that the tendency for fish diversity to increase downstream in natural river ecosystems is not only the result of the reduction in natural harshness but also due to the increase in riverine habitat complexity by riparian/floodplain interactions. Schiemer and Zalewski (1992) reported that habitat complexity creates conditions for the coexistence of a large number of fish species and their life stages, reduce competitive interactions, pressure of predators , catastrophic disturbances and provide feeding and spawning /rearing grounds.

Though altitude showed an inverse relationship with fish diversity, conversely, the upstream reaches of Chalakudy and periyar river systems are an exception to the trend. The unusually high biodiversity observed in the high altitudes of these rivers can be attributed to the presence of moderate populations of hill stream species (Fig.1). This situation was very well glaring at 1000-1200m stretch of Periyar river system. The dominance of some of the critically endangered endemic species such as *Lepidopygopsis typus,Gonoproktopterus micropogon periyarensis and Crossocheilus periyarensis* which were characterized by high degree of habitat selectivity and assemblage with the microhabitats prevailing in these areas have already been reported(Manojkumar and Kurup,2002). Habitat suitability index models of the above three species revealed that abundance of *L.typus* showed a positive correlation with the amount of bedrock substrate, chute type microhabitat, overhanging boulders, overhanging vegetation, total shade and stream cover (Manojkumar and Kurup, 2002). Optimum habitat of *G.micropogon periyarensis* has been reported as midchannel pools with comparatively good depth, overhanging vegetation, slope and excellent shade while that of *C. periyarensis* are lateral pools and scour out pools with enough woody debris, overhanging vegetation and tree cover (Manojkumar and Kurup, 2002). In Chalakudy river system the 800-1000m stretch was blessed with moderate population of hill stream fishes such as *Tor khudree, Barilius gatensis, Barilus bakeri,Danio malabaricus, Garra mullya, Hypselobarbus kolus* and *Garra surendranathanii* which can survive well in the alternating cascade and pool-riffle channel reaches prevailing in these areas of the river system.

Diversity measures based on species richness (d) showed that maximum richness was observed at 0-600m altitude in all the river systems studied. This may be due to the presence of more species in these altitude ranges when compared to the high ranges, a finding which corroborated with that of Boyce and McDonald(1999)who reported that the highest value of Margalef's index denotes highest alpha diversity and is actually correlated with total number of species(S)alone. The species richness towards downstream is due to the increasing habitat heterogeneity and complexity towards downstream which supports the view of Horowitz(1978) who described that the fish diversity in rivers increases in the downstream reaches due to the declining abiotic stress and increasing habitat heterogeneity.

The results of species evenness indicate that the species equitability is more in the 400-800m stretch of all the river systems. This is due to the habitat homogeneity observed in the high ranges and high rates of habitat degradation in the lower stretches. The upstream torrential reaches of many of the river systems are highly homogenous and supports only those species, which can survive only in these peculiar habitats. The present observation also corroborates with the findings of Dukes *et al* (2000) who reported that at the second order sites of Collowhee creek in United states, where the habitat is of riffle type the number of species is comparatively less when compared to the run habitats prevailing in the fourth order streams. On the contrary, the downstream reaches of all the river systems were posed to high degree of habitat destruction in the form of pollution, agricultural activities and illegal fishing activities. The low fish species evenness in the 0-600m stretch of Bharathapuzha river system when compared to 600-1200m stretch and 0-400m stretch of Kallada river system with that of 400-800m ranges are clear manifestation of the high degree of habitat alteration brought about in the downstream regions of this river which led to the selective proliferation of some species. Gatz and Harig (1994) and Dyer *et al.*(1998) reported that antropogenic changes in physical habitat parameters of streams leads to more homogeneous stream conditions and consequently to the depletion of fish communities.

While comparing the altitude wise overall fish diversity in each river system studied, Chalakudy river showed the highest value of Shanon diversity index 2 (D'=0.83) followed by Pamba 1.5(D'0.8), Kabbini 1.5(D'=0.7), Periyar 1.4(D'=0.67),Kallada 1.2(D'=0.62) and Bharathapuzha 0.9(D'=0.57) (Fig.2). The optimal physical habitat conditions and less human intervention on the riverine habitats might be the major contributing factors supporting the high fish diversity at Chalakudy river system. On the other hand, Bharathapuzha and Kallada were prone to severe anthropogenic activities like construction of dams, commissioning of hydroelectric projects, conversion of catchments into cultivable lands, sand mining, pollution, etc. which might have brought about serious alterations in the habitats and consequently the decline of fish biodiversity. Lachavanne and Juge (1997) reported that due to the construction of dam eutrophication rate will increase which inturn results in the fluctuation of many biotic and abiotic characteristics above the tolerance level of many fish species which may leads to the decline of fish diversity in the system. Talmage *et al.* (2002) reported that agricultural activities in the catchment areas of Red river basin and Minnesota river basin in United States adversely affected the hydrologic regime, channel morphology, riparian zones and water chemistry of the river systems. In Kabbini river system majority of the locations surveyed were coming under protected areas and characterized by very good fish diversity. While locations outside the protected areas are suffering severe habitat destruction activities, which led to low fish diversity in these zones (Table 3.11). Andren and Angelstam (1988) reported that landscape degradation and reduction of the spatio-temporal heterogeneity of the streams have a direct and far-reaching influence on gene pools, population and communities as well as an indirect influence on biotic relations.

4.4.1. Longitudinal zonation and distribution of fishes in Western Ghat streams

Fish assemblage in rivers and streams worldwide show longitudinal zonation (Hynes, 1970; Hawkes, 1975; Fisher, 1983) and the relationship between assemblage composition and physicochemical variability continues to be actively studied (Matthews, 1986;Hughes and Gammon,1987;Meffe and Sheldon,1988).The results of the present study conducted at six major river systems of Kerala also revealed the longitudinal zonation in the fish assemblage from the mountain peaks in Western ghats to lowland plains. Although zonal boundaries cannot be simply demarcated by the icthyofauna, however, the presence of certain fishes may be very typical of some of the regions in these Western Ghat streams. Based on the species assemblage structure the stream reaches of these six major river systems of Kerala were classified into following zones following Edds (1993).

1. Mountain zone (<1200m)

In the mountain zone of Western Ghat streams, the diversity is comparatively less and there is the dominance of some loaches belonging to the genus *Nemacheilus* among the fish fauna. Members of the genus *Garra* and *Homoleptera* are also showing their presence in this zone. Eventhough some cyprinids like *Barilius bakeri, Danio spp.* etc. are present in some regions, however their occurrence is very sparse and sporadic. This part of the riverine habitat is mainly of step-pool and cascade type. The fishes occupying these areas possess some peculiar anatomical and behavioral adaptations for their inhabitation in the torrential streams such as vibrant colouration, sucker like disc for clinging to the substrate, etc.

2. High hill zone (600-1200m)

This zone of the riverine habitat was mainly dominated by bedrock and pool-riffle microhabitats. *Danio malabaricus, Barilius gatensis, Barilius bakeri, Tor khudree* suckers like *Garra mullya,Bhavania auistralis,Glyptothorax spp., Travancoria spp.* etc. were found very common at these reaches. Many of the endemic fish species of Western Ghats such as *Lepidopygopsis.typus, Gonoproktopterus. thomasi,Gonoproktopterus micropogon periyarensis, Crossocheilus periyarensis ,Osteocheilus longidorsalis, Neolissocheilus wynadensis, Silurus wynadensis* etc. showed their presence at this zone in various rivers studied.

3. Low hill zone (50-600m)

The low hills zone was dominated by several geneus of the family Cyprinidae, especially *Puntius*. Regular occurrence of species such as *Garra spp.,Bhavania australis* and *Glptothorax spp.* were also observed from this reach. The riverine habitat was mainly of pool-riffle, braided and plane-bed type. Carnivorous species like *Clarias, Heteropnuestes* and nocturnal species like *Anguilla* showed their occurrence in this zone

4. Low lands zone (0-50m)

The riverine habitat was mainly of regime or plane bed type. Occurrence of pool-riffle microhabitat was sparse and sporadic. Species like *Puntius sarana subnasutus,Channa striatus,Channa marulius,Pristolepis marginata,Clarius dussumieri,Parambassis thomassi,Wallago atu, Mastocembelus armatus, Aplocheilus spp.* etc.were found very common in this zone.Flow velocity was comparatively negligible in most of the areas of this zone.

Fish assemblage in the mountains zones of Western Ghat streams bears some resemblance to that of other mountain fish communities. In the Mountain zones of Himalayan Gandaki river, comparable ecological equivalents can be found, including *Noemacheilus,* drift feeding cyprinids (*Barilius*) and snow trout Schizothorax (Cyprinidae) (Edds,1993) (*Lepidophygopsis typus* is one of the Schizothoracinae member abundant in the upstreams of Periyar river).In North America, this zone is generally inhabited by trout(Salmonidae), Sculpians(Cottidae), Suckers(Catostomidae), and dace(Cyprinidae) (Moyle and Herbold,1987;Rahel and Hubert,1991).While in the northern European streams the mountain zone is mainly occupied by trout, Sculpins, Loaches(Balitoriade, mainly *Noemacheilus*), and Minnows(Cyprinidae) .

According to Groosman *et al.* (1990) in order to discern long term structure of fish species assemblage and variability in stream fish populations, a short term study is insufficient. However, this scheme of work was ecologically meaningful and that it may be of use to planners and administrators of Western Ghat fish conservation policies and river management. The present study revealed that physical parameters such as instream cover, substrates, distribution of microhabitats, nature of riparian zone and flow velocity have vital role in determining fish species assemblage structure in six major river systems in Kerala part of Westernghats. Edds (1993) reported that geography, waterquality and stream hydraulics such as substrate type; stream depth and current speed were the major physicochemical parameters governing the fish assemblage structure in Gandaki river. Seasonal changes have substantial, but secondary effects while abundance and composition of vegetation were also found significant in supporting biodiversity.

The results of the present study indicate that combination of physical variables such as the percentage occurrence of different types of microhabitats, nature and quantity of various instream cover and riparian zone along with components of 'stream hydraulics' (Statzner and Higler, 1986), were the major abiotic factors characterizing longitudinal zonation of fish assemblage structure in the six major river systems of Kerala. According to Sousa (1984) and Schlosser (1987), both physico-chemical and biological interactions were involved in determining assemblage organization in streams. Edds (1993) reported that biotic interactions may increase in importance as abiotic conditions become more benign downstream. The present study also revealed that there exist very high correlation between physical parameters such as substrates, instream cover, nature of microhabitats in different stream reaches, type of riparian zone and flow velocity with fish species assemblage structure in six major river systems of Kerala. However, the actual mechanisms determining community organization remain to be investigated.

Table 4.1 Fish diversity at different altitude ranges in Bharathapuzha river system

Altitude range(m)	d	j'	h(lodge)	1-lambada
0-200	1.76	0.73	1.59	0.73
200-400	1.78	0.58	0.83	0.46
400-600	1.4	0.45	1.1	0.45
600-800	1.08	1.86	1.34	0.74
800-1000	0.58	1.83	0.79	0.53
1000-1200	0.6	0.5	0.67	0.4

Table 4.2 Fish diversity at different altitude ranges in Periyar river system

Altitude range(m)	d	j'	h(lodge)	1-lambada
0-200	1.91	0.84	1.87	0.82
200-400	1.47	0.77	1.5	0.69
400-600	1.47	0.87	1.68	0.79
600-800	1.25	0.97	1.34	0.8
800-1000	0.99	0.69	1.17	0.57
1000-1200	1.52	0.79	1.77	0.8
1200-1400	1.27	0.74	1.27	0.64
1400-1600	0.26	0.43	0.3	0.24

Table 4.3 Fish diversity at different altitude ranges in Chalakkudy river system

Altitude range(m)	d	j'	h(lodge)	1-lambada
0-200	3	0.83	2.13	0.84
200-400	2.8	0.8	2.43	0.88
400-600	2.03	0.89	2	0.83
600-800	1.27	0.91	1.59	0.78
800-1000	1.97	0.82	1.84	0.81

Table 4.4 Fish diversity at different altitude ranges in Kallada river system

Altitude range(m)	d	j'	h(lodge)	1-lambada
0-200	1.02	0.66	1.13	0.54
200-400	0.86	0.79	1.16	0.62
400-600	1.45	0.7	1.12	0.6
600-800	0.68	0.92	1.01	0.7

Table 4.5 Fish diversity at different altitude ranges in Kabbini river system

Altitude range(m)	d	j'	h(lodge)	1-lambada
600-800	1.89	0.71	1.63	0.69
800-1000	1.88	0.78	1.42	0.71

Table 4.6 Fish diversity at different altitude ranges in Pamba river system

Altitude range(m)	d	j'	h(lodge)	1-lambada
0-200	1.74	0.84	1.71	0.79
200-400	1.61	0.86	1.78	0.82
400-600	1.33	0.91	1.85	0.78
600-800	1.11	0.75	1.08	0.8
800-1000	1.26	0.74	1.2	0.81

Table 4.7 Location wise fish diversity at different altitude ranges in Bharathapuzha river system

	Altitude(m)	d	j'	h(lodge)	1-lambada
Cheruthuruthy	18.4	2.02	0.80	1.72	0.77
Kanakkanoor	39.4	4.00	0.88	2.37	0.90
Thonikadavu	39.7	1.55	0.81	1.43	0.71
Cheerakuzhi	40.3	2.75	0.80	2.02	0.81
Meenvallam I	42	0.00	0.00	0.00	0.00
Cherakuzhi	42.3	0.14	0.80	1.35	0.74
Cheerakuzhi	42.3	1.36	0.84	1.35	0.74
Pambadi east	42.9	3.11	0.87	2.08	0.87
Manarkkad	46	2.44	0.80	2.02	0.84
Mudappallur	55.2	0.75	0.85	1.18	0.66
Yakkara	56	2.89	0.90	2.32	0.83
Churiode	61.6	2.42	0.91	1.90	0.88
Kalpathi	69	1.54	0.80	1.51	0.74
Pezhumkara	75.5	1.77	0.84	1.50	0.76
Choorapara	104	1.6	0.70	1.41	0.68
Chittur	113.2	1.76	0.76	1.37	0.66
Kavarakundu	212	1.47	0.70	1.51	0.82
Velampattapuzha	235.2	0.00	0.00	0.00	0.00
Kanjirapuzha	236.5	1.54	0.83	1.15	0.71
karimala	26	0.80	0.90	1.33	0.67
Thippilikayam	477	0.00	0.00	0.00	0.00
Thodunnampara	516	1.03	0.80	1.35	0.69
Meenvallam II	589	2.80	0.90	2.11	0.89
Atla	627	1.14	0.96	1.33	0.78
Thodunnampara	639	1.03	0.75	1.35	0.69
Puchappara	945	0.77	0.80	1.04	0.62
Cheriawalakkad I	992	0.74	0.80	0.88	0.59
Karingathodu	995	0.37	0.70	0.55	0.34
Cheriawalakkad II	995	0.46	1.00	0.69	0.56
Syrendri	1001	0.60	0.50	0.67	0.40

Table 4.8 Location wise fish diversity at different altitude ranges in Periyar river system

	Altitude(m)	d	j'	h(lodge)	1-lambada
Bhoothathankettu	20	2.41	0.85	2.03	0.84
Neriyamangalam	20	1.90	0.86	1.91	0.82
Pooyamkutty	76	2.08	0.86	1.99	0.85
Purakkallu	76	1.26	0.79	1.54	0.76
Thnadmankuthu	226.5	1.96	0.85	1.95	0.83
Neendapara	342	1.21	0.87	1.39	0.75
Mangappara	360	1.64	0.89	1.85	0.82
Pindiparra	362	1.15	0.42	0.75	0.34
Thannimoodu	392	1.37	0.81	1.57	0.73
Panniarkutty	578	1.69	0.79	1.63	0.76
Mukkan	596	1.24	0.96	1.72	0.83
Nallathanni	775	1.25	0.97	1.34	0.80
Kunchithanni	867	0.49	0.28	0.30	0.14
Madrappara	988	1.26	0.87	1.56	0.78
Choorapara	994	1.21	0.92	1.66	0.81
Ummikuppanthodu	1023	0.53	0.84	0.92	0.58

Thannikudy	1050	1.51	0.84	1.74	0.79
Pillakayam	1069	1.84	0.13	1.87	0.82
Nadathottam	1078	1.42	0.91	1.99	0.86
Moolavaiga	1208	1.35	0.68	1.22	0.60
Kundamkallu	1240	1.34	0.71	1.38	0.65
Mukkar	1254	1.10	0.55	0.98	0.46
Chembakavalli	1359	1.43	0.86	1.54	0.77
Kattamadithodu II	1378	1.11	0.90	1.25	0.72
Kattamadithodu I	1412	0.51	0.86	0.60	0.48
Kunthrapuzha	1540	0.00	0.00	0.00	0.00

Table 4.9 Location wise fish diversity at different altitude ranges in Chalakkudy river system

	Altitude(m)	d	j'	h(lodge)	1-lambada
Vettilapara	40	3.40	0.80	2.17	0.87
Athirappally I	87	3.40	0.80	2.17	0.83
Athirappally II	104	2.20	0.90	2.04	0.81
Vazachal	204	2.80	0.80	2.43	0.88
Karapara	410	2.20	0.90	2.09	0.88
Orukomban I	451	2.60	1.40	2.58	0.88
Sholayar	497	1.70	0.70	2.00	0.85
Orukomban II	498	2.10	0.90	2.14	0.85
Kurirkutty	524	2.00	0.90	2.16	0.86
Puliyala	535	2.50	0.90	2.21	0.87
Thekkadiyar	535	1.40	0.70	1.49	0.72
Thekkadiyar II	539	1.40	0.80	1.40	0.74
Thekkadiyar III	549	1.98	0.75	1.73	0.77
Orukomban	561	2.40	0.90	2.16	0.87
Malakkapara	743	1.24	0.91	1.63	0.80
Vallakayam	764	1.30	0.90	1.55	0.77
Anakkallankayam	990	1.70	0.80	1.70	0.79
Padikutty	995	2.80	0.80	2.09	0.87
Karappara river	996	1.75	0.80	1.75	0.79
Vetti Ar	996.4	1.63	0.86	1.80	0.81

Table 4.10 Location wise fish diversity at different altitude ranges in Kallada river system

	Altitude(m)	d	j'	h(lodge)	1-lambada
Urukunnu	20.3	1.04	0.46	0.63	0.31
Ottakkal	25	0.82	0.78	1.08	0.62
Meenmutty	89	1.77	0.86	1.89	0.83
Dali	115.5	1.07	0.92	1.72	0.79
MSL	194	0.42	0.30	0.33	0.15
Chenkali	209.4	1.38	0.77	1.54	0.72
Kazhuthuruty	217	0.70	0.84	1.17	0.64
Ariyankavu	233	0.72	0.64	0.88	0.47
Palaruvi II	381.3	0.63	0.90	1.07	0.64
Palaruvi I	502.3	1.45	0.70	1.12	0.60
Chenthuruny	641	0.68	0.92	1.01	0.70

Table 4.11 Location wise fish diversity at different altitude ranges in Kabbini river system

	Altitude(m)	d	j'	h(lodge)	1-lambada
Sugardagiri	721	0.94	0.54	0.87	0.42
Begur	723	2.81	0.84	2.25	0.87
Kamambatta	750	1.76	0.85	1.76	0.81

Kuruvaddep	769	3.10	0.79	1.80	0.81
Palvelicham	771	2.57	0.87	2.00	0.85
Achoor	772	1.44	0.84	1.50	0.74
Begur I	783	1.83	0.88	2.47	0.84
Begur II	783	2.51	0.82	1.98	0.85
Thariyod	796.5	0.00	0.00	0.00	0.00
Amagiri I	824	1.44	0.65	1.14	0.64
Amagiri II	862	1.53	0.69	1.24	0.57
Aranagiri	879	1.49	0.87	1.88	0.56
Ponkuzhy	914.8	2.22	0.89	1.95	0.86
Noolpuzha	946	2.80	0.87	0.76	0.86
Muthanga	950.2	1.83	0.73	1.57	0.76

Table 4.12 Location wise fish diversity at different altitude ranges in Pamba river system

	Altitude(m)	d	j'	h(lodge)	1-lambada
Thottapuzhassery	4.5	1.78	0.83	1.87	0.82
Tiruvillapra	6.8	2.32	0.79	1.96	0.78
Perunthenaruvi	48.1	1.71	0.86	1.90	0.83
Azutha	84.8	1.09	0.87	1.49	0.75
Angamoozhi	133	1.18	0.76	1.42	0.65
Nilakkalthodu	143.9	2.47	0.83	1.92	0.84
Attathodu	145.8	1.64	0.91	1.42	0.85
Kakkad Ar I	257	1.37	0.91	1.78	0.82
Kakkad Ar II	300.3	2.02	0.87	1.99	0.85
Pamba	388.4	1.44	0.80	1.56	0.73
Moozhiyar I	413.9	1.33	0.91	1.85	0.78
Moozhiyar II	612	1.11	0.75	1.08	0.84
Kakki I	824	1.10	0.64	0.91	0.92
Kakki II	829	1.21	0.72	1.29	0.74
Kochupamba	1000	1.47	0.88	1.40	0.76

Table 4.13.Analysis of variance of Shannon-weiner diversity index at different altitude ranges in six major river systems of Kerala

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	13.2226126	7	1.88894466	6.9750806	3.20952E-05	3.19994
Columns	5.888631692	5	1.17772634	4.3488496	0.003497253	3.59191
Error	9.478465807	35	0.27081331			
Total	28.5897101	47				

Table 4.14.Analysis of variance of Simpson index at different altitude ranges in six major river systems of Kerala

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	3.069194657	7	0.43845638	8.7700357	3.41388E-06	3.19994
Columns	1.205800783	5	0.24116016	4.8237026	0.001852222	3.59191
Error	1.7498188	35	0.04999482			
Total	6.02481424	47				

Table 4.15.Analysis of variance of Species richness at different altitude ranges in six major river systems of Kerala

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	14.21204919	7	2.03029274	5.4774867	0.000260658	3.19994
Columns	5.793591222	5	1.15871824	3.1260831	0.019506814	3.59191
Error	12.97314813	35	0.37066138			
Total	32.97878854	47				

Table 4.16.Analysis of variance of Species evenness at different altitude ranges in six major river systems of Kerala

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	3.64199442	7	0.52028492	8.9646731	2.71916E-06	3.19994
Columns	1.424574612	5	0.28491492	4.9091739	0.0016552	3.59191
Error	2.031303537	35	0.05803724			
Total	7.097872568	47				

Fig.4.1.Fish diversity based on Shanon-Weiner diversity index at different altitude ranges in six major river systems of Kerala

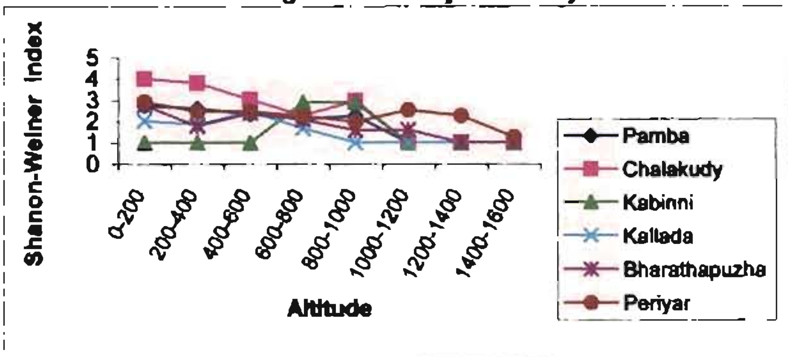


Fig.4.2.Fish diversity based on Simpson divery index at different altitude ranges in six major river systems of Kerala

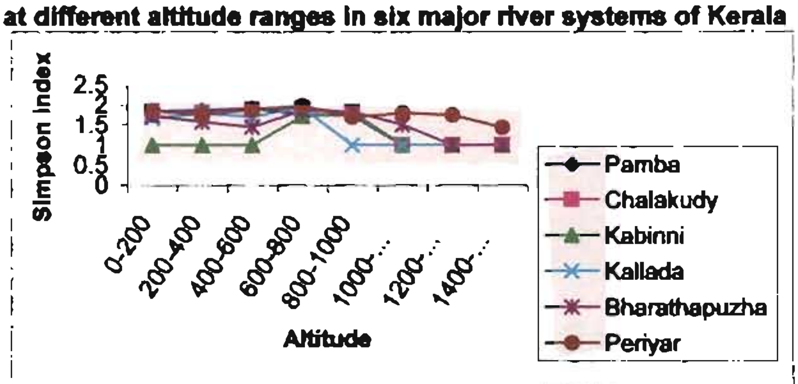


Fig.4.3.Species richness at different altitude ranges in six major river systems of Kerala

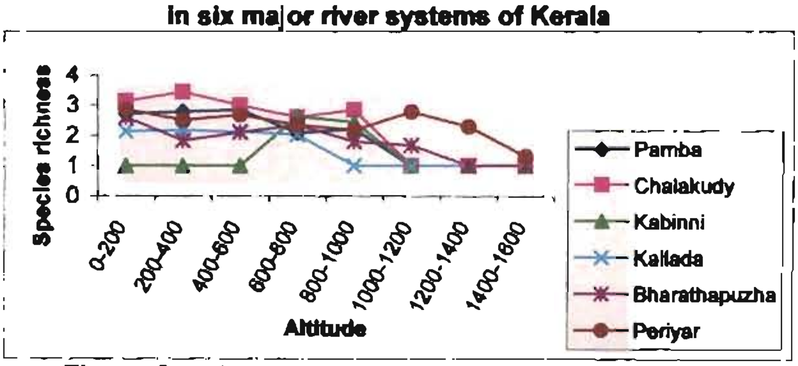
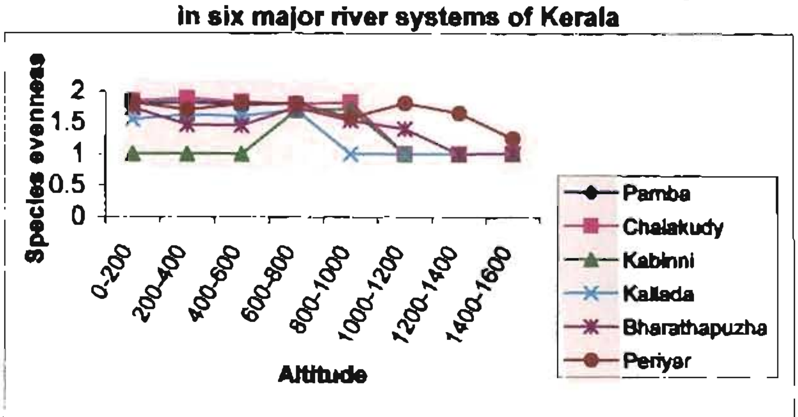


Fig.4.4.Species evenness at different altitude ranges in six major river systems of Kerala



Chapter 5

On the extent of degradation of fish habitats in the major river systems of Kerala and management plans for fish germplasm conservation

5.1. Introduction

We do not know how many species live on earth. Estimates vary from 5 to 50 millions (Osborne, 2000). Like determining the number of extant species, it is also difficult to determine the number of species going to be extinct each year. According to Groombridge(1992) the rate of erosion of biological diversity far exceeds any reasonable estimates of background extinction rates and identified habitat perturbation as the major reason. Significant areas of natural habitat have been replaced by human dominated systems, and this process of habitat destruction is probably the major cause of biodiversity loss (Osborne, 2000). This process is escalating owing to enhance the living standards and our ever increasing capacity to exploit natural resources. It has been estimated that 90 million km^2, roughly 52%, of largely undisturbed land remains on earth (Hannah *et al.* 1994). If we exclude inhospitable land (rock, ice, deserts), the proportion of human impacted land rises to 75%(Osborne,2000).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 the biodiversity decline(Hannah *et al.*1994).

Habitat is a principal determinant of biological potential and can be used as a general predictor of biological conditions (Plafkin *et. al*, 1989) or there are links between the diversity of species (biological diversity or biodiversity) and the way ecosystem functions (Osborne, 2000). Petts (1990) reported that the diversity increases with the heterogeneity of the environmental conditions and with the types of microhabitats. According to Rabeni and Sowa (1996), the physical and chemical characteristics of the stream and landscape features such as stream size, basin area and spatial geometry have high correlation with the variation in fish density. Moreover, there is some experimental evidences that reduction of the complexity of aquatic ecosystem drastically reduces establishment of large specimens (Portt *et al.,* 1986), so that the trophic structure of the fish community is modified(Schliosser,1992)and, even more important, the reproductive potential of the population might be sharply reduced leading to the greater variability and smaller numbers of specimens in a population (Lachavanne and Jugė,1997).So assessments of any aquatic system start with an evaluation of habitat quality(Stauffer and Goldstein,1997).

Restoration of stream habitats towards pristine conditions is an utopuian view. In most cases river basins have experienced extensive land-use changes because of human activity. The most dramatic impacts resulted from deforestation, land use, intensification of agricultural and industrial activity, and the modification of river channels to control floods, provide power and improved navigation. Moreover, recently, demands for water resources and electricity have created new impacts. All these changes have been superimposed upon environmental changes caused by recent climatic variations.

In 1972 United States introduced 'clean water act' to restore and maintain the chemical, physical and biological integrity of the nation's waters (Talmage *et al.*, 2002). In India, there is 18 major river basins. The rapid industrialization during the second half of 1900's leads to severe land reformation, habitat destruction and aquatic pollution (Tiwari, 1988). As a result, the physical, chemical and biological integrity of most of the freshwater ecosystems were lost. The water Act of 1974 and Environmental Act of 1986 are concentrating mainly on the water quality of the aquatic ecosystems. Even though the Ministry of Environment and Forest introduced many promotional measures and research projects covering studies on impact of development activities on natural ecosystems, survey and monitoring of environmental indications, pollution control, ecoregeneration energy use etc., standards for measuring the instream habitat and physical conditions are still lacking for Indian rivers. On the contrary, according to Sreevastava and Sarkar(1998),the habitat of freshwater strem fishes is more dependant on physical features rather than on chemical features, which indicate that a multiple scale approach ,considering the physical chemical and biological integrity is essential for the conservation and management of natural aquatic ecosystems and thereby the resources.

The purpose of the present study was to examine the relationship between instream habitat and physical conditions and fish community composition in six major river systems of Kerala and to isolate the habitat variables which are most important to fish communities. The study also pays attention to find out the extent of ecosystem imbalance by comparing the species diversity, abundance and index of biotic integrity scoring with habitat variables. With knowledge of these relationships, the stream restoration activities may successfully target on those features that are important to the stream fish community, which will helps to achieve the physical, chemical and biological integrity of our river systems.

5.2. Materials and methods

Materials and method used for in the study are illustrated in chapter 2.

5.3. Results

5.3.1. Bharathapuzha river system

Mean fish community diversity was relatively low (mean=1.3, SD=0.65.). Location wise diversity was highest at Kanakkanoor(2.373) and lowest at Meenvallam and

Velampattapuzha(0)(Table 5.1). Fish species abundance ranged from 3(Meenvallam I) to 131(Thodunnampara) and the mean abundance was 39.3(SD=34.6)(table 5.1). Index of Biotic Integrity scores ranged from 0(Velampattapuzha) to 60(Yakkara) and the mean IBI score was 21.7(SD=13.7)(Table 5.1).

Instream cover varied among sites. Depth was the dominant instream cover (38.68%) (SD=33.3) followed by overhanging vegetation (18.9%), emergent vegetation (17.5%) and turbulence (12.1%) (Fig.5.1). Riverbed was dominated by Bedrock (28.6%) followed by gravels (17.85%) and fines (16.57%) (Fig.5.7).

Among physical conditions sinuosity varied between 1-1.63(SD=0.14) and stream gradient ranged between0.001-0.25 (SD=0.06). Mean entrenchment ratio and w/d ratios were 1.46(SD=0.9) and16.42 (SD=19.3) respectively. Midchannel pools (23.3%) were the dominant channel geographical unit followed by run (18.35). glide (12.3%) and landslide (9.6%)(Fig.5.13). Mean flow velocity was comparatively less with 0.31(SD=0.35). Vegetation cover was comparatively less on the riparian zone and 29.4% of the riparian zone was without any vegetation. While 26.2% having shrub cover and 44.4% of the riparian zone was covered with trees.

The first 10 PCA axes explained 78.3%of the total variance in instream habitat and physical conditions (Table 5.7). The variables with greatest loadings in each axes were w/d ratio, percentage of large woody debris, fines, total instream cover, riffles, floating vegetation, rapids abandoned channel, pocket water pools, sheet type channel geographical unit and turbulent white water boulders (Table 5.7).

Multiple linear regression analysis of the selected habitat variables which showed maximum loadings in the first 10 PCA axis with Shannon -Weiner diversity index revealed that these parameters together explaining 70.6% of the fish species diversity in Bharathapuzha river system. Except in the case of percentage large woody debris, total instream cover, riffle,floating vegeation and rapids all other habitat variables showed significant positive and linear correlation with the fish diversity in Bharathapuzha river system (Table 5.13). While the selected habitat variables explained only 24.5% of the fish species abundance in Bharathapuzha river system. Among the 10 habitat variables except w/d ratio, percentage sheet, riffle and abandoned channel all other habitat variables showed significant negative correlation with the fish species abundance (Table 5.19) .In the case of index of biotic integrity scoring the selected habitat variables explained only upto 14.8% of the trophic structure. All the critical habitat variables except floating vegetation showed significant positive correlation with the Index of biotic integrity (IBI) scores. While the relationship of floating vegetation with IBI scores was negative (Table 5.25).

5.3.2. Chalakudy river system

Mean fish community diversity was 1.96 (SD=0.31) which was highest at Orukomban I (2.58) and lowest at Thekkadiyar II(1.4)(Table 5.2).Fish species abundance ranged from 53(Vallakayam) to 206(Orukomban II) and the mean abundance was 98.3(46.1)(Table 4.2).Index of biotic integrity scores ranged from 25(at Malakkapara) to 64(at Kuriarkuutty) with a mean of 44.1(SD=9.5)(Table 5.2).

Instream habitat and physical conditions are highly heterogenic in this river system. Depth (38.1%) was the dominant instream cover followed by overhanging vegetation (26.8%), emergent vegetation(8.5%), turbulence(7.1%), large woody debris (4.8%), undercut bank (4.3%) and overhanging stream boulders (4.2%) (Fig.5.2).On an average bed rock constituted 47.8% of the river bed followed by fines(14.9%), boulders(12.9%), rock(12.6%) and gravels(8.9%)(Fig.5.8).

Among physical conditions, sinuosity varied between 1-1.5(SD=0.15) and stream gradient varied from 0.001-0.1 (SD=0.03). While the mean entrenchment ratio and w/d ratios were 1.23(SD=0.27) and 9.59(SD=9.74) respectively. Channel geographical units were highly heterogenic dominated by midchannel pools (30.5%), riffle (17.9%), run (16.9%), rapids(13.7%) and pocket water pools(9.9%)(Fig.5.14).Mean flow velocity was 0.25m/s(SD=0.23).Riparian zone having 87.65% tree cover while 7.6% of the riparian zone was with shrub cover and bare ground occupied only 4.75% of the riparian zone.

The first 10 PCA axes explained 74.2% of the total variance in instream habitat and physical conditions (Table 5.20). The variables with the greatest loadings on each axis were flow velocity, mean channel width, percentage shrub cover, tree cover, bare ground along the bank, total instream cover, falls, riffles, midchannel pools and water temperature.(Table 5.8). Multiple linear regression analysis of these selected habitat variables with Shanon-Weiner diversity index explained 90.5% of the fish species diversity in Chalakudy river system (Table 5.14). Except percentage falls and mean channel width, with all other habitat variables, the fish diversity showed a negative correlation while with falls type microhabitat and mean channel width the relationship was positive. The habitat variables explained 67.3% of the fish species abundance in Chalakudy river system and except bare ground, shrub cover,tree cover, riffle and total cover , with all other variables the fish species abundance showed a significant positive correlation while with bare ground, shrub cover, tree cover, riffle and total cover the relationship was significantly negative (Table 5.20). In the case of Index of Biotic

Integrity scoring (IBI) the selected habitat variables explained 58.9% of the biotic integrity of this river system. Except percentage bare ground along bank, shrub cover along the bank, midchannel pools, tree cover , riffle and total cover, all other habitat variables showed significant positive correlation with the IBI scores while the relationship between IBI scores and percentage bare ground along bank, shrub cover along the bank, midchannel pools, tree cover , riffle and total cover was negative (Table 5.26).

5.3.3. Pamba river system

Mean fish community diversity was 1.59(SD=0.33) with a peak at Kakkad Ar I(1.99) and lowest at Kakki I(0.91)(Table 5.3).Fish species abundance ranged from 38(Attathodu) to 119(Thottapuzhassery) and the mean abundance was 70(SD=30.8)(Table 5.3). Index of biotic integrity ranged from 17(Nilakkalthodu) to 50(Peruthenaruvi) with a mean value of 34.2(SD=9.7) (Table 5.3).

Among instream habitat conditions, instream cover did not show much oddity. Depth alone contributed 48.75% followed by turbulence (22.3%) and overhanging vegetation (16.8%) (Fig.5.3). In the riverbed, bedrock was dominating (24.8%) followed by fines (19%) and gravels (16.75%). While the other types of substrates such as cobbles, boulders and rock together contributed to only 39.45% of the total riverbed (Fig.5.9). Sinuosity varied between 1-1.3 (SD=0.15) and channel gradient varied from 0.001-0.1(SD=0.04).The mean entrenchment ratio and w/d ratios were 1.21(SD=0.28) and 7.13(SD=5.61) respectively. Heterogeneity of channel geographical units was comparatively less and midchannel pools (45.5%), rapids (19.8%) and run (18.8%) together contributed to 84.1% of the total river reach (Fig.5.15). Mean flow velocity was

0.38 (SD=0.3). Riparian zone was having 13% tree cover, 66% tree cover while 20.25% of the riparian zone was without any vegetation.

The first 7 PCA axes explained 89.1% of the total variance in instream habitat and physical conditions. The variables with the greatest loadings on each axis were temperature, dissolved oxygen level, percentage of bedrock type substratum, cascade and falls type channel geographical units and overhanging vegetation (Table 5.9). Multiple linear regression analysis of the selected habitat variables which showed maximum loadings in the first 7 PCA axes with the Shanon-Weiner diversity index showed that these variables explained the fish diversity in Pamba river system upto 72.6% and the habitat variables such as Cascade type microhabitat, sinuosity, and overhanging vegetation showed significant negative correlation with the fish diversity. On the other hand, variables such as atmospheric temperature, percentage bedrock and dissolved oxygen showed significant positive correlation with the fish diversity in Pamba river system (Table 5.15). Abundance of fish species was explained upto 40.9% by the selected habitat variables and among them except dissolved oxygen concentration all other variables showed significant positive correlation with the fish abundance (Table 4.21).Index of biotic integrity can be explained upto 50.9% by the selected variables. All the variables except cascade and overhanging vegetation showed a significant positive correlation with the IBI scores while the relationship of IBI with cascade and overhanging vegetation was negative (Table 5.27).

5.3.4. Kabbini river system

Mean fish community diversity was 1.5(SD=0.62) with a highest recorded value of 2.47 at Begur I while it was 0 at Thariyod (Table 4.4). Fish abundance ranged from 2(Tariyod) to 135(Noolpuzha) and the mean abundance was 67.6(SD=43.6). Index of biotic integrity ranged from 5(Aranagiri II) to 65(Ponkuzhy) with a mean of 38.4(SD=18.8) (Table 5.4). Among the habitat variables instream cover was dominated by overhanging vegetation (59.6%) followed by depth (24.8%). All the other types of instream cover together constituted only 15.6%. (Fig.2.4) .On an average, gravels (38.4%) and fines (18.6%) together constituted 57% of the river bed while the contribution of bedrock was only 13.5% which is indication of the high degree of bank erosion and embedness of fine materials in the river bed (Table 5.10).

Sinuosity of the river system varied from 1-2.6(SD=0.58) while stream gradient ranged from 0.001-0.1(SD=0.03). Mean entrenchment ratio and w/d ratios were1.33 (SD=0.87) and 8.17(SD=7.78) respectively. Heterogeneity of channel geographical units was comparatively less and was dominated by run (39.6%) followed by lateral pool (18.8%) (Table 5.16). Mean flow velocity was 0.3(SD=0.23).Riparian zone having 26.1% shrub cover,58.6% tree cover while 15.3% of the riparian zone was without any vegetation.

The first 7 PCA axes explained 89.1% of the total variance in instream habitat and physical conditions The variables with greatest loadings in each axes were sinuosity, shrub cover along bank, percentage of small woody debris, submerged vegetation, emergent vegetation, overhanging vegetation and pocket water pools(Table 5.10).Multiple linear regression analysis of the selected variables with the Shannon-Weiner diversity index revealed that the variables explaining the fish diversity in Kabbini river system were up to 70%.Among the habitat variables except submerged vegetation and overhanging vegetation all other variables showed significant negative correlation with the fish diversity. (Table 5.16). The selected variables explained the fish abundance only upto 29.3% and the variables such as sinuosity, shrub cover along bank, percentage small woody debris, emergent vegetation and pocket water pools showed significant negative correlation with the species abundance. While variables such as overhanging vegetation and submerged vegetation showed significant positive correlation with the species abundance (Table 5.22). In the case of IBI scoring, the selected variables explain the variation in IBI scoring up to 50.1% and among the seven habitat variables, sinuosity, shrub cover and pocket water pools showed significant negative correlation with the IBI scores while with other habitat variables the relationship was positively significant (Table 5.28).

5.3.5. Kallada river system

Mean fish community diversity was 1.13(SD=0.45) with highest at Meenmutty (1.89) and lowest (0.33) at MSL (Table 4.5). Fish species abundance ranged from 18(Urukunnu) to 151(Chenkali) and the mean abundance was 65.6(SD=40.4) (Table 5.5). Index of biotic integrity ranged from 25(Chenturuny, Urukunnu and MSL) to 40(Chenkali) with a mean of 27.3(SD=10.5) (Table 5.5).

Compared to other river systems habitat heterogeneity was very less in this river system. Overhanging vegetation (35.2%), depth (25.7%) and turbulence (21.9%) together contributed to 82.8% of the total instream cover in this river system (Fig.5.5). Gravels (30.2%) and fines (10.2%) together contributed to 40.4% of the riverbed, which indicated high degree of bank erosion and embedness while the contribution of bedrock was only 21.9 %(Fig.2.11).

Sinuosity varied between 1-1.4(SD=0.15) and slope ranged from 0.001-0.1(SD=0.037) while mean entrenchment ratio and w/d ratios were 1.25(SD=0.5) and 5.9(SD=4.94) respectively. Three microhabitats such as Midchannel pools (28.6%), run (25.5%) and riffles (24.3%) together contributed to 78.4% of the total river reach in this river system (2.17). Flow velocity was comparatively high especially in the upper reaches and the mean flow velocity was 0.48m/s(SD=0.78).Riparian zone having 17.9% shrub cover, 62.6% tree cover while 19.5% of the riparian zone was without any vegetation.

The first seven PCA axes explained 90% of the total variance in instream habitat and physical conditions. The variables with the greatest loadings on each axes were mean channel width, percentage of shrub cover along bank, cobbles type substratum, sinuosity, temperature and total alkalinity (Table 5.11)). Multiple regression analysis of the selected habitat variables with Shanon-Weiner diversity index explained 77.4% of the fish diversity in Kallada river system. Among the habitat variables mean channel width, total alkalinity and overhanging vegetation showed positive correlation with the fish diversity while variables such as shrub cover along the bank, cobbles, sinuosity and rapids showed inverse relationship with the fish diversity (Table 5.17). Habitat variables defined the fish species abundance only upto 27.4%, which is a sign of severe habitat alteration and highly unbalanced ecosystem. Except shrub cover and sinuosity all other habitat variables showed negative correlation with fish species abundance in this river system (Table 5.23). In the case of IBI score the selected variables explained the trophic structure only upto 26.8% and among the habitat variables, percentage shrub cover,cobbles and sinuosity showed negative correlation while all the other variables showed significant positive correlation with the trophic structure of fish species in this river system (Table 5.29).

5.3.6. Periyar river system

Mean community diversity (H') was 1.48(SD=0.52) which showed the maximum value (2.04) at Anakkallankayam while it was 0 at Kuntrapuzha(Table 5.6). Fish species abundance ranged from 0(Kuntrapuzha) to 284(Nadathottam) and the mean abundance was 71.6(SD=51.8)(Table 5.6) Index of biotic integrity score varied from 0 (Kuntrapuzha) to 62(Thandamankuthu) with a mean value of 34.1(SD=11.8)(Table 5.6).

In Periyar river system among the various habitat variables, the instream cover was dominated by depth (40.8%) followed by turbulence (31.4%) (Fig.5.6). On an average bedrock formed 45.5%of the river bed followed by boulders (14.6%), cobbles (14.5%), gravels (12.6%), rock (6.6%) and fines (6.2%) (Fig.5.12).

Among the physical conditions sinuosity varied from 1-1.4(SD=0.12) and stream gradient ranged from 0.01-0.15 (SD=0.03). Mean entrenchment ratio and w/d ratios were1.39 (SD=0.03) and 5.1(SD=3.6) respectively. Midchannel pools made up 24% of the total geomorphic units followed by run (19.8%), riffle (15.5%) and cascade (11%) (Fig.5.18). Mean stream velocity was 0.49(SD=0.35) and the riparian zone having 23.7% shrub cover, 48.8% tree while 17.38 of the riparian zone was without any vegetation.

The first ten PCA axis explained 81% of the total habitat variability among instream habitat, physical and chemical conditions in Periyar river system. The variables with the maximum loadings on each axis were water temperature, tree cover along bank, flow velocity, falls, lateral pools, gravels, overhanging stream boulders, slope, abandoned channel and cascade (Table 5.12). Multiple regression analysis of these selected habitat variables with Shannon-Weiner diversity index explained 68% of the variability in fish species diversity in Periyar river system. Except flow velocity, mean channel width, total alkalinity and dissolved oxygen concentration all other habitat variables showed significant positive correlation with the fish diversity while the relationship of flow velocity, mean channel width, total alkalinity and dissolved oxygen concentration with that of fish diversity was inverse (Table 5.18). Fish species abundance in Periyar river system could be explained up to 59% by the selected ten habitat variables and all the variables except flow velocity, w/d ratio, submerged vegetation and mean channel width showed significant positive correlation with the species abundance (Table 5.24). The habitat variables explained the index of biotic integrity up to 61.8% in Periyar river system and among the variables flow velocity, mean channel width and total alkalinity showed negative correlation with the index of biotic integrity score. While variables such as air temperature, percentage cobbles, rapids, w/d ratio, submerged vegetation, overhanging vegetation and dissolved oxygen concentration showed significant positive correlation with the biotic integrity of this river system (Table 5.29).

5.4. Discussion

The results of the present study suggest that channel geomorphology have substantial role in determining fish diversity, fish species abundance and biotic integrity of the river system. According to Krebs (1985), 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. Among the six river systems studied only Chalakudy river only showed the sign of a healthy ecosystem where the interrelationship of habitat variables with species abundance and diversity was high. On the other hand, in Bharathapuzha, Kallada and Kabbini river systems even though the relationship between habitat variables and fish diversity was high, the habitat variables failed to explain the fish species abundance and their trophic structure .The extent of relationship of habitat variables with fish abundance and trophic structure in Periyar and Pamba river systems revealed that even though not severe as in the case of Bharathapuzha and Kallada river systems habitat degrdation activities were also high in these river systems.

While when compared the instream habitat and physical conditions prevailing in Bharathapuzha and Kallada river systems with other river systems studied, it is very clear that both the river systems were subjected to high degree of habitat alteration activites which led low fish diversity, dominance of some tolerant species and highly altered trophic structure.In Bharathapuzha river system, the high w/d ratio indicates that the contribution of pool type microhabitat was very less in this river system which is in well agreement with the findings of Schlosser (1992) who reported that both fish species richness and fish species diversity increased with the presence of pools. Felley and Hill (1983) reported that combination of riffle-pool microhabitats have very high influence on the faunastic diversity in streams. The marked contribution of Glide (12.3%) and landslide (9.6%) among microhabitats indicated the sign of increased human intervention, which have significant negative influence on the fish diversity. The present finding strongly supports the view of Cowx and Welcomme(1998) that on an average species diversity is 60% low in altered sections of the river systems when compared to natural conditions. Due to the over dominance of depth (38.68%), heterogeneity of other types of instream cover was very less which in turn affected the fish diversity in Bharathapuzha river system. The present finding is highly corroborating with that of Lachvanne and Juge(1997) that due to human intervention the river systems become more homozygous which will drastically reduces the faunstic diversity. Among substrates, high contribution of fines (16.57%) and gravels (17.85%) are indicators of the high level of bank erosion and siltation which have a significant effect on the high w/d ratio, low heterogeneity of microhabitats and high contribution of low productive glide type microhabitats. Cowx and Welcomme(1998) reported that increased sedimentation will reduce the spawning grounds and heterogeneity of river bed which will adversely affect the fish diversity. The high level of siltation also pointing towards the high sand mining activity going on in this river system. In Many areas of the Bharathapuzha river system the shallow areas of the river itself was converted into agricultural lands which was reflected from the high contribution of bare ground (29.4%) in the riparian zone. Riparian zone was identified as the most disrupted component in Bharathapuzha river system and restoration of stock is possible only through the replenishment of riparian zone. The present finding shows full agreement with that of Thalmage *et al.* (2002) who opined that the most effective restoration effort for Midwestern agricultural streams in United states is possible only by giving maximum attention to riparian zone.

In Kallada river system, high contribution of fines and gravels in the riverbed was an indication of high bank erosion and siltation. It also has significant influence on the low heterogeneity of microhabitats and instream cover. The present finding is in compliance with that of Judy *et al.* (1984) and Waters (1995) who reported that silation is one of the most important factors reducing the availability of usable fish habitat. Talmage *et al.* (2002) reported that when the substratum type increased from silt, fish diversity in the red river and Minnesota river basins responded positively. In the present study it can be seen that the low heterogeneity of microhabitats and instream cover is highly influencing the low fish diversity in Kallada river system which is in compliance with the view of Denslow(1985),Doeg *et al.*(1989) and Lake *et al.*(1989) who reported that heterogeneity of microhabitats are positively correlated with the community structure in a river system. Low heterogeneity of instream cover and the associated low fish diversity in Kallada river system are well in agreement with the findings of Cowx and Welcomme(1998) who reported that the fish abundance increases with the increase of hiding places such as undercut banks, pools, overhanging vegetation, submerged boulders, woody debris, stumps and roots. Presence of 19.5% bare ground in the riparian zone was an indication of high degree of human intervention and ecosystem degradation, which were shadowing in the low fish diversity of this river system. According to Williams *et al.* (1997) tree vegetation in the riparian zone improves the bank stability and improves the instream conditions.

In Chalakudy river system the w/d ratio (9.5) and flow velocity (0.25m/s) was minimum when compared to other river systems. The heterogeneity of microhabitats and instream cover was comparatively high. The contribution of fines (14.9%) and gravels (8.9%) in the riverbed was moderate which was an indication of low level of embedness. The high concentration of trees (87.65%) and shrubs (7.6%) in the riparian zone and low contribution of bare ground (4.75%) are indicators of low intervention into the ecotone between the land - water ecosystem.According to Schiemer and Zalewski(1992)the most important direct effect of diversified habitats is that which create conditions for the coexistence of a large number of fish species and their life stages, reduce competitive interactions, pressure of predators, catastrophic disturbances and provide feeding and spawning grounds.

In Pamba river system, heterogeneity of microhabitats and the contribution of alternating pool-riffle microhabitats were very less. According to Rabeni and Jacobson (1993) riffle-pool combination is very essential for stream biodiversity on local scales. Contribution of fines and gravels together upto 35.75% was an indication of low bank stability and high degree of siltation in this river system. Berkman and Rabeni(1987) reported that increased siltation affects fish communities by decreasing fish production and diversity , specifically by reducing the abundance of benthic invertivores, herbivores and simple lithophilic spawners. When compared to other instream and physical variables riparian zone was the highly altered component and 20.25% of the riparian zone was without any vegetation. According to Cowx and Welcomme(1998) in spite of providing the hiding places for fish and invertebrates riparian vegetation is very essential for water purification, nutrient recycling, establishing physical link between aquatic and terrestrial ecosystems, affects flow pattern and providing spawning areas and food source for fishes. In Periyar river system w/d ratio was comparatively less while flow velocity was maximum among all the river systems. Heterogeneity of microhabitats was comparatively good and the low concentration of fines and gravels (22.5) when compared to the bigger substrates (77.5%) indicated that the bank erosion and embedness were comparatively less in this river system. High proportion (17.38%) of bare ground indicated that the ecotone between land water ecosystems were under great threat in this river system and according to Cowx and Welcomme(1998) healthy fisheries may depend upon or be considerably enhanced by the vegetation of the riparian zone. Ward and Stanford (1989) reported that tree roots, fallen trunks and branches increase retention of organic matter and therefore can maintain large amounts of invertebrates, which become food for fish.

In Kabbini river system heterogeneity of microhabitats and instream cover was comparatively less. Among substrates, the high concentration of gravels (38.4%) and fines (18.6%) in the riverbed was the sign of conversion of undisturbed areas into agricultural lands. The present finding is in well agreement with that findings of Waters (1995) who reported that silt, which is often associated with agricultural land use, can be one of the most important factor reducing the availability of usable fish habitat. The high contribution of bare ground (15.3%) was an indication of the increasing human intervention into the catchment area of the river system. Portt *et al.* (1986) and Schlosser (1992) reported that reduction of the complexity of instream habitat and physical conditions drastically reduces the establishment of large specimens , trophic structure of the community and also reduces the reproductive potential of the population leading to greater variability and smaller number of specimens in a population.

The significance of instream habitat and physical features in this study demonstrates the necessity of management and restoration of multiple-scale features in the river systems of Kerala. Instream habitat and physical conditions are not independent each other they are linked by direct and indirect casual relationships (Talmage *et al.*2002). These features need to be considered while preparing restoration design and its implementation. Hawkes *et al.* (1986) stated that environmental variables function in concert to produce a system of dependant interactions that define the community structure in an ecosystem. Based on the result of the present study it can be stated that the most effective restoration efforts in the streams of Kerala would be the one focusing on riparian zone. Riparian restoration increase instream habitat with inputs of woody debris and overhanging vegetation. It also stabilizes stream banks, provides allocchthonous organic material encourages geomorphic diversity and reduces the nutrient and sediment run off from the neighbouring fields.

Management implications

From the above findings it can be concluded that the biotic integrity in Bharathapuzha, Kallada and Kabbini river systems were drastically declined due to the destruction of instream habitat and physical conditions. So in order to improve the biotic integrity in these river systems, increase of microhabitat diversity, instream cover, development of riparian zone and improvement of substratum are inevitable. The following management measures are proposed for restoration of fishery wealth.

1. Keep the longitudinal connectivity of rivers as intact not only to permit passage of migratory fish species but also for the free movement of all species within the maximum range; obstructions presented by dams and weirs may be bypassed by fish passes but the influence of water quality barriers must also be considered.
2. To maintain the lateral connectivity between the channel and river margin or flood plains in the middle and lower stretches, should not remove the flood plain ponds and backwaters associated with the river system.
3. In Bharathapuzha, problems of effluent discharges should be assessed and consideration given to the influence of any reduction in flow or water quality parameters.
4. In braided reaches, improvement of current speed diversity through the installation of rapids by the construction of different types of low weirs. The weirs

shall be placed over the full or partial width and at different angles to the riverbank. It may be straight, 'V' shaped in the upstream or downstream direction or with an irregular crest form. The weirs can built with boulders, cobbles, stone filled gabions or with concrete. But maximum height of these weirs should not exceed 1.5m or it should be completely submerged in water.

5. Instream and stream side cover can be improved by boulder placement, placement of stumps, roots or debris, artificial undercut banks formed by overhanging cover structure, tree planting in banks and stop the removal of overhanging vegetation
6. Because pool-riffle reaches can be identified as most diversified macrohabitat it can be achieved by current deflectors, stream narrowing deflectors, installation of low weirs and mechanical construction of pools.
7. Substrate reinstatement by replacing the sediments with well-sorted gravels, cobbles or even with crushed rocks which will helps to improve the fish and invertebrate habitat.
8. The micro invertebrates which form a good source of food to stream fishes can be motivated by increasing the concentration of woody debris, wet land vegetation and restoration of riffle type microhabitats in streams.

Table 5.1.Fish diversity, abundance and Index of Biotic Integrity(IBI) at selected locations of Bharathapuzha river system.

Location	Shanon-Weiner diversity index	IBI	Abundance
Cheruthuruthy	1.72	30	72
Kanakkanoor	2.373	40	33
Thonikadavu	1.434	10	25
Cheerakuzhi	2.018	30	79
Meenvallam I	0	10	3
Cherakuzhi	1.353	10	19
Pambadi east	2.078	32	25
Manarkkad	2.02	55	69
Mudappallur	1.183	25	56
Yakkara	2.32	50	112
Churiode	1.899	5	18
Kalpathi	1.51	25	57
Pezhumkara	1.498	20	17
Choorapara	1.41	14	41
Chittur	1.371	10	30
Kavarakundu	1.51	35	117
Velampattapuzha	0	5	24
Kanjirapuzha	1.154	15	7
karimala	1.334	20	14
Thippilikayam	0	15	24
Thodunnampara	1.35	20	131
Meenvallam II	2.113	0	25
Atla	1.334	20	14
Puchappara	1.04	5	29
Cheriawalakkad I	0.88	30	15
Karingathodu	0.554	15	15
Cheriawalakkad II	0.687	40	9
Syrendri	0.67	5	21

Table 5.2.Fish diversity, abundance and Index of Biotic Integrity(IBI) at selected locations of Chalakudy river system.

Location	Shanon-Weiner diversity index	IBI	Abundance
Vettilapara	2.17	55	146
Athirappally	2.17	40	41
Athirappally	2.041	40	101
Vazachal	2.43	52	151
Karapara	2.093	42	64
Orukomban I	2.578	50	63
Sholayar	1.999	50	151
Orukomban II	2.14	45	206
Kurirkutty	2.16	64	157
Puliyala	2.205	45	116
Thekkadiyar	1.487	30	126
Thekkadiyar II	1.4	30	42
Thekkadiyar III	1.728	45	94
Orukomban	2.16	57	61
Malakkapara	1.633	25	56
Vallakayam	1.55	45	53

Anakkallankayam	1.701	40	60
Padikutty	2.093	45	109
Karappara river	1.749	45	96
Vetti Ar	1.797	35	73

Table 5.3.Fish diversity, abundance and Index of Biotic Integrity(IBI) at selected locations of Pamba river system.

Location	Shanon-Weiner diversity index	IBI	Abundance
Thottapuzhassery	1.87	40	119
Tiruvillapra	1.96	27	115
Perunthenaruvi	1.9	50	108
Azutha	1.49	45	53
Angamoozhi	1.42	40	38
Nilakkalthodu	1.92	17	38
Attathodu	1.42	40	38
Kakkad Ar I	1.779	45	80
Kakkad Ar II	1.99	34	87
Pamba	1.56	25	65
Moozhiyar I	1.85	40	54
Moozhiyar II	1.08	20	49
Kakki I	0.91	25	54
Kakki II	1.29	30	112
Kochupamba	1.4	35	40

Table 5.4.Fish diversity, abundance and Index of Biotic Integrity(IBI) at selected locations of Kabbini river system.

Location	Shanon-Weiner diversity index	IBI	Abundance
Sugardagiri	0.867	30	5
Begur	2.25	62	14
Karnambatta	1.76	37	8.5
Kuruvaddep	1.8	65	15
Palvelicham	1.999	45	10
Achoor	1.504	20	6
Begur I	2.466	50	9
Begur II	1.98	55	14
Thariyod	0	15	1
Arnagiri I	1.136	15	3
Arnagiri II	1.24	5	3
Aranagiri	1.88	47	6
Ponkuzhy	1.95	60	9
Noolpuzha	0.76	45	12
Muthanga	1.57	22	6

Table 5.5.Fish diversity, abundance and Index of Biotic Integrity(IBI) at selected locations of Kallada river system.

Location	Shanon-Weiner diversity index	IBI	Abundance
Urukunnu	0.63	20	18
Ottakkal	1.08	25	43
Meenmutty	1.89	45	92
Dali	1.72	25	93
MSL	0.33	20	92
Chenkali	1.54	45	151

Kazhuthuruty	1.168	20	71
Ariyankavu	0.88	25	68
Palaruvi II	1.07	40	50
Palaruvi I	1.12	20	25
Chenthuruny	1.013	15	19

Table 5.6.Fish diversity, abundance and Index of Biotic Integrity(IBI) at selected locations of Periyar river system.

Location	Shanon-Weiner diversity index	IBI	Abundance
Bhoothathankettu	2.028	50	63
Neriyamangalam	1.91	35	68
Pooyamkutty	1.991	40	76
Purakkallu	1.541	40	117
Thnadmankuthu	1.951	52	98
Neendapara	1.394	30	27
Mangappara	1.847	25	77
Pindiparra	0.7468	30	78
Thannimoodu	1.57	30	80
Panniarkutty	1.633	20	63
Mukkan	1.723	45	56
Nallathanni	1.342	35	11
Kunchithanni	0.3027	30	57
Madrappara	1.564	30	53
Choorapara	1.657	30	62
Ummikuppanthodu	0.9235	10	43
Thannikudy	1.779	40	95
Anakkallankayam	2.044	50	70
Pulikayam	1.849	40	54
Mlappara	1.976	50	104
Thannikudy	1.741	35	103
Pillakayam	1.872	40	132
Nadathottam	1.991	50	284
Moolavaiga	1.223	40	41
Kundamkallu	1.38	30	87
Mukkar	0.9801	40	94
Chembakavalli	1.54	45	33
`Kattamadithodu II	1.245	25	15
Kattamadithodu I	0.5983	25	7
Kunthrapuzha	0	0	0

Table 5.7. Principal component loading for the first 10 axes for instream habitat and physico-chemical conditions in Bharathapuzha river system

Variables	Axis									
	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Sinuosity	0.122	0.082	-0.277	0.064	-0.171	-0.097	0.001	0.112	-0.193	-0.178
Entrenchment ratio	-0.031	0.020	-0.189	0.000	0.126	-0.226	0.195	-0.436	-0.089	0.160
Slope	0.213	0.099	0.122	0.061	0.076	-0.119	-0.109	0.088	0.219	-0.083
W/d ratio	**-0.256**	-0.063	0.010	-0.127	0.053	-0.014	-0.064	0.126	-0.134	-0.108
Shrub cover along bank	-0.155	0.126	-0.226	0.008	0.052	0.011	0.217	0.055	0.034	-0.229
Tree cover along bank	0.181	-0.134	-0.008	0.155	-0.129	-0.003	-0.204	0.311	-0.110	0.000
Bare ground along bank	-0.225	0.097	0.063	-0.119	0.090	-0.015	0.079	-0.164	-0.105	-0.099
Fines	-0.124	0.101	**-0.319**	-0.002	0.010	0.120	-0.158	0.238	0.091	0.034
Gravels	0.022	-0.168	-0.199	-0.147	-0.296	-0.102	0.210	-0.005	-0.056	0.033
Cobbles	0.243	-0.171	-0.014	-0.071	0.043	0.024	-0.013	-0.055	-0.071	0.109
Boulders	0.229	0.181	0.028	-0.014	0.136	0.129	0.003	0.051	-0.049	0.092
Rock	0.159	0.166	0.018	0.126	0.207	-0.136	0.040	-0.021	-0.047	-0.058
Bedrock	-0.185	0.163	0.200	0.101	-0.130	-0.033	-0.043	-0.179	0.050	0.138
Turbulance	0.230	0.197	-0.037	-0.085	-0.006	0.152	0.062	-0.040	-0.017	0.057
Depth	-0.132	0.057	-0.216	0.170	-0.047	-0.060	-0.014	-0.049	0.185	0.072
Small woody debris	0.044	-0.336	0.083	-0.052	-0.043	-0.060	-0.100	-0.032	0.151	0.046
Large woody debris	0.077	**-0.351**	0.057	0.027	-0.012	-0.010	0.016	-0.068	0.274	-0.115
Overhanging vegetation	0.239	-0.099	-0.025	-0.012	-0.096	-0.200	-0.107	-0.007	0.062	-0.096
Emergent vegetation	-0.196	0.106	-0.068	-0.043	0.115	0.007	-0.095	0.048	-0.119	-0.155
Floating vegetation	-0.078	0.008	0.009	0.164	-0.091	0.042	**-0.394**	-0.041	-0.033	-0.030
Turbulant white water boulders	0.230	0.171	0.065	-0.090	0.078	0.149	0.024	0.016	0.074	0.036
Scour out pools	-0.044	-0.047	-0.075	-0.197	-0.068	0.190	-0.052	-0.361	0.182	0.046
Overhangs stream boulders	0.035	-0.003	-0.058	-0.026	0.024	0.329	0.141	-0.145	0.402	-0.273
Undercut bank	0.170	0.152	0.176	0.089	-0.120	-0.165	0.159	-0.110	0.031	-0.034
Total cover	-0.105	0.107	-0.069	**0.309**	0.034	-0.057	-0.069	-0.003	0.288	0.113
Falls	0.144	0.136	-0.006	0.081	-0.379	-0.078	0.154	0.087	-0.009	-0.006
Cascade	0.175	0.179	0.033	0.097	0.202	-0.158	-0.006	-0.031	-0.028	-0.002
Rapids	0.125	0.024	-0.204	0.203	0.087	0.051	0.188	0.037	0.047	**-0.398**
Riffle	0.036	0.059	-0.064	-0.112	0.074	**0.448**	-0.006	0.063	0.055	0.239
Sheet	0.049	0.062	0.018	-0.010	**-0.463**	-0.053	0.098	0.024	-0.067	0.137
Run	0.117	0.048	-0.049	-0.295	-0.175	0.067	-0.200	-0.123	-0.133	0.167
Trench	0.091	0.099	0.171	-0.043	0.129	-0.141	-0.303	0.045	0.113	0.039
Midchannel	0.010	0.041	-0.258	0.233	-0.212	0.216	-0.263	-0.093	0.011	-0.112
Pocket water pools	-0.089	0.010	0.252	0.044	0.010	0.068	0.196	0.091	**-0.289**	-0.196
Plane bed	0.049	-0.019	-0.146	0.180	0.192	0.222	0.136	0.088	-0.196	0.360
Glide	0.048	-0.343	0.071	-0.081	0.010	0.037	0.061	0.029	0.130	-0.162
Landslide	-0.141	0.030	-0.048	-0.001	0.082	-0.274	0.225	0.100	0.277	0.310
Abandened channels	-0.090	0.030	-0.032	-0.051	0.050	-0.126	0.065	**0.423**	0.263	0.157
Air temperature	-0.114	0.185	0.090	-0.255	-0.123	0.072	-0.040	0.188	0.159	0.010
Water temperature	-0.036	0.214	0.183	-0.267	-0.199	0.045	0.154	0.093	0.119	-0.082
pH	0.056	-0.145	0.303	0.125	0.042	0.221	0.222	0.199	-0.035	0.012
Dissolved oxygen	0.084	-0.287	-0.067	0.020	0.145	0.057	0.067	0.026	-0.108	0.162

Total hardness	-0.133	-0.022	0.248	0.309	-0.070	0.085	-0.035	-0.132	-0.059	0.001
Total alkalinity	-0.096	0.097	0.289	0.211	-0.074	0.138	-0.080	-0.107	0.045	0.009
Flow velocity	0.191	0.159	-0.010	-0.204	0.142	0.040	-0.045	-0.060	-0.014	-0.150
Mean channel width	-0.251	-0.062	0.021	0.034	-0.047	0.127	0.084	0.092	-0.112	-0.009
Mean channel depth	0.137	0.035	-0.017	0.271	-0.168	0.189	0.232	-0.052	0.095	0.140
% total variance explained	23.8	11.9	8.2	8.0	5.5	5.4	4.3	4.1	3.9	3.2

*Bold values indicate the component with the highest loading on each axis

Table 5.8. Principal component loading for the first 10 axes for instream habitat and Physico-chemical conditions in Chalakudy river system

	Axis									
Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10

Table 5.9. Principal component loading for the first 10 axes for instream habitat and physico-chemical conditions in Pamba river system

	Axis									
Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7			
Cascade	0.178	-0.112	0.170	-0.109	0.134	0.160	-0.008	-0.058	-0.124	-0.096
Rapids	0.227	-0.100	-0.059	-0.172	-0.057	0.117	0.006	0.211	0.118	-0.081
Riffle	-0.012	-0.017	-0.274	0.022	0.179	-0.239	-0.035	**-0.325**	-0.010	-0.064
Chute	0.096	-0.058	0.124	0.042	-0.076	-0.224	0.086	0.201	0.252	0.286
Run	0.135	0.094	0.273	0.101	-0.200	-0.009	-0.041	-0.188	0.070	0.005
Trench	-0.122	-0.139	0.042	0.219	-0.228	0.189	-0.012	-0.164	-0.009	-0.154
Midchannel	0.016	0.203	-0.152	-0.013	**-0.337**	-0.131	-0.068	0.058	-0.097	-0.003
Glide	-0.123	-0.188	0.019	0.115	-0.162	-0.015	0.142	-0.261	-0.262	-0.025
Plane bed	-0.135	-0.156	0.084	0.224	-0.120	0.199	-0.149	-0.059	0.266	-0.119
Pocket water	-0.206	-0.099	0.094	0.049	0.256	0.134	-0.032	0.106	0.144	-0.054
Plunge	-0.135	-0.156	0.084	0.224	-0.120	0.199	-0.149	-0.059	0.266	-0.119
Backwater	0.159	-0.067	0.054	-0.079	0.135	0.287	-0.221	-0.034	-0.196	0.077
Abandened channels	0.160	-0.099	0.041	-0.138	-0.030	0.271	-0.160	0.110	-0.200	-0.003
Air temperature(OC)	0.032	-0.180	-0.103	-0.139	-0.240	-0.032	-0.207	0.121	-0.179	0.159
Water temperature	-0.167	-0.132	-0.052	0.064	-0.065	-0.230	-0.163	0.024	**-0.282**	0.110
pH	0.108	-0.213	-0.093	-0.219	0.023	-0.049	0.012	-0.115	0.195	-0.086
Dissolved oxygen	0.250	0.120	0.127	0.097	-0.063	0.061	0.089	-0.030	-0.023	0.081
Total hardness	-0.214	-0.115	-0.099	0.187	-0.004	0.060	-0.041	-0.097	0.180	0.110
Total alkalinity	0.103	-0.060	0.280	-0.002	-0.110	0.028	0.150	-0.028	-0.182	-0.122
Flow velocity	**0.272**	0.010	0.118	0.123	0.065	-0.043	0.190	-0.030	0.072	-0.024
Mean channel width	0.170	**-0.310**	0.022	-0.053	-0.045	0.020	0.120	0.067	-0.019	-0.001
Mean chanel depth	0.179	0.142	-0.123	0.166	0.127	0.235	0.002	-0.061	-0.051	0.193
% total variance explained	19.6	14.1	12.2	8.3	7.1	6.5	5.1	4.5	4.1	3.7

*Bold values indicate the component with the highest loading on each axis

Bedrock	0.010	**-0.325**	-0.014	-0.050	-0.139	0.046	-0.018
Turbulance	0.224	0.123	-0.176	0.047	-0.127	-0.153	0.117
Depth	-0.250	-0.036	-0.095	0.053	0.036	0.043	0.177
Small woody debris	0.166	-0.119	0.236	-0.197	0.095	0.035	0.072
Overhanging vegetation	0.119	-0.049	0.074	0.078	0.165	**0.444**	-0.095
Submerged vegetation	-0.212	-0.116	0.072	0.089	0.125	0.119	-0.214
Emergent vegetation	0.126	-0.136	0.075	0.041	0.261	-0.236	0.267
Scour out pools	-0.014	-0.147	0.044	0.288	0.219	-0.002	-0.229
Overhangs stream boulders	-0.030	-0.273	-0.118	0.151	0.061	-0.086	-0.186
Undercut bank	0.126	-0.243	0.061	-0.250	-0.029	-0.048	0.065
Total cover	-0.158	-0.037	-0.030	-0.110	-0.038	0.402	0.208
Falls	0.079	-0.156	**-0.334**	-0.110	0.017	-0.006	0.032
Cascade	0.079	-0.156	-0.334	-0.110	0.017	-0.006	0.032
Rapids	0.132	0.091	-0.182	0.145	-0.118	0.150	0.315
Riffle	0.180	-0.205	-0.085	-0.226	0.082	0.021	0.076
Chute	-0.012	-0.044	-0.296	-0.178	0.181	0.064	-0.069
Run	0.019	0.147	-0.020	0.179	0.069	-0.038	-0.291
Trench	-0.133	-0.142	0.062	-0.057	-0.279	-0.174	-0.031
Midchannel	-0.205	-0.065	0.206	0.058	0.158	-0.004	0.160
Lateral pools	-0.133	-0.142	0.062	-0.057	-0.279	-0.174	-0.031
Glide	0.166	-0.119	0.236	-0.197	0.095	0.035	0.072
Plane bed	0.166	-0.119	0.236	-0.197	0.095	0.035	0.072
Air temperature	**-0.265**	-0.043	0.001	-0.041	-0.233	0.000	-0.049
Water temperature	-0.242	-0.036	0.036	-0.128	-0.255	-0.027	-0.027
pH	-0.193	-0.009	-0.138	0.226	-0.079	0.116	-0.109
Dissolved oxygen	-0.023	0.165	-0.127	-0.102	**0.348**	0.023	-0.095
Total hardness	-0.210	0.129	-0.009	-0.243	0.050	-0.015	-0.104
Total alkalinity	-0.236	0.114	0.124	-0.129	0.084	0.021	0.121
Flow velocity	0.140	-0.064	-0.257	0.240	0.046	-0.020	0.089
Mean channel width	-0.161	0.012	-0.228	-0.172	0.147	-0.196	0.024
Mean channel depth	-0.217	-0.151	-0.067	0.135	0.124	-0.134	0.182
% total variance explained	23.8	17.5	14.2	11.6	9.4	6.7	5.9

*Bold values indicate the component with the highest loading on each axis

Table 4.10. Principal component loading for the first 10 axes for instream habitat and physico-chemical conditions in Kabbini river system

Variable	Axis PC1	PC2	PC3	PC4	PC5	PC6	PC7
Sinuosity	0.028	**-0.273**	-0.080	-0.081	0.271	0.064	0.104
Entrenchment ratio	0.062	-0.076	0.025	0.298	-0.139	-0.035	-0.086
Slope	-0.059	0.262	-0.272	-0.018	-0.025	-0.026	-0.034
W/d ratio	-0.120	-0.017	**0.362**	-0.037	-0.025	0.043	0.135
Shrub cover along bank	0.169	-0.132	-0.100	0.107	-0.305	0.070	0.001
Tree cover along bank	-0.164	0.145	-0.028	-0.270	0.181	0.100	0.084
Bare ground along bank	0.216	-0.215	0.070	0.150	0.015	0.114	0.064
Fines	0.011	-0.225	0.021	0.203	0.142	-0.029	0.042
Gravels	0.166	0.075	-0.225	0.131	0.159	-0.056	-0.047
Cobbles	0.134	0.309	-0.038	0.149	-0.108	0.030	-0.173
Boulders	-0.020	0.104	0.098	-0.219	-0.211	0.149	0.066
Rock	-0.151	0.032	0.164	-0.275	0.057	0.006	-0.010
Bedrock	-0.151	-0.007	0.168	-0.044	-0.124	0.237	0.283
Turbulance	0.195	0.204	0.213	-0.005	-0.123	-0.039	-0.102
Depth	-0.235	-0.103	-0.091	0.135	-0.020	-0.279	-0.155
Small woody debris	0.120	-0.050	0.099	**-0.333**	0.158	-0.077	0.025
Large woody debris	-0.103	0.161	0.064	-0.048	0.325	-0.193	-0.108
Overhanging vegetation	-0.127	-0.051	0.005	0.123	0.215	**0.357**	0.150
Submerged vegetation	**0.345**	0.047	0.046	-0.055	-0.062	-0.063	0.098
Emergent vegetation	-0.070	-0.065	0.200	0.070	**-0.365**	-0.101	0.019
Turbulant white water boulders	0.248	0.103	0.132	-0.199	-0.046	-0.096	-0.082
Scour out pools	-0.066	0.149	-0.333	0.007	-0.107	-0.094	0.182
Overhangs stream boulders	0.264	0.165	0.054	0.037	0.055	-0.084	0.314
Undercut bank	-0.098	0.050	0.083	-0.163	0.183	0.013	-0.502
Riffle	-0.141	0.191	-0.141	-0.027	-0.030	0.309	0.115
Run	0.111	-0.301	0.138	-0.103	-0.055	0.020	-0.140
Trench	0.334	0.054	0.017	-0.134	-0.028	-0.049	0.130
Midchannel	-0.096	0.202	0.191	0.059	0.063	0.204	-0.149
Pocket water pools	-0.048	0.185	0.028	0.111	0.162	-0.128	**0.390**
Glide	-0.047	0.221	0.083	0.280	0.122	-0.155	-0.006
Lateral pools	-0.048	-0.106	-0.296	-0.060	0.110	-0.107	0.067
Plunge	0.005	0.058	-0.059	0.022	-0.012	0.399	0.043
Air temperature	-0.053	0.132	0.144	0.290	0.101	0.017	0.012
Water temperature	-0.020	0.222	0.164	0.272	-0.016	0.111	-0.049
pH	-0.266	-0.056	-0.052	-0.006	-0.136	-0.133	0.163
Dissolved oxygen	0.254	0.227	-0.039	-0.122	0.118	-0.030	0.078
Total hardness	-0.107	-0.078	0.193	0.135	0.025	-0.237	0.102
Total alkalinity	0.044	0.022	0.243	0.087	0.275	-0.190	0.092
Flow velocity	-0.125	0.214	0.002	-0.069	-0.201	-0.023	-0.176
Mean channel width	-0.184	0.033	0.250	-0.125	-0.121	-0.166	0.184
Mean channel depth	-0.144	0.085	-0.148	-0.144	-0.209	-0.298	0.117

% Variance explained	16.7	16.0	13.5	12.4	9.8	8.8	5.1

*Bold values indicate the component with the highest loading on each axis

Table 5.11.Principal component loading for the first 10 axes for instream habitat and physico-chemical conditions in Kallada river system

Variable	Axis						
	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Sinuosity	0.053	0.110	-0.146	0.094	0.038	**-0.465**	0.096
Entrenchment ratio	0.231	0.040	0.157	-0.088	0.163	0.056	0.187
Slope	-0.228	0.086	0.000	-0.143	0.233	-0.059	0.034
W/d ratio	0.152	-0.284	-0.089	0.075	0.026	-0.145	-0.070
Shrub cover along bank	-0.127	-0.106	0.075	**0.334**	-0.088	0.031	0.132
Tree cover along bank	-0.186	0.048	-0.255	0.203	0.041	-0.061	-0.005
Bare ground along bank	-0.130	-0.230	0.132	-0.118	-0.216	0.127	-0.080
Fines	0.137	0.102	0.135	0.140	-0.061	0.416	0.030
Gravels	0.181	0.161	0.050	0.244	-0.107	-0.164	0.015
Cobbles	0.106	-0.088	-0.192	-0.044	**-0.345**	-0.070	-0.177
Boulders	-0.203	0.036	-0.057	-0.195	-0.149	-0.009	0.353
Rock	-0.251	0.149	0.126	-0.060	0.069	0.104	0.098
Bedrock	-0.192	0.042	-0.034	0.178	0.274	0.130	-0.058
Turbulance	-0.128	-0.196	0.102	-0.278	-0.032	0.010	-0.028
Depth	-0.205	-0.021	0.003	0.148	-0.144	-0.176	0.154
Large woody debris	0.013	-0.179	-0.141	-0.309	-0.124	0.054	-0.184
Overhanging vegetation	0.128	0.134	-0.314	0.099	0.080	0.106	-0.148
Submerged vegetation	0.238	0.053	0.203	-0.120	0.159	0.029	0.101
Emergent vegetation	-0.052	0.047	0.244	0.005	-0.367	-0.098	-0.030
Turbulant white water boulders	-0.166	-0.174	0.101	-0.173	-0.116	-0.179	0.226
Scour out pools	-0.175	-0.151	0.152	-0.045	0.270	-0.083	0.034
Overhangs stream boulders	-0.082	0.268	-0.199	-0.071	0.044	-0.151	0.125
Undercut bank	-0.111	0.265	-0.018	-0.102	0.076	0.073	-0.215
Total cover	-0.196	0.046	-0.265	0.102	-0.113	0.205	-0.061
Falls	-0.175	-0.151	0.152	-0.045	0.270	-0.083	0.034
Cascade	-0.121	0.286	-0.006	-0.051	-0.062	0.047	-0.106
Rapids	-0.040	-0.049	-0.003	0.060	-0.049	0.241	**0.423**
Riffle	-0.047	-0.247	-0.288	0.012	0.068	0.006	0.062
Run	0.199	0.014	0.134	0.139	-0.178	-0.080	0.301

Midchannel	-0.035	-0.225	-0.221	0.249	0.093	0.036	0.030
Plunge	-0.125	0.245	0.152	-0.079	-0.190	-0.009	-0.193
Air temperature	0.005	0.007	0.185	0.093	0.069	-0.225	-0.359
Water temperature	0.004	-0.089	**0.308**	0.203	-0.086	-0.082	-0.204
pH	-0.170	0.132	-0.106	0.086	-0.295	-0.141	0.075
Dissolved oxygen	-0.036	-0.110	0.049	0.196	-0.160	0.392	-0.024
Total hardness	-0.176	-0.160	0.163	0.184	0.006	-0.082	-0.150
Total alkalinity	**-0.272**	0.072	0.042	0.105	-0.057	-0.078	0.031
Flow velocity	-0.004	-0.138	-0.185	-0.321	-0.156	0.026	-0.076
Mean channel width	-0.153	**-0.295**	-0.017	0.140	0.039	-0.011	-0.099
Mean channel depth	-0.288	0.133	0.071	0.001	0.030	0.136	-0.087
% Variance explained	23.2	17.6	13.5	12.5	10.2	7.4	5.6

*Bold values indicate the component with the highest loading on each axis

Table 5.12.Principal component loading for the first 10 axes for instream habitat and physico-chemical conditions in Periyar river system

	Axis									
Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Sinuosity	0.255	-0.049	-0.044	-0.082	0.132	-0.141	0.008	-0.034	-0.172	0.137
Entrenchment ratio	0.122	0.232	0.005	-0.020	0.057	0.187	-0.026	0.279	0.102	0.117
Slope	-0.151	-0.119	0.043	0.046	0.122	0.080	0.038	0.276	0.310	-0.084
w/d ratio	-0.101	0.082	0.013	-0.001	**-0.326**	0.134	0.029	-0.242	-0.059	0.061
Shrub cover along bank	-0.076	-0.012	0.109	0.074	-0.057	-0.302	-0.270	0.208	-0.098	-0.101
Tree cover along bank	0.146	-0.259	0.098	0.001	0.027	0.148	0.124	-0.175	0.185	0.176
Bare ground along bank	-0.110	0.304	-0.191	-0.056	0.011	0.053	0.056	0.047	-0.138	-0.126
Fines	-0.123	-0.086	-0.267	-0.181	0.132	0.147	-0.234	0.074	-0.066	-0.060
Gravels	0.183	-0.006	-0.239	-0.016	-0.076	-0.262	0.044	-0.130	0.110	-0.132
cobbles	0.022	**0.367**	-0.001	-0.026	-0.004	0.203	0.037	0.034	0.022	0.069
Boulders	0.217	-0.132	0.061	-0.140	-0.043	0.001	-0.129	0.220	-0.123	0.024
Rock	-0.053	-0.163	0.173	-0.130	-0.132	0.150	0.216	0.046	0.002	-0.124
Bedrock	-0.206	-0.113	0.164	0.236	0.165	-0.074	0.119	-0.118	0.054	0.056
Turbulance	-0.182	0.139	0.242	0.036	-0.007	-0.131	-0.049	0.019	-0.148	-0.207
Depth	-0.072	-0.170	-0.223	0.084	-0.208	0.118	-0.153	-0.096	0.134	0.106
Small woody dedris	-0.023	-0.001	0.118	-0.300	-0.113	-0.153	-0.175	0.100	0.267	-0.135
Large woody debris	0.155	-0.081	0.035	0.003	-0.130	0.067	-0.111	0.006	0.310	-0.291
Overhanging vegetation	0.284	-0.085	0.064	-0.042	0.158	-0.058	0.018	-0.032	-0.149	0.068
Submerged vegetation	-0.007	0.037	-0.252	0.021	-0.050	**-0.372**	0.278	0.058	0.092	-0.017
Emergent vegetation	-0.010	0.254	-0.060	-0.067	-0.100	-0.082	0.101	0.008	0.029	0.041
Floating vegetation	-0.007	0.037	-0.252	0.021	-0.050	-0.372	0.278	0.058	0.092	-0.017
TWW	-0.113	-0.141	0.041	-0.307	0.100	0.063	0.047	-0.030	-0.211	0.020

scour out pools	-0.141	-0.152	0.182	-0.166	-0.035	-0.018	0.134	0.132	0.017	0.052
Overhanging stream boulders	0.032	-0.149	-0.029	0.017	0.090	0.033	**0.338**	0.234	-0.192	-0.223
Undercut bank	-0.172	-0.104	-0.240	-0.127	0.273	0.016	0.080	-0.051	0.093	-0.055
Toal cover	0.191	-0.175	0.022	-0.116	-0.076	-0.126	0.101	-0.224	-0.133	-0.073
Falls	-0.101	0.005	0.133	-0.336	-0.061	-0.168	-0.095	0.101	0.158	-0.028
Cascade	-0.096	0.028	0.112	0.111	0.031	0.003	0.149	0.053	-0.159	-0.398
Rapids	-0.105	-0.002	0.097	**-0.357**	-0.136	-0.075	-0.053	-0.066	-0.081	0.111
Riffle	0.154	-0.117	0.183	0.020	0.035	0.071	0.178	-0.180	0.003	-0.198
Chute	-0.106	-0.019	0.116	0.219	0.166	-0.203	-0.250	0.017	-0.036	0.132
Sheet	-0.056	-0.073	0.024	0.131	0.070	0.072	0.083	0.187	0.137	0.056
Run	0.001	0.316	-0.038	0.038	0.032	0.079	0.208	0.073	0.109	0.230
Tench	-0.023	-0.042	0.029	0.067	0.073	-0.043	-0.089	-0.251	0.176	0.143
Midchannel pool	0.079	-0.141	-0.206	0.049	-0.313	0.037	-0.121	0.124	0.096	-0.019
Lateral pool	0.166	-0.038	-0.001	-0.051	0.236	-0.022	0.053	-0.002	-0.203	0.178
Plunge pool	-0.065	-0.059	-0.196	-0.027	0.305	0.120	-0.130	-0.144	0.022	-0.092
Lasndslide	-0.089	-0.062	0.064	-0.266	-0.002	-0.061	-0.008	-0.046	0.071	0.252
Backwater	-0.082	-0.037	-0.257	-0.146	0.275	0.161	-0.140	-0.003	-0.050	-0.198
Abandened channel	-0.087	0.031	0.119	0.145	0.100	-0.246	-0.263	0.070	-0.165	0.045
Air temperature	**-0.307**	-0.120	-0.055	-0.028	-0.039	0.021	0.071	0.007	-0.068	-0.017
Water temperature	-0.300	-0.115	-0.103	0.049	-0.056	-0.091	0.132	-0.053	-0.049	0.071
pH	0.033	-0.080	0.094	0.319	-0.097	0.102	-0.109	-0.126	0.006	-0.190
Dissolved oxygen	0.040	0.236	0.035	-0.155	0.089	0.043	-0.060	-0.215	0.105	**-0.327**
Total hardness	-0.090	-0.250	-0.127	0.050	-0.216	0.110	0.040	0.249	-0.144	0.068
Total alkalinity	0.114	0.066	-0.067	0.010	-0.267	0.165	-0.051	0.124	**-0.349**	-0.006
Flow velocity	-0.102	0.132	**0.285**	-0.125	0.016	0.060	0.165	-0.083	0.043	0.005
Mean channel width	-0.165	0.036	-0.126	-0.046	-0.182	-0.049	-0.070	**-0.346**	-0.188	-0.064
Mean channel depth	0.296	-0.026	-0.026	-0.085	0.047	-0.103	-0.028	0.060	0.062	-0.151
% variance explained	15.0	11.3	9.5	8.0	6.8	5.9	5.3	5.2	4.6	4.1

*Bold values indicate the component with the highest loading on each axis

Table 5.13. Multiple linear regression analysis between critical habitat variables and Shanon-Weiner diversity index in Bharathapuzha river system

H'(R2=70.6, P<0.03)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Constant	0.173883662	0.146799073	1.184501092	0.253512375
w/d ratio	0.028985341	0.052654081	0.550486129	0.589589798
Large woody debris	-0.20322237	0.08609816	-2.36035671	0.031287636
Fines	0.099214955	0.044352028	2.236988019	0.039873144
Total cover	-0.068108085	0.090311597	-0.754145503	0.461717464
Sheet	0.322088358	0.779186935	0.413364679	0.684826605
Riffle	-0.055386434	0.043348376	-1.277704927	0.21958153
Floating vegetation	-0.032535621	0.09883169	-0.329202311	0.746272765
Abondoned channel	0.052429418	0.091967621	0.570085615	0.57653793
Pocket water pools	0.092368253	0.070946084	1.301949978	0.211366204
Rapids	-0.041258655	0.053626605	-0.769369149	0.452883285

Table 5.14. Multiple linear regression analysis between critical habitat variables and Shanon-Weiner diversity index in Chalakudy river system

H'(R2=90.5, P<0.004)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Constant	171.6534095	81.76972876	2.099229289	0.065199776
Flow velocity	-0.065887693	0.057268084	-1.150513305	0.279582971
Mean channel width	0.134705298	0.129179611	1.042775231	0.324252085
Bare ground along bank	-0.309068189	0.237882412	-1.299247749	0.226153424
Shrub cover along bank	-0.279641857	0.223736039	-1.249873996	0.242868198
Midchannel	-0.041948851	0.037393793	-1.121813215	0.290978752
Tree cover along bank	-252.0408552	120.2102348	-2.09666719	0.065471395
Falls	1106.993694	527.307349	2.099332954	0.065188809
Riffle	-0.033095151	0.031420021	-1.053314082	0.319653281
Water temperature	-0.5517529	0.651654649	-0.846695256	0.419108756
Total cover	-0.013576552	0.06962827	-0.194986204	0.849734462

Table 5.15. Multiple linear regression analysis between critical habitat variables and Shanon-Weiner diversity index In Pamba river system

H'(R2=72.6,P<0.002)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Constant	-4.140033272	1.327807551	-3.117946776	0.035597196
Air temperature	1.161011087	0.536478403	2.164133876	0.09644143
Percent bedrock	0.101933893	0.055666793	1.831143643	0.141040219
Percent cascade	-0.008384148	0.15869054	-0.052833317	0.960398039
Sinuosity	-0.16937042	0.728699478	-0.232428353	0.827613257
Dissolved oxygen	5.396545485	1.303113768	4.141269641	0.0143617
Overhanging vegetation	-0.114406212	0.051161655	-2.23617104	0.088999164

Table 5.16. Multiple linear regression analysis between critical habitat variables and Shanon-Weiner diversity index in Kabbini river system

H'(R2=70,P<0.02)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Constant	0.051692832	0.690129498	0.07490309	0.942387461
Submerged vegetation	0.178323522	0.259607904	0.686895582	0.514252928

Sinuosity	-0.598675199	0.404834184	-1.478815826	0.182722048
Shrub cover along bank	-0.064341753	0.080694744	-0.797347515	0.451443603
Small woody debris	-0.012650986	0.187487217	-0.067476528	0.948089242
Emergent vegetation	-0.089921689	0.121050248	-0.742845968	0.481754924
Overhanging vegetation	0.171037628	0.383825322	0.445613194	0.669332439
Pocket water pools	-0.029691139	0.121474828	-0.244422155	0.813913659

Table 5.17.Multiple linear regression analysis between critical habitat variables and Shanon-Weiner diversity index in Kallada river system

H'(R2=77.4,P<0.01)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Constant	-0.061127097	0.565028819	-0.108184034	0.920679468
Total alkalinity	0.062302154	0.730656047	0.085268786	0.937419528
Mean channel width	0.14600512	0.287036101	0.508664659	0.646035267
Overhanging vegetation	0.05400811	0.141900006	0.38060682	0.728846446
Shrub cover along bank	-0.066294925	0.224550762	-0.29523358	0.787069022
Cobbles	-0.054612052	0.160430467	-0.340409479	0.755990955
Sinuosity	-2.548522996	1.786601725	-1.426463973	0.248995946
Rapids	-0.264698739	0.51701269	-0.511977258	0.643973633

Table 5.18.Multiple linear regression analysis between critical habitat variables and Shanon-Weiner diversity index in Periyar river system

H'(R2=68,P<0.05)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Constant	-0.148758426	0.871035668	-0.170783392	0.86629917
Air temperature	0.437477304	0.295391536	1.481008257	0.15589726
cobbles	0.069780718	0.069867769	0.998754056	0.331151893
Flow velocity	-0.198504783	0.139340772	-1.424599421	0.171380681
Rapids	0.05952509	0.057907777	1.027929116	0.317599188
w/d ratio	0.053363849	0.079614457	0.670278374	0.511189092
Submerged vegetation	0.003768094	0.119823586	0.031447016	0.975259118
Overhanging stream boulders	0.118578876	0.103447921	1.146266405	0.266695372
Mean channel width	-0.014504896	0.13444686	-0.107885718	0.915279823
Total alkalinity	-0.054021359	0.26054516	-0.207339715	0.838072183
Dissolved oxygen	-0.505539104	0.830946245	-0.608389661	0.550529871

Table 5.19.Multiple linear regression analysis between critical habitat variables and index of biotic integrity score in Bharathapuzha river system

IBI(R2=14.8, P<0.04)

	Coefficients	Standard Error	t Stat	P-value
Constant	1.263003556	0.465113897	2.715471551	0.01527978
w/d ratio	0.075788989	0.166827653	0.454295124	0.655718734
Large woody debris	0.334915669	0.272790897	1.227737703	0.237302154
Fines	0.052114362	0.14052367	0.370858249	0.715607486
Total cover	0.016874171	0.286140627	0.058971602	0.953704992
Sheet	1.035808399	2.468753137	0.419567426	0.6803809
Riffle	0.080711085	0.13734373	0.587657586	0.564964506
Floating vegetation	-0.011345976	0.313135443	-0.036233444	0.971544431
Abondoned channel	0.160144261	0.291387527	0.549592027	0.590188755
Pocket water pools	0.126622428	0.224783502	0.563308368	0.581034183
Rapids	0.069271136	0.169908969	0.40769558	0.688900326

Table 5.20. Multiple linear regression analysis between critical habitat variables and index of biotic integrity score in Chalakudy river system

IBI(R2 =58.9,P<0.009)

	Coefficients	Standard Error	t Stat	P-value
Constant	216.1735457	127.6535388	1.693439506	0.124618755
Flow velocity	0.045412347	0.089403178	0.507950025	0.623703013
Mean channel width	0.221874725	0.201666738	1.100204863	0.299798156
Bare ground along bank	-0.510337296	0.371366424	-1.37421496	0.202624371
Shrub cover along bank	-0.424194993	0.349282034	-1.214476989	0.255468382
Midchannel	-0.090358209	0.058376737	-1.54784616	0.156065574
Tree cover along bank	-315.2502032	187.6643362	-1.679862085	0.12728745
Falls	1380.300939	823.197657	1.676755184	0.127905405
Riffle	-0.007472857	0.049050877	-0.152349107	0.882272298
Water temperature	0.151164145	1.017320509	0.148590482	0.885152836
Total cover	-0.023852734	0.10869909	-0.219438208	0.831204736

Table 5.21. Multiple linear regression analysis between critical habitat variables and index of biotic integrity score in Pamba river system

IBI(R2=50.9,P<0.0005)

	Coefficients	Standard Error	t Stat	P-value
Constant	-0.945106505	1.621938286	-0.58270189	0.591362228
Air temperature	0.236658343	0.655317001	0.361135668	0.736264021
Percent bedrock	0.070604794	0.067997883	1.038338125	0.357755286
Percent cascade	-0.198150176	0.193843048	-1.022219668	0.364467167
Sinuosity	0.211483158	0.890118137	0.237589988	0.8238725
Dissolved oxygen	2.829465039	1.591774433	1.777554018	0.150111615
Overhanging vegetation	-0.033400806	0.062494785	-0.534457494	0.621349316

Table 5.22. Multiple linear regression analysis between critical habitat variables and index of biotic integrity score in Kabbini river system

IBI(R2=50.1,P<0.003)

	Coefficients	Standard Error	t Stat	P-value
Constant	1.218794153	1.882603458	0.647398234	0.538018613
Submerged vegetation	0.669196136	0.708184101	0.944946568	0.376151821
Sinuosity	-1.69974246	1.104346702	-1.539138439	0.167662792
Shrub cover along bank	-0.275504152	0.220127098	-1.25156855	0.250928918
Small woody debris	0.137172542	0.511446163	0.268205242	0.796273155
Emergent vegetation	0.153322287	0.330212832	0.464313532	0.656517941
Overhanging vegetation	0.41789495	1.047036652	0.399121606	0.701699677
Pocket water pools	-0.045221609	0.331371043	-0.136468197	0.895293088

Table 5.23. Multiple linear regression analysis between critical habitat variables and index of biotic integrity score in Kallada river system

IBI(R2=26.8,P<0.005)

	Coefficients	Standard Error	t Stat	P-value
Constant	1.468223971	0.152400621	9.63397632	0.002373888
Total alkalinity	0.324239909	0.197073903	1.645270646	0.198464478
Mean channel width	0.062483848	0.077419909	0.807077255	0.478676045
Overhanging vegetation	0.063919513	0.038273533	1.67007088	0.193498005
Shrub cover along bank	-0.223601997	0.060566248	-3.691858177	0.034472055

Cobbles	-0.023310079	0.043271603	-0.53869229	0.627504971
Sinuosity	-1.309748069	0.48188553	-2.717965137	0.072674031
Rapids	0.122477529	0.139449621	0.878292301	0.444446348

Table 5.24.Multiple linear regression analysis between critical habitat variables and index of biotic integrity score in Periyar river system

IBI(R2=61.8,P,0.05)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Constant	-1.786769541	1.724530669	-1.036090325	0.313879594
Air temperature	2.070958636	0.584834562	3.541101653	0.002333637
cobbles	0.054477974	0.138328561	0.393830263	0.698332709
Flow velocity	-0.434140364	0.27587554	-1.573681975	0.13297321
Rapids	0.082810284	0.114649424	0.722291325	0.479395032
w/d ratio	0.065217834	0.157625661	0.413751377	0.68394423
Submerged vegetation	0.206706308	0.237234199	0.871317495	0.395053913
Overhanging stream boulders	0.116990104	0.204812636	0.571205499	0.574923744
Mean channel width	-0.512521201	0.266186268	-1.925423142	0.070124603
Total alkalinity	-0.085614094	0.515843537	-0.165969113	0.870031233
Dissolved oxygen	1.127529448	1.645159132	0.685361936	0.501847391

Table 5.25.Multiple linear regression analysis between critical habitat variables and fish abundance in Bharathapuzha river system

A(R2=24.5, P<0.004)

	Coefficients	Standard Error	t Stat	P-value
Constant	1.793029056	0.460617614	3.892662811	0.001293615
w/d ratio	0.074583968	0.16521492	0.451436033	0.657734173
Large woody debris	-0.437920215	0.270153811	-1.621003284	0.124554859
Fines	-0.112541886	0.13916522	-0.808692619	0.43055334
Total cover	-0.228642451	0.283374489	-0.806856156	0.431580376
Sheet	0.589453639	2.444887555	0.241096421	0.812542778
Riffle	0.11938483	0.13601602	0.877726242	0.393081838
Floating vegetation	-0.047291691	0.310108344	-0.152500545	0.880698705
Abondoned channel	0.472203738	0.288570666	1.636353909	0.12128124
Pocket water pools	-0.110096792	0.222610506	-0.494571408	0.627624614
Rapids	-0.014158845	0.168266449	-0.084145386	0.933984681

Table 5.26.Multiple linear regression analysis between critical habitat variables and fish abundance in Chalakudy river system

A(R2=67.3, P<0.03)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Constant	264.9558284	249.1300192	1.063524296	0.315245781
Flow velocity	0.088807946	0.174480204	0.508985797	0.62300532
Mean channel width	0.072937375	0.393574974	0.185320155	0.85708707
Bare ground along bank	-0.4384045	0.724762707	-0.604893844	0.560189325
Shrub cover along bank	-0.303634141	0.681662574	-0.445431732	0.666529134
Midchannel	-0.091851056	0.113928668	-0.806215478	0.440900436
Tree cover along bank	-388.6711016	366.2477369	-1.061224582	0.316234406
Falls	1706.078605	1606.561401	1.061944227	0.315924781
Riffle	-0.155824366	0.095728218	-1.627778818	0.138013718
Water temperature	0.457358296	1.985413646	0.230359199	0.822963521
Total cover	-0.010190859	0.212138314	-0.048038747	0.962734504

Table 5.27. Multiple linear regression analysis between critical habitat variables and fish abundance in Pamba river system

A(R^2=40.9, $P<0.007$)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Constant	0.351162457	3.080858815	0.113982003	0.914744093
Air temperature	1.382167231	1.244769407	1.110380142	0.329084764
Percent bedrock	0.113953448	0.129161435	0.882255978	0.427467938
Percent cascade	0.08268316	0.368203321	0.224558432	0.833327394
Sinuosity	1.531154917	1.690772288	0.905594992	0.416366088
Dissolved oxygen	-0.890094007	3.023562816	-0.294385816	0.783108317
Overhanging vegetation	0.052486089	0.118708344	0.442143213	0.681239474

Table 5.28. Multiple linear regression analysis between critical habitat variables and fish abundance in Kabbini river system

A(R^2=29.3, $P<0.02$)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Constant	1.071278352	0.677901278	1.580286669	0.158052852
Submerged vegetation	0.81272841	0.255007981	3.187070483	0.015339013
Sinuosity	-1.56806514	0.397661036	-3.94322048	0.005580262
Shrub cover along bank	-0.071615418	0.079264935	-0.903494311	0.396289992
Small woody debris	-0.448929056	0.184165182	-2.437643488	0.044913964
Emergent vegetation	-0.161571876	0.118905391	-1.358827168	0.216358517
Overhanging vegetation	0.093972356	0.377024424	0.249247396	0.810324896
Pocket water pools	-0.135806958	0.119322448	-1.13815095	0.292507787

Table 5.29. Multiple linear regression analysis between critical habitat variables and fish abundance in Kallada river system

A(R^2=27.4, $P<0.008$)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Constant	0.287725858	0.412986181	0.69669609	0.536123983
Total alkalinity	1.033501936	0.534045061	1.935233583	0.14840296
Mean channel width	0.658355728	0.209798048	3.138045068	0.051741802
Overhanging vegetation	0.228079278	0.103716376	2.19906717	0.115272411
Shrub cover along bank	-0.521947402	0.164126781	-3.180147677	0.050088339
Cobbles	0.079570816	0.117260507	0.678581546	0.54606079
Sinuosity	-0.537395374	1.305848122	-0.411529767	0.708318567
Rapids	0.656215581	0.377890629	1.736522503	0.18087044

Table 5.30. Multiple linear regression analysis between critical habitat variables and fish abundance in Periyar river system

A(R^2=59, $P<0.01$)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Constant	-2.773751344	2.72548534	-1.017709141	0.322301159
Air temperature	2.46055571	0.924285114	2.662117644	0.015876795
cobbles	0.009928562	0.218617431	0.045415234	0.964276394
Flow velocity	-0.507605598	0.435999633	-1.164234002	0.259528862
Rapids	0.091608293	0.181194414	0.505580115	0.619286423
w/d ratio	-0.044048728	0.249114983	-0.17682087	0.861623454
Submerged vegetation	-0.390640188	0.374930027	-1.041901579	0.311250047
Overhanging stream boulders	0.019688718	0.323690293	0.060825792	0.952168228

Chapter 6

Habitat Suitability Index (HSI) models of selected endangered and endemic fish species of Kerala

6.1. Introduction

The convention on International Trade in Endangered species (CITES) was established in 1973 under the auspices of the United Nations Environmental Programme (UNEP) identified that because of the biased nature of endangered species list and the lack of information regarding the endangered species the species to species approach to biodiversity conservation faces a major hurdle. They also pointed out that habitat conservation through the establishment of protected areas is the suitable method to overcome this problem. There are links between the diversity of species (biological diversity or biodiversity) and the way ecosystems functions (Osborne, 2000). From this statement it is clear that any change in the ecosystem will have significant influence on the inhabiting fauna and flora. With this view Conservation International (CI) was formed in 1987 with a mission that is focused on the protection and sustainable use of biologically diverse ecosystems and in 1989 they developed the Rapid Assessment Programme (RAP) to provide information necessary to develop a rational conservation management strategy for a particular area. More than 48%of natural habitats have been severely affected by human activities (Hannah *et al.*, 1994), and this process of habitat destruction is probably the major cause of biodiversity loss. This process is escalating owing to the enhance living standards and our ever increasing capacity to exploit natural resources.

River fish provide a major source of food and recreation and are also useful in predicting ecological conditions in streams and rivers. The biotic diversity and natural characteristics of fish communities are directly related to the variety and extent of natural habitats in a river basin (Cowx and Welcomme, 1998). In its broadest sense, the term habitat defines where a fish species lives without specifying resource availability or use. (Cowx and Welcomme, 1998) Many species of fish are endangered because of habitat change brought about by human interventions, and many more will be affected as alteration of habitat and human abuse of freshwater resources continue (Postel *et al.*, 1996; Sala *et al.*, 2000; Tilman *et al.*, 2001).Understanding and managing human impacts on fish require a clear understanding of the relationship between a species and its environment (Rosenfeld, 2003). The habitat associations, usage and requirements of fish species could reveal delicate relationships with their environment (Arun, 1998). Habitat requirements of fish have to be considered in any effort to maintain or rehabilitate rivers for fish biodiversity (Freeman *et al.*, 1997). Studies on the habitat use and requirements are very essential for the proper management and restoration activities or translocation of populations to new habitats (Harig *et al.*, 2000). Basic information on life history and habitat requirements are essential for species conservation. So identifying the suite of conditions that defines the habitat requirement of a species is a primary goal of aquatic research. The concept of habitat requirement, however, is poorly defined (Rosenfeld, 2003). Suitability criteria rest on the assumption that animals preferentially occupy areas that best support survival, growth and reproduction (Freeman *et al.*, 1997). Broadly speaking, requirements can be defined as features of environment that are necessary for the persistence of individuals or populations (Bjornn and Reiser, 1991).

The concepts of habitat selection, preference and requirement are sometimes confused in habitat studies, and information on habitat selection is frequently used to infer habitat requirement (Rosenfeld, 2003). Habitat selection (ie. differential occupancy) occurs when an organism avoids a particular habitat (negative selection) or uses a habitat in greater proportion than its availability in the environment (positive selection) Selective use of different habitats is often used to infer habitat preference. But true preference can only be estimated when the influence of extraneous factors like predation risk, competition, availability of different habitats etc. are controlled (Rosenfeld, 2003). Therefore, differential use of habitats in the wild is usually referred to as habitat selection rather than preference. On the other hand, habitat requirements are abiotic features of the environment that are necessary for the persistence of individuals or populations. The individual habitat requirement considers only the essential habitat conditions where individuals will achieve positive growth and reproduction. But the requirements for a population (fundamental niche) will include the habitat requirements of individuals and the metapopulation requirements such as landscape-scale features related to immigration and emigration rates between populations and the minimum population size (Pulliam 1988; Dunning *et al.*1992) as well as broader regional constraints acting as conditional filters on species presence (Poff 1997).

Most habitat models are based on covariation between environmental variables and habitat use in the wild (Rosenfeld, 2003). Stream habitats are strongly hierarchical (Frissel *et al.*1986; Hawkins *et al.*1993), and habitat associations can be modeled at a variety of spatial scales. According to Rosenfeld (2003), there are usually three fundamental types of predictive models which 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 (eg., 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.(eg. water velocities and depths selected by different species). Bioenergetic habitat models for stream fishes have recently emerged as an additional class of habitat model (Hughes and Dill 1990; Guensch et al.2001). These models differ fundamentally from other model types in that they are inherently mechanistic (ie., their predictions are based on explicit biological mechanisms rather than observational data). In the present study Capacity (multiple regressions) models were used to develop the habit suitability index models of 10 critically endangered and endemic fish species in Kerala part of Western ghats. Regression models can be applied at any scale but are typically used to model fish abundance at the reach or channel unit scales. Multiple regression models give more insight into the critical factors that influence the abundance of each species than any other methods (Rosenfeld, 2003).

Habitat suitability index models have a wide range of applications. To conserve the extreme fish germplasm resources and endemism of Western Ghats, declaration of aquatic sanctuaries and mitigation of 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 conservation and management tool for conserving 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. Suitability Index (HSI) models will give some technical guidelines for stream restoration and management activities. By the monitoring and maintenance of the critical parameters deciding the distribution and abundance of endangered species an automatic ecosystem management will occur which will helps 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 were immensely used for species conservation programmes. Even though the importance of HSI models in endemic and threatened fish diversity conservation are very clear from the remarkable progress happened in U.S.A, Canada and many European countries, unfortunately in India, there is no concreted effort has been done in this line. Studies on community level of fishes are rather very common in temperate systems (Ross, 1986), while tropical fish communities especially of the Southeast Asia, are thoroughly under investigated (Moyle and Senanayake, 1984; Wikramanayke and Moyle, 1989).

Against this background, a pioneer attempt was made to isolate and identify critical controlling habitat parameters which govern the availability, abundance and endemism of 10 threatened freshwater fish species in Kerala such as *Lepidopygopsis typus,H.micropogon periyarensis, Crossocheilus periyarensis, Osteocheilichthys longidorsalis, Puntius jerdoni,Silurus wynadensis, Neolissocheilus wynadensis,Homaloptera pillai* , *Garra menoni* and *Mesonemacheilus remadevi* . Habitat suitability Index models of these ten species were also established for a clear cut understanding of the relationship between a species and its environment enabling understanding and managing human impacts on fish (Rosenfeld, 2003). An attempt was also made to evaluate the impact of National level policy of river interlinking on the sustenance of threatened fish species. The resurgence of constructing the proposed hydel project across Kunthipuzha has evoked much controversy recently on the potential negative impacts on the aquatic ecosystem of this biosphere and therefore, in this study, the possibilities of obliterating fish habitats of Kunthipuzha and *inter alia* the extermination of endemic fish germplasm due to the construction of the proposed dam has also been evaluated in the light of the HSI models of three species developed from Silent valley national park.

6.2. Materials and methods

Materials and method used for the study is illustrated in chapter 2.

6.3. Results

6.3.1. *Lepidopygopsis typus* (Raj, 1941b)(plate 6.1)

Order	:Cypriniformes
Family	:Cyprinidae
Subfamily	:Shizothoracinae

This species is an endemic to the headwaters of Periyar river system and is commonly known as Peninsular hill trout. Because of its peculiar scale pattern through the lateral line this species is locally known as Bramnakanda. *L.typus* is a typical coldwater species of Himalayan origin and is the only species, which is found outside the Himalayan ranges and its existence in Periyar remains inexplicable (Arun, 1998). In periyar river system, the distribution ranged between Mukkar($9^0$19'27N and $77^0$16'30E)in the upstream having an elevation of 1254m from the mean sea level and Thannikudy in the downstream($9^0$28'56N and $77^0$16'22E) having an elevation of 1029m from the mean sea level. In the present study, specimens upto 25cm were collected. Menon (1999) included this species under endangered (EN) category and Molur and Walker (1998) placed this species under critically endangered category. As per the IUCN categorization conducted in the present study, the species is coming under CR (critically endangered) category.

Relationship between habitat features and species abundance

Wide ranges of conditions were found in the 29 sites selected for habitat inventory studies in Periyar river system (Table 6.1). *L.typus* was found at 7 locations and the maximum recorded population size was 32.Out of the 54 habitat variables studied 8 showed significant positive correlations with the abundance of this species (Table 6.5).

Habitat Suitability Index models

8 habitat variables showing significant correlation with the species abundance were further evaluated by simple regression analysis to study the effect of each parameter on the abundance of *L.typus* individually (Table 6.15). A single multiple regression model was developed for *L.typus* using 8 habitat variables (Table 6.16) is as follows.

Y = O.618078 + 0.090476 B + 0.733442 C-0.00054 L+3.001654 OS+ 2.767946 OV+ 0.057609 S- 48.0834 SL + 0.09624 T

Where Y-Species abundance, B- Bed rock, C-Chute, L-Lux, OS-Overhanging stream boulders, OV- Overhanging vegetation, S- Total shaded area of the stream, SL- Slope, T- Total tree cover

The present regression model showed a significant correlation with the biomass of *L.typus* (R^2 =0.864733 P_<0.004717)

6.3.2. *Gonoproktopterus micropogon periyarensis*(Raj,1941a)(Plate 6.2)

Order:Cypriniformes

Family:Cyprinidae

Subfamily:Cyprininae

This is an endemic species to Periyar river and is commonly known as Periyar barb. Locally this species is known as Kariyan and is distributed in between Mukkar in the upstream ($9^0$19'27N and $77^0$16'30E) having an elevation of 1254m from the mean sea level and Thannikudy in the downstream ($9^0$28'56N and $77^0$16'22E)having an elevation of 1029.m from the mean sea level. The maximum recorded size of this species was 50cm and is commonly using as a food fish. In the present study, specimens upto 27cm were collected. Menon (1997) and Molur and Walker (1998) included this species under endangered category. But as per the IUCN categorization, in the present study, this species is categorised as CR (Critically endangered) category.

Relationship between habitat features and species abundance

Of the total 28 locations studied in Periyar river system *Gonoproktopterus micropogon periyarensis* was found only at two locations and the maximum recorded population size was seven. Out of the 54 habitat variables studied, abundance of Gonoproktopterus *micropogon periyarensis* showed significant correlation with 7 parameters (Table 6.6).

Habitat Suitability Index models

Seven variables such as depth (D),midchannel pools(MD), overhanging vegetations(OV), total shaded area(S),slope(SL), total instream cover(TC) and total tree cover(T) were further studied using single regression analysis(Table 6.15) as these parameters are having significant influence on the distribution and abundance of *Gonoprktopterus* *micropogon periyarensis* (Y). A single multiple regression model was developed (R^2=0.872885 P_<0.004717) (Table 6.17) which can be depicted as follows

$$\mathbf{Y = 0.426997 - 0.08742\ D + 0.027539MD + 0.83743OV + 0.065797\ S\text{-}8.17775\ SL + 0.012339\ TC - 0.02475\ T}$$

6.3.3. *Crossocheilus periyarensis*(Menon and Jacb,1996)(Plate 6.3)

Order;Cypriniformes

Family;Cyprinidae

Subfamily:Garrinae

Commonly known as Periyar latia and is locally known as Karimbachi. This species is also an endemic to periyar and have a stratified distribution in between Mukkar in the upstream ($9^0$19'27N and $77^0$16'30E) having an elevation of 1254m from the mean sea level and Thannikudy in the downstream ($9^0$28'56N and $77^0$16'22E) having an elevation of 1029.m MSL. The maximum recorded size of the species is 11.5cm but in the present study specimens upto 13.4cm were collected. . Because of the smaller size, peculiar behaviour (sucker) and vibrant colouration, this species is getting some ornamental value. Molur and Walker (1998) categorised this species under vulnerable category while Menon (1999) listed this species under endangered category .In the present study, this species was identified as one of the rare varieties among the 145 species identified so far from Kerala part of Western Ghats (Kurup *et al.*, 2003) and as per IUCN categorization this species is treated under CRB1 (Critically endangered, extent of occurrence estimated to be less than 100km^2 and severely fragmented) category.

Relationship between habitat features and species abundance

Of the 28 locations where the habitat inventory and species assemblage studies were conducted in Periyar river system, *C.periyarensis* was identified only from 3 locations. The maximum recorded population size of this species was seven. Out of the 54 habitat parameters studied 5 were showed significant correlation with the abundance of *C.periyarensis*(Table 6.7).

Habitat suitability index models

Five habitat variables such as Lateral pool (LP), Large woody debris (LW), Overhanging vegetation (OV), scour out pools (SOP) and total tree cover (T) were identified as having habitat assessment value in the stream reaches where abundance of *C. periyarensis* (Y) was observed were further subjected to simple regression analysis to find out the extent of influence of each parameter individually (Table 6.15). The multiple regression model so developed (Table 6.18) is as follows

Y=-0.52679-0.00702LP+0.859692LW+0.254735OV+0.139841SOP+0.010297T

The regression model showed a significant correlation with the biomass of *Crossocheilus periyarensis*(R^2=0.78362 P-<0.004129).

6.3.4. *Silurus wynaadensis*(Day,1868)(Plate 6.4)

Order:Siluriformes

Family:Siluridae

This species is commonly known as Malabar Silurus and in Kerala its distribution is recorded only from the headwaters mainly I order streams of Kabbini river system. It is locally known as Thonnivala or Wynadan mushi. This species is highly nocturnal and due to the increasing human intervention its distribution is restricted to some isolated patches situated between Kattikunnu($11^0$30'42N and $76^0$02'09E) in the upstream having an elevation of 879.m MSL and Aranagiri($11^0$30'47N and $76^0$02'12E)in the downstream having an elevation of 824m.The maximum recorded size of this species is 30cm(Menon,1999) and is a food fish. In the present study, the maximum recorded size was 20.2cm which is an indication of its endangerment. Molur and Walker (1998), Kurup(2000, 2002) and Shaji *et al.*(2000) included this species under critically endangered category. While Menon(1999) included this species under rare category. As per the IUCN categorization conducted in the present study *S.wynaadensis* is coming under CRB, 2a,b, c, d, e, 2D (critically endangered, extent of occurrence estimated to be less than 100km^2,severly fragmented, continuing decline in the extent of occurrence, area of occupancy, extent or quality of habitat, number of subpopulations, number of mature individuals estimated to be less than 50) category.

Relationship between habitat features and species abundance

Wide ranges of conditions in respect of nature of microhabitat, instream cover, substrate and nature of riparian zone were found in the 15 sites selected for habitat inventory studies in Kabbini river system (Table 6.2).*S. wynadensis* was found only at two locations and the maximum population number registered was 8. Out of the 53 habitat variables studied, 7 showed significant correlation with the occurrence and abundance of this species (Table 6.8).

Habitat Suitability Index models

7 habitat variables identified as critical in deciding the occurrence of this species were further subjected to simple regression analysis to bring out the effect of independent parameter on the occurrence of *S.wynaadensis* (Table 6.15). Subsequently, a single

multiple regression model was developed for *S.wynaadensis* using 7 habitat variables (Table 6.19) which can be represented as follows:

Y=-0.20-1.01AT-0.11CW-0.05FV+0.330OSB+0.05TC+0.13TP+1.29WT

Where Y-Species abundance, AT- Atmospheric temperature, CW-Channel width, FV-Flow velocity, OSB-Overhanging stream boulders, TC- Total cover, TP- Trench pool, WT-Water temperature

The regression model so developed showed a significant correlation with the occurrence of *S. wynaadensis* (R^2 =0.75 $P \leq 0.0805$)

6.3.5. *Neolissochilus wynaadensis***(Day,1873)(Plate 6.5)**

Order: Cypriniformes

Family: Cyprinidae

Subfamily:Cyprininae

Commonly known as South Indian barb having a fragmented distribution only at the headwater streams of Kabbini river system in Kerala. This species is locally known as Manjakadanna. It is highly sensitive to physical and chemical habitat variables and having comparatively good abundance at Kattikunnu I (11^{0}30'42N and 76^{0}02'09E ele.879m.), Kattikunnu II (11^{0}30'59N and 76^{0}02'06E ele.862m.)Aranagiri(11^{0}30'47N and 76^{0}02'12E ele.824m.)Thariyod (11^{0}38'10N and 77^{0}58'43E ele.796.5m.) and its adjoining areas. Due to the increasing human intervention the population of this species showed a drastic decline in the past three years. The maximum recorded size of this species was 25cm (Menon, 1999; Talwar and Jhingran, 1992) while in the present study specimens only upto 17.4cm could be collected from its place of inhabitance which is indicating of its endangerment. Even though this species is having the utilization status as a food fish because of its attractive colouration it also gaining some ornamental importance Molur and Walker (1998) and Shaji *et al.*(2000) described this species under endangered category while Menon(1999) included this species under rare category. As per the IUCN categorization conducted in the present study *N. wynaadensis* belongs to E,B1,2a,b,c,d,e, D (endangered, extent of occurrence less than 5000km^2,severly fragmented, continuing decline in the area of occurrence, extent and quality of habitat, number of subpopulations and number of mature individuals estimated to less than 250) category.

Relationship between habitat features and species abundance

Of the 15 locations studied *N. wynaadensis* was reported from 4 locations and the maximum population size recorded was 15.Out of the 54 habitat parameters studied four habitat variables showed significant positive correlation with the occurrence of *N.wynadensis* while two variables have significant negative correlation with the availability of the species (Table 6.9).

Habitat Suitability Index models

The relationship between *N.wynaadensis* and variables such as Alkalinity (A), channel width (CW), hardness (H), lateral pools (LP), overhanging stream boulders (OSB) and plunge pools (PL) were further examined using simple regression analysis (Table 6.15) .The single multiple regression model so developed (R^2=0.82 P_<0.0122) (Table 6.20) can be expressed as follows:

$$\mathbf{Y=7.62-0.38A-0.007CW-0.5H+0.1LP-0.30OSB-7.7PL}$$

Where Y=Species abundance

r

6.3.6. *Osteochilichthys longidorsalis*(Petiyagoda and Kottlet,1994)(Plate 6.6)

Order: Cypriniformes

Family: Cyprinidae

Subfamily:Cyprininae

It is an endemic species to Kerala and is described only from the headwaters of Chalakudy and Pooyamkutty river systems .The common name of the species was long finned barb while it is locally known as Kadimeen or Modon. In Chalakudy river system, the distribution of this species is limited in between Kuriarkuuty(($10^0$24'26N and $76^0$43'14N ele.524m.) in the upstream and Athirappaly in the down stream($10^0$17'53N and $76^0$34'17E ele.104m.).In pooyamkutty river system this species is distributed from Purakkallu ($10^0$08'48N and $76^0$47'20E) in the downstream towards the upstream reaches. The maximum recorded size of this species was 13.5cm while in the present survey specimens upto36cm were collected. Even though the species is treated as a food fish the young ones have some ornamental value Molur and Walker (1998) included this species under critically endangered category. Biju *et al.* (2000) and Thomas *et al.* (2002) described this species under endangered category. As per the IUCN categorization conducted in the present study this species is coming under E, B, 2a,b, c, d, e, D (endangered, extent of occurrence estimated to be less than 5000km2, continuing decline in the extent of occurrence, extent and quality of habitat, number of subpopulations and number of mature individuals less than 250) category.

Relationship between habitat features and species abundance

Wide ranges of conditions in respect of nature of microhabitat, instream cover, substrate and nature of riparian zone were found in the 20 sites selected for habitat inventory studies in Chalakudy river system (Table 6.3) .In Chalakudy river system, out of the 20 locations studied, the presence of *O. longidorsalis* was encountered only at 5 locations. In Pooyamkutty tributary, out of the 5 locations surveyed, *O.longidorsalis* was located only from 2 stations. Highest population number recorded was seven and out of the 54 habitat parameters studied, the abundance of *O.longidorsalis* showed significant correlation with six parameters (Table 6.10).

Habitat Suitability Index models

In the case of *O.longidorsalis*, six habitat variables such as abandoned channel (ABC), backwater (BW), emergent vegetation (EV), glide (G), overhanging stream boulders (OSB) and channel width (CW) were found important in developing habitat assessment value in the stream reaches where abundance of *O.longodorsalis* (Y) was observed(Table 6.15) . The multiple regression model so developed (Table 6.21) can be expressed as follows

$$\mathbf{Y{=}{-}0.104{+}0.149ABC{+}4.82BW{+}0.179EV{+}0.123G{+}0.09OSB{-}0.09CW}$$

The regression model showed a significant correlation with the abundance of *O.longidorsalis* (R^2=0.89,P-<0.00001).

6.3.7. *Puntius jerdoni* (Day, 1876) (Plate 6.7)

Order: Cypriniformes

Family: Cyprinidae

Subfamily:Cyprininae

This species is described from Chalakudy river system and is commonly known as jerdon's barb. Locally this species is known as Chameen or tolu. Its distribution range extended from Kuriarkutty($10^0$24'26N and $76^0$43'14N ele.524m)in the upstream and Athirappally ($10^0$17'53N and $76^0$34'17E ele.104m)in the downstream. The maximum recorded size of this species is 46cm (Talwar and Jhingran, 1992) and in the present study the maximum recorded size was 30cm. Even though the larger specimens are known as a food fish the young ones are having good ornamental value with comparatively high market price. Menon (1999) treated this species under endangered category while Biju *et al.*(2000) described this species from Bharathapuzha,Chandragiri, Chalakudy and Meenachil river systems and treated under vulnerable category. As per IUCN categorization conducted in the present study this species is coming under E, B, 2a,b, c, d, e, C2a (endangered, extent of occurrence estimated to be less than 5000km^2, continuing decline in the extent of occurrence, extent and quality of habitat, subpopulations and number of mature individuals estimated to be less than 250) category.

Relationship between habitat variables and species

Out of the 20 locations studied the species was identified only from 3 locations and the maximum recorded population size was 5.Out of the 54 habitat parameters studied the abundance of this species showed significant correlation with five parameters (Table 6.11).

Habitat suitability index models

In the case of *P.jerdoni*, five habitat variables such as abandoned channel (ABC). Cascade(C), rocky substratum(R), alkalinity (A) and channel width (CW) were identified as having habitat assessment value in the stream reaches where abundance of *P.jerdoni* (Y) was observed (Table 6.15). The multiple regression model so developed (Table 6.22) is as follows:

$$Y=-0.38+0.34ABC-0.04C+0.03R-0.45A+.04CW$$

The regression model showed a significant correlation with the abundance of *P.jerdoni*(R^2=0.78, P-<0.0003).

6.3.8. *Mesonemacheilus remadevi*(Shaji,2002)(Plate 6.8)

Order: Cypriniformes

Family: Balitoridae

Subfamily:Nemacheilinae

This is an endemic species to Kerala and is recently described by Shaji *et al.* (2002) from the silent valley region of Kunthi river system. The distribution range of the species extended from Valiya Walakkad ($11^0$8'41N and $76^0$25'18E ele.995m) in the upstream and Synendr ($11^0$5'49N and $76^0$26'44E ele.1001m) in the downstream. During the present study specimens having a total length of 6.8cm were collected. As per utilization status this species coming under ornamental category and based on the IUCN categorization it comes under CR, B1 (critically endangered, extent of occurrence estimated to be less than 100km^2 and severely fragmented population) category.

Relationship between habitat variables and species

Wide ranges of conditions in respect of nature of microhabitat, instream cover, substrate and nature of riparian zone were found in the 27 sites selected for habitat inventory studies in Bharathapuzha river system (Table 6.4).*M.remadevi* was found only at 5 locations and the maximum population number registered was sixteen. Out of the 54 habitat variables studied, 6 showed significant positive correlation and 3 having significant negative correlation with the occurrence and abundance of this species (Table 6.12).

Habitat Suitability Index models

9 habitat variables identified as critical in deciding the occurrence of this species were further subjected to simple regression analysis to bring out the influence of each parameter on the occurrence of *Mesonemacheilus remadeviensis* individually (Table 6.15). Subsequently a single multiple regression model was developed for *Mesonemacheilus remadeviensis* using 9 habitat variables (Table 6.23) which can be represented as follows.

$$Y=-1.95-0.08B+0.07BE-0.04C-0.12D+3.05DI+0.21G+0.24LWD+0.21R-0.29SWD$$

Where Y-Species abundance, B- Bare ground,BE-Bedrock, C-Cobbles, DE-Depth, DI-Dissolved oxygen,G-glide,LWD-large woody debris,R-Riffle,SWD-Small woody debris

The regression model so developed showed a significant correlation with the occurrence of *M. remadeviensis* (R^2 =0.86 $P\_<1.18^{-05}$)

6.3.9. *Homoletera pillai*(Indira and Remadevi, 1981)(Plate 6.9)

Order: Cypriniformes

Family: Balitoridae

Subfamily:Balitorinae

This is an endemic species to Kerala and is recorded only from the headwaters (Silent valley) of Kunthi river. It is commonly known as Silent valley loach and is locally known as Kallepatti.The distribution range extended between Valiyawalakkad($11^0$8'41N and $76^0$25'18E ele.995m) in the upstream and Puchappara ($11^0$06'51N and $76^0$25'50E ele.945m) in the downstream. The maximum recorded size of this species is

7.5cm(Menon, 1999) and in the present study specimens upto 6.2 cm were collected. The utilization status is only as an ornamental fish and as per the IUCN categorization conducted in the present study this species included under CRB1 (critically endangered, extent of occurrence estimated to be less than $100km^2$ and severely fragmented) category.

Relationship between habitat variables and species

Out of the 27 locations studied occurrence of *H.piilai* was recorded only from 2 locations and the maximum population size recorded was six.Among the 54 habitat parameters, six habitat variables showed significant positive correlation with the occurrence of *H.pillai* while one variable have significant negative correlation with the availability of the species(Table 6.14).

Habitat Suitability Index models

The relationship between *H.pillai* and variables such as Bedrock (B), cobbles(C), dissolved oxygen (DO), glide (G), large woody debris (LWD), shrub cover (SC) and small woody debris (SWD) were further examined using simple regression analysis to bring out the influence of each parameter individually (Table 6.15) .The single multiple regression model so developed (R^2=0.9 P_<2.46^{-08}) (Table 6.24) can be expressed as follows:

Y=-0.136+0.076B-0.003C+|0.05DO+0.08G+0.119LWD+0.059SC+0.418SWD

Where Y=Species abundance

6.3.10. ***Garra menoni***(Remadevi and Indira,1984)(Plate 6.10)

Order: Cypriniformes

Family: Cyprinidae

Subfamily:Garrinae

This species is strictly endemic to Kerala and in the present study it is recorded from the headwaters (Silent valley) of Kunthi river system. The distribution range extended from Valiya Walakkad ($11^0$8'41N and $76^0$25'18E ele.995m) in the upstream and Synendri($11^0$5'49N and $76^0$26'44E ele.1001m) in the downstream. The maximum recorded size of this species was 6.9m(SL) while in the present study specimens upto 7.4.cm TL were collected. This species is an ornamental fish. Menon (1999) treated this species under rare category while according to Biju *et al.* (2000) this species coming under endangered category. As per the IUCN categorization conducted in the present study this species is coming under EN, B1 (endangered, extent of occurrence estimated to be less than 5000km^2 and severely fragmented population) category.

Relationship between habitat variables and species

Among the 27 locations studied, this species was recorded only from 4 locations and the maximum recorded population size was thirty six. Out of the 54 habitat parameters studied occurrence and abundance of *G.menoni* showed significant correlation with 6 habitat variables (Table 6.14).

Habitat Suitability Index models

The 6 habitat variables such as bedrock (B), dissolved oxygen (DO), glide (G), large woody debris (LWD), shrub cover (SC) and small woody debris (SWD) were found important in developing habitat assessment value in the stream reaches where abundance of *G.menoni* (Y) was observed (Table 6.15). The multiple regression model so developed (Table 6.25) can be expressed as follows:

$$Y=-0.5+0.056B+0.62DO-0.008G+0.204LW-0.04SC+0.99SWD$$

The regression model showed a significant correlation with the abundance of *G.menoni* (R^2=0.92, P-<8.98^{-10}).

6.4. Discussion

Populations of many endemic and rare fishes in the Western ghats streams occur as fragmented populations isolated in headwater tributaries. Understanding the factors that determine why they persist in some areas and not in others is a major challenge for conservation research (Rieman and Dunham, 2000). Studies on the microhabitat of some critically endangered species should reflect those habitat conditions, which are most critical for preserving fish populations Results of the present study showed that some of the physico-chemical habitat parameters like nature and distribution of different channel geographical units, instream cover, substrate, riparian cover, etc. are acting as critical parameters on the occurrence and abundance of these endangered species and this finding is complementary to that of Sreevastava and Sarkar(1997)that in freshwater lotic ecosystems , physical habitat plays major role in species assemblage than chemical variables. According to Hubert and Rahel(1989), physical habitat or abiotic habitat variables are believed to influence both the occurrence and biomass of fishes in stream systems, but these relations are not well understood for majority of the fish species.

The present study revealed that *L.typus* tolerate only a narrow range of environmental conditions and is found as a highly habitat specific species. Abundance of *L.typus* showed a positive correlation with amount of bed rock substrate, chute type channel geographical unit, overhanging boulders, overhanging vegetation, total shade and tree cover and negative correlation with light intensity and slope. The affinity of the species to bedrock type substratum is identical with the findings of Ziller(1992) who recorded a positive correlation between abundance of bull trout and larger substrates. The positive correlation of the species to overhanging stream boulders indicates that they are using overhanging stream boulders as hiding structures, which is in agreement with the findings of McPhail and Murray (1979), Ptolemy (1979) and Shepard *et al.* (1984) who recorded that occurrence of bull trout showing positive correlation to undercut banks. Hubert and Rahel(1989) found that abundance of Longnose dace is positively correlated to the overhead cover which is in complaince with the positive correlation of *L.typus* with overhanging vegetation. The penchant of *L.typus* to total shade is identical with the findings of McMohan(1982) who reported a positive correlation between creek chub and total cover in the streams. The positive correlation between tree cover and the abundance of *L.typus* is corroborating with the observation in bull trout with tree cover (Watson and Hillman, 1997). The negative correlation of *L.typus* with slope is in well agreement with the findings of Moshenko and Gee (1973) who reported a negative correlation between stream gradient and abundance of creek chub.

Optimum habitat of *H.micropogon periyarensis* was found as midchannel pools with moderate depth, overhanging vegetation, less slope and excellent shade. The negative correlation of *H.micropogon periyarensis* with depth and positive correlation with midchannel pools clearly indicate that this species prefer only pools in flowing water ecosystems and there is no preference towards deep dammed pools which is corollary with the findings of Minckley(1963) and Scott and Crossman(1973) who reported that white sucker occur most frequently in pools, backwaters and slow sections of streams. The present finding also unravel the complexity that why this species is not showing distribution in the Periyar lake even though it is abundant in the associated streams. The affinity of *H. micropogon periyarensis* with midchannel pools is in well agreement with the finding s of Watson and Hillman (1997) who observed that abundance of bull trout is positively correlated with the frequency of pools in streams. The direct proportionality between total shaded area of the riparian zone and the abundance of *H.micropogon periyarensis* is identical with the findings of Hubert and Rahel(1989) who established a positive correlation between standing stock of white sucker and total shaded area of the stream. The negative correlation of *H. micropogon periyarensis* with the slope is similar to the findings of Hocutt and Stauffer (1975) who observed that creek chub is very abundant in low gradient streams.

C. periyarensis is most abundant in scour out pools with enough woody debris, overhanging vegetation and tree cover. The positive correlation of *C.periyrensis* with scour out pools is identical with the strong positive correlation between the abundance of bull trout and scour out pools (Watson and Hillman, 1997). Dare *et al.* (2002) reported that biomass of cutthroat trout and brown trout showed a strong positive correlation with the presence of pools. The strong positive correlation between *C.periyarensis* and large woody debris is in complaince with the findings of Hubert and Rahel(1989) who observed a positive correlation between biomass of white sucker and large woody debris. The positive correlation between the abundance of *C.periyarensis* and overhanging vegetation is corroborating with the findings of Hubert and Rahel (1989) who observed a positive correlation between the biomass of longnose dace and overhanging cover. Talmage *et al.* (2002) reported that woody debris and overhanging vegetation provide fish communities with cover, temperature stabilization, food source and reduced fine sediment. Angermeier and Karr (1984) revealed that in spite of contributing shelter and food woody debris contributes to the local physical complexity of the stream and can form pools in stream channels. The affinity of *C.periyarensis* with riparian zone with good tree cover is in well agreement with the findings of Buckman *et al.* (1992) who observed a positive correlation between riparian tree cover and occurrence of bull trout.

S. wyndensis can tolerates only a narrow range of habitat parameters and was found as a highly habitat specific species. Biomass of *S.wyndensis* showed a positive correlation with total instream cover, trench pool, water temperature, and overhanging stream boulders which is strongly concur with the findings of Kavaliers (1982) who reported that biomass of white sucker showed a strong positive correlation with total instream cover in its natural habitats. The relationship between instream cover and species distribution seen in the Habitat Suitability Index models of *S. wynadensis* is in compliance with the findings of Copes and Tubbs (1966) who observed that there exist a strong positive correlation with instream cover and the distribution of creek chub. Distribution and abundance of *S. wynadensis* showed negative correlation with temperature, channel width and flow velocity. The negative correlation seen in *S.wynadensis* with flow velocity corroborated with that of creek chub in the horse creek drainage of United States (Hubert and Rahel, 1989). The relationship between channel width and distribution of *S.wynadensis* also showed agreement with that of common shiner whose abundance was more in small streams having 7-10m width. Nevertheless, this attempt being a pioneer in this line, there is no scope to compare the present HSI with previous findings of any fish species of Western ghat streams. The present study revealed that the high degree of habitat specificity shown by the fishes studied poses one of the major reasons for the endangerment of this species and any severe alteration in these critical parameters in future would leads to their extermination from the universe.

The results revealed that the optimum habitat of *N.wynadensis* was lateral and plunge pools with less channel width, low alkalinity and hardness conditions. The affinity of *N.wynadensis* towards the presence of plunge pool conform with that of creek chub whose distribution and abundance showed a strong correlation with the presence of riffles and plunge pools (McMohan, 1982; Hubert and Rahel, 1989;Barber and Minkley, 1971 and Moshenko and Gee, 1973). The strong positive correlation between *N.wynadensis* and small sized stream is identical with the strong positive correlation between the biomass of common shiner and small to medium sized streams by Lee *et al.* (1980) and Trial *et al.* (1983).

It is interesting to note that the distribution of *O.longidorsalis* was positively correlated with abandoned channel, backwater pools, emergent vegetation, glide and overhanging stream boulders and is negatively correlated with channel width. Talmage *et al.* (2002) reported that overhanging vegetation provide fish communities with cover, temperature stabilization, food source and reduced fine sediment. A positive correlation was observed between the distribution of *O.longidorsalis* and emergent vegetation and these findings are very much in agreement with that of Moyle (1973) in common shiner at Minnesota lake where the species abundance showed strong positive correlation with aquatic vegetation. In the present study, a positive correlation between the distribution of O.longidorsalis with backwater pools was established and these findings is concurring with that of Hubert and Rahel(1989)in longnose dace and Dare *et al.* (2002) in culthroat trout and brown trout.

P. jerdoni was found in abandoned channels of III order streams with good channel width and rocky substratum and its abundance was negatively correlated with alkalinity and cascade type instream habitat. The positive correlation shown *P.jerdoni* and channel width is similar to the finding s of Rich *et al.* (2003) in Bull trout. Moreover, the positive correlation reported in bull trout with large substrate and slow water habitat(Watson and Hillman ,1997)is in conformity with that of *P.jerdoni* with rocky substratum and negative correlation with cascade type instream habitat

Among the three species studied, *M.remadevi* can tolerates only a narrow range of habitat parameters and is found that out of the 54 habitat parameters studied occurrence of *M. remadevi* showed negative correlation with bare ground (river banks without vegetation), cobbles type substratum and depth. On the contrary, the species showed positive correlation with bedrock type substratum, dissolved oxygen, riffle and glide type microhabitats, large and small woody debris. The negative correlation of *M. remadevi* with bare ground is in concurring with the findings of Thompson and Hunt (1930) and Kavaliers(1982)who reported a positive correlation between shaded area and the occurrence of white sucker. Moreover, the positive correlation reported in bull trout with large substrate (Watson and Hillman, 1997) is in conformity with that of *M.remadevi* with rocky substratum and negative correlation with cobbles. The strong positive correlation shown by *M. remadevi* with that of woody debris is identical with the positive correlation shown by bull trout (Rich *et al.* 2003) and white sucker (Propst, 1982b) to woody debris. The positive correlation of *M.remadevi* with that of dissolved oxygen level is in well agreement with the that of *Salmo salar* which showed reduced sustainable swimming speed when dissolved oxygen concentration falls between 4 and 5 mgl^{-1}

(Cowx and Welcomme,1998). The positive correlation shown by *M.remadevi* to riffle and glide type of channel geographical units is showing resemblance with that of creek chub which are showing a positive correlation with streams with alternating pools and riffle –run areas (Moshenko and Gee, 1973). This indicates that the optimum habitat of *M.remadevi* was flowing water with alternating riffle and glide type of microhabitats, bedrock type substratum, good dissolved oxygen concentration, moderate depth, good riparian vegetation and instream cover with good strength of large and small woody debris. As a result of the dam construction there should a loss of riverbank vegetation and it may converted to bare ground, which will badly affect the species. The formula developed as part of this HSI model also reveals that with the increase of depth there are also chances for the decrease in the population size of this species. The strong positive correlation with bedrock and negative correlation with cobbles indicate the species abundance will decline with the reduction in the size of the riverbed material and with the construction of dam the substratum may entirely change into muddy type which will adversely affect the species. The level of dissolved oxygen, the most important parameter affecting this species, will drastically reduces with the construction of the dam. The typical microhabitats in flowing water ecosystems such as riffle and glide, which are having strong influence on the species will completely vanish as a result of dam construction. The typical hiding places such as large woody debris and small woody debris will loss as a result of dam construction. All these results lend support the fact that with the construction of dam, *M. remadevi* would disappear from Silent valley national park.

Occurrence of *H. pillai* showed positive correlation with Bedrock, dissolved oxygen level, glide type microhabitat, large woody debris, small woody debris and shrub cover and negative correlation with cobbles type substratum. The positive correlation shown by *H.pillai* to Bedrock type substratum and negative correlation to cobbles are in well agreement with the findings of Fontaine (1987) who found that rock structures with greatest number of crevices held the highest winter densities of salmon. The positive correlation shown by *H.pillai* to that of small and large woody debris is concurring with the findings of Tschaplinski and Hartman (1983) who reported a strong positive relationship between the volume of woody debris and the number of juvenile coho salmon *Onchorhynchus kisutch* during winter season in sections of Carnation Creek, British Coloumbia. The positive correlation of *H. Pillai* to the level of dissolved oxygen is in compliance with the findings of Cowx and Welcomme(1998) who reported that the overall dissolved oxygen concentration required for salmon is at least 9mg/l.The positive correlation shown by *H.pillai* to glide type of channel geographical unit is in well agreement with the findings of Scott and Crossman(1973) who reported that the White sucker prefer the slow sections of streams. The positive relationship of *H. Pillai* to shrub cover is identical with that of Watson and Hillman (1997) who reported a positive correlation between the abundance of bull trout and shrub cover. As a result of dam construction the bottom material will definitely converted to fines (mud) and other variables such as glide, shrub cover, large woody debris, small woody debris etc. will completely vanish from the aquatic system. On the other hand, the level of dissolved oxygen will decreases as a result of dam construction.

The occurrence of *G.menoni* showed positive correlation with bedrock, dissolved oxygen level, large woody debris and small woody debris and negative correlation with glide type microhabitat. The positive correlation of *G.menoni* with bedrock type substratum is in compliance with the findings of Huber and Rahel(1989)who observed a positive relationship between white sucker abundance and bedrock type substratum .The positive correlation between the occurrence of *G.menoni* and dissolved oxygen level is identical with the strong positive correlation established between the biomass of *Leuciscus cephalus* and dissolved oxygen level (Cowx and Welcomme,1998).The negative correlation of *G.menoni* to glide type channel geographical unit indicated its affinity to fast flowing channel geographical units which is in well agreement with the high water velocity requirement of *Chondrostoma nasus*(50-110ms-1) reported by Cowx and Welcomme(1998). The positive correlation of *G.menoni* with woody debris is in complaince with Watson and Hillman (1997) who reported a positive correlation between woody debris and the relative density of Bull trout. Goetz (1989) and Martin *et al.* (1992) reported that woody debris provide concealment cover and possibly increasing the carrying capacities. But after dam construction the level of bedrock type substratum, dissolved oxygen level, large woody debris, small woody debris and shrub cover showed a reduction which became a malediction to this species.

The multiple regression models presented here are the first quantitative descriptions of the relationship between abiotic habitat features and the distribution and abundance of *L.typus, H.micropogon periyarensis* and *C.periyarensis* in the headwaters of Periyar river system,*Silurus wynadensis and N. wynadensis* in the head waters of Kabbini river system, *O.longidorsalis* in the headwaters of Chalakudy and Pooyamkutty river systems, *P.jerdoni* in the headwaters of Chalakudy river system and *M.remadevi, H.Pillai* and *G.menoni* in the headwaters of Bharathapuzha river system. The multiple regression models also revealed that along with community structure, habitat also plays a crucial role in the distribution and abundance of each species. This study also identified the critical stream habitats necessary for the persistence of these species. Freeman *et al.* (1997) reported that although fishes respond simultaneously to multiple habitat variables, it is also likely that some variables can strongly influence the microhabitat use than others. But it is also important to identify and protect the processes that ultimately generate and maintain these features (Imhoff *et al.,* 1996; Roni *et al.,* 2002). Similarly, though this study focuses on habitat, it is equally important to recognize that there are critical non habitat factors such as illegal fishing activities and invasion by exotic species which were also strongly influencing species persistence. Dyer *et al.* (1998) reported that anthropogenic activities brought about changes in the physical conditions of the streams, thus leading to the degradation of fish communities, which is magnified by reduced species richness and decreased biotic integrity. If knowledge on critical habitat issues of each species is deficient, research efforts need to be directed at defining less ambiguous habitat suitability criteria. Hence management on fish and wildlife remains centered on an accurate understanding of habitat requirements as supported by Rosenfeld (2003).

Another very significant implication of this study is on the National Policy of river linking. The results indicate that the linking of rivers will permanently alter the HSI indices of fish species, which are now protected by the individuality of the rivers. Any such interlinking would bring about severe alterations of habitat parameters such as flow velocity, nature of substratum, type of microhabitat and vegetation governing the presence of these fishes and consequently there is every possibility of extinction of these species from the universe. No attempt has made to find out the reason of endemism in fishes related with HSI in the Indian context and therefore this subject was never surfaced while taking policy decisions on the fate of Indian rivers. The present information may dissuade the policy makers from interlinking rivers with such endemic fish habitat with other river systems, which would potentially damage such HSI factors and *interalia* the extermination of these species.

The result of the present study also revealed that the construction of the proposed Pathrakadavu dam will adversely affect the aquatic ecosystem of Silent valley National park and many endemic species will vanish from Silent valley. Even though the dam is coming 500m away from the boundary of the Silent Valley National park, the proposed place and the silent valley is coming under the same class such as High hill zone (600-1200), based on the distribution of fish species in Western ghat streams (Manojkumar and Kurup, 2004) which indicate that the distribution of the above said rare and endangered species may extend upto Pathrakadavu region. There are numerous evidences in the history for the direct impact of dams on the aquatic ecosystem. Osborne (2000) reported that the Aswan high dam on Nile valley downstream constructed on 1964 with a view to ensure regular water supply to the fertile Nile valley downstream and to generate electricity for the industries in Egypt. But after dam construction the water supply was not increased as much as hoped and on the other hand the dam acts as a sediment trap, and the sediments that previously built up the rich, alluvial soils of the Nile valley now accumulates in the reservoir and the productive sardine fishery in the Mediterranean, off shore from the Nile delta, has been fully collapsed. Kanehl *et.al.* (1997) studied the changes in the habitat and fish community of the Milwaukee river, Wisconsin, following the removal of the Woolen mills dam and found that construction of Woolen mills dam in the Milwaukee river in United states leads to the habitat quality loss, poor biotic integrity, reduction in the population of endemics such as small mouth bass *Micropterus dolomieu.* and a rampant increase of exotics such as *Cyprinus carpio* was noted after the commissioning of the dam. While the dam was removed during 1988 and five years after that habitat quality was excellent, small mouth bass abundance and biomass had increased substantially, on the contrary, common carp abundance and biomass had declined drastically, and biotic integrity was good. Kurup *et al.* (2004) reported similar situation from the Periyar lake in Kerala, where the endemic critically endangered species like *Lepdopygopsis typus,Gonoprktopterus micropogon periyarensis* and *Crossocheilus periyarensis* were completely disappeared from the lake region and now only limited to the head water streams. While in the lake, more than 66%(2003) of the fishery is contributed by two exotics such as *Cyprinus carpio and Oreochromis mossambicus.* So before the construction of the proposed Pathrakadavu dam its impacts on the economic and ecological environment begs the question: what price for development? This question can only be answered by carrying a detailed environmental impact assessment programme.

Table 6.1. Physical and chemical variables measured at 30 stream sites in Periyar river during the period from January 2001-January 2004.

Habitat variables	Range
Reach descriptions	
Sinuosity	1-1.4
Entrenchment ratio	1-2
Slope	0.01-0.15
W/d ratio	0.5-5.7
Riparian zone	
Shrub cover along bank(%)	7-93
Tree cover along bank(%)	3-72
Bare ground along bank(%)	0-72
Substrates	
Fines (%)	0-89
Gravels(%)	0-42
Cobbles (%)	0-32
Boulders(%)	0-82
Rock(%)	0-39
Bedrock(%)	0-70
Instream cover	
Turbulance(%)	0-25
Depth(%)	5-38
Small woody debris(%)	0-1
Large woody debris(%)	0-5
Overhanging vegetation(%)	0-5
Submerged vegetation(%)	0-10
Emergent vegetation(%)	0-5
Floating vegetation(%)	0-5
Turbulant white water boulders(%)	0-10
Scour out pools(%)	0-10
Overhanging stream boulders(%)	0-5
Undercut bank(%)	0-5
Total cover(%)	11-60
Channel geographical units	
Falls(%)	0-8.8
Cascade(%)	0-19.6
Rapids(%)	0-61.88
Riffle(%)	0-38.5
Chute(%)	0-6.2

Sheet(%)	0-2.64
Run(%)	0-55.17
Eddy(%)	0-0
Trench(%)	0-11
Midchannel(%)	0-77.2
Pocket water pools(%)	0-0
Cinvergence(%)	0-0
Glide(%)	0-0
Lateral pools(%)	0-11.7
Plunge(%)	0-32.4
Debris(%)	0-0
Landslide(%)	0-100
Backwater(%)	0-0
Abandened channels(%)	0-30.9
Water quality parameters	0-0
Air temperature(^{0}C)	26-38
Water temperature(^{0}C)	21-34
pH	6.6-8.2
Dissolved oxygen(mg/l)	4.92-7.56
Total hardness(mg/l)	8-29
Total alkalinity(mg/l)	2-11
Flow velocity(m/s)	0-.99
Mean channel width(m)	6.45-85
Mean chanel depth(m)	0.23-4.8

Table 6.2.Physical and chemical variables measured at 15 stream sites in Kabbini river during the period from January 2001-January 2004.

Habitat variables	Range
Reach descriptions	
Sinuosity	1 - 2.6
Entrenchment ratio	1 - 4.3
Slope	0.001 - 0.1
W/d ratio	0.51 - 31.3
Riparian zone	
Shrub cover along bank(%)	0 - 80
Tree cover along bank(%)	0 - 100
Bare ground along bank(%)	0 - 60
Substrate	
Fines(%)	0 - 70
Gravels(%)	2 - 78
Cobbles(%)	0 - 41.7
Boulders(%)	0 - 40
Rock(%)	0 - 30
Bedrock(%)	0 - 60
Instream cover	
Turbulance(%)	0 - 20
Depth(%)	0 - 50
Small woody debris(%)	0 - 10
Large woody debris(%)	0 - 7.7
Overhanging vegetation (%)	29.4 - 95.2
Submerged vegetation(%)	0 - 10
Floating vegetation(%)	0 - 0
Emergent vegetation(%)	0 - 37
Turbulant white water boulders(%)	0 - 20
Scour out pools(%)	0 - 10
Overhanging stream boulders(%)	0 - 10
Undercut bank(%)	0 - 11.8
Total cover(%)	10 - 90
Channel geographical units	
Falls(%)	0 - 0
Cascade(%)	0 - 0
Rapids(%)	0 - 0
Riffle(%)	0 - 39.6
Chute(%)	0 - 0

Sheet(%)	0 - 0
Run(%)	0 - 100
Eddy(%)	0 - 0
Trench(%)	0 - 52.4
Midchannel(%)	0 - 84.9
Pocket water pools(%)	0 - 55.2
Cinvergence(%)	0 - 0
Glide(%)	0 - 32.1
Lateral pools(%)	0 - 80
Plunge(%)	0 - 9.9
Debris(%)	0 - 0
Landslide(%)	0 - 0
Backwater(%)	0 - 0
Abandened channels(%)	0 - 0
Water quality	
Air temperature(^{0}C)	20.5 - 32.8
Water temperature(^{0}C)	18.2 - 32
pH	6.9 - 7.8
Dissolved oxygen(mg/l)	5.98 - 7.61
Total hardness(mg/l)	9 - 20
Total alkalinity(mg/l)	2 - 10
Flow velocity(m/s)	0 - 0.88
Mean channel width(m)	6.1 - 188
Mean chanel depth(m)	1.04 - 16

Table 6.3. Physical and chemical variables measured at 20 stream sites in Chalakudy river during the period from January 2001-January 2004.

Habitat variables	Range
Reach descriptions	
Sinuosity	1 - 1.5
Entrenchment ratio	0.76 - 1.9
Slope	0.001 - 0.1
W/d ratio	0.5 - 35.75
Riparian zone	
Shrub cover along bank(%)	0 - 20
Tree cover along bank(%)	75 - 96
Bare ground along bank(%)	0 - 20
Substrates	
Fines (%)	0 - 75
Gravels(%)	0 - 95
Cobbles (%)	0 - 10
Boulders(%)	0 - 73
Rock(%)	0 - 58
Bedrock(%)	0 - 95.97
Instream cover	
Turbulance(%)	0 - 25
Depth(%)	0 - 98
Small woody debris(%)	0 - 14.3
Large woody debris(%)	0 - 14.4
Overhanging vegetation(%)	0 - 96.2
Submerged vegetation(%)	0 - 0
Emergent vegetation(%)	0 - 56.5
Floating vegetation(%)	0 0
Turbulant white water boulders(%)	0 - 18.8
Scour out pools(%)	0 - 14.3
Overhanging stream boulders(%)	0 - 17.2
Undercut bank(%)	0 - 28.9
Total cover(%)	18 - 84
Channel geographical units	
Falls(%)	0 - 5.1
Cascade(%)	0 - 6.8
Rapids(%)	0 - 69.1
Riffle(%)	0 - 100
Chute(%)	0 - 27.4

Sheet(%)	0 - 0
Run(%)	0 - 73.8
Eddy(%)	0 - 0
Trench(%)	0 - 17.1
Midchannel(%)	0 - 100
Cinvergence(%)	0 - 0
Glide(%)	0 - 62
Pocket water(%)	0 - 100
Lateral pools(%)	0 - 0
Plunge(%)	0 - 13.8
Debris(%)	0 - 0
Landslide(%)	0 - 0
Backwater(%)	0 - 1.4
Abandened channels(%)	0 - 16.5
Water quality parameters	
Air temperature(^{0}C)	26 - 37.4
Water temperature(^{0}C)	23 - 29
pH	6.1 - 8.92
Dissolved oxygen(mg/l)	4.51 - 8.14
Total hardness(mg/l)	12 - 75
Total alkalinity(mg/l)	3.58 - 8
Flow velocity(m/s)	0 - 0.7
Mean channel width(m)	13 - 140.5
Mean chanel depth(m)	3.25 - 50

Table 6.4. Physical and chemical variables measured at 30 stream sites in Bharathapuzha river during the period from January 2001-January 2004.

Habitat variables	
Reach descriptions	
Sinuosity	1-1.63
Entrenchment ratio	0.7-5.1
Slope	0.001- 0.25
W/d ratio	0.48 - 83.3
Riparian zone	
Shrub cover along bank(%)	3 - 80
Tree cover along bank(%)	0 - 97
Bare ground along bank(%)	0 - 88
Substrate	
Fines(%)	0 - 75
Gravels(%)	0- 98
Cobbles(%)	0 - 82.3
Boulders(%)	0 - 60
Rock(%)	0 - 52
Bedrock(%)	0 - 94
Instream cover	
Turbulance(%)	0 -75
Depth(%)	0 - 100
Small woody debris(%)	0 -17.6
Large woody debris(%)	0 -14.3
Overhanging vegetation (%)	0 - 71.4
Submerged vegetation(%)	0 - 0
Emergent vegetation(%)	0-90
Turbulant white water boulders(%)	0-25
Scour out pools(%)	0-30.8
Overhanging stream boulders(%)	0-5.1
Undercut bank(%)	0-16
Total cover(%)	0-100
Channel geographical units	
Riffle(%)	0-68.9
Run(%)	0 - 100
Eddy(%)	0 - 0
Trench(%)	0-22.7
Midchannel(%)	0 - 100
Pocket water pools(%)	0 - 100

Glide(%)	0 - 100
Lateral pools(%)	0 - 0
Plunge(%)	0 - 0
Abandened channels(%)	0 -40
Water quality	
Air temperature(0C)	21.3 - 35
Water temperature(0C)	19.8-31
pH	6.8 -8.7
Dissolved oxygen(mg/l)	4.35 -6.61
Total hardness(mg/l)	11-134
Total alkalinity(mg/l)	2 - 22
Flow velocity(m/s)	0-1.03
Mean channel width(m)	10-250
Mean chanel depth(m)	1.5-25

Table 6.5. Co-efficient of correlation between habitat variables and abundance of *Lepidopygopsis typus*

Parameters	*r*	*p*
Bedrock	0.531	0.034
Chute	0.52	0.039
Lux	0.503	0.047
Overhanging stream boulders	0.819	0
Overhanging vegetation	0.616	0.011
Total cover	0.545	0.029
Slope	0.593	0.016
Tree cover	0.545	0.029

Table 6.6. Co-efficient of correlation between habitat variables and abundance of *Gonoproktopterus micropogon periyarensis*

Parameters	*r*	*p*
Depth	0.78	0
Midchannel pools	0.612	0.012
Overhanging vegetation	0.881	0
Shaded cover	0.698	0.003
Slope	0.521	0.033
Total cover	0.533	0.033
Tree cover	0.6	0.014

Table 6.7. Co-efficient of correlation between habitat variables and abundance of *Crossocheilus periyarensis*

Parameters	*r*	*p*
Lateral pool	0.529	0.035
Large woody debris	0.801	0
Overhanging vegetation	0.651	0.008
Scour out pools	0.636	0.008
Tree cover	0.523	0.038

Table 6.8. Co-efficient of correlation between habiatat variables and abundance of *Silurus wynaadensis*

Parameters	*r*	*p*
Air temperature (^{0}C)	0.716	0.003
Channel width (m)	-0.519	0.048
Flow velocity (m/s)	-0.696	0.004
Overhanging stream boulders (%)	-0.579	0.024
Total cover (%)	-0.579	0.024
Trench pool (%)	0.616	0.014
Water temperature (^{0}C)	0.543	0.037

Table 6.9. Co-efficient of correlation between habitat variables a abundance of *Neolissochilus wynaadensis*

Parameters	*r*	*p*
Alaklinity (mg/l)	-0.519	0.048
Channel width (m)	-0.53	0.042
Hardness (mg/l)	0.696	0.004
Lateral pool (%)	0.716	0.003
Overhanging stream boulders (%)	0.579	0.024
Plunge pool (%)	0.543	0.037

Table 6.10. Co-efficient of correlation between habitat variables and abundance of *Osteochilichthys longidorsalis*

Parameters	*r*	*p*
Abandoned channel(%)	0.584	0.007

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Backwater pools (%)	0.651	0.002
Emergant vegetation (%)	0.534	0.015
Glide (%)	0.445	0.049
Overhanging stream boulders (%)	0.447	0.048
Channel width (m)	0.459	0.042

Table 6.11. Co-efficient of correlation between habitat variables and abundance of *Puntius jerdoni*

Parameters	*r*	*p*
Abandoned channel (%)	0.849	0
Cascade (%)	-0.458	0.042
Rapids (%)	0.538	0.014
Total alkalinity (%)	0.456	0.044
Channel width (m)	0.547	0.013

Table 6.12. Co-efficient of correlation between habitat variables and abundance of *mesonemacheilus remadevi*

Parameters	*r*	*p*
Bare ground	-0.496	0.009
Bedrock	0.456	0.017
Cobbles	-0.498	0.008
Depth	-0.4	0.039
Dissolved oxygen	0.669	0
Glide	0.687	0
Large woody debris	0.61	0.001
Riffle	0.404	0.038
Small woody debris	0.49	0.01

Table 6.13. Co-efficient of correlation between habitat variables and abundance of *Homoloptera pillai*

Parameters	*r*	*p*
Bedrock	0.434	0.024
Cobbles	0.426	0.027
Dissolved oxygen	0.485	0.01
Glide	0.658	0
Large woody debris	0.856	0
Shrub cover	-0.391	0.044

Table 6.14. Co-efficient of correlation between habitat variables and abundance of *Garra menoni*

Parameters	*r*	*p*
Bedrock	0.648	0
Dissolved oxygen	0.57	0.002
Glide	0.657	0
Large woody debris	0.86	0
Shrub cover	-0.431	0.025
Small woody debris	0.948	0

Table 6.15.Simple regression models that accounted for variation in abundance and had potential habitat assessment value for *L.typus,G.micropogon periyarensis,C.periyarensis,S.wyndensis,N. wynadensis,O.longidorsalis,P.jerdoni,N.remadevi,H.pillai and G.menoni*

Regression equation	r^2	P
Lepidopygopsis typus		
-0.7156+0.1946 Bedrock substratum	0.327	0.0206
2.6038+1.6959 Chute habitat	0.1944	0.0873
11.0622-0.0093 Lux	0.2001	0.0823
0.3542+4.2083 Overhanging stream boulders	0.6151	0.0003
-0.3711+3.2891 Overhanging vegetation	0.501	0.0022
-4.236+0.8532 Total shaded area	0.5033	0.0002
-6.2094+146.069 Slope	0.391	0.0095
-3.3725+0.24 Total tree cover	0.3702	0.0124
Gonoproktopterus micropogon periyarensis		
-1.1635+0.0887 Depth	0.6088	0.0004
-0.2727+0.0435 Midchannel pools	0.3739	0.0118
-0.3789+0.517 Overhanging vegetation	0.777	0.2031
-1.078+0.1712 Total shaded area	0.487	0.0026
-1.14+24.778 Slope	0.2712	0.0386
-1.4834+0.0543 Total instream cover	0.2844	0.0334
-0.907+0.0482 Total tree cover	0.3596	0.0141
Crossocheilus periyarensis		
0.2675+0.2927 Lateral pools	0.2798	0.0351
0.333+1.333 Large woody debris	0.641	0.0002
-0.2344+0.656 Overhanging vegetation	0.424	0.0063
-0.0537+0.3782 Scour out pools	0.4044	0.0081
-0.7289+0.0447 Total tree cover	0.2734	0.0377
Silurus wynadensis		
-0.15825+0.155919 Air temperature	0.844808	0.003058
0.286572+ -0.17101 Channel width	0.202746	0.092135
0.031909+ -0.06732 Flow velocity	0.627343	0.018662
0.07628 + -0.26121 Overhanging stream boulders	0.36861	0.016384
0.076182+ -0.00792 Total cover	0.968055	0.000128
0.06816+ -0.03964 Trench pool	0.710039	0.010989
-0.8667+ 0.68532 Water temperature	0.23616	0.106079

Neolissochilus wynadensis

0.68356+ -0.74708 Alkalinity	0.268995	0.047605
0.584608+ -0.34504 Channel width	0.281246	0.041986
2.161612+ -1.83322 Hardness	0.484387	0.003954
-0.00464+ 0.24.3849 Lateral pools	0.512289	0.002694
0.15542+ -0.42645 Overhanging stream boulders	0.334747	0.023846
6.088099+ -6.82332 pH	0.194292	0.125947

Osteochilichthys longidorsalis

0.082358+ 0.405413 abandened channel	0.340396	0.006926
0.093684+ 5.175706 Backwater pools	0.42552	0.001826
0.044195+ 0.217195 Emergent vegetation	0.282884	0.015791
0.08632+ 0.227943 Glide	0.196097	0.050542
0.050142+ 0.222576 Overhanging stream boulders	0.199561	0.048313
-0.5724+ 0.411587 Channel width	0.2101165	0.04206

Puntius jerdoni

0.016634+ 0.398499 Abandened channel	0.721127	0
0.038849+ 0.323483 Cascade	0.21133	0.04
-0.01521+ 0.127599 Rapids	0.290124	0.014274
-0.56822+ 0.899533 Total alkalinity	0.207529	0.043538
-0.50128+ 0.331286 Channel width	0.297856	0.012804

Nemacheilus remadevi

0.315 - 0.184999 Bare ground	0.245807	0.008541
0.269842-0.16195 Bedrock	-0.181349	0.026778
-0.00703 + 0.210778 Cobbles	0.247982	0.008209
0.423247 - 0.21218 Depth	0.159957	0.038733
-3.00512+4.410245 Dissolved oxygen	0.447758	0.000135
0.041118+0.316682 Glide	0.471545	0.00007
0.04118+0.316682 Large woody debris	0.371883	0.000733
0.087787+0.033783 Riffle	0.163572	0.036399
0.099799+0.553623 Small woody debris	0.239787	0.009526

Homaleptera pillai

0.006552+0.13218 Bedrock	0.187931	0.023884
-0.02222+0.096669 Cobbles	0.181835	0.026553
-1.17561+1.712174 Dissolved oxygen	0.235259	0.010338
-0.00572+0.16263 Glide	0.433521	0.000189
-0.00429+0.448114Large woody debris	0.733469	0
0.294278-0.19175 Shrub cover	0.152523	0.04
0.003891+0.548568 Small woody debris	0.820714	0

Garra menoni

0.02893+0.398311Bedrock	0.42	0.0002
-3.07786+4.47606 Dissolved oxygen	0.324	0.002
0.000983+0.361469 Glide	0.432	0.0002
0.003409+1.002687 Large woody debris	0.74	0
0.725293-0.47071Shrub cover	0.185265	0.025
0.017747+1.278555 Small woody debris	0.898679	0

Table 6.16. Multiple regression habitat suitability index model of *Lepidopygopsis typus*

Regression Statistics	
Multiple R	0.9299101
R Square	0.8647329
Adjusted R^2	0.7101418
Standard Error	5.1676291
Observations	16

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	1195.006765	149	5.5937	0.017523454
Residual	7	186.930735	26.7		
Total	15	1381.9375			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.6180779	4.462044087	0.14	0.8937	-9.93297217	11.16913	-9.9329722	11.16912806
X1 Variable 1	0.0904756	0.06786462	1.33	0.2242	-0.06999859	0.25095	-0.0699986	0.250949833
X2 Variable 2	0.733442	0.712273221	1.03	0.3374	-0.95081534	2.417699	-0.9508153	2.41769931
X3 Variable 3	-0.00054	0.004645859	-0.12	0.9108	-0.01152532	0.010446	-0.0115253	0.010446088
X4 Variable 4	3.0016543	1.604727732	1.87	0.1036	-0.79292109	6.79623	-0.7929211	6.796229707
X5 Variable 5	2.767946	1.328705672	2.08	0.0757	-0.37394145	5.909833	-0.3739414	5.909833367
X6 Variable 6	0.0576089	0.3488016	0.17	0.8735	-0.76717523	0.882393	-0.7671752	0.882393032
X7 Variable 7	-48.08336	59.3204836	-0.81	0.4443	-188.353912	92.1872	-188.35391	92.18719531
X8Variable 8	-0.096239	0.128478968	-0.75	0.4782	-0.40004288	0.207566	-0.4000429	0.207565656

Table 6.17. Multiple regression habitat suitability index model of Gonoproktopterus micropogon periyarensis

Regression Statistics	
Multiple R	0.9341761
R Square	0.8726849
Adjusted R^2	0.7612843
Standard Error	0.9560765
Observations	16

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	7	50.12484133	7.16	7.8337	0.004717067
Residual	8	7.312658669	0.91		
Total	15	57.4375			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.4269966	0.735152342	0.58	0.5773	-1.26826887	2.122262	-1.2682689	2.122262009
X1 Variable 1	-0.087415	0.071967456	-1.21	0.2591	-0.25337261	0.078542	-0.2533726	0.078542105
X2 Variable 2	0.0275387	0.014557943	1.89	0.0952	-0.00603196	0.061109	-0.006032	0.061109433
X3 Variable 3	0.83743	0.21332422	3.93	0.0044	0.345503118	1.329357	0.34550312	1.329356821
X4 Variable 4	0.0657968	0.075703559	0.87	0.4101	-0.10877603	0.24037	-0.108776	0.240369641
X5Variable 5	-8.177745	9.254726137	-0.88	0.4027	-29.5191957	13.16371	-29.519196	13.16370535
X6 Variable 6	0.0123387	0.021405569	0.58	0.5802	-0.0370227	0.0617	-0.0370227	0.06170002
X 7Variable 7	-0.024745	0.01824874	-1.36	0.2121	-0.06682675	0.017337	-0.0668267	0.017336647

Table 5.18. Multiple regression habitat suitability index model of *Crossocheilus periyarensis*

Regression Statistics	
Multiple R	0.8852412
R Square	0.783652
Adjusted R^2	0.675478
Standard Error	1.1858593
Observations	16

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	50.9373779	10.2	7.2444	0.004128515
Residual	10	14.0626221	1.41		
Total	15	65			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.526787	0.648506135	-0.81	0.4355	-1.97174932	0.918175	-1.9717493	0.918174614
X Variable 1	-0.007023	0.12238944	-0.06	0.9554	-0.27972405	0.265677	-0.279724	0.265677384
X Variable 2	0.8596924	0.444544045	1.93	0.0819	-0.13081363	1.850198	-0.1308136	1.850198427
X Variable 3	0.2547349	0.280490057	0.91	0.3851	-0.37023605	0.879706	-0.3702361	0.879705755
X Variable 4	0.1398411	0.114298897	1.22	0.2492	-0.1148328	0.394515	-0.1148328	0.394514919
X Variable 5	0.010297	0.022589603	0.46	0.6583	-0.04003579	0.06063	-0.0400358	0.060629772

Table 5.19.Multiple regression habitat suitability index model of *Silurus wynadensis*

Regression Statistics	
Multiple R	0.8688504
R Square	0.7549011
Adjusted R^2	0.5098021
Standard Error	0.1175416
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	7	0.297871978	0.04	3.08	0.080451014
Residual	7	0.096712154	0.01		
Total	14	0.394584132			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.204037	0.869446656	-0.23	0.8212	-2.25994987	1.851876	-2.2599499	1.851876485
X Variable 1	-1.011653	1.091943094	-0.93	0.385	-3.59368582	1.570381	-3.5936858	1.570380729
X Variable 2	-0.110378	0.082694513	-1.33	0.2237	-0.3059191	0.085164	-0.3059191	0.08516352
X Variable 3	-0.052794	0.098803512	-0.53	0.6097	-0.28642705	0.180839	-0.286427	0.180838978
X Variable 4	-0.329165	0.133023172	-2.47	0.0426	-0.64371442	-0.01462	-0.6437144	-0.014615232
X Variable 5	0.0450205	0.139702342	0.32	0.7567	-0.28532279	0.375364	-0.2853228	0.375363835
X Variable 6	0.1255285	0.124497821	1.01	0.3469	-0.16886191	0.419919	-0.1688619	0.419918808
X Variable 7	1.293825	0.774731459	1.67	0.1388	-0.53812244	3.125773	-0.5381224	3.12577253

Table 6.20. Multiple regression habitat suitability index model of *Neolissochilus wynadensis*

Regression Statistics	
Multiple R	0.9041198
R Square	0.8174326
Adjusted R^2	0.6805071
Standard Error	0.162566
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	6	0.946625713	0.16	5.9699	0.012166729
Residual	8	0.211421664	0.03		
Total	14	1.158047377			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	7.6158597	3.269604709	2.33	0.0482	0.076132799	15.15559	0.0761328	15.15558651
X Variable 1	-0.382961	0.309881429	-1.24	0.2516	-1.09754974	0.331627	-1.0975497	0.331626898
X Variable 2	0.0072828	0.146665853	0.05	0.9616	-0.33092947	0.345495	-0.3309295	0.345495095
X Variable 3	-0.510353	0.751634268	-0.68	0.5163	-2.24362594	1.22292	-2.2436259	1.222919764
X Variable 4	0.0956303	0.103414365	0.92	0.3822	-0.14284382	0.334104	-0.1428438	0.334104399
X Variable 5	-0.265312	0.143196386	-1.85	0.101	-0.595524	0.064899	-0.595524	0.06489935
X Variable 6	-7.663966	4.115581372	-1.86	0.0996	-17.1545202	1.826587	-17.15452	1.826587369

Table 6.21. Multiple regression habitat suitability index model of *Osteochilichthys longidorsalis*

Regression Statistics	
Multiple R	0.9456048
R Square	0.8941685
Adjusted R^2	0.8453232
Standard Error	0.1019625
Observations	20

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	6	1.141902394	0.19	18.306	1.20217E-05
Residual	13	0.135152606	0.01		
Total	19	1.277055			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.1039469	0.165234327	0.63	0.5402	-0.25302009	0.460914	-0.2530201	0.460913894
X Variable 1	0.1486036	0.095663891	1.55	0.1443	-0.05806563	0.355273	-0.0580656	0.355272834
X Variable 2	4.8169324	1.030878929	4.67	0.0004	2.589854305	7.04401	2.58985431	7.044010499
X Variable 3	0.1791773	0.05631068	3.18	0.0072	0.057525486	0.300829	0.05752549	0.300829097
X Variable 4	0.1248116	0.063838493	1.96	0.0724	-0.01310306	0.262726	-0.0131031	0.26272625
X Variable 5	0.0878536	0.049409034	1.78	0.0988	-0.01888812	0.194595	-0.0188881	0.194595298
X Variable 6	-0.090357	0.101960112	-0.89	0.3916	-0.31062845	0.129914	-0.3106284	0.129914329

Table 6.22.Multiple regression habitat suitability index model of *Puntius jerdoni*

Regression Statistics	
Multiple R	0.8867863
R Square	0.7863899
Adjusted R^2	0.7101006
Standard Error	0.0944899
Observations	20

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	0.460166473	0.09	10.308	0.000264998
Residual	14	0.124996758	0.01		
Total	19	0.585163231			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.381776	0.231627199	-1.65	0.1216	-0.87856744	0.115015	-0.8785674	0.11501531
X Variable 1	0.3352807	0.070406111	4.76	0.0003	0.184274437	0.486287	0.18427444	0.486286884
X Variable 2	-0.044133	0.117981458	-0.37	0.714	-0.29717835	0.208912	-0.2971783	0.208912224
X Variable 3	0.029003	0.042840374	0.68	0.5094	-0.06288053	0.120887	-0.0628805	0.120886559
X Variable 4	0.4536832	0.305335483	1.49	0.1595	-0.20119688	1.108563	-0.2011969	1.108563243
X Variable 5	0.0421351	0.108390595	0.39	0.7033	-0.19033985	0.27461	-0.1903399	0.274609974

Table 6.23. Multiple regression habitat suitability index model of *Nemacheilus remadevi*

Regression Statistics	
Multiple R	0.9274424
R Square	0.8601494
Adjusted R^2	0.7861109
Standard Error	0.1490631
Observations	27

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	9	2.323265565	0.26	11.618	1.18432E-05
Residual	17	0.377736775	0.02		
Total	26	2.70100234			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1.951782	0.593951594	-3.29	0.0044	-3.2049123	-0.69865	-3.2049123	-0.698652146
X Variable 1	-0.076154	0.044435793	-1.71	0.1047	-0.16990593	0.017597	-0.1699059	0.017596988
X Variable 2	0.0655076	0.047478683	1.38	0.1855	-0.03466385	0.165679	-0.0346638	0.165678962
X Variable 3	-0.0448	0.066462981	-0.67	0.5093	-0.1850246	0.095425	-0.1850246	0.095425056
X Variable 4	-0.117601	0.062793797	-1.87	0.0784	-0.25008413	0.014883	-0.2500841	0.014882902
X Variable 5	3.0539744	0.813102151	3.76	0.0016	1.338476438	4.769472	1.33847644	4.769472397
X Variable 6	0.211938	0.071777601	2.95	0.0089	0.060500325	0.363376	0.06050032	0.363375751
X Variable 7	0.242479	0.223183774	1.09	0.2924	-0.22839826	0.713356	-0.2283983	0.71335626
X Variable 8	0.2050327	0.057113208	3.59	0.0023	0.084534205	0.325531	0.0845342	0.325531213
X Variable 9	-0.286504	0.200662149	-1.43	0.1715	-0.70986481	0.136857	-0.7098648	0.136856624

Table 6.24. Multiple regression habitat suitability index model of *Homoloptera pillai*

Regression Statistics	
Multiple R	0.9501121
R Square	0.9027129
Adjusted R Squ	0.8668703
Standard Error	0.0629864
Observations	27

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	7	0.699426006	0.1	25.185	2.46025E-08
Residual	19	0.07537846	0		
Total	26	0.774804465			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.135554	0.234830622	-0.58	0.5706	-0.62706024	0.355952	-0.6270602	0.355952346
X Variable 1	0.0763625	0.024217797	3.15	0.0052	0.025674019	0.127051	0.02567402	0.127050912
X Variable 2	-0.002978	0.02283828	-0.13	0.8976	-0.05077884	0.044823	-0.0507788	0.044823327
X Variable 3	0.0514559	0.335374335	0.15	0.8797	-0.65049091	0.753403	-0.6504909	0.753402624
X Variable 4	0.0076149	0.028229317	0.27	0.7903	-0.05146978	0.0667	-0.0514698	0.066699533
X Variable 5	0.1185228	0.090946626	1.3	0.2081	-0.07183076	0.308876	-0.0718308	0.308876307
X Variable 6	0.0588392	0.046455936	1.27	0.2206	-0.0383942	0.156073	-0.0383942	0.156072645
X Variable 7	0.4178722	0.090519359	4.62	0.0002	0.228412978	0.607331	0.22841298	0.607331488

Table 6.25. Multiple regression habitat suitability index model of *Garra menoni*

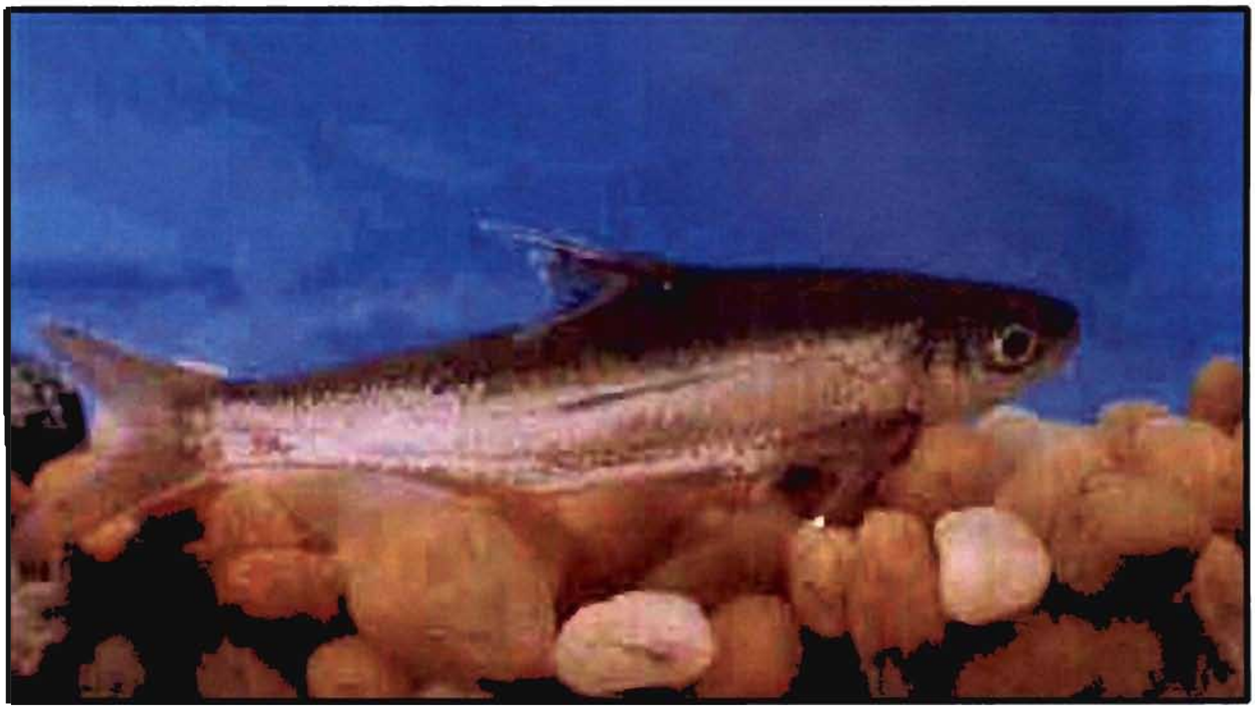
Regression Statistics	
Multiple R	0.9574902
R Square	0.9167874
Adjusted R Squ	0.8918236
Standard Error	0.1264614
Observations	27

ANOVA

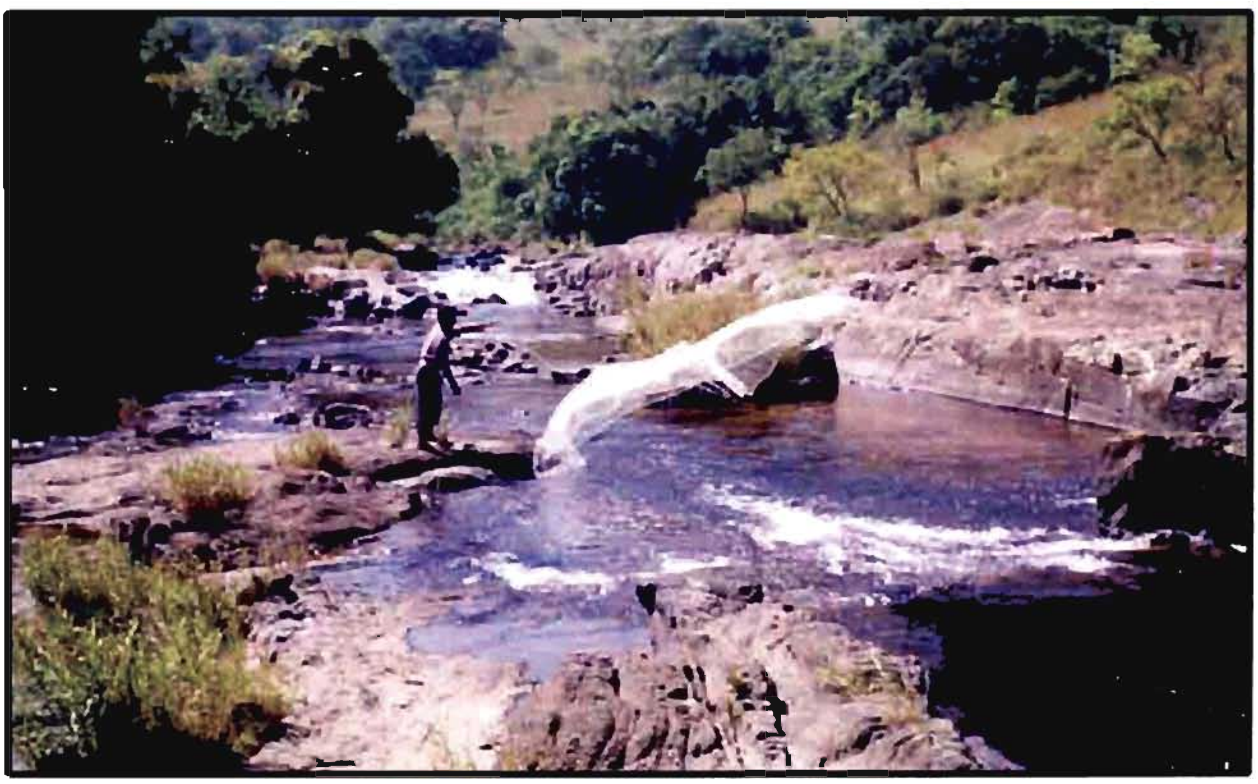
	df	*SS*	*MS*	*F*	*Significance F*
Regression	6	3.523913423	0.59	36.725	8.97707E-10
Residual	20	0.31984954	0.02		
Total	26	3.843762963			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.523212	0.469037669	-1.12	0.2779	-1.50160696	0.455183	-1.501607	0.455182998
X Variable 1	0.0564754	0.057785054	0.98	0.3401	-0.06406201	0.177013	-0.064062	0.177012897
X Variable 2	0.6151394	0.63503991	0.97	0.3443	-0.70953	1.939809	-0.70953	1.939808853
X Variable 3	-0.007503	0.056500053	-0.13	0.8957	-0.12536032	0.110354	-0.1253603	0.110353663
X Variable 4	0.2037551	0.17338061	1.18	0.2537	-0.15791037	0.565421	-0.1579104	0.565420523
X Variable 5	0.064116	0.086023333	0.75	0.4647	-0.11532544	0.243557	-0.1153254	0.243557452
X Variable 6	0.9908693	0.190248404	5.21	4E-05	0.594018257	1.38772	0.59401826	1.387720322

Plate 6.1



Lepidopygopsis typus (Raj,1941 b)



Typical habitat of *Lepidopygopsis typus*

Plate 6.2

Gonoproktopterus micropogon periyarensis Raj, 1941 a

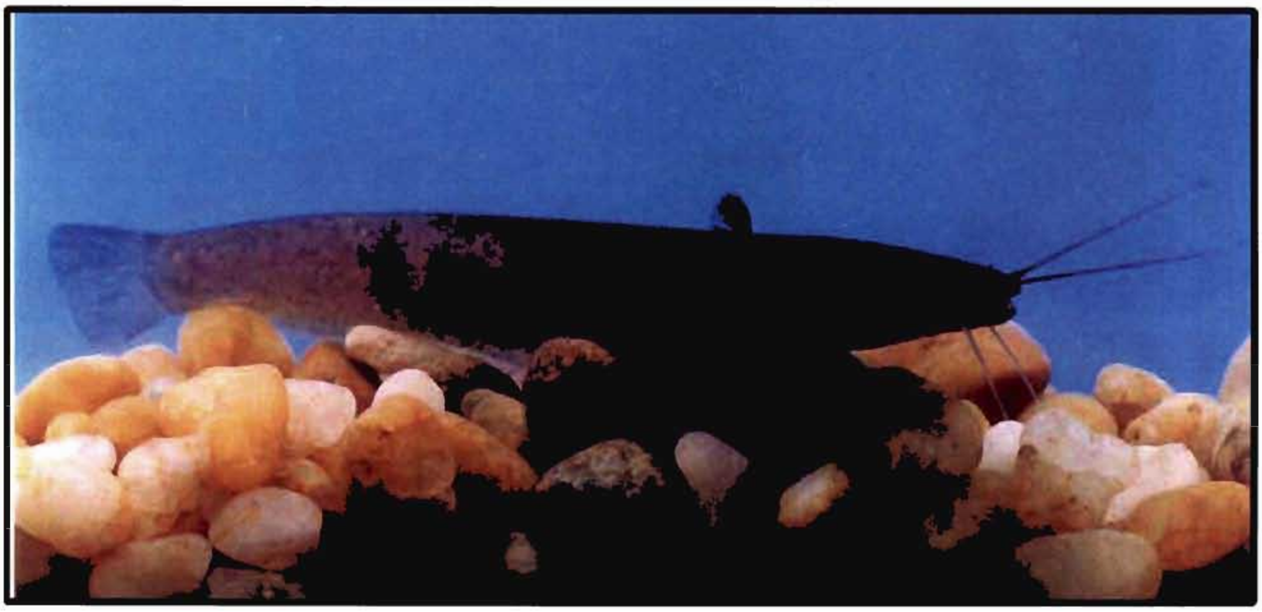
Typical habitat of *Gonoproktopterus micropogon periyarensis*

Plate 6.3

Crossocheilus periyarensis (Menon & Jacob, 1996)

Typical habitat of *Crossocheilus periyarensis*

Plate 6.4



Silurus wynaadensis Day, 1868

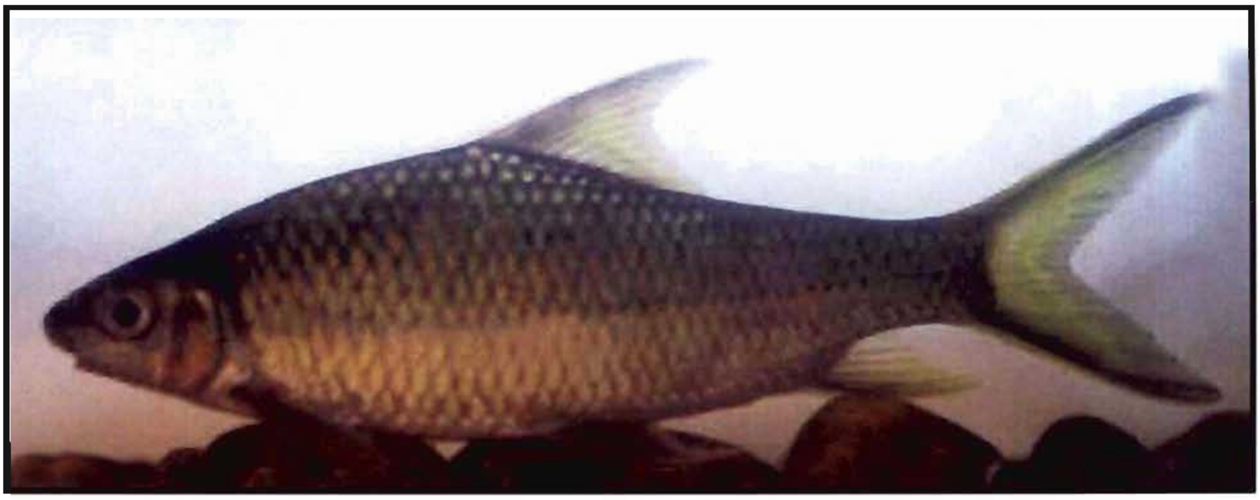
Typical habitat of *Silurus wynaadensis*

Plate 6.5

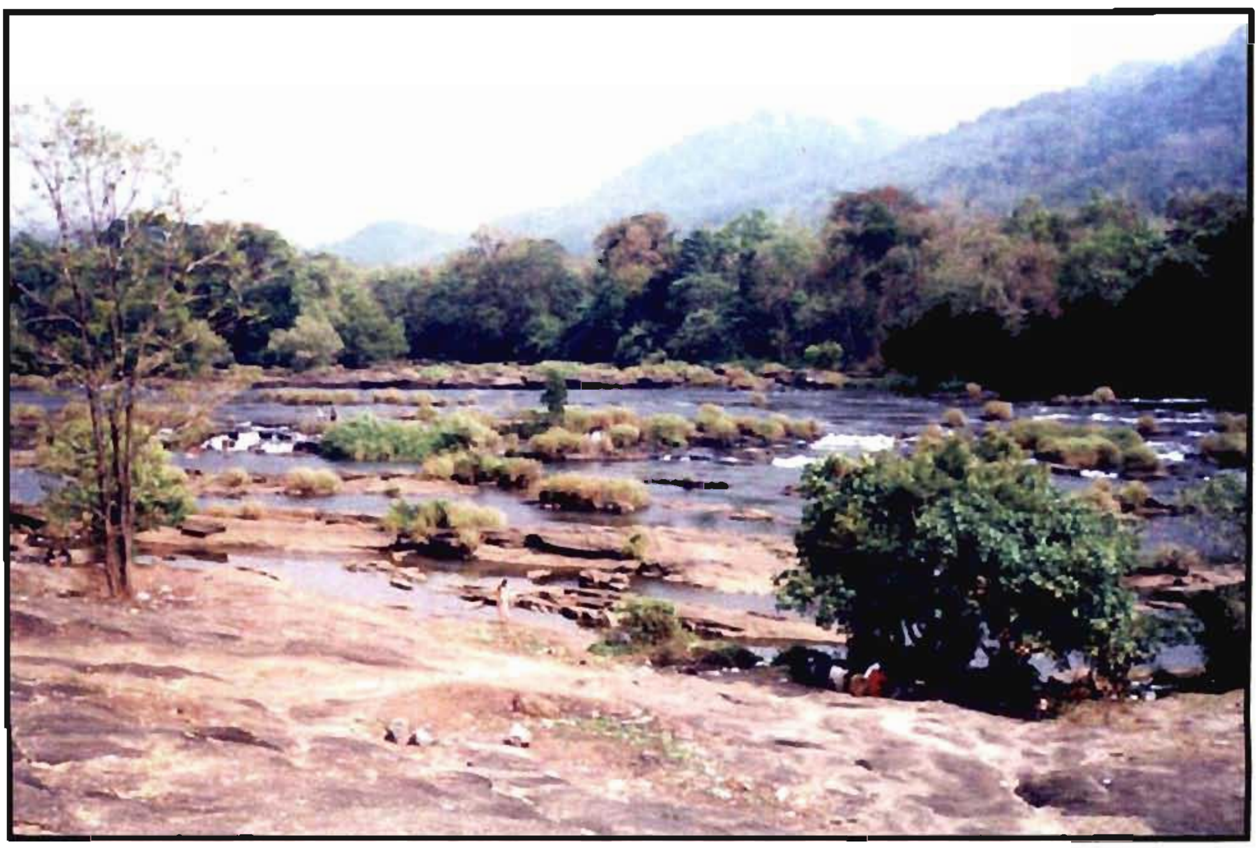
Neolissochilus wynaadensis **(Day,1873)**

Typical habitat of *Neolissochilus wynaadensis*

Plate 6.6



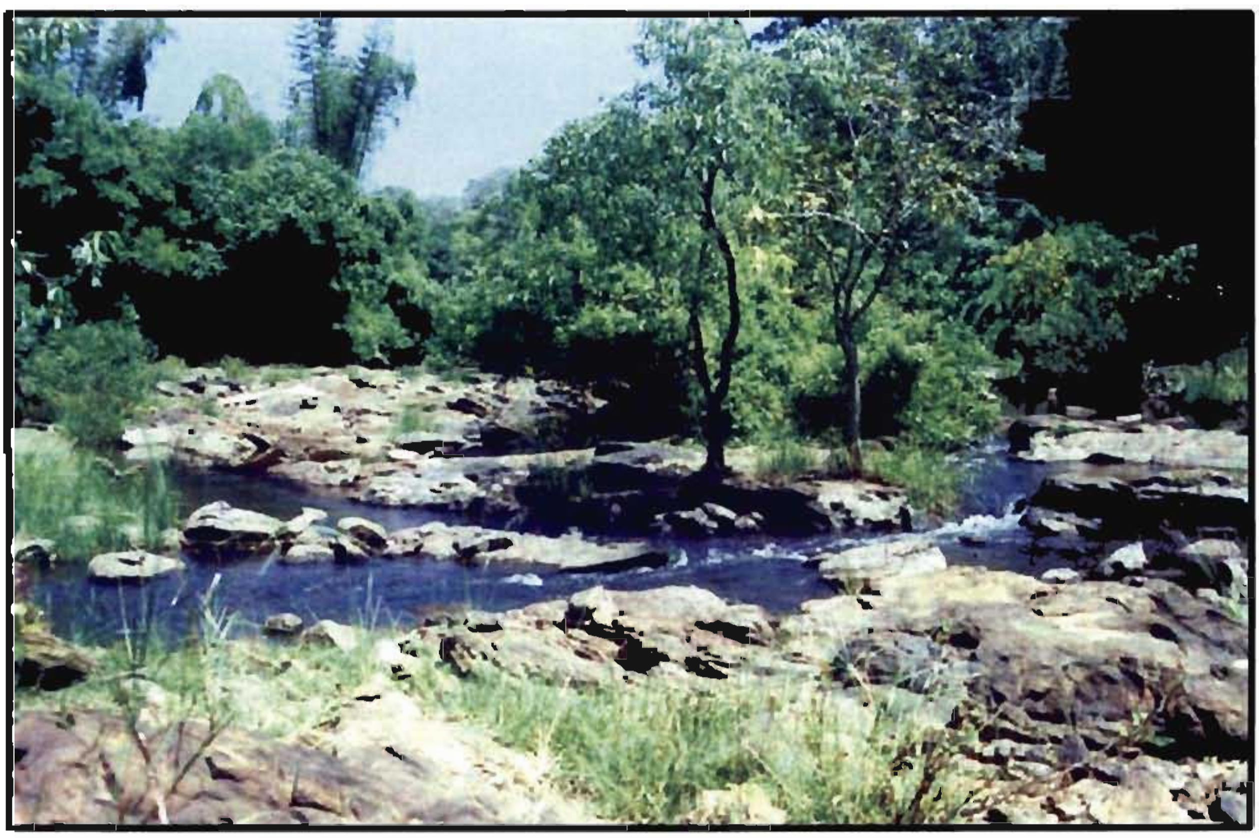
Osteochilichthys longidorsalis Pethiyagoda &Kottlet, 1994



Typical habitat of *Osteochilichthys longidorsalis*

Plate 6.7

Puntius jerdoni Day, 1876



Typical habitat of *Puntius jerdoni*

Plate 6.8

Mesonemacheilus remadevi Shaji, 2002

Typical habitat of *Mesonemacheilus remadevi*

Plate 6.9

Homaloptera pillaii Indira &Remadevi,1984

Typical habitat of *Homaloptera pillai*

Plate 6.10

Garra menoni Remadevi & Indrira,1984

Typical habitat of *Garra menoni*

Section II

Life history traits and resource characteristics of *Puntius carnaticus*(Jerdon,1849)

Chapter 7

Systematics of *Puntius carnaticus*(Jerdon,1849)

7.1. Introduction

Kerala is a land of rivers, which harbours a rich and diversified fish fauna characterized by many rare and emdemic fish species. According to Kurup(2002) of the 170 freshwater fish species collected from the rivers and streams of Kerala 66 species belong to potential food fish category, while 104 species can be considered as potential ornamental species. The state abounds extensive inland water bodies, which are suitable for fish culture, including 0.3 lakh ha. of reservoirs, 0.03 lakh ha. of tanks and ponds and 0.85 lakh ha. of rivers. In spite of having immense scope and potential for the development of freshwater fish culture as well as capture fisheries in the state, the yield from these water bodies are far below optimal. However, with the increasing demand for fish as a source to cater the ever-increasing demand for protein requirements of the human being, extension of aquaculture activities to more areas and utilization of indigenous fish germplasm resources are the way outs. An effort in this direction was attempted by investigating the life history traits of *P.carnaticus* an endemic threatened fish species of Western ghats .

7.2. Description of the species

P.carnaticus is a cyprinid fish, which is commonly known as 'carnatic carp' and is locally known as 'Pachilavetti' (Plate 7.1)

Systematic position

Phylum	Chordata
Sub-Phylum	Vertebrata
Super-class	Gnathostomata
Grade	Pisces
Class	Osteichthyes

Sub-class	Actinopterygii
Sub-Division	Teleostei
Order	Cypriniformes
Sub-order	Cyprinoidei
Family	Cyprinidae
Sub-Family	Cyprininae
Genus	*Puntius*
Species	*Carnaticus*

P.carnaticus can be diagnosed with the help of following characteristics

D iv 8; A ii-iii 5; P i 14; V i 8

Body elongate its depth 2.5 to 3.4 times in standard length. Mouth slightly subterminal; lips moderately fleshy. Barbles two pairs; maxillary pair as long as orbit, rostral ones much shorter. Dorsal fin inserted slightly nearer to tip of snout than to base of caudal fin; its last unbranched ray is osseous, strong and smooth. Scales fairly large. Lateral line complete, with 28-32 scales; lateral transverse scale rows 51/2 /31/2; predorsal scales 10 to 12.

Colour is olivaceous green on back, fading to dull –white glossed with gold on flanks and abdomen. Usually a faded band is seen above the lateral line.

7.3. Earlier reports

Available literature revealed that *P.carnaticus* was diagnosed and described by Jerdon (1849).

Barbus carnaticus Jerdon, 1849, Madras J.Lit.& Sci.,15:311(type –locality:Cauvery river).

The previous reports of *P.carnaticus* shown below:

Barbus carnaticus	Day, 1878.Fishes of India: 563,pi.137, fig.3; Day 1889.Fauna Br.India, Fishes, 1:305 Mukerji, 1937*J.Bombay nat.Hist.Soc.*,35(2):164
Barbodes carnaticus	Yazdani, 1992. Proc.J.Nat.Synp. Env. Hydraulics,Pune:134-147 Menon and Remadevi, 1995,*J.Bombay nat.Hist.Soc.*,92:389-393
Puntius carnaticus	Jayaram, 1981. Handbook of freshwater fish, India, p.113 (Kottayam, Kerala) Talwar and Jhingran, 1991.Inland fishes of India and adjacent countries, 1; 262(Kerala) Easa and Basha, 1995. A survey of the habitat and distribution of stream fishes in Kerala part of Nilgiri Biosphere Reserve.KFRI Research report No.104. Jayaram, 1999. The freshwater fishes of the Indian region,p.101 Ajithkumar et al., 2000.Ecology of hill streams of Western Ghats with special reference to fish community, Final report, pp.203, Bombay Nat.Hist.Soc.Mumbai. Gopi, 2000. Endemic fish diversity of Western Ghats, NBFGR-NATP publication No.1, Lucknow.p.62. Shaji et al., 2000.Endemic fish diversity of Western Ghats,NBFGR-NATP publication No.1,Lucknow.p.62. Shaji and Easa, 2001.Field Guide. Freshwater fishes of the Western Ghats, p.101.KFRI, Kerala and NBFGR, Lucknow.p.108.

The genus *Puntius* is represented by 55 species, of which 44 species are available in India (Jayaram, 1999). Many of the species coming under this genus are small fishes and have no fishery potential while some species have good ornamental value. On the contrary *P.carnaticus* attains big size and the maximum size recorded is 12 kg (Talwar and Jhingran, 1991). According to the earlier reports this carp provide a minor fishery in the Mettur reservoir area. However, the catch of this carp have significantly declined in recent years. In the present study specimens upto 1.75 kg were collected and specimens in the wild range 0.25kg to 1.5kg were very common. In Kerala *P.carnaticus* is available in five river systems such as Chalakudy, Kabbini, Achenkoil, Pambar and Chinnar. Among these river systems except Chalakudy and Kabbini, the occurrence of this species was sparse and sporadic. This species contributes a fishery in the Peringalkuthu reservoir and the adjacent areas of Chalakudy river system and Muthanga,Ponkuzhy, Begur and Baveli regions of Kabbini river system almost year round.

Even since the description of *P.carnaticus* in 1849 by Jerdon as *Barbus carnaticus*, virtually nothing has been added to our knowledge on this species other than the very few references came across in general surveys. This paucity of information on this valuable fish germplasm prompted to undertake studies on life history traits and resource characteristics of this species. During the period of study from April 2001 to March 2003, the following aspects were studied

1. Food and feeding habits to provide information on basic components of diet as well as season and size related variability in feeding behaviour.

2. Reproductive biology to observe spawning season, sex ratio, fecundity and other related aspects for asserting the rate of reproductive potential of this species.

3. Length-weight relationship and condition factor to ascertain the relationship between length and weight and the general well being of the fish

4.Age and growth to understand the age composition of the exploited stock, age at maturation and life span of the species, growth rate and its comparison with other species.

5.Population dynamics to estimate mortality rates, exploitation ratio, exploitation rate, relative yield per recruit etc. so as to bring out the level at which the exploitation of the stock is presently carried out which is essential for examining whether the present exploitation rate is at judicious level or not ?

Plate 7.1 *Puntius carnaticus* (Jerdon, 1849)

Systematic position

Phylum : Chordata
Sub-Phylum : Vertebrata
Superclass : Gnathostomata
Grade : Pisces
Class : Osteichthyes
Sub-class : Actinopterygii
Sub-Division : Teleostei
Order :Cypriniformes
Sub-Order : Cyprinoidei
Family : Cyprinidae
Sub-family : Cyprininae
Genus : *Puntius*
Species : *carnaticus*

Chapter 8

Food and Feeding

8.1. Introduction

All living organisms depend on food for a regular supply of energy to keep working and so stay alive. Food is an important factor influencing the growth pattern, distribution and abundance of stock and migratory habits of fishes. Information on natural diet of fish is a necessity for understanding its nutritional requirements, its interaction with other organisms and evaluation for aquaculture (Royce, 1987). Assessment of the food items and feeding habits are helpful in defining the trophic relationship of fish in the food web of the ecosystem. Once the food preference of a species is ascertained, an evaluation on the trophic relationship of the species such as the overlapping of the food spectrum with other co-existing species, competition from other species, selectivity or flexibility in feeding on the food items, etc. can be made. Based on this information, compatibility of different fish species with least inter-specific competition for natural food can be ascertained for farming purposes. It would also be useful in developing proper supplementary feed. The food and feeding habits of the same species differ in time, space as well as at different stages of growth (Hardy, 1924) and this would, in turn, pinpoint the importance of detailed study on this aspect. The age related information on feeding habit is invaluable in nursery and hatchery operations. Feeding habit is an important factor to be considered while transplanting a species to a new ecosystem so as to leave the native fauna in their natural habitat with least disturbance. The applicability of food and feeding habits of fishes becomes apparent while examining their role in controlling water-born diseases (Menon and Chacko, 1958). Many fishes have been successfully used in biological control of mosquito larvae and molluscs, which serve as intermediate hosts of many helminth parasites and algal blooms. Investigations of the feeding ecology of a species can also throw light upon how the organisms have evolved ecologically to meet the pressure (Grossman *et al.*, 1990).

Studies on the dietary habits of freshwater fishes are available from different parts of India. The important contributions are those of Mookherjee(1944); Chacko and Kuriyan(1949); Das and Moitra (1955, 1956, 1958, 1963); Chacko and Kuriyan(1949) Menon and Chacko(1957,1958);Natarajan and Jhingran(1961); Bhatnagar(1963); Qayyum and Qasim(1964); Rajan(1965); Pandian(1966); Chakrabarthy and Singh(1967); Sinha(1972);David and Rajagopal(1975); Pathak(1975); Badola and Singh(1980); Gupta(1981); Vinci and Sugunan(1981); Nautiyal and Lal(1984); Biswas(1985,1986); Dasgupta(1988,1990,1991);Sharma *et al.*(1992); Nath(1994), Kohli and Goswami(1996), Kishore *et al.*(1998), Basuda and Viswanath(1999) and Singh and Subbaraj(2000). Nevertheless, reports on the feeding habits of fishes inhabiting the rivers and streams of Kerala are very few. Ritakumari(1977) studied the diets of loaches, *Lepidocephalus thermalis* and *Noemacheilus triangularis*. The food preference, seasonal and lengthwise fluctuations in the food items and variations in the feeding intensity of *Puntius sarana subnasutus* were analysed in detail by Nair and Shobana(1980). Sheila (1981) recorded the food and feeding habits of *Aplocheilus lineatus* and *Macropodus cupanus*. A detailed illustrative account on the morphological adaptations of the digestive system of *Puntius vittatus* in relation to its mode of life in the environment was furnished by Geetha *et al.*(1990) along with the food and feeding habits of the species. Besides providing information on the diet preferences and seasonal and lengthwise variations in the gut contents of *Labeo dussumieri*, Kurup (1993) extended his work to the study of the food of spawn, fry, fingerlings and juveniles which helped in identifying this species as a cultivable fish.

Studies on food and feeding of animals are of great importance in understanding growth, migration, reproduction, seasonal variation in body condition, etc. (Sureshkumar, 1998). Assessment on the food and feeding habit of the fish helps us determining its habitats and its preferred food items. Moreover, observations on food and feeding along with the species assemblage structure will help us to understand the extent of competition for food among different populations. Basic knowledge on the food preference and feeding habits of a species are of primary necessity for ascertaining its suitability for aquaculture because it will helps to determining the desirable species combinations in culture systems with minimum interspecies competition for the natural food (Anon, 2001). It also provides vital clues in developing supplementary feed for the species.

Puntius carnaticus attains more than 12kg.(Talwar and Jhingran,1991) and the large size it could attain in the wild call for assessing its suitability for aquaculture. Knowledge on the food and feeding habit is a prerequisite for taking decisions in respect of its candidature for farming purpose and therefore an attempt in this direction was made as part of the present study.

8.2. Materials and methods

A total of 904 specimens comprising of 262 males (232-430mm TL), 150 females (270-472mm TL) and 480 indeterminates (52-227.1mmTL) were examined. The samples were collected from the commercial landings at Peringal region of Chalakudy river and were preserved in 8%formalin after making some perforation in the vent region for better preservation of the internal organs. After taking the morphometric measurements such as total length, standard length, total weight, etc., the stomach was dissected out. The fullness, length, weight and volume of the gut were examined.

The extent of feeding can be judged by the degree of fullness of stomach or from the amount of food contained in it. The food item in general showed a high degree of mutilation as they were already subjected to the strong action of digestive juices. Therefore, the gut contents could only be identified up to generic level or group depending on the state of digestion. Feeding intensity was also assessed by classifying the stomach as nil, trace, 1/4full, 1/2full, 3/4full and full depending on the state of distention and amount of total food in the stomach.. Depending upon the degree of fullness of the gut, points, 0, 5, 7.10.15 and 20 were given to nil, trace, 1/4full,1/2full,3/4full,and full gut respectively (Anon, 2001).

The feeding intensity was also estimated by calculating the gastrosomatic index (GSI) by applying the formula,

$$GSI = \frac{\text{Weight of the gut}}{\text{Total weight of the fish}}$$

Monthly as well as size-wise variations in gastro-somatic indices were worked out. The relative length of gut (RLG) was estimated by dividing the gut length by total length of the body (Al-Hussaini, 1949).

$$RLG = \frac{\text{Length of the gut}}{\text{Total length of the body}}$$

The contents of the intestinal bulb and intestine proper were taken out separately for the analysis of food components. Because of the occurrence of different types of food items such as macro vegetation, animal matter, filamentous algae, diatoms etc. in the diet, the percentage composition of the diet was determined following the occurrence method as described by Hynes (1950). The points (volumetric) method, as described by Pillay(1952) was used for estimating the volume index. The points gained by each food item altered proportionally to the total points allocated for the stomach.

The Index of Preponderance' (Natarajan and Jhingran, 1961) was worked out to assess the food preference of males, females and indeterminates. This index accounts for both the frequency of occurrence of food items (occurrence index) as well as its size (volume index). The Index of Preponderance was resolved by the formula:

$$I = \frac{ViOi}{\Sigma ViOi} \times 100$$

Where I = Index of preponderance of the food item

Vi= Percentage of volume index of the food item

Oi= Percentage of occurrence index of the food item.

8.3. Results

Alimentary canal comprises of mouth, buccal cavity, oesophagus, stomach, intestine and rectum. Mouth is sub terminal in position. Gill rakes are moderately long. Stomach is well distinguishable from the intestine. This species appear to be a voracious feeder as in most of the occasions the gut was found completely full.

The gut of this species has been found to be comparatively large with the relative gut length varying between 2.1 to 4. The relative gut length of different length groups of *P.carnaticus*, ranged from 2.1 to 3.2 in indeterminates, 3.1 to 3.8 in males and 3.3 to 4 in females (Fig.8.1). The stomach is well developed and can accommodate bigger sized particles.

8.3.1General diet composition of *P. carnaticus*

Analysis of gut contents showed that food items could be assorted into 7 groups. Semi digested plant matter was the most predominant dietary item recorded from the gut of the fish almost round the year. It was represented by leaves, roots and parts of stem. During the field observations it was observed that this species showed very good affinity towards fecal matter of elephants.

Filamentous algae were regularly encountered in the gut of the fish species. *Spirogyra, Ulothrix, Shizogonium, Pleurodiscus, Uronema* and *Hormidium* were regularly present in the gut.

Bacillaiophyceae also present as an important food item represented by *Dinophysis, Navicula, Clostrium, Calothrix, Bulbocheate, Pinnularia, Fragillaria, Nitzchia* and *Rhizosolenia,* among them. Dinophysis was the dominant diatom (42%) followed by Navicula(27%).

Semi digested animal matter, which was also found in the food spectrum of *P. carnaticus*. Insects (50-60%) were the predominant group under this category and was represented by Diptera(Chironomus larve and pupae,Tanypus and Ablabesmiya larvae), Hemiptera (Corixa and Micronecta),Ephemeroptera(Mayfly nymphs), Coleoptera(Hydrophilus larvae) and Odonata(dragonfly nymph).Semidigested and mutilated parts of other small fishes and crustaceans were also encountered in the gut contents.

Seeds of plants along the riparian zone were observed in the gut contents of *P.carnaticus*. Presence of sand was encountered in some samples and was separated by continuous washing

8.3.2. Variation in the diet composition of indeterminates , males and females

The food of indeterminates, males and females were analyzed separately to find out the differences, if any. The percentage composition of different food items of indeterminates, males and females are given in Fig.8.2a, 8.2b and 8.2c respectively. The index of preponderance of different food items of *P.carnaticus* is presented in Table 8.1.The food preferences of males, females and indeterminates were similar with variations in the magnitude of different food items consumed. Semidigested plant matter, filamentous algae, diatoms, semidigested animal matter and seeds were the order of preference in all groups. Semidigested plant matter contributed to 31.1% in indeterminates, 32.3% in males and 30.7% in females. While filamentous algae formed 17.16% in the diet of indeterminates, 17.2% in males and 18.6% in females. The preference for diatoms was found to be higher in indeterminates (16.5%) than to males(14%) and females(11.6%).Semi digested animal matter formed 26.5% in indeterminates followed by 19.1% in females and 18.2% in males. While the occurrence of seeds of some plants found at the river banks were observed in the gut of some specimens and it contributed to 3.3% in indeterminates, 12.5% in males and 12.2% in females. Miscellaneous matter including the sand formed 5% of the diet in indeterminates, 5.8% in males and 7.8% in females.

8.3.3. Seasonal variations in the diet of males and females

The monthly fluctuations in the diet composition of males and females, based on index of preponderance, for the year 2001-02 and 2002-03 are given in Tables 7.2, 7.3.7.4 and 7.5. During 2001-02, semi digested plant matter formed the dominant food item throughout the year in males with highest occurrence in March with an index value of 71.4 while it was minimum in September with 64.3(Table 8.2). Filamentous algae and diatoms formed the second and third dominant food items respectively. The index value of semi digested animal matter ranged between 4.5 in October and 8.4 in May. Seeds of plants growing in the riparian zone formed a minor portion of the diet during all months and its contribution varied from 2.9 in March to 5.8 in June. Miscellaneous matter varied from 0.3 in October to 3.4 in June. The pattern of variation was more or less on a similar line during 2002-03 with slight difference (Table 8.3). The quantity of semidigested plant matter, filamentous algae, diatoms and semidigested animal matter followed similar trend during both the years. While the occurrence of seeds in the gut content was not observed during July, November, January and March in 2002-03. Presence of miscellaneous matter showed a decreasing trend and its contribution varied from 1.5 in September, November and March while it was higher in May with 3.5.

Semidigested plant matter was the dominant food item of females in all the months during 2002-03(Table 8.4). The highest contribution was observed during May (70.3) and October (69.3). Filamentous algae which formed the second dominant food item varied its contribution from 11.1 during June to 15.1 in October. Diatoms showed their peak occurrence during November (9.3) and declined to 7.9 during May. Semidigested animal matter showed its highest occurrence during August (7.7) and reduced to 4.2 during May.

Seeds of plants growing in the riparian zone contributed to substantial quantity during some months while it was totally absent in the diet during May, July, August and March. Presence of miscellaneous matter varied from 0.6 during January to 7.3 in July. Similar trend was observed during 2002-03 with slight variations (Table 7.5). In males, a decrease in the proportion of semidigested plant matter was discernible during May, September and December in 2001 and May and September in 2002.In females also similar trend was observed during July in 2001 and October in 2002.Index of prepondarence value of indeterminates of *P.carnaticus* from April 2001-March 2003 are given in Table 8.6.Among the different food items semidigested plant matter (71.9%) was the dominant food item followed by filamentous algae (14.7%),Bacilllariophyceae(9.1%), semidigested animal matter(3.3%) and seeds(0.9%) in the order of their dominance. Miscellaneous items formed 0.1% of the diet.

8.3.4. Feeding intensity

Guts in different degrees of fullness

The data on the percentage occurrence of guts in different degrees of fullness in males and females of *P.carnaticus* during the years 2001-02 and 2002-03 are depicted in Figs 8.3, 8.4, 8.5 and 8.6 respectively.

In males, full gut was present during all the months. During June, September, November and January the guts of all the fishes were full. The lowest representation for full guts was observed during April and only 21.4% individuals showed the full gut condition. Individuals with 3/4 th full gut showed maximum occurrence during December followed by April, October, March and February.1/2 full individuals was maximum (33.3%)during July, followed by August (16.7%), May (12.5%) and October (11.1%). 1/4 full individuals showed their occurrence only during March (22.2%) and May (21.4%). Individuals with only trace amount of food materials in the gut were observed during March (22.2%) and April (7.1%), while empty guts were observed only during August (16.7%). During 2002-03 the gut of all fishes collected during most of the months was full.3/4 full guts were observed only during July, August, October, December and February.1/2full guts formed 40% during August and 11.1% during September.

In Females, during 2001-02 full gut was encountered only during June, September and February. While ¾ full gut was highest during December (58.4%) followed by March (30.8%), April (25%), October (20%), January (20%) and November (12.8%). During 2002-03, full gut was observed in May, June, September, January and February.Individuals with 3/4 full gut were observed during April, July, November, December and March with a maximum of 66.6%during April and December. During August 100% individuals have ½ full guts whereas in July fishes with ½ full guts contributed to only 25%. During October 66.6% of the specimens were having empty guts.

8.3.5. Gastrosomatic index

Monthly variations in gastrosomatic index of male and female *P.carnaticus* during 2001-02 and 2002-03 are shown in Figs 8.7 and 8.8 respectively. In males during 2001-02 there was a sharp increase in GSI from September onwards and registered the peak value of 7.2 in December. Thereafter the GSI showed a decreasing trend in the proceeding months and reached the lowest value of 4.5 during August. During 2002-03 also the GSI showed the similar trend but for the highest GSI of 7.5 registered in October and December. In females, during 2001-02, the GSI gradually increased from 4.5 during August and reached the highest of 7.4 during September. From December onwards the GSI declined and reached to 4.6 during August. During 2002-03 also the GSI showed the similar trend except that the peak GSI was recorded during October and not in September as in 2001-02

Lengthwise variation in GSI of males, females and indeterminates is depicted in Fig.8.9.In males from a higher value of 5.7 in 220-240mm size group the GSI showed a gradually declining trend and declined to 4.3 in 420-440mm size group. In females also the GSI showed the similar trend. From a higher value of 5.7 in 260-280mm size group, the GSI showed a gradually declining trend and touched 4 in 460-480mm size group. In indeterminates the highest value of 4.8 was recorded in 100-120mm size group. Thereafter, the GSI showed a gradually declining trend and touched to 4.1 in 140-160mm size group. The GSI increased to 4.3 in 160-180mm size group and declined to the lowest value of 3.9 in 180-200mm size group. Generally GSI values of females were found higher than their male counterparts and among the three groups studied females showed the higher GSI values when compared to males and indeterminates.

It is worth reporting that Males, Females and Indeterminates follow almost similar trends in feeding intensity as manifested by gastro-somatic index during both the two years with minor variations (Fig.8.10 and 8.11).

8.4. Discussion

The alimentary canal of fishes is well adapted and modified in accordance with their nature of diet and mode of feeding habits. The variation in the position, shape and size of the mouth can be correlated to the dietary habits of fishes. The subterminal mouth seen in

P.carnaticus is well adapted to suit its column feeding habit. According to Gupta *et al.* (1999), the column feeders are characterized by sub-terminal mouth.

The coiling of intestine is regarded as a specific feature of herbivores and omnivores. In *P.carnaticus* , the intestine is somewhat elongated which represents the omnivores nature of this fish with more affinity towards plant matter. According to Suyehiro(1942), the lack of space in the body cavity for accommodating the full length of the intestinal coils leads to coiling of the intestinal tract.

Generally any change in gut length is believed to be closely related to the nature of diet of fishes. Khanna (1961) supported this view and stated that the guts of predatory and carnivores fishes are generally short, on the other hand, that of omnivores are comparatively longer, whereas in herbivores, it is still longer. According to Nikolsky(1963), in cyprinids, gut length less than 100%of body length indicate carnivory while more than 100% indicates herbivory. Low relative gut length (RLG) is indicative of carnivory while greater RLG of herbivory. An intermediate value indicates omnivorous mode of feeding (Das and Moitra, 1956a; Das and Nath, 1965; Gupta *et al.*, 1999). While studying cyprinid gut morphology, Junger *et al.*(1989)observed that fishes with RLG ranging between 0.776 and 0.869 showed carnivorous tendencies while those with values from 0.913 to 1.254 were omnivores whereas RLG value of 2.053 was recorded in a herbivorous species.

The results of the gut analysis of *P.carnaticus* revealed that there exists a strong preference towards plant materials in indeterminates, males and females. Plant matter formed the most preferred category of food which is regularly consumed by all fishes irrespective of sex and size, followed by filamentous algae. Diatoms and animal matter appeared as respectively of 3rd and 4th preferential food groups of *P.carnaticus*. According to Nikolsky(1963), based on the importance of food items in the diet of fishes, 4 categories of food can be recognized. 1) Basic food-normally eaten by fish and comprise of most of the gut contents. 2) Secondary food-frequently found in the gut, but in small quantities. 3) Incidental food-found rarely in the gut. 4) Obligatory food- found in the absence of basic food. In accordance with the above categorization, semidigested plant matter, filamentous algae and diatoms could be discerned as the basic food in all groups of *P.carnaticus* while semidigested animal matter coming under the category of secondary food item whereas the seeds can be adjudged as an incidental food item.

According to the diversity in the types of food consumed, Nikolsky(1963)classified fishes as 1)euryphagic – feeding on a variety of food 2)stenophagic-feeding on a few different type 3)monophagic- feeding on only one type of food. Based on this classification all size and sexes of *P.carnaticus* including indeterminates can be categorized as stenophagic feeders.

On the basis of the nature of food consumed and the percentage of ingested food stuff as the criterion, Das and Moitra(1955,1956,1958,1963)classified the freshwater teleosts into 3 primary groups: 1)Herbivores- more than 80% of food plant material 2)Omnivores- approximately 50% of both plant and animal food, usually with variation in their percentage 3)Carnivores-more than 80% of animal matter. Later two more categories were added: 1) Herbi-omnivore-greater amount of plant matter 2) Carni-omnivore-greater amount of animal matter. While evaluating *P.carnaticus* in the light of above categorization, it appears that this species belonged to herbi-omnivore group because in males 91.95% of the food spectrum was comprised of materials from plant origin while in females and indeterminates it was respectively 90.95% and 96.6%.

While analyzing the food preferences of indeterminates and both the sexes, it is worth noticing that though the dietary items of the three groups were more or less same, there was conspicuous variation in the percentage of occurrence of different food items. Indeterminates showed more affinity towards animal matter than both the sexes. While in both male and female the affinity towards the plant matter was almost same.

Monthly variation in the gut contents confirmed that indeterminates and both the sexes have identical feeding habits, more or less consuming the same food items, but the extent to which each dietary item consumed was different. It was very glaring that the greater portion of the diet consisted of plant matter during all the months of the year. It appeared that among the three major groups of food items such as semidigested plant matter, filamentous algae and diatoms, a decrease in any of the category was duly compensated by another group.

The feeding intensity of the fish was found to be very high. During few months in both the years studied full gut was found as the dominant category in both sexes, which indicates the voracious feeding nature of this species. Gastrosomatic index showed an inverse relationship with the occurrence of empty guts. Feeding intensity of fish was related to maturity, spawning and the availability of food items (Malhotra, 1967;Khan *et al.*, 1988;Gowda *et al.*,1988;Keshava *et al.*,1988;Geetha *et al.*,1990;Das and Goswami,1997; Rao *et al.*,1998;Kiran and Waghray,1998;Pandian and Rahman,1999).It appears that in *P.carnaticus* the rate of feeding was very much influenced by the reproductive cycle. Feeding intensity was found to be less during the pre-spawning and spawning periods in females as indicated by the low gastro-somatic index and low degrees of gut fullness. Higher feeding intensity observed during the periods of May-June and September, might be attributed to the occurrence of (a) spent fishes which tried to make good the loss caused by the reduced rate of pre-spawning feeding and (b) presence of immature individuals which require a rigorous feeding for the ensuing vitellogenesis for the subsequent breeding season. When compared to females the feeding intensity of males didn't show much variation during pre-spawning and spawning periods. The low pre-spawning feeding intensity seen in females might be due to the pressure exerted on the alimentary canal by the voluminous ovary whereas in males, the testes do not grow much in size. But it appears that there exists a feeding rhythm in both males and females. A period of high feeding activity was found to alternate with a period of low feeding. Lagler *et al.* (1952) had suggested that feeding pattern of fishes is influenced by a number of factors such as light intensity, time of day, season, temperature, salinity, pH and any internal rhythm that may exist. Perhaps there might be an internal rhythm that acts in someway to bring about the alternate high and low feeding pattern shown by *P.carnaticus*.

Gastro-somatic index indicated higher percentage of feeding among females than males and indeterminates. Generally females consumed more food than their male counterpart. Higher feeding intensity in females when compared to males had been reported by Pandian and Rahman(1999) in *Etroplus suratensis*. Influence of feeding intensity on condition factor was clearly evident during some of the months in both the sexes of *P.carnaticus*. (This aspect has been dealt within detail in Chapter 9 on 'Length –Weight relationship and condition factor').

The present study revealed that *Puntius carnaticus* is an omnivore, showing more preference towards plant materials as food. Presence of sand and detritus in the gut content indicates the bottom feeding habit of the species. Based on the results of the present study it can be concluded that it would be possible to develop *P.carnaticus* as a substitute for grass carp in composite culture since this species is having the rare distinction of voracious feeding on vegetation, other plant matters, leaves, stem, roots, fruits and seeds mostly seen in the fringes of the rivers. Since this species is categorized under endangered category, its germplasm needs to be protected and conserved by utilizing in the culture basket so easily and rehabilitation of streams through aquaranching. Development of captive breeding technique was found to be an immediate prerequste for the implementation of the above programme.

Table 8.1.Index of preponderance value of different food items in the gut of *Puntius carnaticus*

Food items	2001-02	2002-03	Pooled
Semidigested plant matter	67.13	67.24	67.19
Filamentous algae	12.99	13.96	13.48
Bacillariophyceae	8.60	8.84	8.72
Semidigested animal matter	5.95	6.34	6.15
Seeds	2.82	1.30	2.06
Miscellaneous	2.42	2.28	2.35

Table 8.2.Monthly Index of Preponderance values of different food items in males of *Puntius carnaticus* during 2001-02

	April	May	June	July	August	September	October	November	December	January	February	March	Average
No. of specimens	11	19	15	20	17	8	6	9	6	11	9	10	12
Food items							Index of preponderence						
Semidigested plant matter	68.1	65.4	66.2	70.1	65	64.3	66.5	69.8	65.4	67.6	66.2	71.4	67.17
Filamentous algae	12.86	13.9	11.4	12.8	14.6	12.1	14.2	11.7	12.8	11.2	12.2	11.9	12.64
Bacillariophyceae	7.1	6.4	5.9	4.5	8.3	9.7	10.6	9	10.1	8.7	9.5	8.7	8.21
Semidigested animal matter	5.63	8.4	7.3	6.3	5.2	6.9	4.5	5.2	4.7	5.6	5.7	4.7	5.84
Seeds	4.54	3.5	5.8	4.7	4.4	4.4	3.9	3.6	3.4	4.8	4.2	2.9	4.18
Miscellaneous	1.77	2.4	3.4	1.6	2.5	2.6	0.3	0.7	2.6	2.1	2.2	0.4	1.88

Table 8.3.Monthly Index of Preponderance values of different food items in males of *Puntius carnaticus* during 2002-03

	April	May	June	July	August	September	October	November	December	January	February	March	Average
No. of specimens	10	13	9	11	15	8	9	5	7	12	9	13	10
Food items						Index of preponderence							
Semidigested plant matter	67.4	65.1	66.9	68.4	66	65.1	67.4	68.2	67.6	67.1	65.9	70.6	67.14
Filamentous algae	13.7	15.4	14.8	12.6	12.9	14.3	13.9	15.7	14.3	15.2	15.7	12.4	14.24
Bacillariophyceae	8.2	7.7	9.6	8.9	8.2	8.8	7.5	9.2	8.6	9.2	7.6	9.8	8.61
Semidigested animal matter	4.9	5.1	4.7	6.5	7.1	6.4	5.6	5.4	6.3	5.4	6.2	5.7	5.78
Seeds	3.7	3.2	2.1	-	2	3.9	2.4	-	1.3	-	1.8	-	1.70
Miscellaneous	2.1	3.5	1.9	3.6	3.8	1.5	3.2	1.5	1.9	3.1	1.8	1.5	2.45

Table 8.4.Monthly Index of Preponderance values of different food items in females of *Puntius carnaticus* during 2001-02

	April	May	June	July	August	September	October	November	December	January	February	March	Average
No. of specimens	6	5	9	7	10	5	3	3	2	5	4	7	6
Food items						Index of preponderence							
Semidigested plant matter	68.2	70.3	66.4	63.2	66.7	62.8	69.3	67.8	66.2	67.4	68.2	68.6	67.09
Filamentous algae	13.8	14.2	11.1	14.7	12.5	13.7	15.1	12.8	11.3	14.2	12.8	13.9	13.34
Bacillariophyceae	8.5	7.9	9.7	8.3	9.2	10.6	8.7	9.3	8.6	9.3	8.7	9.2	9.00
Semidigested animal matter	4.6	4.2	7.3	6.5	7.7	6.9	5.5	6.4	5.8	6.2	5.4	6.1	6.05
Seeds	1.7	-	2.1	-	-	2.8	1.4	1	2.4	2.3	3.9	-	1.47
Miscellaneous	3.2	3.4	3.4	7.3	3.9	2.2	-	2.6	5.7	0.6	1	2.2	2.96

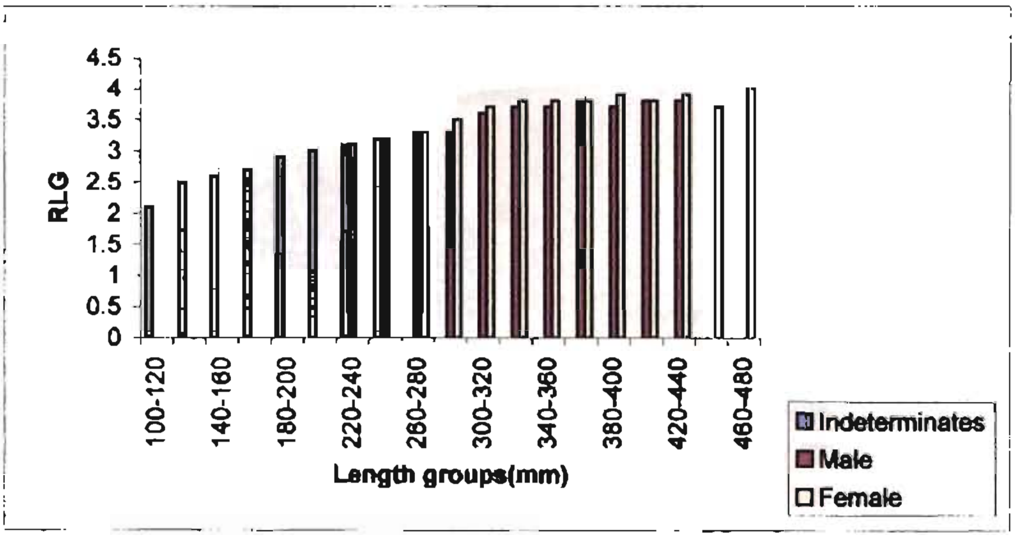
Table 8.5.Monthly Index of Preponderance values of different food items in females of *Puntius carnaticus* during 2002-03

	April	May	June	July	August	September	October	November	December	January	February	March	Average
No. of specimens	9	11	8	9	13	5	5	4	5	4	4	7	7
Food items						Index of preponderence							
Semidigested plant matter	67.1	66.2	68.7	69.3	65.1	67.6	64.2	70	65.6	66.4	68.7	69.2	67.34
Filamentous algae	12.6	15.3	12.4	14.4	14.9	14.5	13.7	12.8	11.7	14.5	14.9	12.4	13.68
Bacillariophyceae	9.5	10.6	9.8	7.7	8.6	9.2	8.2	9.3	10.8	9.2	7.8	8.2	9.08
Semidigested animal matter	5.2	7.4	6.5	5.9	7.3	6.9	7.1	6.5	7.6	8.3	7.1	7	6.90
Seeds	2.8	-	0.9	2.4	-	-	4	-	-	0.6	-	-	0.89
Miscellaneous	2.8	0.5	1.7	0.3	4.1	1.8	2.8	1.4	4.3	1	1.5	3.2	2.12

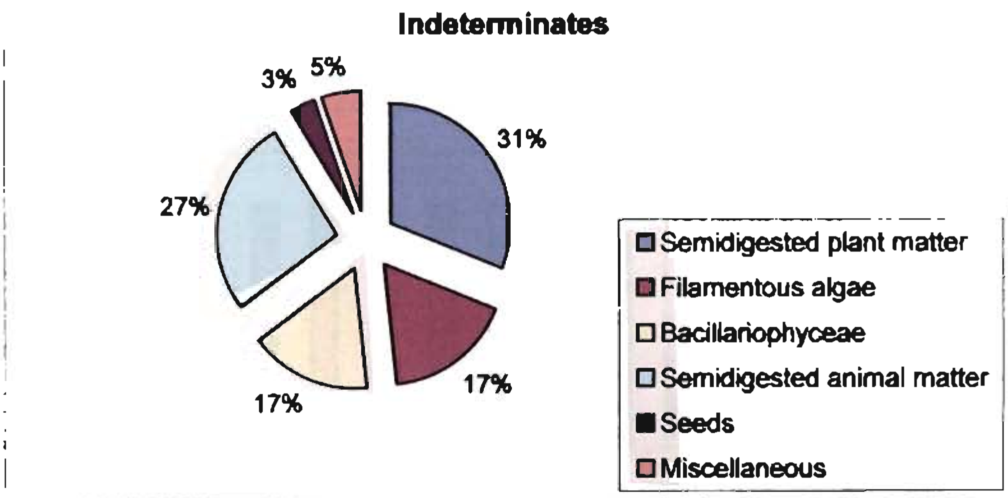
Table 8.6.Index of Preponderance values for different food items in indeterminates of *Puntius carnaticus* from April 2001 to March 2003

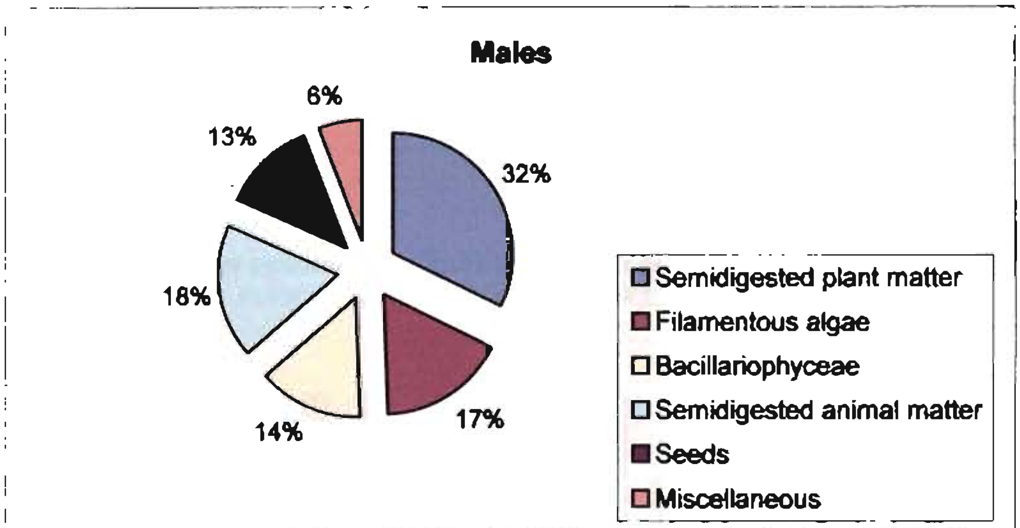
Food items	% Volume	% Occurrence	ViOi	ViOi/Σ ViOi
Semidigested plant matter	37.1	53.5	1984.85	71.9
Filamentous algae	20.16	20.1	405.23	14.7
Bacillariophyceae	16.5	15.3	252.45	9.1
Semidigested animal matter	12.5	7.2	90	3.3
Seeds	8.3	3	24.9	0.9
Miscellaneous	5.44	0.9	4.9	0.1
Total	100	100	2762.33	100

Fig.8.1.Variation in relative gut length in different length groups of *Puntius carnaticus*



.8.2.Diet composition of indeterminates,males and females of *Puntius carnaticus* (Pooled for 2001-02 and 2002-03)





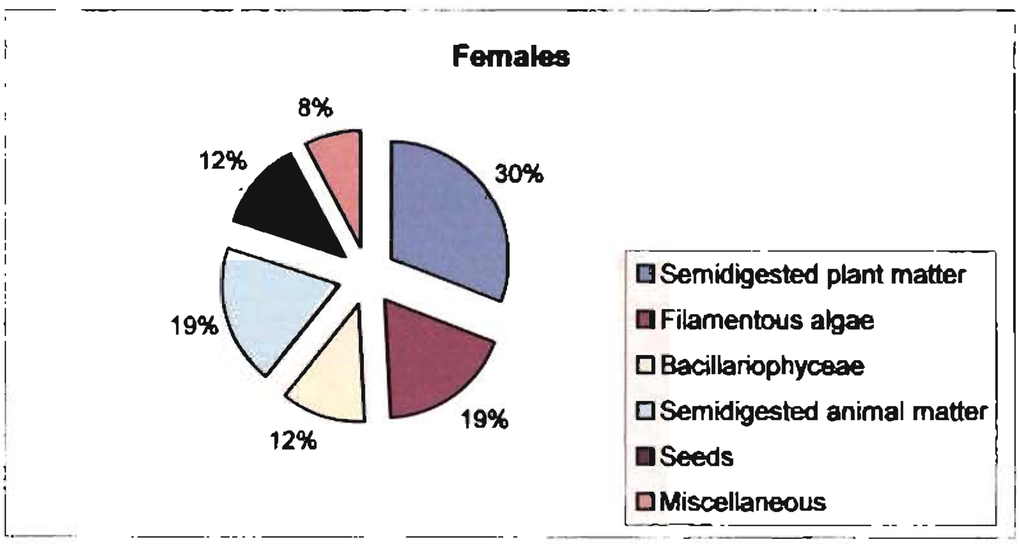


Fig.8.3.Percentage occurrence of guts in different degrees of fullness in females of *Puntius carnaticus* during April 2001 to March 2002

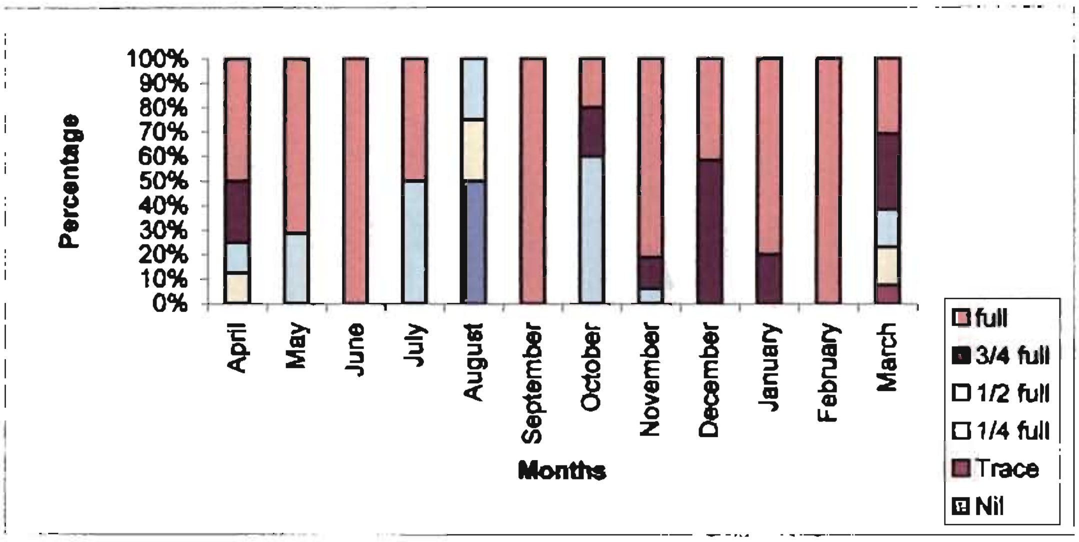


Fig.8.4.Percentage occurrence of guts in different degrees of fullness in males of *Puntius carnaticus* during April 2001 to March 2002

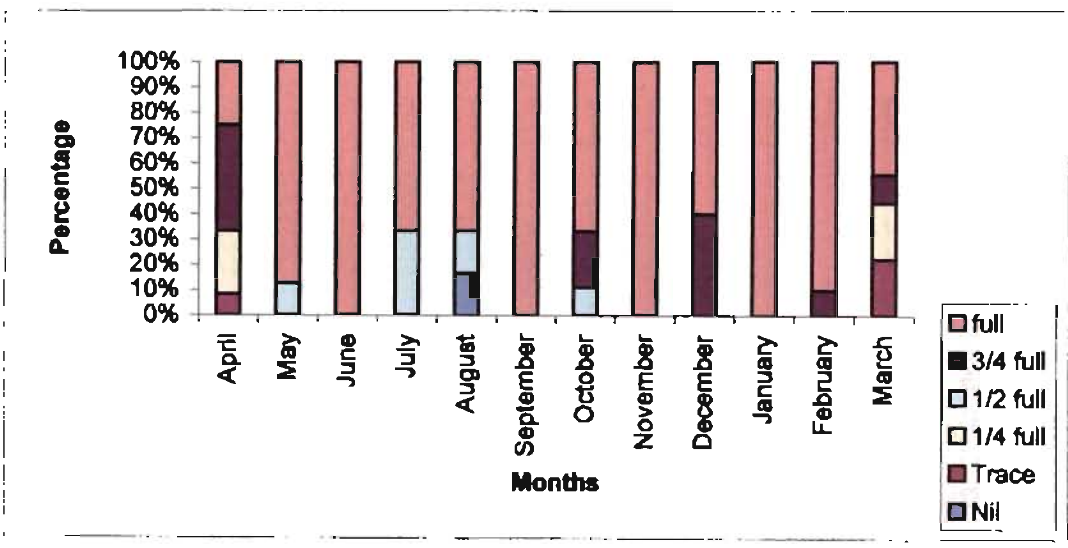


Fig.8.5.Percentage occurrence of guts in different degrees of fullness in females of *Puntius carnaticus* during April 2002 to March 2003

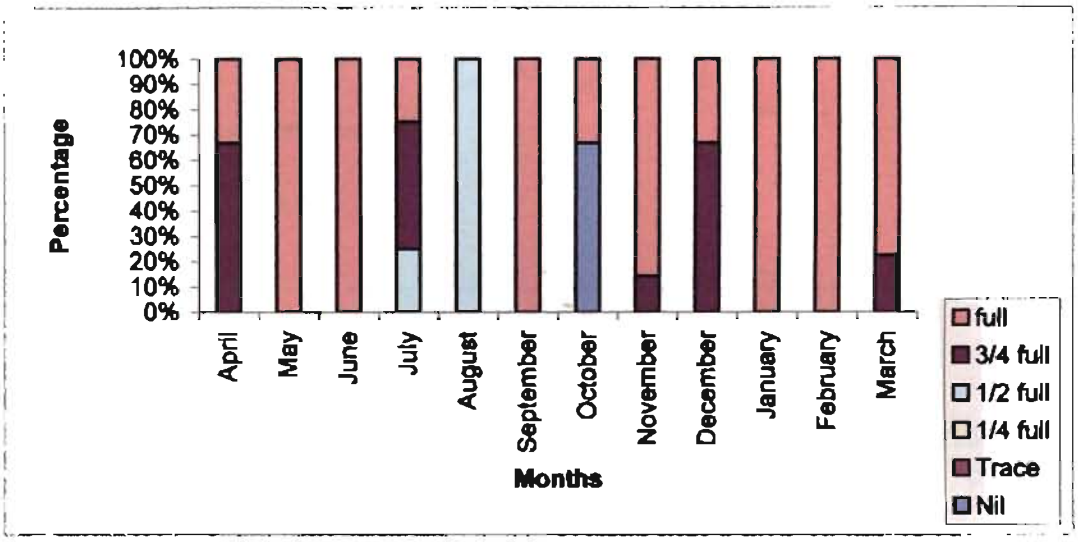


Fig.8.6.Percentage occurrence of guts in different degrees of fullness in males of *Puntius carnaticus* during April 2002 to March 2003

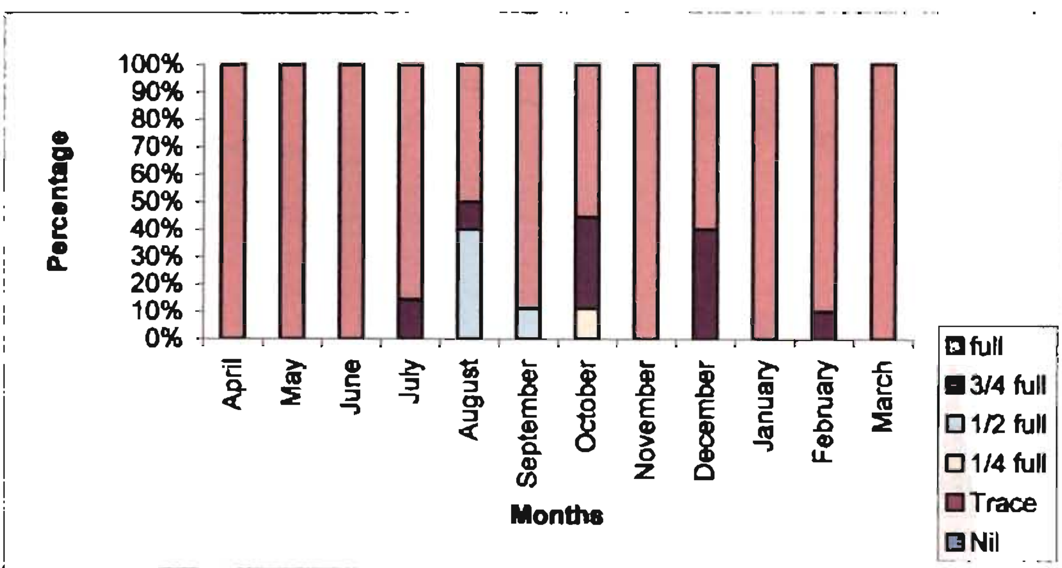


Fig.8.7.Monthly variation in gastrosomatic index of males of *Puntius carnaticus*

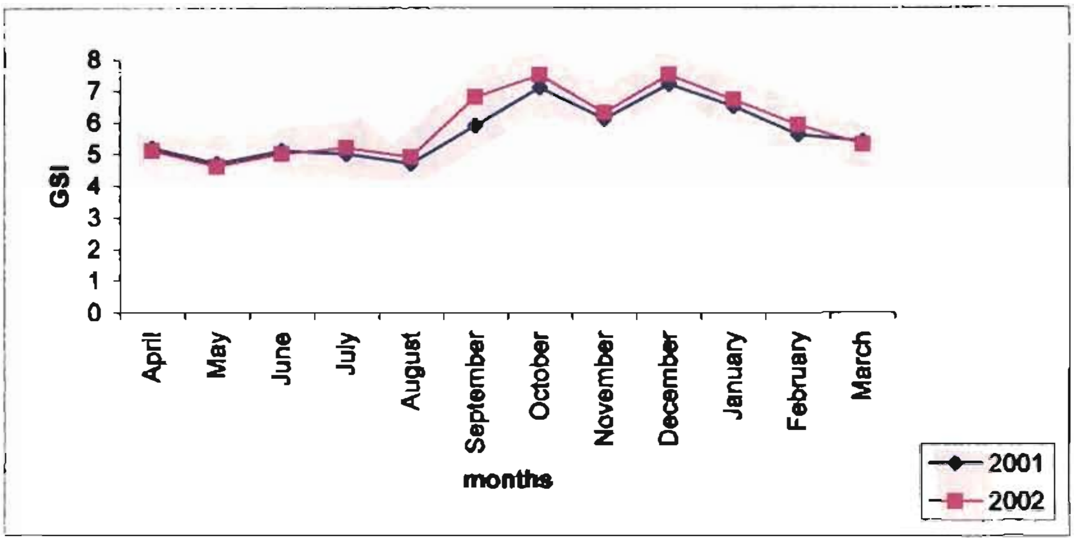


Fig.8.8.Monthly variation in gastrosomatic index of females of *Puntius carnaticus*

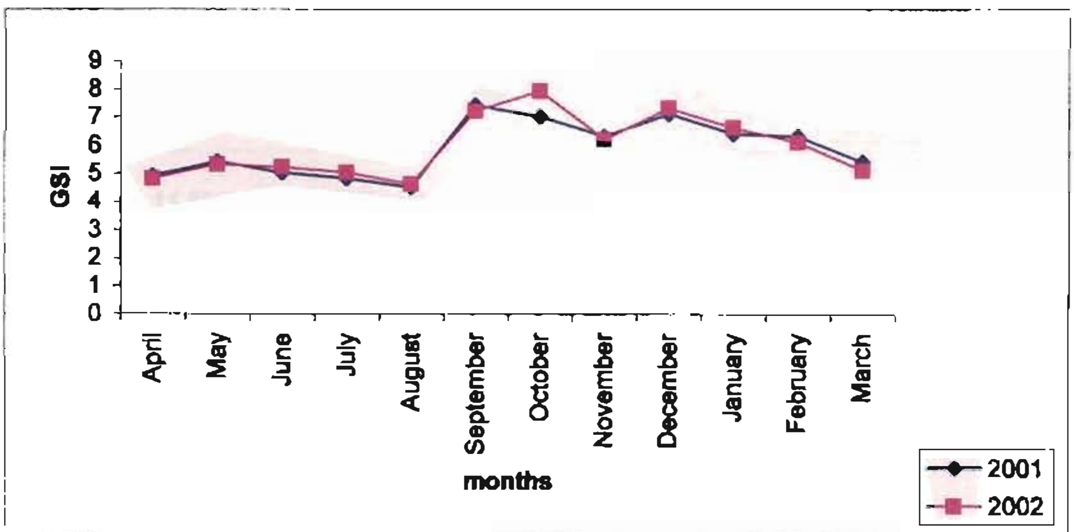


Fig.8.9.Lengthwise variation in gastrosomatic index of *Puntius carnaticus*

Fig.8.9.Lengthwise variation in gastrosomatic index of *Puntius carnaticus*

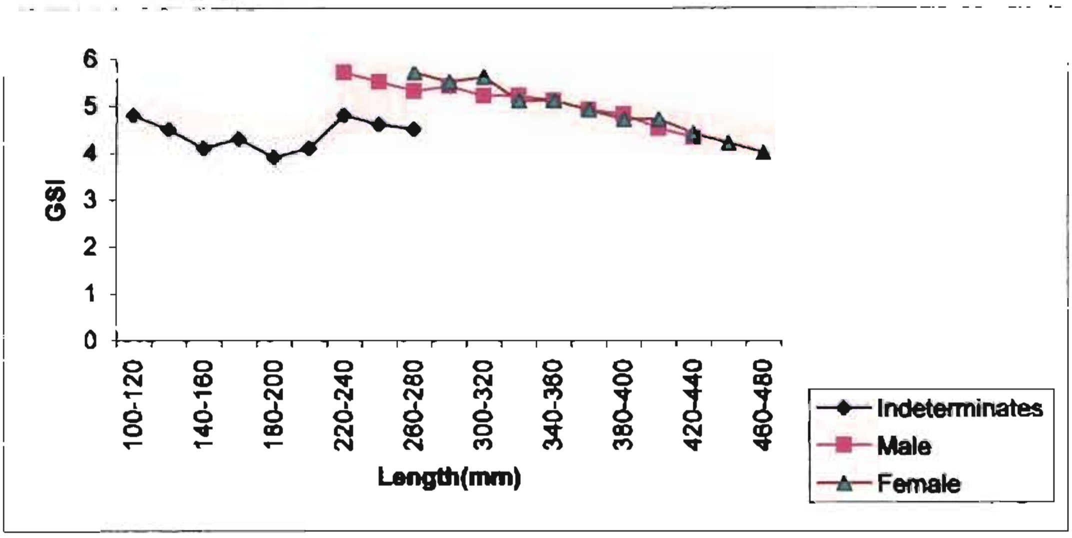


Fig.8.10.Monthly variation in gastrosomatic index of *Puntius carnaticus* during April 2001-March 2002

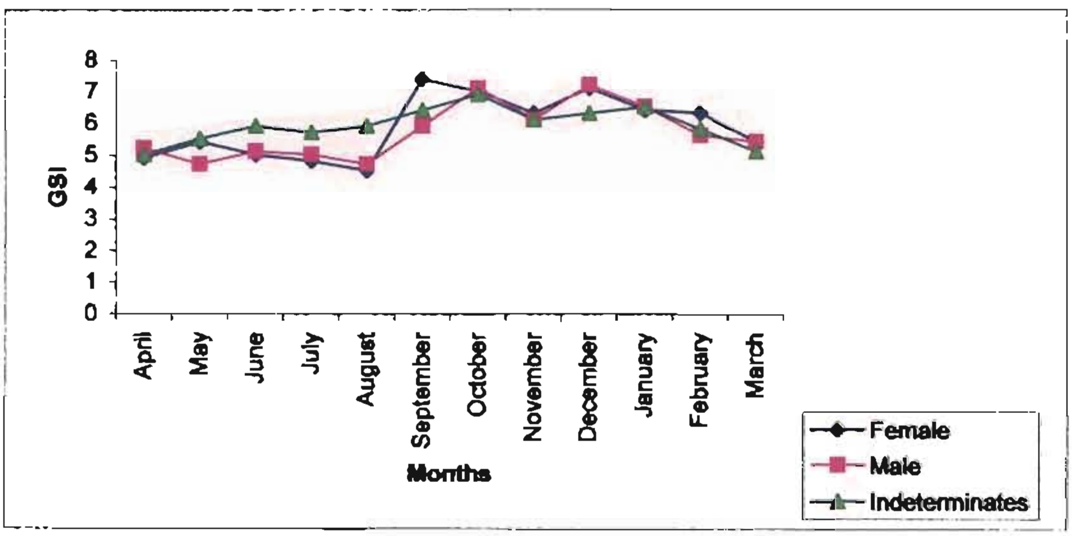
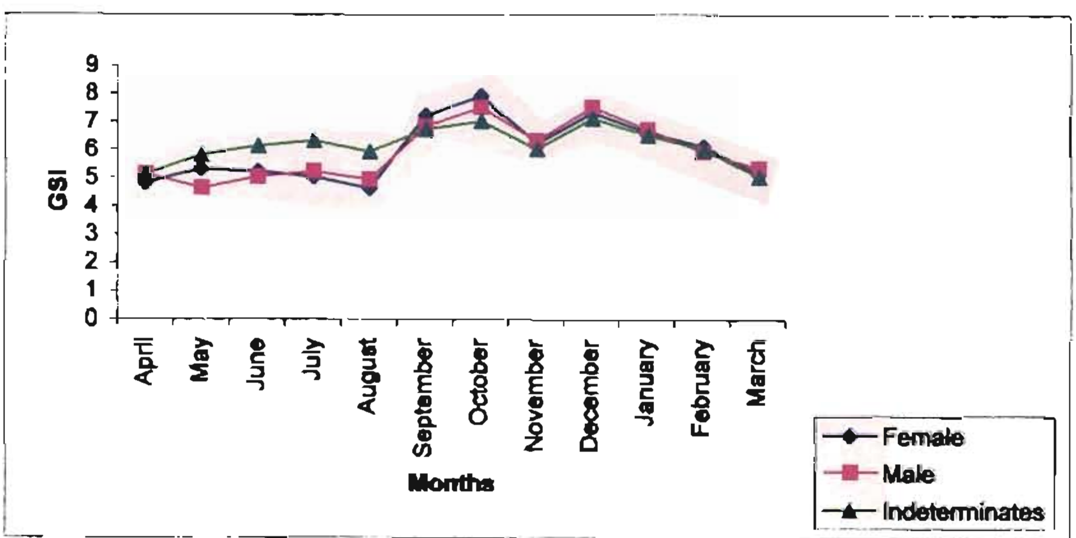


Fig.8.11.Monthly variation in gastrosomatic index of *Puntius carnaticus* during April 2002-March 2003



Chapter 9

Maturation and Spawning

9.1. Introduction

Every living organism has immense power of reproduction and recruitment. Under favorable conditions tremendous increase in their number may lead to population explosion. However, this does not happen in nature because right from the beginning of gametogenesis to the attainment of maturity, there are several factors adversely affecting organism in different stages of reproduction and growth and majority of the off-springs perishes before reaching maturity. During recent past, the natural and antropogenic stresses have been bringing about drastic reduction in the population of many fish species, even leading to the endangerment of some of them. If any fish species is to be managed, conserved and exploited scientifically, a thorough knowledge on the various intricacies of reproduction is of paramount importance. Qasim(1973), while explaining the importance of studying the maturation and spawning of fishes, has stated that the main purpose of such studies is to understand and predict the biological changes undergone by the population as a whole during the year. Information on related aspects such as ecological conditions which lead to the synchronization of maturity and breeding activity in males and females, size at first maturity, breeding migration, sex ratios, sexual dimorphism, fecundity, etc, are having immense application for the conservation and management of fish stocks and also for developing captive breeding techniques and undertaking aquaculture programmes. Size at first maturity is the prime factor in determining the size at first capture of the natural population. Each fish should be given a chance to contribute to the population by breeding at least once in their lifetime. So also, the over exploitation of immature juveniles will reduce the size of breeding population which would, in turn, lead to the decline of population size in the near future. A precise knowledge on the maturity stage, breeding period, fecundity in relation to size/ age is of great practical utility in fish culture programmes for proper planning of successful hatching and nursery operations. The number and size of broodstock to be maintained for achieving a certain set target of fish seed production calls for a knowledge of the fecundity of the species in question (Varghese, 1973). Fecundity studies have been considered useful in tracing the different stocks or populations of the same species of fish in different areas (Gupta, 1968). Extreme variations in all aspects of breeding are exhibited by fishes and hence species-wise information is ineludible before venturing into seed production in aquaculture or conservation of natural fauna. The knowledge on the maturing time, breeding migration, breeding grounds and aggregation assume importance in various fishery regulation and conservation programmes. Information on breeding habitats and breeding migration helps in identifying habitats that require conservation and declaring them as aquatic sanctuaries (Anon, 2001).

Reproductive capacity provides the rate of replenishment of the stock, which is very essential for the sustenance of fish species and its abundance. The reproductive capacity is an adaptation, which ensures the survival of the species under the conditions in which it is originated and survives. A study on fecundity is essential from the viewpoints of regeneration, stock recruitment relationships and stock assessment in any water body (Nautiyal and Lal, 1985). In recent decades much attention has been given by research workers on the gonadal cycle, reproductive physiology and induced breeding of many species of freshwater fishes from Indian waters (Simpson, 1951; Pillay, 1958;Begenal, 1957,1978;Sarojini, 1957;Das, 1964;Varghese, 1973,1976;Chondar, 1977;Nautiyal and Lal,1982 ;Kurup and Kuriakose,1994).

A review of literature showed that hitherto no information is available on the reproductive biology of *P.carnaticus*. Hence, a pioneer attempt was done in this direction to delineate various aspects related to the maturation and spawning of *P.carnaticus* such as size at first maturity, breeding season, breeding migration, sex ratios, fecundity, etc.

9.2. Materials and methods

The study was based on 508 specimens of *B.carnaticus*, 262 males and 150 females ranging in total length from 232mm to 430 mm and 270 to 472mm respectively and weight between 292g to 1120g and 348g to 1750g in males and females respectively. Fortnightly sampling of fishes were done from the commercial landings at Peringalkuthu region of Chalakudy river system (Kerala, S.India) during April 2001 to March 2003. The specimens were preserved in 8%formalin after making some perforation in the vent region and brought to the laboratory for further investigation. After removing the excess water by blotting, total length, standard length, total weight and colour of the fishes were recorded. Fishes were then dissected out to identify the sex and the condition of the gonad. Gonads were taken out and their length and weight were recorded to the nearest millimeter and milligram respectively following Kurup and Kuriakose (1994). After assessing the stage of maturation, the ovary was preserved in 4% formalin for ova diameter and fecundity studies. The spawning season was delineated on the basis of: (1) quantification of maturity stages, (2) the monthly percentage occurrence of fish with gonads in different stages of maturity, (3) pattern of progression of ova during different months and (4) variation in gonadosomatic index. Based on the scheme proposed by Qayyum and Qasim (1964 a,b,c) and Qasim(1973), the testis and ovary were grouped under five maturity stages. Quantification of maturity stages was done following morphological characteristics of the gonad such as appearance, colour, degree of distension, relative space occupied in the body cavity and ova diameter measurement. To trace the development of ova, ova diameter was measured from ovaries belonging to all the five stages of maturity, following the method of Clark (1934). A total of 150 ovaries in different stages of maturation were examined. Altogether 300 ova with 100 each from the anterior, middle and posterior region of each ovary were taken for ova diameter study. Measurements of ova diameter were taken by an ocular micrometer, which was calibrated using stage micrometer. Each ocular micrometer division was equal to 0.014 mm. Ova measurements were classified into groups of 0.1mm intervals and the monthly percentage frequency of each size group was calculated and the prominent mode recorded. Immature oocytes (0.5 to 0.8mm) were present in varying proportions all the year round and they were not considered while preparing the percentage frequencies.

Gonadosomatic index (GSI) was calculated month-wise, applying the formula of June(1953) and Yuen(1955)

$$GSI = \frac{\text{Weight of gonad}}{\text{Weight of fish}} \times 100$$

The percentage occurrence of males and females in 3 to 5 stages of maturity in different length groups of the fishes examined was plotted to calculate the length at first maturity. The length at which 50% of the fishes attained maturity was taken as the minimum length at first maturity (Kagwade, 1968; Geevarghese and John, 1983; Kurup, 1994). Sex-ratio data was analyzed month wise and size-wise. Chi-square formula (Snedecor and

Cochran, 1967) was employed to test whether the observed ratio between males and females deviated from the expected 1:1 ratio for the two sexes using the formula:

$$X^2 = \frac{(O-E)^2}{E}$$

Fecundity was estimated on the basis of 35 ripe ovaries of *P. carnaticus* in the length range of 274mm to 472 mm. Sub samples from the anterior, middle and posterior regions of the ovary were weighed and the number of ova in each sub-sample was counted manually. Fecundity was estimated by the gravimetric method, applying the formula:

F= NG/g where F= Fecundity

N= number of eggs in the sub-sample

G=Total weight of the ovary

G= weight of the subsample

Fecundity indices such as the number of ova produced per gram weight of the body or relative fecundity (Bagenal, 1963), the number of ova produced per gram ovarian weight, the ovarian weight as percentage of total fish weight or the coefficient of maturity (Bagenal and Braum, 1968) and the gonadosomtic index or the ovarian weight in relation to the fish weight excluding the ovary weight (Somavanshi, 1985) were worked out. Regression analysis was employed to find out the correlation between fecundity and various body parameters such as total body length, total body weight, ovary length and ovary weight and also between ovary weight and parameters such as total body length and total body weight.

9.3. Results

As in most teleosts, the gonads in the males and females of *P.carnaticus* are paired, elongated structures lying on the side of the air bladder ventral to kidneys. The ovary is attached to the dorsal wall of the body cavity by the mesovarium and the testes by means of mesoarchium. Posteriorly, the two lobes of the ovary unite to form a short oviduct, which opens to the exterior by the genital aperture. The testes communicate to the exterior through the genital aperture via the sperm duct.

Stages of maturation

The following stages of maturation were identified in the males and females of *P.carnaticus*

Degree of Maturation	Description
Immature virgins	**Ovaries**: Slender, elongated jelly-like, flesh coloured, occupy a little more than ¼ of the body cavity. Ova invisible to the naked eye. **Testes**: Extremely thin, thread-like, translucent, occupy nearly 1/5 of the body cavity
Maturing virgins/ Recovered spents	**Ovaries**: Somewhat flattened pale yellow, occupy ½ of the body cavity

Testes: Opaque, firm, white, occupy nearly 1/3 of the body cavity.

Ripening **Ovaries**: Slightly cylindrical, yellow. Opaque, occupy ¾ of the body cavity, the inner side slightly depressed to accommodate the gut. Usually asymmetry observed between the two lobes of ovary.

Testes: Creamy white, lobulated with irregular outer margin, occupy ½ of the body cavity.

Ripe **Ovaries**: Considerably enlarged, occupy nearly the entire length of the body cavity, golden yellow in colour, distended outer membrane, loosely arranged and clearly visible mature and ripe ova having a diameter ranging from 1.4-1.8.The ovary is highly vasculated with rich blood supply.

Testes: Very soft, cream coloured, occupy more than ¾ of the body cavity

Spent **Ovaries**: Shrunken, flaccid, blood shot, translucent, occupy a little more than ½ of the body cavity. Few residual eggs, which are in different stages of maturity were observed.

Testes: Shrunken, flabby, partly opaque and partly semitransparent occupy less than ½ of the body cavity.

9.3.1. Monthly percentage occurrence of fish with gonads in different stages of maturity

The monthly percentage occurrence of males and females in different stages of maturity during 2001-02 and 2002-03 are shown in Fig.9.1and 9.2 respectively. In males the immature individuals (Stage I) appeared from August onwards and reached the maximum in October and were contributed 95.7% in 2001-02 and 100% during 2002-03.After October the stage I individuals showed a sharp decline and after December their presence in the catch was not observed. Recovering spent (Stage II) fishes started to appear in the catch from November onwards and reached a peak during December with a contribution of 72.7% during 2001-02 and 77.4% in 2002-03.From January onwards the recovering spent individuals showed a sharp decline. Fishes with gonads in stage III or ripening individuals appeared in the catch from December onwards and reached the peak during February and contributed to 51.6% in the catch during 2001-02 and 48.3% during 2002-03. Ripe (stage IV) individuals were available in the catch from March onwards and reached the peak during May in 2001-02 and July in 2002-03, contributed to 81.6% and 75.3% respectively. Spent (stage V) fishes were present from May onwards and reached the peak during August and showed their presence in the catch upto September.

In females the immature (stage I) individuals appeared in the catch from August to December and reached the peak during October with a contribution of 90.1% in 2001-02 and 92.8% during 2002-03.Maturing virgins or fishes with gonads in Stage II appeared in the catch from October onwards and reached the peak during December with a contribution of 72.5% during 2001-02 and 69.4% during 2002-03.After March, maturing virgins were not observed in the catch. Ripening (Stage III) fishes appeared in the catch from December onwards and reached the peak during February with a contribution of 88.2% during 2001-02 and 85.5% in 2002-03.Fishes with gonads in stage III condition showed their presence in the catch till June. Ripe (Stage IV) fishes appeared in the catch from March to August and reached its peak during March with a contribution of 75.8% during 2001-02 and 83.2% in 2002-03. From April onwards the ripe females showed a decline and reached the second minor peak during July with a contribution of 74.9% during 2001-02 and 74.6% in 2002-03.Spent (stage V) fishes appeared in the catch from March to September and reached the peak during August with a contribution of 92.1%during 2001-02 and 94.9% in 2002-03

9.3.2. Pattern of progression of ova during different months

The pattern of progression of ova during November to August is depicted in Fig.9.3.All the ova less than 0.8mm diameter were immature. The next group of ova between 08-1.00mm was identified as maturing ones. The ova in the range between 1.00-1.39mm were belonged to the ripening eggs. Ova measuring 1.4mm and above were in fully ripe condition. The development of ova during different months showed the preponderance of immature and maturing ova during November and December. Oocytes up to 1.17mm were appeared in January with a major mode at 0.8-0.9mm.Thereafter; the progression of ova was very rapid with the result that ripening oocytes were very prominent with the mode shifting to 1.00-1.1mm in February. In March the ova diameter ranged between 0.8-1.6 with a major mode at 1.4-1.5mm and minor mode at 1.00-1.1mm ova diameter. During April and May the ova diameter ranged between 0.9-1.8mm size class and the ripe ova contributed to 75% and 70% respectively during both the months. During June and July only ripening and ripe eggs having a diameter ranged between 1.14-1.77mm were observed in the ovary. In August only ripe eggs having a diameter of 1.42-1.78mm were identified from the ovary.

During January to August wide range of ripening and ripe eggs having 1.04-1.78mm diameter were observed in the ovaries in varying proportions. Largest oocytes having the diameter ranged between 1.7-1.8mm were encountered during the months of April, May, June and August. While ripening oocytes were dominated only in February.

9.3.3. Gonadosomatic index

The mean monthly variation of gonadosomatic index (GSI) values of males and females during April 2001 to March 2003 are depicted in Fig.9.4 and 9.5respectively.During 2001-02, the testicular weight started increasing from September (0.72) and attained the peak in July (3.9). Thereafter the GSI showed a drastically declining trend. The trend was more or less the same during 2002-03 except for the variation in the values. Females showed distinct seasonality in GSI values similar to those of males. Index values which were lowest in September (1.26) steadily increased and attained peak in July (7.1) during 2001-02.The GSI value showed a declining trend from August onwards and reached the lowest level during September. During 2002-03 also, the females exhibited similar trend but for the highest GSI recorded in March.

9.3.4. Length at first maturity

Occurrence of males and females at different stages of maturity in various size groups are shown in Table 9.1 and 9.2 respectively. Fig.9.6. represents the relation between maturity and length of the male and female *B.carnaticus*. It appeared that in females, specimens up to 270mm total length and in males specimens up to 231mm were belonged to immature and maturing fishes. The percentage of ripening fishes increased rapidly up to 290mm TL in males and 310mm TL in females beyond which there was a sudden increase in the occurrence of fishes with ripe gonads. The smallest ripe male belonged to the 231-250mm TL size group while the smallest ripe female belonged to 271-290mm TL group. The length at which 50% of the specimens attained maturity, taken as the mean length at which maturity is attained (Kagwade, 1968), were 280mm and 318mm for males and females respectively. Thus males were found to mature at a lower size than their female counterpart.

9.3.5. Sex ratio

Altogether 882 specimens were examined in the laboratory to determine the sex-ratio. Due to the absence of sexual dimorphism in *P.carnaticus*, the fishes were sexed by internal examination. Out of the 508 specimens examined, 262 were males, 150 females and the remaining 470 indeterminates. The month wise distribution of the two sexes (Table 9.3) revealed that the sexes were disproportionate in the population. Males outnumbered the females in almost all months during 2001-02.Chi-square test confirmed the significant dominance of males during 2001-02(Table 9.3). During 2002-03, the preponderance of males in all months except March was glaringly evident from the chi-square values. During March the females showed significant dominance in the population (Table 9.3). Though there was considerable variation in the distribution of the sexes in some of the months of both the years, the overall sex ratio showed significant dominance of males ($P<0.003$). The mean ratio of males to females was 1:0.61for the year 2001-02 and 1:0.7 for 2002-03 and the respective chi-square values of 104.42 and 86.18 lend to support to the above observation that the sex ratio significantly skewed from the expected 1:1 ratio ($P<0.01$).

Table 9.4 shows the variation in sex ratio among the various size groups. Males were predominating up to 310mm TL and thereafter the percentage occurrences of males were reduced and females showed much higher contribution in the fishery. Beyond the 390mm TL, females dominated in the fishery. Chi-square values indicated that there was significant variation from 1:1 ratio in the size groups between 271 and 430mm TL. The chi-square value of 59.02 for the overall sex ratio showed that the variation was highly significant ($p<0.01$).

9.3.6. Fecundity

The average values of fecundity indices of *P.carnaticus* are given in Table. 9.5. Relationship of fecundity with total body length, body weight, ovary length and ovary weight were worked out by regression analysis and the results are depicted in Fig.9.7 – 9.10. Fig.9.11and 9.12.represent the regression of ovary weight on total body length and body weight.

9.3.6.1. Fecundity indices

The absolute fecundity varied from 2763-14071 eggs in specimens ranging from 216.83 – 445mm in total length and the average was worked out to be 5806 ova. The relative fecundity was estimated to be vary between 4(381.9mm TL) and 27(338.2mm TL) with an average of 17, while the number of ova per gram ovarian weight varied between 144(367mm TL) and 329(278.1mm TL), with the average 222. The co-efficient of maturity showed higher values up to 331-350mm length group, thereafter a decreasing trend was noticed. Similarly, gonosomatic values also showed an increasing trend upto

311-330mm length group, thereafter a diminishing trend was observed. The coefficient of maturity and gonosomatic values varied between 3.6(371-390mm size group) and 5.8(331-350mm size group) and between 3.8(371-390mm TL) and 7(251-270mm TL) respectively.

8.3.6.2. Relationship between fecundity and body parameters

The relationship between total length (x) and number of ova (y) was calculated and the result is depicted in Fig.8.7. The regression equation after logaritamatic transformation of the variables can be expressed as follows:

Log F= 0.4266+1.3048 log TL; $r^2 = 0.22$

The degree of correlation indicates that the number of ova produced have a direct relationship with the length of the fish.

The logarithamatic relationship between fecundity and fish weight (Fig.9.8) was found to be

Log F=2.7132+0.3639 log W; $r^2 = 0.11$

which shows a linear relationship between them

Fecundity was related to the measurements of ovary, the ovary length (OL)(Fig.9.9) and ovary weight (OW)(Fig.9.10) which can be expressed as follows:

Log F =0.9366+1.340 log OL; $r^2 = 0.4$

Log F = 2.516+0.8532 log OW; r^2=0.62

The results indicate a direct proportional increase in fecundity with increase in length and weight of the ovary.

The regression equation of ovarian weight (OW) on body weight (TL)(Fig.9.11) and body length (W)(Fig.9.12) are given below.

Log OW = -0.5098+0.7011 log W; r^2 = 0.49

Log OW = -3.21+1.8317 log TL; r^2 = 0.51

The results indicate a direct proportional increase in ovary weight with increase in total length and weight.

9.4. Discussion

The male and female reproductive organs of *P.carnaticus* are built on the general telestean pattern as observed in other teleosts. The paired testes in teleost fishes are either fused along the entire length or completely separate or fused posteriorly. In *P.carnaticus*, the testes are united at the posterior region to form a spermatic duct as reported in *Channa gachua*(Sanwal and Khanna,1972a).

Breeding season of fishes was ascertained by applying indirect methods such as quantification of maturity stages, monthly occurrence of gonads in different stages of maturity, monthly progression of ova towards maturity and seasonal variations in the gonadosomatic index. Results of the two years data have shown that as far as occurrence of gonads in different stages of maturity is concerned, females mature slightly earlier than males. During September, all fishes collected belonged to immature and maturing stages.

Thenceforth, majority of the fishes underwent ripening rapidly and by the end of December majority of the males and females were in the maturing virigin stage. At the end of February, most of males and females reached the ripening stage. From February onwards the maturation in males was a slow process and from the end of April onwards ripe males appeared in the population. While maximum number of ripe males appeared in the population during May. In the case of females, ripe fishes were observed in the population from March to August with a peak during March. Females showed strong oscillations in their occurrence from March to July. Though ripe individuals appeared in insignificant numbers during March, the presence of spent fishes was observed only by the end of April in females, which would suggest that actual spawning might have commenced in April. The fish might have completed its spawning by the end of August, as manifested by the total absence of spent fishes during October and November. Based on the results of the present study, it can well be concluded that *P. carnaticus* inhabiting Chalakudy river has a prolonged spawning period extending from April to August with a distinct peak during July –August.

It is well known that ova diameter measurements can give reliable evidence about the time of spawning and spawning periodicity of fishes. Clark (1934) made the first attempt to study the maturity of California sardine (*Sardina caerulea*) based on the size frequency of ova in the ripe ovary. This method has been successfully applied for delineating the spawning period of many Indian fishes by several authors (Prabhu, 1956;Qasim and Qayyum, 1961;Sathyanesan, 1962;Annigeri, 1963;Bhatnagar, 1967;Desai and Karamchandani, 1967;Qasim, 1973;Murthy, 1975;James and Baragi, 1980;Jayaprakash and Nair, 1981;Thakre and Bapat, 1981;Geeevarghese and John, 1983;Kurup, 1994).

In *P.carnaticus*, all the ova measuring 1.4mm and above were fully ripe while the group having diameter between 1-1.4mm were the ripening ones. Those falling below 1mm were adjudged as maturing and immature categories. From the appearance of largest oocytes of 1.75mm in fully ripe conditions in April, 1.73 in July and August, it can be reasonably concluded that this species starts spawning during April and this is in close agreement with the spawning season delineated for *P.carnaticus* in the present study. From the pattern of ova diameter frequencies arrived at different months, a distinct mode of 1.4-1.5mm size class were observed during March, April and May while during June, July and August, 1.5-1.6mm size class dominated in the ovary. During November and December the immature oocytes of 0.5-0.6mm size class showed their dominance in the ovary. While in January the predominance of 0.8-0.9mm size class was noteworthy whereas in February size class1.00-1.1mm showed their dominance. The results revealed that *P. carnaticus* has a prolonged spawning season with two peaks with former in April-May while the second one during July –August. The prolonged spawning may be atonement against the low fecundity of this species. The present finding is in corroboration with the findings of Nikolskii(1961) and Wootton(1984) who opined that multiple spawning is helpful in increasing the fecundity of fishes. A relatively long lasting spawning readiness which could explain the continuous presence of mature females has been previously reported by Alkins-koo(2000)while studying the reproductive timing of fishes in a tropical intermittent stream in West Indies.

Ova diameter of *P.carnaticus* indicated the presence of oocytes in varying maturity stages in the ovaries. The wide size range of mature ova with indistinct minor modes within the group of these mature ova would manifest the tendency of the fish for fractional spawning within the season. According to Nikolskii(1963), fractional spawning and prolonged spawning are characteristic of tropical and subtropical fishes and may not only be just an adaptation to increased food supplies, besides they also ensure the survival of the species under unfavorable spawning conditions. Fulton (1899) stated that the occurrence of large number of ova of different sizes between immature and ripe ones in mature fishes can be considered as an evidence of its prolonged spawning period. Norman (1931) reported that the actual rate of extrusion of ova will vary in different species. While in some species, majority of the eggs become ripe more or less at the same time whereas in others the process is comparatively slow and only a part of the ova ripen and are getting released at a time. According to Hickling and Rutenberg(1936), a single group of ova will get differentiated when the spawning is short and definite while in the case of long and indefenite spawning, no distinct separation exists between the general stock of eggs and the maturing eggs.

Marza (1938) described three categories of rhythm in the maturation of oocytes.(1)Total synchronism- all oocytes in the ovary develop synchronously as in *Onchorhyncus masou*(Yamamoto *et al.*,1959) (2) Group or partial synchronism-two groups of oocytes are distinguished indicating spawning once a year within a short and definite period as in *Clarius batrachus*(Lehri,1968).(3) Asynchronism –oocytes in different stages of development are present indicating a long spawning season with several spawning within the season as in *Schizothorax richardsonii*(Bisht and Joshi,1975).In *P. carnaticus*, different batches of oocytes continuously passing from one stage to other were observed and hence the fish exhibited asynchronism in oocyte maturation. As far as the duration of breeding season is concerned, Kramer (1978) suggested that it ranges from extremely brief (1-2 days) through moderately long (2-4 months) to continuous spawning. Prabhu(1956) treated the duration of 2-3 months as prolonged breeding season. Qasim and Qayyum(1961)stated that the breeding season is short when it lasts for about 2-4 months and relatively long when it lasts for 4-5 months and non-seasonal occurring over a greater part of the year. In *P. carnaticus,* breeding season lasts for 4-5 months and therefore, this species can be categorized under 'relatively long' following Qasim and Qayyum(1961).

The timing of annual spawning for each species inhabiting a particular niche has evolved to ensure that the young hatch and commence feeding in a season which is most conducive to their survival (Bye, 1984). Stancey(1984) reported that ovulation in most teleosts occurs rapidly in response to specific exogenous factors relevant to reproductive success. These factors include photoperiod, temperature, spawning substrate, visual and chemical stimuli, pH, turbidity of water and availability of food items. In Indian subcontinent, most of the freshwater fishes are reported to be monsoon breeders (Jhingran, 1982). The earlier reports of Khan (1945), Kulkarni(1950,1971), Khanna (1958), David(1959), Karamchandani(1961), Belsare(1962),Bhatnagar(1967), Parameswaran et al.(1972), Rao and Rao(1972), Khan and Jhingran(1975), Murty(1975), Sidiqui et al.(1976), Pathak and Jhingran(1977), Somavanshi(1980), Vinci and Sugunan(1981), Badola and Singh(1984), Shreshtha(1986), and Kurup(1994) lend support the above observation. Most of the factors triggering spawning in tropical fishes are supposed to be associated with onset of monsoon and flooding. Fishes are thought to be sensitive to the rising water levels (Alikunchi and Rao, 1951; Khanna, 1958; Kulkarni, 1971; Shreshtha, 1986). Habitat expansion in the rainy season leads to decreased crowding and predation pressure (Alkins-koo, 2000). Improved productivity and food availability (Hails and Abdullah, 1982) and optimum temperature (Qasim and Qayyum, 1961) during rainy season are the other reported factors influencing the spawning of freshwater fishes. Qasim and Qayyum(1961) stated that the breeding seasons in freshwater fishes are adapted to provide optimum conditions of temperature and shelter for the newly hatched fishes. The results of the present study indicate that the beginning of spawning in *P. carnaticus* coincided with the pre-monsoon showers; however, the juveniles would be present in the population at the time of peak flooding.

The maturation of germ cells in fish gonads is associated with an increase in the weight of gonad and this increase is expressed by the gonadosomatic index (GSI). However, the process of maturation is not exactly identical in males and females. In ovary, as the oocytes grow, they accumulate metabolites leading to an increase in their weight (Nagahama, 1983). GSI is indicative of fish spawning in temperate and tropical regions (Bouain and Sian, 1983; Biswas et al., 1984; Phukon and Biswas, 2002). GSI values of both males and females followed more or less the same trend. Low GSI values in September and October is concomitant with a period of early development of gonads and occurrence of spent fishes. The slightly high values observed from November to February reflected a diversity of gonad stages including a large number of maturing (II stage) and ripening (III stage) gonads. Comparatively high GSI values were encountered from March to August in both the sexes. The peak GSI values encountered during March and July in females while in males the peak GSI was registered during May and July. During spawning season, the GSI show a plummeting due to the release of the gonadal products. Hence breeding season ensues the months with maximal GSI. Reduced GSI in females is a consequence of release of ova from the ovary while in males, it may result from the combined effect of elimination of residual body followed by initiation of spermiation (Stoumboudi et al., 1993).In *P. carnaticus* , the sudden drop in the values in April and August is indicative of the onset of spawning season. The conclusion drawn earlier that

P. carnaticus spawns twice a year can be further be substantiated by the two peaks of GSI, the former in March and the latter in July.

Based on the occurrence of large number of ripe fishes and ripening individuals with advanced stages of oocytes in the ovary, the appearance of spent individuals, the presence of ripe ova and the high GSI values, it can reasonably be inferred that this species is reproductively active for 4-5 months (April-August) with the onset of premonsoon showers and towards the end of south west monsoon. Nath(1994) studied the spawning ecology of fishes in Jammu Province and observed that the cyprinids , *Labeo rohitha, L.calbasu* and *Cirrhinus mrigala* became ripe in May , however, spawning commenced only from the beginning of July with the onset of monsoon. Similarly, other related fishes such as *Chela, Salmostoma, Barilius, Danio, Chanda* and *Puntius* were reported to breed during the early part of the monsoon on the margins of ponds, lakes and rivers.

Prabhu(1956) classified fishes into 4 distinct groups on the basis of the spawning pattern.

Type A: Spawning taking place only once in a year during a definite short period. 2 batches of ova, mature and immature, are found in mature ovaries.

Type B: spawning taking place only once in a year but with a longer duration. The range in size of the mature ova will be nearly half of the total ranges in the size of the whole intra-ovarian eggs.

Type C: Spawning twice a year. Ovaries contain distinct ripe as well as maturing ova.

Type D: Spawning throughout the year but intermittently. Ovaries contain different batches of eggs which are not sharply differentiated from one another.

Qasim and Qayyum (1961), on the basis of ova diameter frequencies, classified fishes into 3 categories.

Category I: Fishes with a well-marked single batch of maturing eggs in their ovaries. Breeding occurs only once a year.

Category II: Fishes with more than one group of maturing oocytes. The breeding season is long.

Category III: Fishes with oocytes of all sizes ranging from the smallest to the largest without well-marked batches. They have non-seasonal breeding.

It would thus appear that *P. carnaticus* fits into Type 'C' of Prabhu(1956) and category II of Qasim and Qayyum(1961).*P.carnaticus* was found to breed twice in an year in the Chalakudy river with ovaries containing more than one group of maturing oocytes. The breeding season was observed to be moderately long.

Usually fishes attain maturity at a particular length of the individuals. The onset of maturity differs considerably inter-specifically as well as intraspecifically (Nikolskii, 1963). Information on the size of maturation is essential for avoiding over exploitation of immature juveniles and ensuring the spawning of the individual fishes at least once in life. The minimum size of maturity has been estimated earlier by several workers (Qayyum and Qasim, 1964a; Parameswaran *et al.*, 1972; Selvaraj *et al.*, 1972; Sobhana and Nair, 1974; Somavanshi, 1980: Nautiyal, 1984; Sunder, 1986; Kurup, 1994; Agarwal, 1996). In *P. carnaticus*, the males and females were found to be mature at 232 and 270mm respectively. Thus, males attain sexual maturity at a smaller length than the females. Similar observations had been reported in many freshwater fishes such as *Cyprinus carpio*(Parameswaran *et al.*,1972),*Labeo boggut*(Selvaraj *et al.*,1972)*Barbus sarana*(Murthy,1975), *Tor tor*(Chaturvedi,1976), *Labeo gonius*(Siddiqui *et al.*,1976a), *Labeo bata*(Siddiqui *et al.*, 1976b), *Noemacheilus triangularis*(Ritakumari and

Nair,1979), *Schizothorax longipinnis*(Sunder,1986) and *Labeo dussumieri*(Kurup,1994). The first appearance of ripe and spent individuals in 230-250mm size group in males and 270-290mm size group in females of *P.carnaticus* suggest that this roughly corresponds to the minimum size group at which the females and males attain ripeness and start spawning. It is a generalized fact that among fishes, males usually grow to a smaller size than females (Sivakami, 1982). In *P.carnaticus* also, females are larger in size. The maximum size of the males and females encountered during the present investigation is 430mm and 472mm respectively. The difference in the size at first maturity and the maximum size attained in the two sexes may be due to differential growth rate or due to the fact that females live longer and hence attain a larger size (Murthy, 1975).

A proper knowledge of sex ratio is important in the management of fishery. It indicates features such as the movement of sexes in relation to season, strength of spawning stock, catch composition, etc. Considerable variation was observed in the ratio of males and females of *P.carnaticus* in some of the months of two years. Murthy (1975) reported similar condition in *Barbus sarana* and opined that the contradictory values of the two years could be due to sampling variation or may reflect actual situation of sex ratio, which shows variation from year to year. However there, was a preponderance of males during almost all the months. This observation closely agreed with the findings of David (1954), Qayyum and Qasim(1964a) and Singh(1997) in *Hilsa ilisha, Channa punctatus* and *Schizothorax plagiostomus* respectively.

The ideal sex-ratio in natural population is close to 1:1(Nikolskii, 1980). A definite ratio of males and females during the spawning season is a prerequisite for most effective fertilization of eggs deposited by spawning females. The deviation in sex ratio from the ideal one during the spawning season encountered during both the years with a distinct predominance of males may be a contributing factor to the endangerment of *P. carnaticus*. Nautiyal(1994) and Singh(1997) reported that spawning migration of fishes can lead to alterations in sex ratio drastically. The changing sex ratios may be associated with the shoaling habits of fishes, which might be a contributing factor for the dominance of either of the sex in the catch composition of different days. Differential mortality may be another cause of skewness in sex ratio (Bhatnagar, 1972).

The higher occurrence of males in lower and females in higher size groups as observed in *P. carnaticus* are corroborating with the findings in a number of fish species (Bennet, 1962; Bailey, 1963; Bhatnagar, 1972; Chaturvedi, 1976; Siddiqui *et al.*, 1976a; Somavanshi, 1980, Vinci and Sugunan, 1981; Kurup, 1994). According to Makeeva and Nikolskii(1965), variation in sex ratio at different sizes and age groups exists even in species with an overall 1:1 ratio. Nikolskii(1980) assigned the dominance of males in smaller size groups to the tendency of males to mature earlier and live less longer. Siddiqui *et al.* (1976b) stated that the increase in contribution of females in higher groups might be due to heavy mortality of males in smaller size groups either due to natural death or fishing pressure as they were more active and caught more easily or more exposed to predation. According to Qasim(1966), the disparity in growth rate between sexes led to the preponderance of one sex and the preponderant sex attains a bigger size. This is at variance with the present observation in *P. carnaticus* in which the males were dominant in the sample population, although the minimum size at maturity and the maximum size of the individual was found to be higher in females.

Lowe-McConnell (1975) defined the fecundity as the number of eggs produced by an individual fish in its lifetime. Bagenal(1978) considered it as the number of ripening eggs found in female prior to spawning and termed it as individual or absolute fecundity. Fecundity is generally regarded as the number of ova in an organism, which has the potential to give rise to the offsprings. Thus, the reproductive potential is a function of the fecundity of fishes. Fecundity varies both within and between fish populations and numerous factors such as nutritional state (Scott, 1962; McFadden *et al.*, 1965; Stauffer, 1976), time of sampling and maturity stage (Healey, 1971), racial characteristics (Bagenal, 1966) and environmental conditions such as rainfall and salinity (Joshi and Khanna, 1980). Fecundity in teleosts range from a few hundreds to several lakhs.

The fecundity estimates of important freshwater cyprinids have been reported by several authors.Fishes such as *Labeo calbasu*(Khan,1934;Rao and Rao,1972;Vinci and Sugunan,1981), *L.rohita*(Khan,1934;Varghese,1973), *Cirrhinus mrigala*(Khan,1934; Chakrabarty and Singh,1967), L.dero(Bhatnagar,1967), *Cyprinus carpio*(Parameswaran *et al.*,1972),*L.fimbriatus*(Bhatnagar,1972),*L. gonius*(Joshi and Khanna,1980) and *L.dussumieri*(Kurup,1994) are highly fecund fishes with several lakhs of eggs. *Puntius vittatus*(Ibrahim,1957)with 26 to 302 ova, *Barilius bendelisis* var. *chedra* (Desai and Karamchandani,1967)with 305-1168 ova, *Glyptothorax kashmirensis*(Kaul,1994) with 692-1392 ova and *Noemacheilus triangularis* (Ritakumari and Nair,1979) with 800-2126 ova are some freshwater fish species with less number of ova in their mature ovaries. The fecundity of other cyprinids are 2368-8590 ova in *Puntius ticto*(Ibrahim,1957),1700-6259 ova in *Garra mullya*(Somvanshi,1985), 3340-6160 in *Crossocheilus latius diplocheilus*(Kaul,1994),3416-53139 in *P.stigma*(Ibrahim,1957)14245-58330 ova in

P.dorsalis (Sivakami,1982) and 58327-139934 ova in *P.sarana*(Sinha,1975). In *P.carnaticus* the fecundity ranged from 2820-14071.Comparitively bigger sizes of the eggs may be identified as one of the reasons for the low fecundity of *P.carnaticus*. Bulkley (1976) discussed the influence of egg size on fecundity in steel head trout, *Salmo gairdneri* and stated that it is possible that a fish producing fewer eggs could produce larger eggs within limits than if it were producing numerous eggs. Fecundity is higher in those fishes in which eggs are smaller in size than those in which the eggs are larger (Kaul, 1994).

The reproductive potential of fishes of different size groups had been expressed as the number of ova produced per gram body weight called relative fecundity. (Bagenal, 1963;De Silva, 1973b) or comparative fecundity (Das, 1964). Relative fecundity provides a better comparison of fecundities and eliminates the alteration in absolute fecundity with fish age and size (Sheila and Nair, 1983). The present study revealed that the average relative fecundity of *P.carnaticus* was 11.This value is very low when compared to a relative fecundity of 252 in *L.calbasu*(Pathak and Jhingran,1977),256 in *L.rohita*(Varghese,1973),285 in *L.bata*(Alikunchi,1956), 275 in *Barilus bendelisis* (Dobriyal and Singh,1987), 271 in *L.gonius* (Joshi and Khanna,1980), 228 in *P.vittatus* (Ibrahim,1957),227 in *P.sarana sunasutus* (Sobhana and Nair,1974),201 in *L.calbasu* (Vinci and Sugunan,1981) and 180 eggs in *L.dussumieri* (Kurup,1994).It can therefore be concluded that the very low relative fecundity of *P. carnaticus* when compared to other species is a major reason for the endangerment of this species in the natural waters.

The number of ova per gram ovarian weight was ranged from 46-630.Sivakami (1982) estimated the average number of ova per gram of ovarian weight in *P.dorsalis* as 3319, which is comparatively very high when compared to that of *P.carnaticus*.

Even though the coefficient of maturity showed some oscillations in different size groups, it showed a decreasing trend after 890g size. According to Hochman(1967), a declining trend in the coefficient of maturity after reaching a particular size could be a manifestation of beginning of aging , connected with decreasing reproductive capacities. Gonadosomatic index and relative fecundity also followed similar trends. As reported in *Garra mullya* by Somavanshi(1985) and *L.dussumieri* by Kurup(1994), the initiation of aging in *P. carnaticus* is marked by changes not only associated with maturity index but also with gonadosomatic index and relative fecundity.

Fecundity is often correlated with length, weight and age of fish and also with the length, weight and volume of ovary. The relationship between total length and fecundity differ in different species of fishes. Clark (1934) opined that the fecundity of a fish increased in proportion to the square of its length. Simpson (1951) established that the fecundity of plaice was related to the cube of its length and was thus directly proportional to fish weight. Many authors have supported Simpson's view of fecundity being related to fish length by a factor closer to the cube (Bagenal, 1957; Sarojini, 1957; Pillay, 1958; Pantalau, 1963; Varghese, 1973, 1976; Kurup, 1994). After surveying 62 fish species, Wooton(1979) concluded that the exponent value varied from 1 to 5 with most of the values lying between 3.25 and 3.75 and invariably higher values were reported in marine species than in freshwater forms. Jhingran(1961) and Qasim and Qayyum(1963) have reported the exponential value to range around 3. In the present study, the exponential value of *P.carnaticus* was observed to be 1.3048 which showed significant difference from the value of '3' and this finding is in total agreement with the above reports. The value of exponent in the length – weight relationship of female was found to be 2.4575 (Chapter 9). Since the exponential value in the length – fecundity relation (1.3048) was observed to be lower than that in length-weight relationship (2.4575), it appears that the fecundity in the species increased at a rate lesser than than the rate of increase of body weight in relation to length.

Fecundity was found to have a linear relationship to body weight. The 'b' values of 0.3639 showed that body weight have very low influence on fecundity. The coefficient of determination (r^2) indicated that only 22% of the variation in fecundity was associated with body length. The correlation of fecundity on body weight indicated that only 11% of the variation in egg production was explained by the changes in weight. Linear relationship between fecundity and body weight has been reported in *L.fimbriatus*(Bhatnagar,1972), *P.sarana*(Sinha,1975), *L.rohita*(Khan and Jhingran, 1975),*L.bata* (Siddiqui *et al.*,1976b), *L.dero* (Raina and Bali, 1982) and *L. Dussumieri*(Kurup,1994). The observations of some early workers (Bagenal, 1957; Sarojini, 1957; Gupta, 1968; Varghese, 1973) also lend support to the linear relationship between fecundity and body weight.

The coefficient of correlation of the various statistical relationships derived between fecundity, body length, body weight, ovary length and ovary weight revealed significant relation between fecundity and the body parameters. The highest degree of correlation was seen between fecundity and ovary weight. This is in agreement with the observations of Chathurvedi(1976) in *Tor tor*,Joshi and Khanna(1980) in *L.gonius*, Qadri et al.(1983)

in *Schizothorax richardsonii*, Sunder(1986) in *S.longipinnis* and Kurup(1994) in *L.dussumieri*. It is well known that the weight of ovaries of a fish is mainly influenced by the ova contained in them. The 'r' value between ovary weight and body length and ovary weight and body weight exhibited a fair correlation between the variables. From the study on the relationship between fecundity and various body parameters it can be concluded that ovary weight was identified as the most appropriate predictor of ovarian egg count, 61.4% of the variation in fecundity being explained by the changes in ovarian weight.

Table 9.1.Percentage Maturity stages in different length groups of male *Puntius carnaticus*

	Maturity stages				
Length group(mm)	I	II	III	IV	V
231-250	9.80	3.92	13.64		4.76
251-270	25.49	9.80	9.09		23.81
271-290	9.80	37.25	9.09	7.69	
291-310	15.69	13.73	18.18		14.29
311-330	17.65	11.76	4.55	7.69	19.05
331-350	13.73	7.84	4.55	7.69	9.52
351-370	3.92	7.84	31.82	7.69	19.05
371-390	1.96	3.92	9.09	23.08	9.52
391-410	1.96	3.92		46.15	

Table 9.2.Percentage Maturity stages in different length groups of female *Puntius carnaticus*

	Maturity stages				
Length group(mm)	I	II	III	IV	V
231-250					
251-270	6.25	12.50		6.82	3.23
271-290	12.50			11.36	12.90
291-310	12.50		37.50	4.55	9.68
311-330	18.75	12.50	12.50	20.45	16.13
331-350	12.50	25.00	12.50	22.73	12.90
351-370	12.50		25.00	9.09	29.03
371-390	25.00			18.18	
391-410		37.50	12.50	2.27	3.23
411-430		12.50		4.55	12.90

Table 9.3.Sex ratio of *Puntius carnaticus* during different months of 2001-02 and 2002-03

Months	Total	M	F	M:F	Chi square	Probability
April	22	14	8	1:0.6	8.50	P<0.05
May	15	8	7	1:0.9	8.87	P<0.05
June	15	12	3	1:0.3	9.37	P<0.05
July	13	9	4	1:0.4	8.49	P<0.05
August	9	5	4	1:0.8	8.46	P<0.05
September	20	11	9	1:0.8	8.76	P<0.05
October	14	9	5	1:0.6	8.98	P<0.05
November	31	23	8	1:0.4	8.51	P<0.05
December	28	17	11	1:0.7	8.73	P<0.05
January	35	24	11	1:0.5	8.72	P<0.05
February	34	24	10	1:0.4	8.50	P<0.05
March	30	18	12	1:0.7	8.53	P<0.05
Total	**266**	**174**	**92**	**1:0.6**	**104.42**	P<0.05
2002-03						
April	9	6	3	1:0.6	7.13	P<0.05
May	13	9	4	1:1	7.13	P<0.05
June	13	4	9	1:0.7	7.09	P<0.05
July	8	5	3	1:0.5	7.11	P<0.05
August	12	6	6	1:0.7	7.13	P<0.05
September	12	7	5	1:0.4	7.85	P<0.05
October	12	8	4	1:0.3	7.13	P<0.05
November	15	9	6	1:1	7.12	P<0.05
December	15	10	5	1:0.4	7.13	P<0.05
January	12	9	3	1:0.5	7.13	P<0.05
February	14	7	7	1:0.4	7.11	P<0.05
March	11	8	3	1:2.25	7.10	P<0.05
Total	**146**	**88**	**58**	**1:0.7**	**86.18**	P<0.05

Table 9.4.Sex ratio in *Puntius carnaticus* at various length groups

Length groups(mm)	Total	Males	Females	M:F	Chi square	Probability
230-250	21	21	0	1:0	1.47	P>0.05
251-270	44	44	0	1:0	1.47	P>0.05
271-290	53	36	17	1:0.5	6.66	P<0.05
291-310	49	32	17	1:0.5	6.57	P<0.05
311-330	62	34	28	1:0.8	6.28	P<0.05
331-350	55	35	20	1:0.6	6.51	P<0.05
351-370	57	24	33	1:1.3	6.00	P<0.05
371-390	29	19	10	1:0.53	6.78	P<0.05
391-410	32	15	17	1:1.13	6.06	P<0.05
411-430	9	2	7	1:3.5	5.96	P<0.05
431-450	0	0	0	0	0.00	
451-470	0	0	0	0	0.00	
471-490	1	0	1	0:1	5.25	P<0.05
	412	262	150	1:0.7	59.02	P<0.05

Table 9.5.Average values of fecundity indices in the spawners of *Puntius carnaticus*

Length group(mm)	Average fish length(mm)	Average fish weight(g)	Average ovarian weight(g)	No. of specimens examined	No. of ova per g of fish weight	No. of ova per g ovarian weight	Maturity index	GSI	Absolute fecundity
211 -230	222.4	152.23	14.2	2	10.1	219.5	4.8	5.1	3016
251 -270	270	300	19.52	1	20.86	321	6.5	6.96	6259
271 -290	284	338.8	19.9	5	12.5	218.2	5.78	6.2	4295
311 -330	318.61	475.57	25.41	7	12.72	223.1	5.5	5.9	5636
331 -350	335.82	520.6	23.58	3	10.4	224.7	5.8	4.76	5511
351 -370	360	617.5	38.47	4	11.4	264.8	5	5.3	6916
371 -390	379.7	837.5	30.4	4	5	137	3.6	3.8	4099
431-450	445	1300	67.76	1	10.8	207.7	5.2	5.5	14071

Fig.9.1.Monthly percentage occurrence of gonads of *Puntius* carnaticus in different stages of maturity during 2001-2002

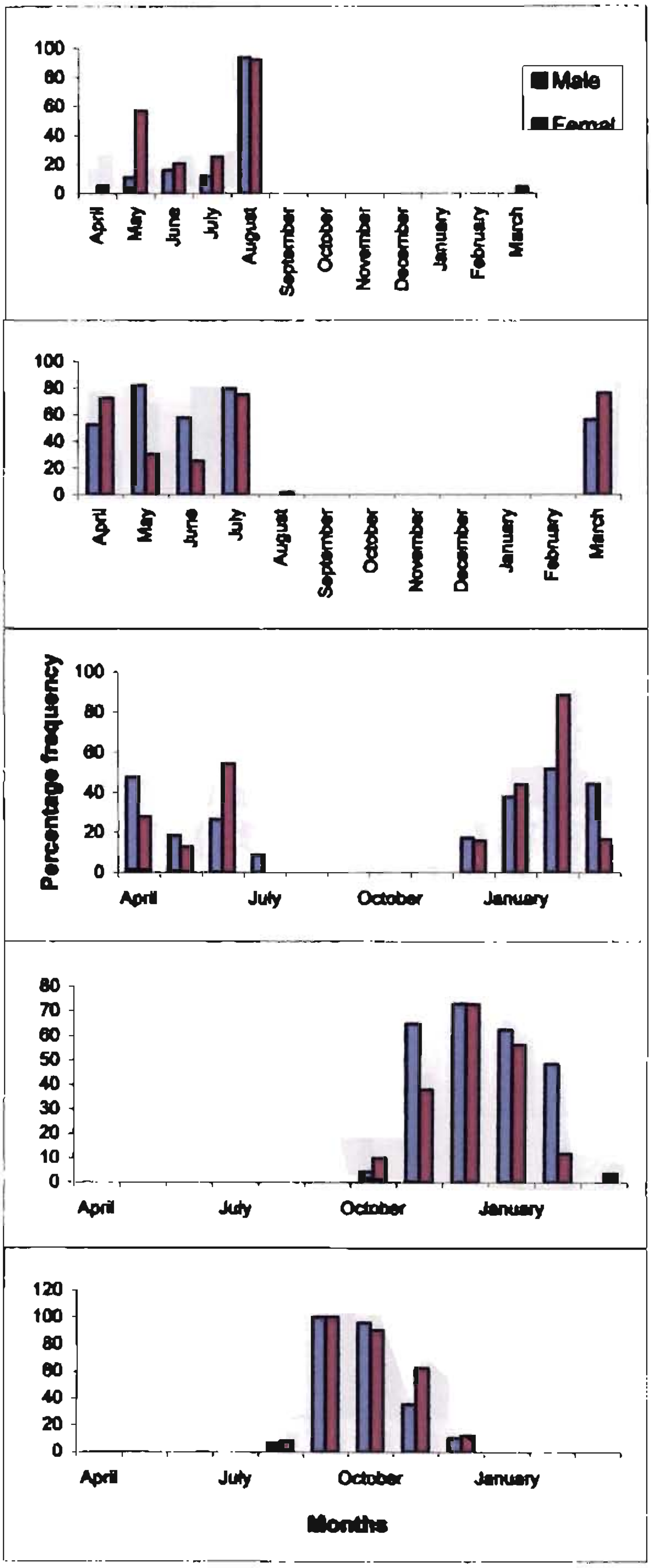


Fig.9.2.Monthly percentage occurrence of gonads of *Puntius carnaticus* in different stages of maturity during 2002-2003

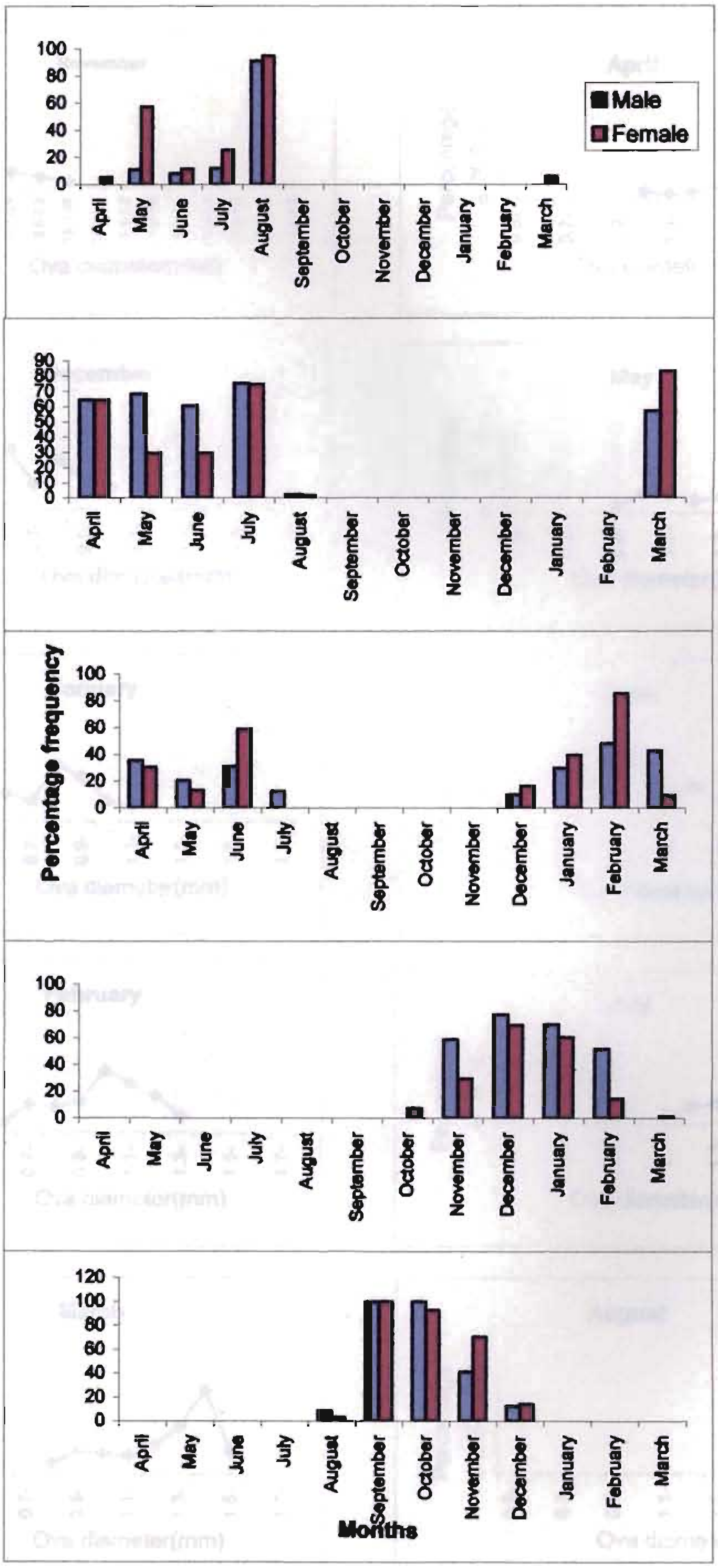


Fig.9.3.Monthly variation in ova diameter percentage frequency of *Puntius carnaticus*

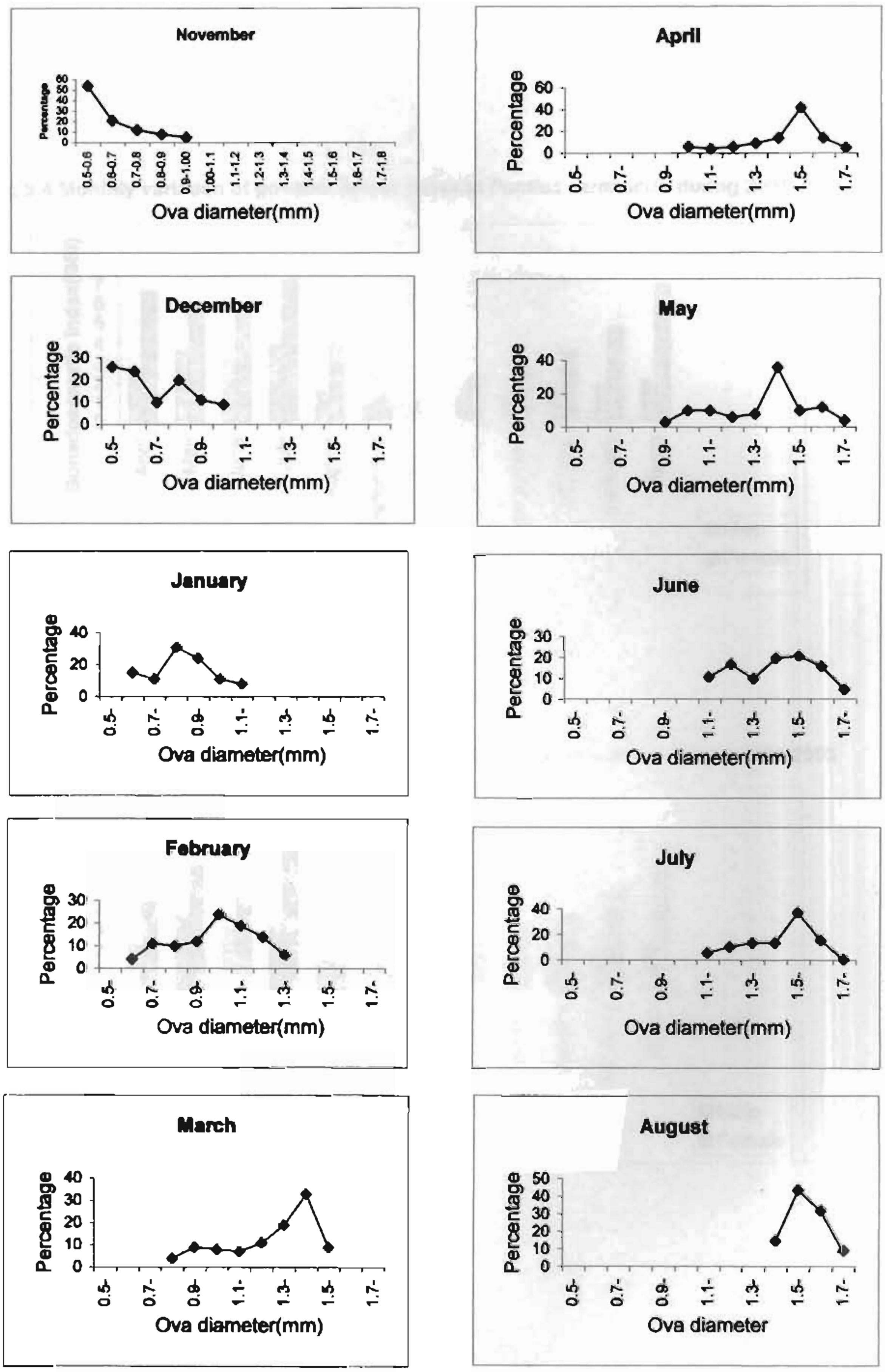


Fig.9.4.Monthly variation of gonadosomatic index in *Puntius carnaticus* during 2001-2002

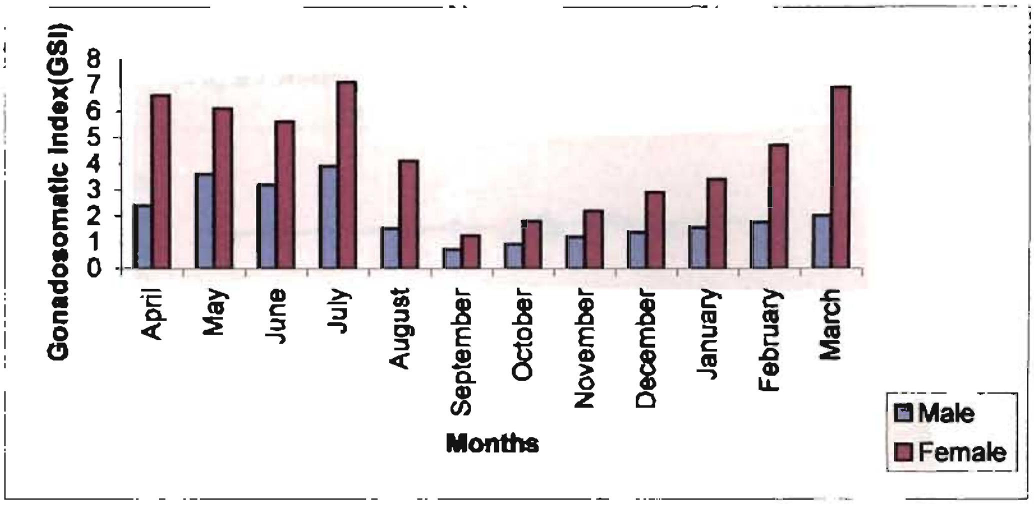


Fig.9.5.Monthly variation of gonadosomatic index in *Puntius carnaticus* during 2002-2003

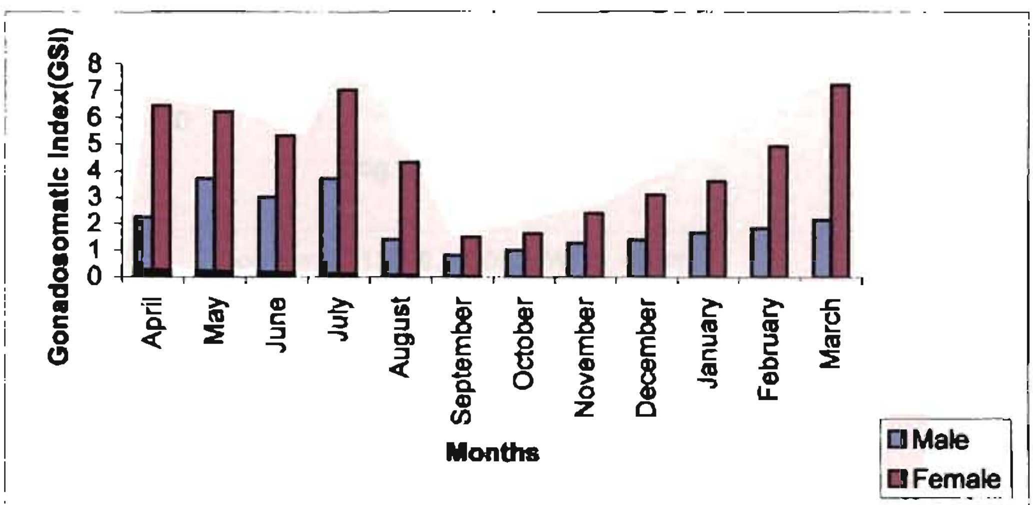


Fig.9.6.Percentage occurrence of mature males and females in *Puntius carnaticus*

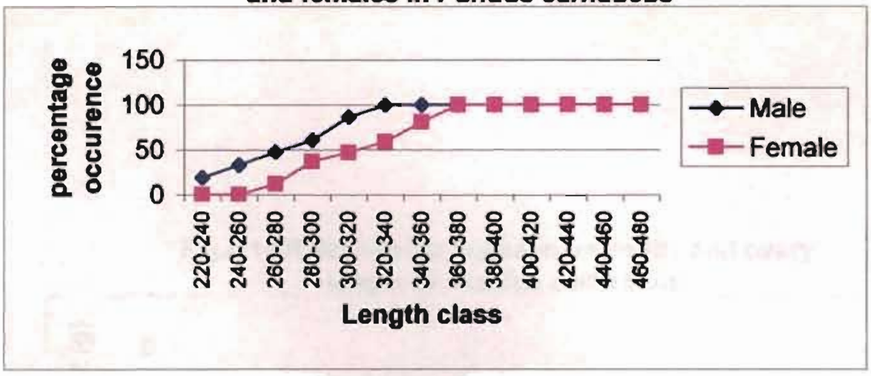
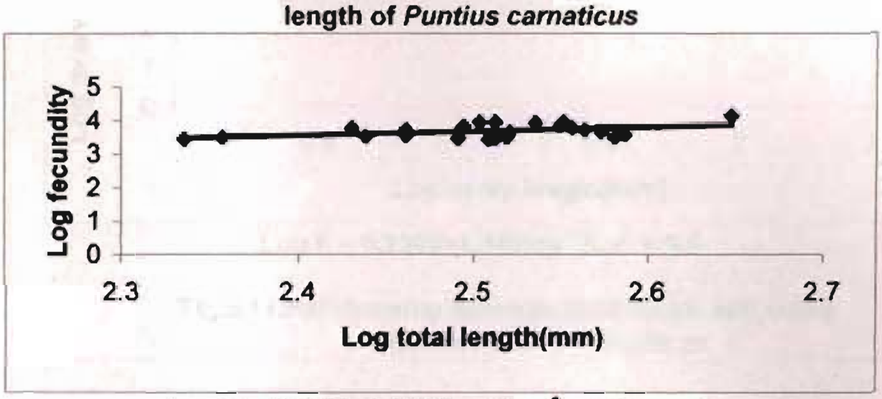
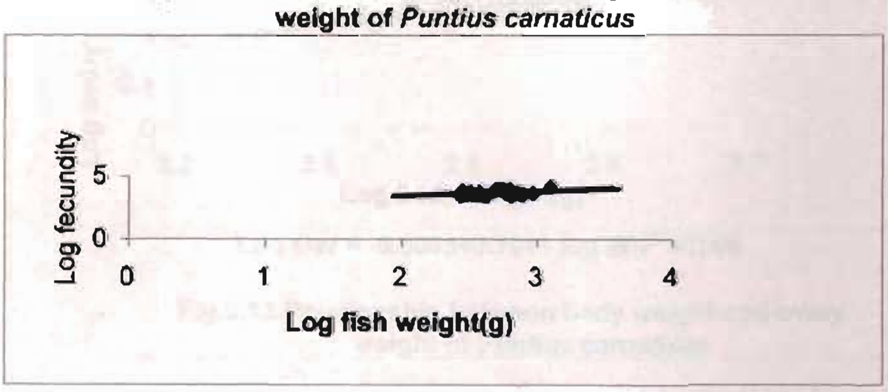


Fig.9.7.Relationship between fecundity and total length of *Puntius carnaticus*



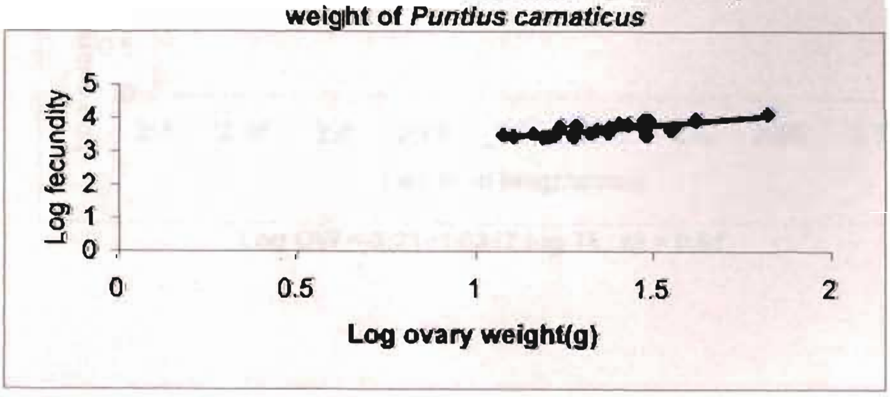
Log F = 0.4266+1.3048log TL; r^2 = 0.22

Fig.9.8.Relationship between fecundity and total weight of *Puntius carnaticus*



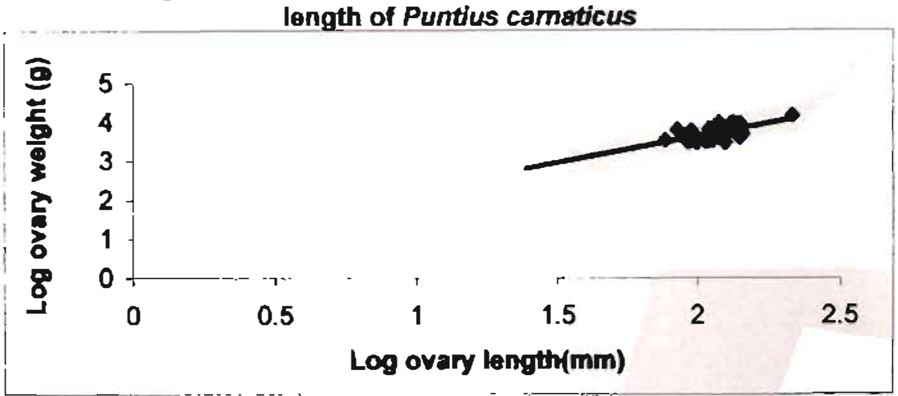
Log F = 2.7132+0.3639log W; r^2 = 0.11

Fig.9.9.Relationship between fecundity and ovary weight of *Puntius carnaticus*



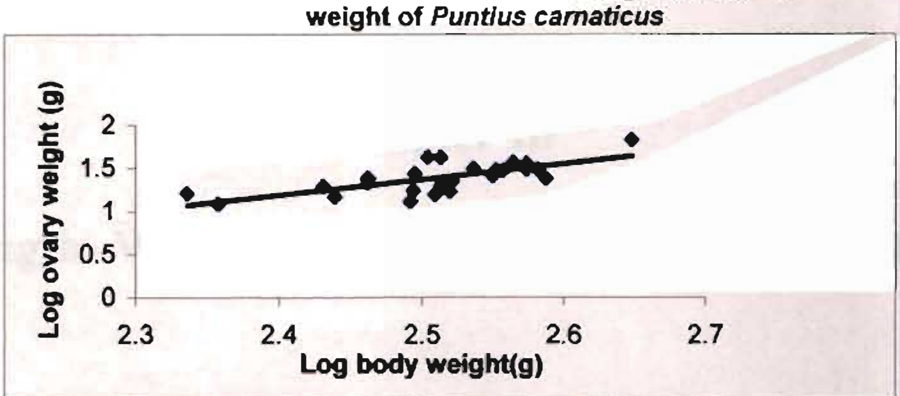
Log F = 2.516 + 0.8532 log OW; r^2 = 0.62

Fig.9.10.Relationship between fecundity and ovary length of *Puntius carnaticus*



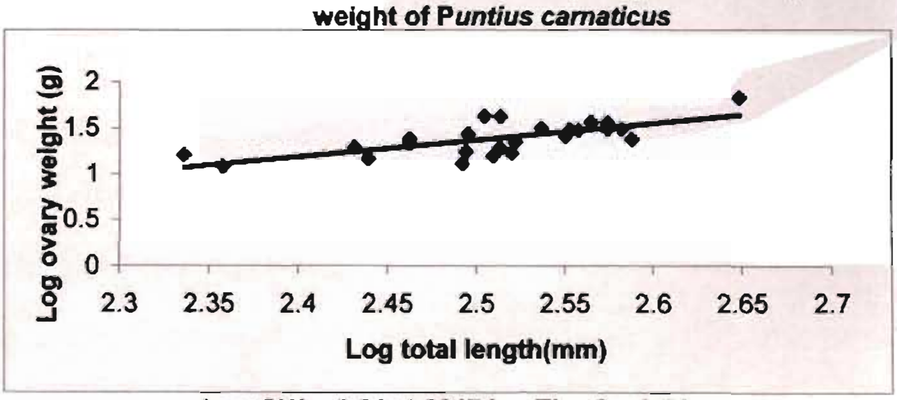
Log F = 0.9366+1.340log OL;r^2 = 0.4

Fig.9.11.Relationship between total length and ovary weight of *Puntius carnaticus*



Log OW = -0.5098+0.7011 log W;r^2 = 0.49

Fig.9.12.Relationship between body weight and ovary weight of *Puntius carnaticus*



Log OW =-3.21+1.8317 log TL; r2 = 0.51

Chapter 10

Length- Weight relationship and Condition factor

10.1. Introduction

Growth is defined as the change in size with reference to time. Weight of a fish is expressed as a function of length. Knowledge of length – weigh relationship is of paramount importance in fishery biology as it serves several practical purposes. The general length-weight relation equation provides a mathematical relationship between the two variables, length and weight, so that the unknown variable can be easily calculated from the known variable. This expression had been extensively used in the study of fish population dynamics for estimating the unknown weights from known lengths in yield assessments (Pauly, 1993), in setting up yield equation for estimating population strength (Beverton and Holt, 1957; Ricker, 1958), in estimating the number of fish landed and in comparing the populations over space and time (Sekharan, 1968; Chanchal *et al.*, 1978). It also yields information on the growth, gonadal development and general well being of the fish (Le Cren, 1951) and therefore, is useful for the comparison of body forms of different groups of fishes. The length –weight relationship also has a biological basis as it depicts the pattern of growth of fishes. According to the general cube law governing length-weight relationship, the weight of the fish would vary as the cube of length. However, all fish species do not strictly obey the cube law and deviations from the law are measured by condition factor (Ponderal index or K factor). Le Cren(1951) proposed relative condition factor(Kn)in preference to K as the former considers all the variations like those associated with food and feeding , sexual maturity, etc., while the latter does so only if the exponenent value is equal to 3. Thus 'K' factor measures the variations from an ideal fish, which holds the cube law while Kn measures the individual deviations from the expected weight derived from the length- weight relationship.

The length- weight relationship of cyprinids from India has been subjected to detailed studies, notably by Jhingran(1952), Bhatnagar(1963), Natrajan and Jhingran(1963), Sinha(1972), Pathak (1975),Chatterji (1980), Chatterji *et al.*(1980),Vinci and Sugunan(1981), Sivakami(1982), Choudary *et al.*(1982), Malhotra(1982, 1985), Mohan and Sankaran(1988), Kurup(1990), Reddy and Rao(1992), Biswas(1993), Pandey and Sharma(1998), Sarkar *et al.*(1999), Sunil(2000) and Kurup *et al.*(2002) . However, no information is available on the length-weight relationship and condition factor of *P. carnaticus* and therefore, the present study was undertaken to establish the pattern of growth and general well-being of this fish species.

10.2. Materials and Methods

882 specimens of *P.carnaticus* comprising 262 males, 150 females and 470 indeterminates were collected from Peringalkuthu region of Chalakudy river (Kerala) using gill nets of varying mesh sizes during March 2001 to February 2003.The specimens were preserved in 8% formalin. After blotting the specimens to remove excess water, the total length to the nearest millimeter and weight to the nearest 0.01 gram were recorded. Total length was measured from the tip of the snout to tip of the longest ray in the caudal fin(Jayaram,1999). Total length of male, female and indeterminates varied between 232 to 430 mm, 270 to 472mm and 52 to 228 mm respectively and the weight from 150 to 1120g in males, 300 to 1750g in females and 15.2to 314g in indeterminates. The data so generated was subjected to statistical analysis by fitting length-weight relationship following Le Cren(1951). Length- weight relationship can be expressed as: $W=aL^b$, the logarithamatic transformation of which gives the linear equation:

$$\log W = a + b\log l$$

where w= weight in gram, l= length in mm, a= a constant being the initial growth index and b= growth coefficient. Constant 'a' represents the point at which the regression line intercepts the y-axis and 'b' the shape of the regression line.

The relationship between length and weight was determined for males, females and indeterminates separately by transforming the values of both variables to logarithamatic values and fitting a straight line by the method of least squares. The data was processed in EXCEL software. The significance of regression was tested by ANOVA. The regression coefficients of the sexes and indeterminates were compared by analysis of covariences (ANACOVA) (Snedecor and Cochran, 1967) to establish the variations in the 'b' values, if any, between them. Bailey's t-test (Snedecor and Cochran, 1967) was employed to find out whether 'b' value significantly deviated from the expected cube value of 3($t=(b-3)/S_b$ where b= regression coefficent , Sb = Standard error of 'b'. The t-test (Snedecor and Cochran, 1967) on 'r' values reveals whether significant correlation exists between length and weight.

Relative condition factor (Kn) as per Le Cren(1951) is expressed as follows:

$Kn = W/\hat{W}$

Where W =observed weight

$\hat{W}$ = calculated weight derived from length-weight relationship

10.3. Results

Length – weight relationship of males, females and indeterminates of *P.carnaticus* can be expressed as follows:

Logarthamatic equation		**parabolic equation**
Males	log W = -4.1567 + 2.7148log l	W=-4.^{1567} l $^{2.7148}$
Females	log W = -4.5089 + 2.8618log l	W=-4.5089 l$^{2.8618}$
Indeterminates :	logW = -0.9611+1.4243 log l	W=-0.9611 l $^{1.4243}$

The 95% confidence limits of 'b' values were:

Male = 2.4705 - 2.959

Female = 2.5386 – 3.1850

Indeterminates = 1.3117 – 1.537

The logarithmic relationship between length and weight of males, females and indeterminates of *P.carnaticus* together with correlation coefficient is depicted in Figs.10.1, 10.2 and 10.3 respectively. The correlation coefficient 'r' between log length and log weight was found to be 0.872 in males, 0.8658 in females and 0.9302 in indeterminates. The't' test on 'r' values (Table 10.1) showed the existence of very good relationship between length and weight (P<0.01). The results of ANOVA on regression of males, females and indeterminates are presented in Tables 10.2, 10.3 and 10.4

respectively. The length-weight regressions were found to be highly significant in both the sexes as well as indeterminates($P<0.001$).Based on the coefficient of determination ($r2$)(Croxton,1953),76% of the variation in weight in males,75% in females and 86.5% in indeterminates were found to be associated with the change in the length of the fish.

The results of the analysis of covariance (ANACOVA) (Table 10.5) revealed significant difference in the regression coefficient of males, females and indeterminates(F value = 69.04, df: 2,1102) thereby indicating heterogeneity of the samples. Hence, pair wise comparison between males and females, males and indeterminates, females and indeterminates were carried out using students't' test (Zar, 1974). The results (Table 10.6) show that 'b' values are significantly different ($P<0.01$) in all except males and females.

The comparison of elevations disclosed significant difference among the three groups ($P<0.01$). Hence, pooling of data to provide a single equation expressing the length-weight relationship of *P.carnaticus* will not be justifiable, thus necessitating fitting up of separate equations for males, females and indeterminates.

The value of the regression coefficient in males was 2.7148 while in females it was 2.8618 whereas in indeterminates, the same was 1.4243. 'The't' test arrived at, 2.3(df: 152) in males manifested the significant departure of 'b' value from 3($P<0.05$). In females't' value (0.8. df: 103) was found as non-significant. In the case of indeterminates the't' value was 27.7(df: 98) which was significantly different from 'b' value of 3($P<0.01$).

The fluctuations noticed in Kn values of males and females during 2001-02 and 2002-03 are represented in Figs 10.4 and 10.5 respectively. In 2001-02 the Kn values of males showed 2 peaks (April and August) and 1 trough (December). In 2002-03 also the relative condition factor (Kn) of males showed the same pattern. In the case of females, during 2001-02 lowest Kn value of 0.64 was observed during December. An increase in Kn value was observed in April while it decreased in May- June followed by a gradual increase in the values upto August. After August the Kn gradually decreased and reached the lowest level in December. In 2002-03 also females followed more or less the same trend.

The average values of relative condition factor in respect of indeterminates and sexes belonging to different size groups are plotted in Figs 10.6 and 10.7 respectively. In males, higher Kn value of 1.08 was reported in 240-260mm length group, followed by a decreasing trend in 260-280 and 280-300mm size group. In 300-320mm length group the Kn value increased up to 1.1 and plummeted upto 0.94 in 340-360mm length group. Thereafter, the Kn value increased and reached the highest value of 1.2 in 360-380mm size class followed by a diminishing trend. In females, after reaching a Kn value of 1.06 in 280-300mm size class the relative condition factor gradually decreased and attained the lowest value of 0.98 in 320-340mm size class. Thereafter, the Kn increased to a peak in 380-400mm length class followed by a gradual decline in the succeeding classes. In the case of indeterminates the Kn gradually increased from 0.73 in 40-60mm length class and showed a comparatively good condition of 1.03 in 120-140mm length class. Thereafter the Kn decreased to 0.96 in 140-160mm length class and reached the peak of 1.08 in 160-180mm length class. Beyond 160-180mm length class the Kn showed a declining trend and plummeted to 0.85 in 200-220mm length group.

10.4. Discussion

Length-weight relationship was expressed by the cube formula $W=aL^3$ by the earlier workers (Brody, 1945; Lagler, 1952; Brown, 1957). Allen (1938) supported this law and declared that for an ideal fish, which exhibits isomeric growth, the value of regression coefficient should not be different from 3.The cube law confers a constancy of form and specific gravity to an ideal fish. However, adverting the inadequacy of the cubic law in explaining the length-weight relationships in fishes, many researchers adopted the general formula in the form $W=aL^b$. LeCren(1951)suggested that the deviations from the cube law might be contributed to the condition of the fish, reproductive activities, taxonomic differences or environmental factors. Ricker (1958) explained that due to changes in body proportions during the various life stages of fishes, their body form and specific gravity can vary and hence cube law does not hold true for them. According to Rounsefell and Everhart (1953), generally the value of 'b' is 3 in fishes but the cube law need not always hold good.

In the present study, the highest 'b' value was arrived at in females of *P.carnaticus* followed by males. The exponential value of 2.8618 implies that the females gain weight at a faster rate in relation to its length whereas the low exponential value 1.4243 observed in indeterminates indicates their low growth rate. The exponential value of 2.7148 of males indicates that the growth rate of males doesn't show much variation from females. It may be concluded that during the early stages of life, the growth rate was very less in this fish while after attaining a length above 200mm the growth rate suddenly increases and after attaining sexual maturity the females grows isometrically, more or less obeying cube law. While the low 'b' value of males indicate negative allometry, which indicates that, the increase in length is not in accordance with a three time increase in weight.

Reports on the length-weight relationship of cyprinid fishes showed that many of them strictly follow cube law while there are many in which the weights of fishes either tend to increase or decrease in proportion to the cube of length. Isometric growth pattern has been reported in *Cirrhinus mrigala* and *Labeo rohita*(Jhingran,1952), *Labeo calbasu*(Pathak,1975), *Puntius sarana*(Sultan and Shamsi,1981), *Puntius dorsalis*(Sivakami,1982), *Catla catla*(Choudhury *et al.*,1982; Kartha and Rao, 1990) and *Schizothorax plagiostomus*(Bhagat and Sunder, 1983).All these earlier reports are in compliance with the present findings on the length-weight relationship in females of *P.carnaticus* in which the 'b'value was very close to the isometric value of 3.

Deviations from cube law has been observed in Indian major carps by many authors (Jhingran, 1952;Natarajan and Jhingran, 1963; Shrivastava and Pandey, 1981; Choudhury et al., 1982; Mohan and Sankaran, 1988;Pandey and Sharma, 1998;Sarkar et al., 1999).The slope value of less than '3' has been reported in *Tor tor*(Malhotra,1982), *Labeo dero*(Malhotra and Chauhan,1984), *Labeo dyocheilus*(Malhotra,1985), *Puntius ticto* and *Barilius bendelesis*(Gairola et al.,1990) and *Cyprinus carpio communis* and *Cteno pharyngodon idella*(Dhanze and Dhanze,1997) and *Rasbora daniconius*(Sunil, 2000).All these earlier reports corroborate with the present findings on the length-weight relationship in *P.carnaticus* in which significant departure of 'b' value from the isometric value of 3 was noticed in respect of both males and indeterminates.

Females of *P.carnaticus* were found to surpass males in weight in relation to length as evidenced from the disparity in 'b' values. Similar trend has been observed in other cyprinids too viz., *Puntius kolus*(hatnagar,1963) *Labeo fimbritus*(Bhatnagar,1972) *L.dero*(Malhotra and Chauhan,1984) *R.daniconius*(Thakre and Bapat,1984) and *L.dussumieri*(Kurup,1990).But in the present study even though the weight at same length range was higher in females when compared to males there was no significant difference between the 'b' values of males and females. On the other hand, the 'b' value of both males and females showed significant difference from that of indeterminates. This indicated that in indeterminates of *P.carnaticus,* the weight of the fish was not increased in proportionate with their length. The present finding is supported by the low feeding intensity, gut fullness and relative gut length of indeterminates(refer Chapter 7).

Le Cren(1951) reported that females are heavier than the males of the same length probably because of the difference in fatness and gonadal development. While discussing the seasonal effect on length-weight relationship of *Clarias batrachus*, Mitra and Naser(1987)found that higher metabolic activity with spawning season lowered the 'b' value while less metabolic activities, accumulation of fat, weight of gonad, etc. during the pre-spawning period increased the values. The higher regression coefficients in female *P.carnaticus* may be attributed to the higher fat accumulation and more gonadal weight when compared to their male counterpart.

Beverton and Holt (1957) opined that since 'a' and 'b' of allometric formula might vary within a wide range for very similar data and are very sensitive to even the unimportant variations in various factors, allometric formula worked better than cubic formula. Any indication in biological events could be recorded by allometric law. The significant departure of regression coefficients from the isometric growth value in male and indeterminates of *P. carnaticus* indicates that the general parabolic equation $W=aL^b$

expresses the length-weight relationship in these groups better than the cubic law while the cube law $W=aL^3$ holds good for the females of this species.

Fluctuations in the condition of the fish is related to reproductive cycle (Le Cren, 1951;Sarojini, 1957;Pantalu 1963; Qayyum and Qasim, 1964a,b,c;Chatterji, 1980;Neelakantan and Pai, 1985;Gairola *et al*, 1990;Narejo *et al.*, 2002), feeding rhythms (Hile, 1948; Qasim, 1957; Bal and Jones, 1960;Blackburn, 1960;Bhatt, 1970,1977; Shrivastava and Pandey, 1981; Das gupta, 1991; Pandey and Sharma 1997) or physico-chemical factors of environment, age, physiological state of fish or some other unknown factors(Brown 1957;Kumar *et al.*,1979:Kurup and Samuel,1987;Kurup,1990;Kalita and Jayabalan,1997).In *P.carnaticus* the higher Kn values recorded in March-April and July – August in females and April-May and July- August in males coincided with the occurrence of high gonadosomatic index (GSI)in both males and females. The Kn values in males showed a decreasing trend during June and from September to December in males. While in females the relative condition factor decreased during May-June and September to December. This may be attributed to the increased spawning strain in them, as opined by Menon(1950).Thus it appears that reproductive cycle in *P. carnaticus* is related to the variations in the condition factor.

Sex-wise analysis of Kn values revealed that the mean Kn values in females (0.96) was higher than that of males (0.91). In indeterminates, the mean value was 0.77. According to Le Cren(1951), Kn values greater than 1 indicated good general condition of the fish whereas values less than 1 denotes reverse condition. Vinci and Sugunan (1981) and Biswas (1993) reported higher Kn values in females of *L.calbasu* and *L.pangusia* respectively. Pandey and Sharma (1997) studied the condition of four exotic carps and only the common carp, *Cyprinus carpio communis* was found to have values above 1(1.0109). High Kn values were recorded in *Labeo rohita*(1.0129) and *Catla catla*(1.0007)and low values in *Cirrhinus mrigala*(0.9967) by Pandey and Sharma(1998). In the present study even though the Kn values of all the groups were below '1' females showed the highest value (0.96) when compared to males (0.91) and indeterminates(0.77). This indicates that females are in better condition when compared to males and indeterminates.

Influence of feeding intensity, as indicated by the gastro-somatic index, on condition factor was apparent during certain months of the year in both the sexes. In females even though the gonad was in far advanced condition during May, low Kn value and comparatively low gastrosomatic index were observed. Similarly in both males and females during June Kn value was less when the GSI was comparatively higher and gastrosomatic index was less. In September the relative condition factor was comparatively good when the GSI was less and gastrosomatic index was high. From these observations it can be concluded that in *P.carnaticus*, though the condition of the fish is more related to gonadosomatic index, there exists some relationship between relative condition factor and gastrosomatic index and other environmental and physiological factors.

Table 10.1.Statistical details showing number of fish studied(n),intercept(log a),regression coefficient(b), standard error of b(sb) and results of bailey's t-test on 'b' and t-test on correlation coefficient (r)

	n	log a	b	sb	t	P	r	t	P
Males	262	-4.1567	2.7148	0.1236	2.3	P<0.05	0.8705	22.65	P<0.01
Females	150	-4.5089	2.8618	0.163	0.8		0.8849	20.1	P<0.01
Indeterminates	470	-0.9611	1.443	0.0568	27.7	P<0.01	0.9311	24.35	P<0.01

Table 10.2.Analysis of varience on the regression of the length weight relationship in males of *Puntius carnaticus*

	SS	*df*	*MS*	*F*	*P-value*	*F crit*
Regression	0.731236	1	0.731236	28.47112	2E-07	3.8698
Residual	8.475527	330	0.025683			
Total	9.206763	331				

Table 10.3.Analysis of varience on the regression of the length weight relationship in females of *Puntius carnaticus*

	SS	*df*	*MS*	*F*	*P-value*	*F crit*
Regression	2.048917	1	2.048917	94.81048	6E-19	330
Residual	4.884009	226	0.021611			
Total	6.932926	227				

Table 10.4.Analysis of varience on the regression of the length weight relationship in indeterminates of *Puntius carnaticus*

	SS	*df*	*MS*	*F*	*P-value*	*F crit*
Regression	29.62695	1	29.62695	203.7777	4E-30	3.9018
Residual	22.68062	156	0.145389			
Total	52.30758	157				
Total	70.05414	183				

Table 10.5.Comparison of slopes of male, female and indeterminate fo *Puntius carnaticus* using ANACOVA

							DEVIATIONS FROM REGRESSION				
								SS	MS		
Sl.No.		df	{x2	{xy	{y2	RC	df	{d y.x2			
1	Males	154	0.6260	1.6995	6.0682	2.7148	153	1.4545	0.0096		
2	Females	105	0.2736	0.7831	2.9899	2.8628	104	0.7479	0.0073		
3	Indeterminates	100	3.4408	4.9007	8.0672	1.4243	99	1.0872	0.0111		
4	Within						356	3.2896	0.0092		
5	Reg.Coeff.						2	1.2760	0.6380		
6	Common	359	4.3403	7.3833	17.1253	1.7011	358	4.5657	0.0128	**69.04**	*
7	Adj.Means						2	0.4111	0.2055	**16.12**	*
8	Total	359	15.6127	24.9342	44.7977	1.5970	360	4.9767			
	Comparison of slopes F=			0.638008	(2,356)	**69.04**		*	=Significant at 1% level		
	Comparison of elevation F=			0.205546	(2,358)	**16.12**			(p= <0.01)		

Table 10.6.Result of pair wise comparison of regression coefficients of male,female and indeterminates of *Puntius carnaticus* using t-test

Between	t	df	Probability
MalesxFemales	**0.7**	257	
MalesxFemales	**9.4**	252	P<0.01
FemalesxIndeterminates	**7.6**	203	P<0.01

Fig.10.1.Length - weight relationship in females of *Puntius carnaticus*

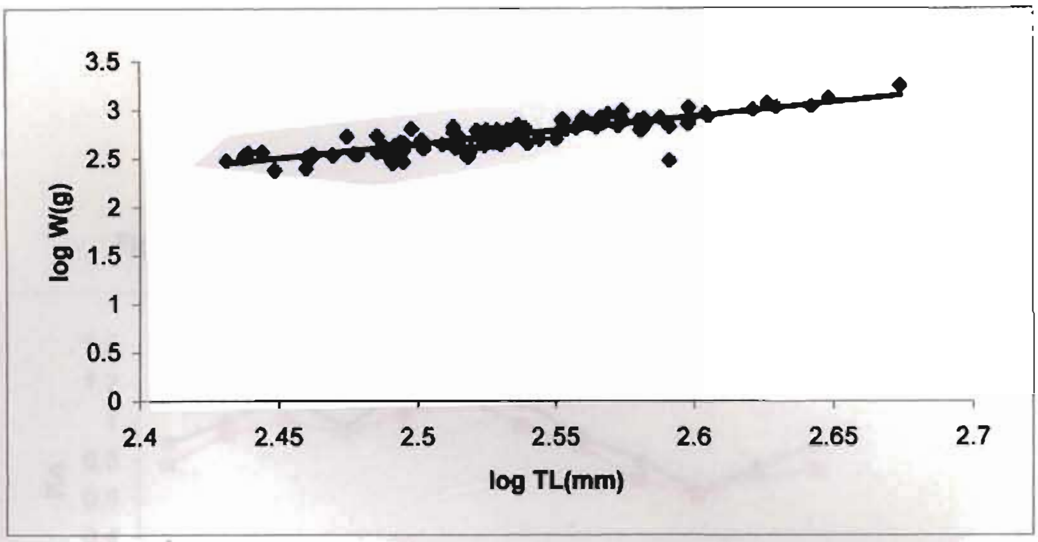


Fig.10.2.Length - weight relationship in males of *Puntius carnaticus*

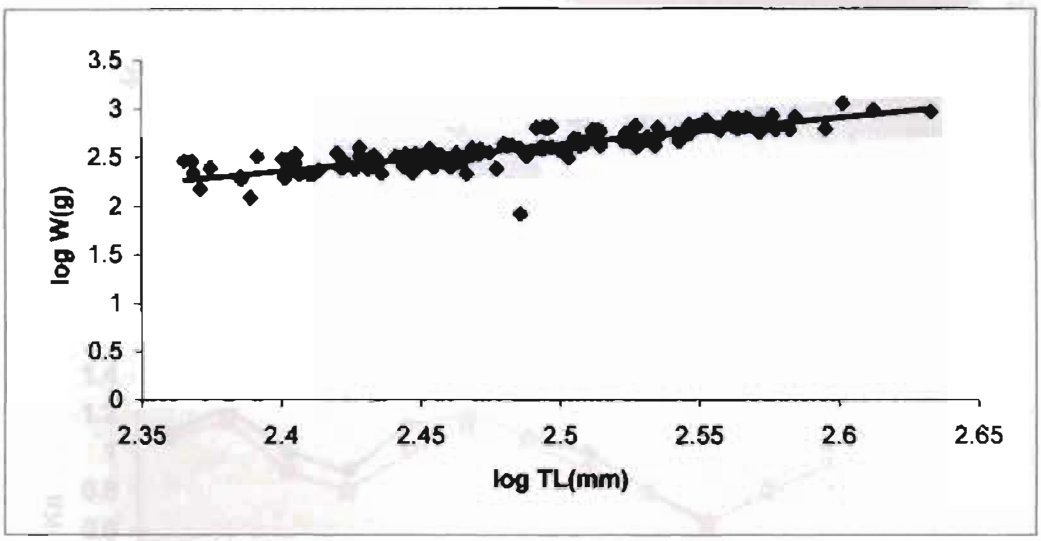


Fig.10.3.Length - weight relationship in indeterminates of *Puntius carnaticus*

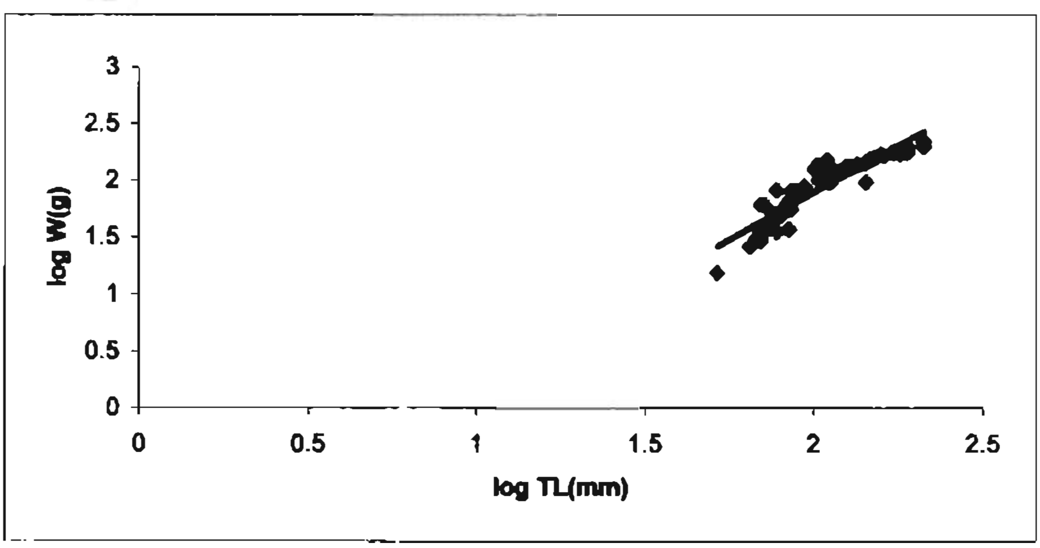


Fig.10.4.Seasonal variation in relative condition factor (Kn) of males of *Puntius carnaticus*

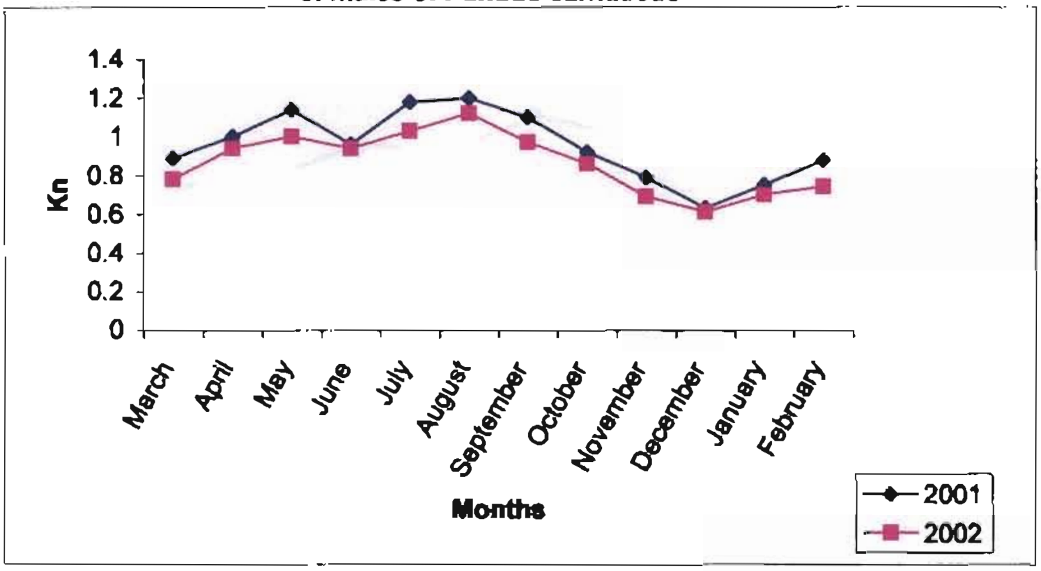


Fig.10.5.Seasonal variation in relative condition factor (Kn) of females of *Puntius carnaticus*

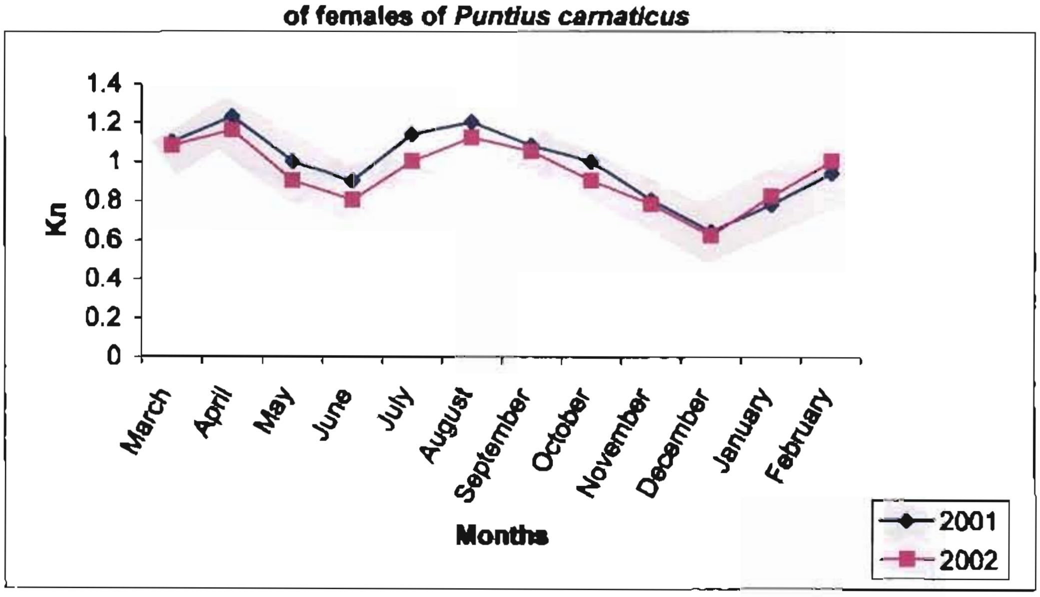


Fig.10.6.Lengthwise variation in relative condition factor(Kn) of indeterminates of *Puntius carnaticus*

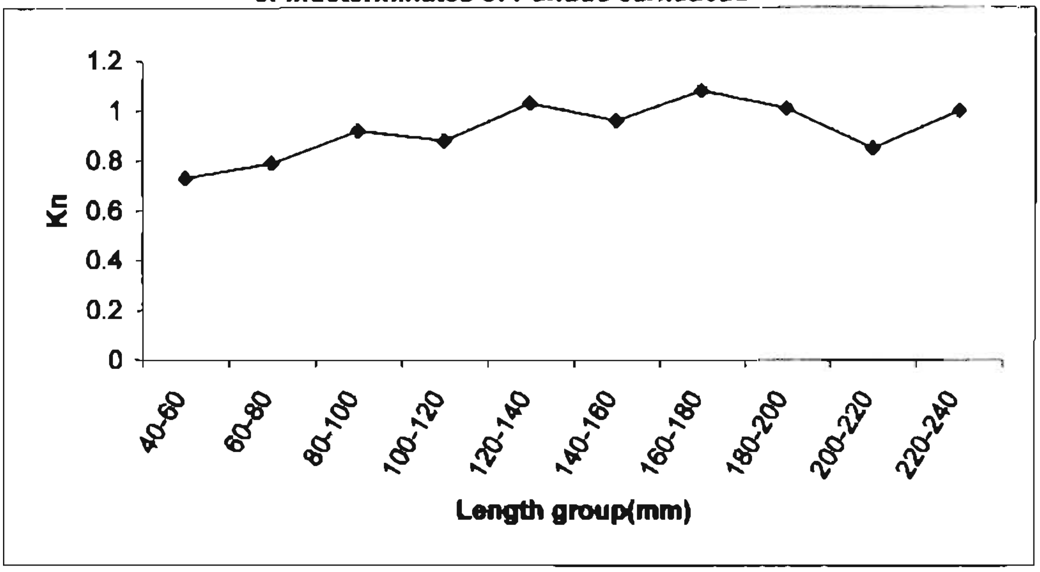
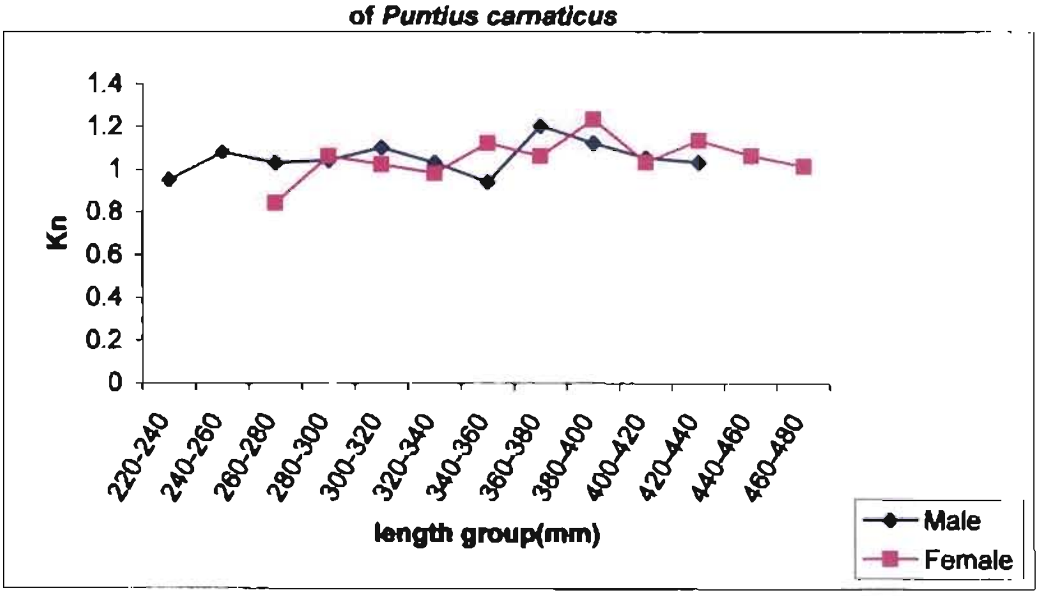


Fig.10.7.Lengthwise variation in relative condition factor(Kn) of *Puntius carnaticus*



Chapter 11

Age and Growth

11.1. Introduction

Age and growth of fishes are very closely interrelated. As age increases, there will be a change in size. Studies on age and growth are important in fisheries research. Besides being of biological interest, the determination of age has significant practical utility. It helps in the study of dynamics of fish populations. Most of the methods employed for assessing the state of exploited fish stocks rely on the availability of age composition data (Ricker, 1975a). Information on growth rate, natural and fishing mortality, age at maturity and spawning, age composition of the exploited population, etc. can be evolved from age data of fish populations. Such information provide essential tools for scientific interpretation of the fluctuations in fish populations over space and time and also in formulating scientific and economic management policies for the fisheries in question (Seshappa, 1999).

The growth process is species specific, however , it can differ in the same fish inhabiting different geographical locations and is easily influenced by several biotic and abiotic factors. Growth is an adaptive property, ensured by the unity of the species and its environment (Nikolsky, 1963). A comparison of rate of growth from different localities may help in identifying suitable environmental conditions for the sustenance of a stock. The purpose of growth studies in any fish species is to determine the amount of fish that can be produced with respect to time (Qasim, 1973b).

The age and growth rate of fishes are determined by both direct and indirect methods. The direct methods include rearing fishes in captivity under controlled conditions and observing their growth and also by using mark recapture method (tagging programmes).

Dissection of annual rings laid down on scales, otoliths and other hard parts of the body and length frequency analysis are the indirect methods mostly relied upon. As the direct methods have limited scope due to practical difficulties, biologists prefer the indirect methods for age and growth studies. The annular rings on scales and other hard parts of the body are effectively used in temperate regions where, during winter seasons, slow growth leaves clear rings of closely placed circuli. On the other hand, in tropics, the age determination based on direct counting of check marks is difficult because the growth rings do not necessarily represent year marks.

The length frequency analysis method of Petersen (1895, 1903) is well known, in which, peaks of length distribution are assumed to represent the different age groups. The method is very good for younger fish (2-4 years life). However, in older fishes, there are possibilities of over lapping of length frequencies in individuals of different age groups, as the growth rates slow down. Furthermore, age determination by length frequency analysis does not hold good to fishes with prolonged breeding season also. Length-frequency method is widely used by fishery biologists in fishes inhabiting tropical waters. A computer based method for the analysis of length frequency data, ELEFAN (Electronic Length Frequency Analysis) (Gayanilo *et al.*, 1988), has been effectively used to separate the composite length frequency into peaks and troughs and the best growth curve passing through maximum number of peaks is selected using a goodness of fit ratio of ESP(Explained sum of peaks)/ASP(Accumulated sum of peaks)(Rn)(Pauly and David,1981;Gayalino *et al.*,1988). The peaks are believed to represent individual cohorts. The module is incorporated into the FISAT (FAO-ICLARM Fish stock assessment tools) Software (Gayanilo and Pauly, 1997).

The age and growth of freshwater fishes of India were studied by several scientists (Jhingran,1959;Qasim and Bhatt,1964; Bhatt,1969; Kamal,1969; Khan and Siddiqui,1973; Murty,1973; Chatterji *et al.*,1979; Pathani,1981; Reddy, 1981;Mathew and Zacharia,1982;Tandom and Johal,1983; Shree Prakash and Gupta,1986; Desai and Shrivastava,1990; Devi *et al.*,1990; Johal and Tandon,1992). Qasim(1973b) made a critical evaluation on the various methods used for age and growth studies in India and described the difficulties encountered in determining the age in tropical fishes. Some of the recent works on age and growth include those of Kurup(1997) in *Labeo dussumieri*, Singh *et al.* (1998) in *L. rohita*, Kamal *et al.*(2002)in *L.calbasu*, Nautiyal(2002) in *Tor Putitora* and Narayani and Tamot(2002) in *Tor tor.* No attempt was made to study the age and growth of *Puntius carnaticus*, and hence a pioneer study is attempted in this direction.

11.2. Materials and methods

882 specimens of *P.carnaticus* comprising of 262 males and 150 females and 470 indeterminates collected from Peringalkuthu region of Chalakudy river system were used for the present study. All specimens were measured to the nearest mm in total length (TL). Length frequency data were grouped into 20mm class interval. Growth was estimated separately for males and females while the pooled population comprised of males,females and indeterminates. The von Bertalanffy growth formula (VBGF) (Bertalanffy, 1938) was used to describe the growth. The equation in growth in length is given by:

$$L_t = L\alpha \, [1 - \exp^{-k\,(t-t0)}]$$

Where L_t = length at age t.

$L\alpha$ = asymptotic length or the maximum attainable length if the organism is allowed to grow.

K = growth coefficient

t_0 = age at which length equals 0, i.e. the theoretical age at zero length

The growth parameters for both the sexes were estimated separately using the ELEFAN 1 programme of FISAT software (Gayanilo and Pauly, 1997).

Powell- Wetherall Method is used to estimate asymptotic length and the ratio of the coefficients of growth (Z/K) using length-frequency data based on Beverton and Holt (1956)

$Z= K [(L\alpha - L)/ \bar{L} - L')]$

It estimates the total instantaneous mortality coefficient (Z) in a steady state population with constant exponential mortality and von- Bertalanffy growth, from mean length (L) of a random sample of fish above cut off length (L'). The mean length of the selected fish (L) is a linear function of the knife edge selection length L' given by

$L= L\alpha \{1/ \{1+(Z+K)]\} + L'\{1/\{1+(Z+K)]\}$

For a series of arbitrary cut off lengths, we can construct a corresponding series of partially overlapping sub samples. If the mean lengths for sub samples are plotted against the cut off lengths, it results in a positive linear relationship as given by the above equation. If the intercept of the straight line is considered as a and slope as b,

$a = L\alpha [1+ (Z+K)]\}$

$b = (Z/K)/ [1+ (Z+K)]$

From this, $L\alpha$ and Z/K can be computed as

$L\alpha = a/(1-b)$

$Z/K= b/(1-b)$

In FiSAT, the modified form of Wetherall method as proposed by Pauly (1986) is incorporated.

$Lt' = a + bLt$

Where $L\alpha = a + b\,Lt$ and $Z/K= (1+b)/-b$

Estimation of t_0

Age length key at 3 months interval was prepared from ELEFAN 1. Estimate of t_0 was done using von Bertalanffy (1934) plot in which the results of the regression of $-\ln(1-Lt/L\alpha)$ against t was used to calculate t_0.

$$t_0 = -a/b$$

Since ELEFAN curves showed the existence of only one brood in *P. carnaticus*, estimation of growth parameters was restricted on one cohort only. Growth performance of this single cohort in both male and female was compared by Munro's PHI prime index, ϕ (Munro and Pauly, 1983) which was computed from the equation:

$$\phi = \log_{10} K + 2 \log_{10} L\alpha$$

where K and $L\alpha$ are Von Bertalanffy's growth parameters.

According to Pauly (1982 b), the structure of a set of length frequency data is dependant on the recruitment pattern into a population and hence it is possible to derive some information on the seasonality of recruitment from the length frequency data. FISAT applies this inverse approach, thereby identifying the number of recruitment pulses per year and evaluating the relative importance of these pulses when compared to each other.

The recruitment patterns of both male and female *P. carnaticus* were obtained from FISAT programme.

11.3. Results

11.3.1. Distribution of length

The lengths of males of *P.carnaticus* ranged from 232 to 467mm in total length. The modal length of males during 2001-02 was estimated to be 294mm, which belonged to the class 280-300mm TL whereas the same during 2002-03 was estimated as 303.07mm in the class 300-320mm TL.

The length of female population ranged from 270 to 472mm in total length. During 2001-02 the modal length was 344.62mm belonging to the size class 340-360mm TL. While during 2002-03 the modal length showed a slight increase with 372mm which comes in the size group 360-380mm TL.

The length of the smallest fish recorded was 52mm TL and belonged to immature class. In the case of immature fishes the highest length class observed was 100-120mm TL during 2001-02 while it was 120-140mm during 2002-03.

11.3.2. Estimation of growth parameters

11.3.2.1. Males:

In males, $L\alpha$ computed following Powell-Wetherall plot was 479.033 mm and Z/K =0.904(Fig.11.1). The data used for estimation of $L\alpha$ and Z/K for male *P.carnaticus* is shown in Table 11.1. ELEFAN 1 growth curve (Fig.11.2) showed that the male population of *P.carnaticus* was composed of a single cohort annually, generated by only one recruitment during August-September. The growth parameters estimated by ELEFAN 1 along with the growth performance index, ϕ are given in Table 11.4.The $L\alpha$

estimated from ELEFAN I with highest Rn value (0.181) was 493.5 and K =0.5 yr^{-1} (Fig.11.4) The growth performance value obtained by ELEFAN I was 5.08 . Based on the values so obtained through ELEFAN I, the von Bertalanffy growth equation (VBGF) of males of *P.carnaticus*(Fig.11.4) can be express as:

Males: $Lt = 493.5(1\text{-}exp^{-0.5(t+7448)}$

On applying the average growth co-efficients estimated by ELEFAN I, the males will be attaining an average length of 286.9, 368.2, 417.6, 447.6 and 477mm at the end of I, II, III, IV^{th} and V^{th} years respectively (Table 11.5).

11.3.2.2. Females:

In females Lα derived using Powell-Wetherall method was 504.612mm and Z/K was 3.173(Fig.11.3). The data used for the estimation of Lα and Z/K for female *P.carnaticus* is shown in Table 11.2.ELEFAN I growth curves (Fig.11.4) showed that the female population of *P.carnaticus* was composed of a single cohort annually generated during August-September. The growth parameters estimated by ELEFAN I along with the growth performance index, ϕ are given in Table 11.4. The Lα computed from ELEFAN I with highest Rn value (0.162) was 504 and K =0.65 yr^{-1} (Fig.11.5). The growth performance value obtained by ELEFAN I was 5.2. Based on the values obtained from ELEFAN I, the von Bertalanffy growth equation (VBGF) of females of *P.carnaticus*(Fig.11.5) can be express as:

Females: $Lt = 504(1\text{-}exp^{-0.65(t+.7802)}$

When compared to males, females attained a higher length during different years with 345.18mm, 421.12mm, 460.85mm and 481.7mm respectively at the end of I, II, III and IVyears (Table 11.5).

11.3.2.3. Estimation of growth parameters of pooled category

In the pooled category which includes male, female and indeterminates the Lα derived using Powell-Wetherall method was 500.83 and Z/K=2.073(Fig.11.5). The data for estimation of Lα and Z/K for male *P.carnaticus* is shown in Table 11.3. ELEFAN I growth curves (Fig.11.6) showed that the whole population of *P. carnaticus* comprised of a single cohort originated during April-May. The growth parameters estimated by ELEFAN 1 along with the growth performance index, ϕ are given in Table 11.4. The Lα obtained from ElEFAN I with highest Rn value (0.131) was 500.83 and K =0.97 yr^{-1} (Fig.11.6).The growth performance values computed using ELEFAN 1 was 5.5. Based on the values arrived at through ELEFAN I, the von Bertalanffy growth equation (VBGF) of females of *P.carnaticus* (Fig.11.6) can be express as:

Pooled (male + female + indeterminates) : $Lt = 500.83(1\text{-}exp^{-0.97(t+.8065})$

11.3.3. Analysis of recruitment pattern

The recruitment pattern obtained for males, females and pooled category through FISAT is given in Figs. 11.7, 11.8 and 11.9 respectively. The occurrence of a long recruitment pulse every year is quite discernible from the recruitment pattern of both male and females. In male *P.carnaticus*, the recruitment period extended from May to October. The major recruit was identified from May to July with a peak of 15.28% in June. The minor mode was appeared in October-November with a peak of 11.95% in October. In the case of females, the recruitment season extended from April to October with two peaks. The major peak extended from August to October with a peak in August (17.97%). Thereafter, it gradually declined and continued till February. The minor peak extended from April to June with a marginal peak in April (16.48%).

11.4. Discussion

In the present study, Lα computed by ELEFAN I and Powell-Weaterall method were almost comparable in both the sexes and also in the pooled category. Among the three groups females showed the highest Lα of 504.612,followed by pooled category(500.83) and males(479.033).While the 'K' value and growth performance index (Φ) were 0.5 and 5.08 in males,0.65 and 5.2 in females and 0.97 and 5.5 in pooled category. The higher values of growth co-efficients in females indicated that females attained asymptotic length at a faster rate than the males. While the much higher ϕ and K values in the pooled category indicated that the growth rate was very high before attaining the sexual maturity.

In the present study, the largest size of male *P.carnaticus* was recorded as 467mm and that of female as 472mm.The length of males at the end of first, second, third, fourth and fifth years of life were estimated to be 286.9, 368.2, 417.6, 447.6 and 465.9mm respectively. Females attained a length of 345.18 at the end of I year, 421.1 at the end of II year, 460.85 at the end of third year and 481.65 at the end of IV year. Based on the results of the present study, it can reasonably be inferred that the longevity of *P.carnaticus* is around four to five years. Since majority of the males fall in the length class 280-300mm and females in 340-360mm, it can be postulated that the exploited stock of males and females invariably belonged to one year age group. Accordingly representation of male and female individuals belonging to age group three and above was sparse and sporadic in the exploited stock.

Puntius carnaticus has been listed under vulnerable category of fishes based on its biodiversity status following IUCN (Walker and Molur, 1997). The basic principle of fishery resource conservation and sustenance of the fish stock is by allowing a fish to breed at least once its life time for ensuring the natural recruitment and regeneration. In *P.carnaticus,* the length at first maturity has been estimated to be 232mm in males and 270mm in females (refer: Chapter 9). It would thus appear that both male and female are getting a chance to complete the maturation and spawning before completing one year of their life cycle. Johal and Tandon(1987 a) found that the Indian Major Carps attains sexual maturity only above 30cm TL during the second or third year of their life span.Singh *et al.*(1998) reported that *L.rohita* attained sexual maturity at a length of 46cmTL after the third year of their life span. Based on the results of the present study, it can be well recommended that both males and females of *P.carnaticus* can be exploited before attaining one year in their life and the growth rate of both the sexes of *P.carnaticus* was perceptably higher than any of the Indian Major Carps of the country.

The Length-weight relationship studies (Chapter 11) also revealed that the 'b' values of males (2.7148) and females were (2.8618) comparatively higher in *P.carnaticus* when compared to other cyprinids like *Tor tor*(Malhotra,1982),*Labeo dero*(Malhotra and Chauhan,1984) and *Labeo dycheilus*(Malhotra,1985).

P.carnaticus was found to exhibit fastest increment in length during the first year of its life history and it was relatively higher in females when compared to its male counterpart. A drastic reduction in the growth rate was observed in the second, third and fourth years of age in both the sexes, while males performed better than females during this period. Similar pattern of faster growth rate during the first year and subsequent decline in the succeeding years have been reported in many cyprinids such as *Cirrhinus mrigala*(Kamal,1969; Desai and Shrivastava,1990), *Labeo calbasu*(Gupta and Jhingran,1973;Kamal *et al*.,2002), *L. dussumieri*(Kurup,1997), *L.rohita*(Singh,*et al*.,1998) and *Tor putitora*(Nautiyal,2002).

The growth co-efficient (K) of *C.catla*(0.1044),*L.rohita*(0.2551) and *C.mrigala*(0.275) reported by Mathew and Zacharia(1982) are relatively less than that of *P.carnaticus*. While Haroon, *et al*.(2002) recorded higher values of 0.8 in *L.rohita*, 0.73 in *C.catla*,0.7 in *C.mrigala* and 0.76 in *L.calbasu* collected from bheels. The growth co-efficient of *L.dussumieri* was estimated as 0.64 for males and 0.81 in females by Kurup(1997) is in compliance with the present finding that females showing a better growth rate than their male counterpart. Pauly(1984 a) reported that species having shorter life span have higher 'K' value and therefore can reach their Lα within one or two years. Conversely, those having flat growth rates are characterized by a lower 'K' values and takes more years to reach their Lα .In *P.carnaticus,* the moderate 'K' value in both the sexes support a moderate life span of the 4-5 years, which shows a strong corroboration with the established relations between is in general agreement with the relationship between 'K' values and Lα as reported (Pauly,1984 a).

Recruitment to the fishery was discernible during May to November in males with the major pulse in May-July and the minor in October-November. In females, the recruitment period extended from April to October with the major pulse from August to October and the minor in April May. This finding is very much in agreement with the results of maturation and spawning studies (see Chapter IX), which could identify an extended spawning season in *P.carnaticus* viz., April to August. The growth curves obtained using ELEFAN I also strongly corroborate the possible existence of a single brood in a year.

The present study revealed that *P. carnaticus* is a fast growing fish which attains marketable size by the end of the first year of its life. The growth co-efficient of *P. carnaticus* (male= 0.5; female = 0.650) was comparable with other freshwater fish species used for aquaculture. Moreover, the extended recruitment period (Male: May-October ; Female: April – October) revealed the long term availability of brooders and fingerlings in the wild. So the present findings are supportive of utilizing *P. carnaticus* as a prime an effective aquaculture species.

P.carnaticus,is having the status of vulnerable species. Non-availability of sufficient numbers of specimens belonging to all groups at regular intervals had been identified as one of the major limiting factor in pursuing the studies on length frequency using more refined methods. Since there is total lack of knowledge on the age and growth of *P.carnaticus*, the results of this pioneer work on these parameters would definitely advance our knowledge on the biology of this species and immensely help in formulating relevant conservation and management programmes for the protection and preservation of this species.

Table 11.1.Data for estimation of Lα and Z/K for male *Puntius carnaticus* using the method of Wetherall (1986 as modified by D. Pauly,1986 both in Fishbyte Vol.4(1):12-14 and 18-20

L(mean)-L	L'	N(cumulative)	
320.706	0.000	131625	
300.706	20.000	131625	
280.706	40.000	131625	
260.706	60.000	131625	
240.706	80.000	131625	
220.706	100.000	131625	
200.706	120.000	131625	
180.706	140.000	131625	
160.706	160.000	131625	
140.706	180.000	131625	
120.706	200.000	131625	
100.706	220.000	131625	
83.382	240.000	127853	
68.711	260.000	119197	
56.472	280.000	105279	
45.495	300.000	88162	
39.354	320.000	63406	
33.121	340.000	43162	
33.237	360.000	23081	
36.492	380.000	11536	
41.038	400.000	5988	***
32.265	420.000	4397	
19.651	440.000	3302	
10.000	460.000	1593	
*** regression line is fitted from this point			
Y= 251.55 + (-0.525)*X , r = -.997			
Estimate of Lα = 479.033mm			
Estimate of Z/K = 0.904			

Table 11.2.Data for estimation of Lα and Z/K for female *Puntius carnaticus* using the method of Wetherall (1986 as modified by D. Pauly,1986 both in Fishbyte Vol.4(1):12-14 and 18-20

L(mean)-L	L'	N(cumulative)	
344.598	0.000	131626	
324.598	20.000	131626	
304.598	40.000	131626	
284.598	60.000	131626	
264.598	80.000	131626	
244.598	100.000	131626	
224.598	120.000	131626	
204.598	140.000	131626	
184.598	160.000	131626	
164.598	180.000	131626	
144.598	200.000	131626	
124.598	220.000	131626	
104.598	240.000	131626	
84.598	260.000	131626	
68.925	280.000	124409	
54.095	300.000	114375	
46.020	320.000	90028	***
37.422	340.000	683821	
33.179	360.000	43427	
28.430	380.000	26193	
28.153	400.000	12653	
22.943	420.000	6972	
24.259	440.000	2634	
10.000	460.000	1878	
***regression line is fitted from this point			
Y=120.92+(-0.240)*X, r = -.960			
Estimate of Lα = 504.612mm			
Estimate of Z/K = 3.173			

Table 11.3. Data for estimation of Lα and Z/K for pooled category of *Puntius carnaticus* using the method of Wetherall (1986 as modified by D. Pauly, 1986 both in Fishbyte Vol.4(1):12-14 and 18-20

L(mean) -L	L'	N(cumulative)	
222.431	0	131627	
202.431	20	131627	
182.431	40	131627	
175.224	60	122535	
170.557	80	112129	
163.218	100	103933	
161.737	120	92726	
163.577	140	81059	
155.642	160	75155	
139.71	180	73113	
124.21	200	70661	
106.86	220	69059	
91.259	240	66059	
75.996	260	62420	
63.603	280	55969	
52.331	300	48132	
44.74	320	37221	
37.193	340	27399	
34.646	360	16688	
32.385	380	9704	
32.432	400	5119	***
26.479	420	3148	
22.768	440	1583	
10	460	1011	
*** regression line fitted from this point Y= 162.98 +(-0.325)*X, r = -.972 Estimate of Lα = 500.827mm Estmate of Z/K = 2.073			

Table 11.4. Growth parameters estimated by ELEFAN I for male and female *Puntius carnaticus*

Sex	Cohort	L_∞ (mm)	K	t_0	Rn	Φ
Males	August-September	493.5	0.5	-0.7448	181	5.08
Females	August-September	504.612	0.65	-0.7802	162	5.22

Table 11.5. Length arrived at various ages in males and females estimated by Elefan I method

Age(Years)	Male	Female
I	286.91	345.18
II	368.2	421.12
III	417.6	460.85
IV	447.62	481.65
V	465.87	-
VI	476.95	-

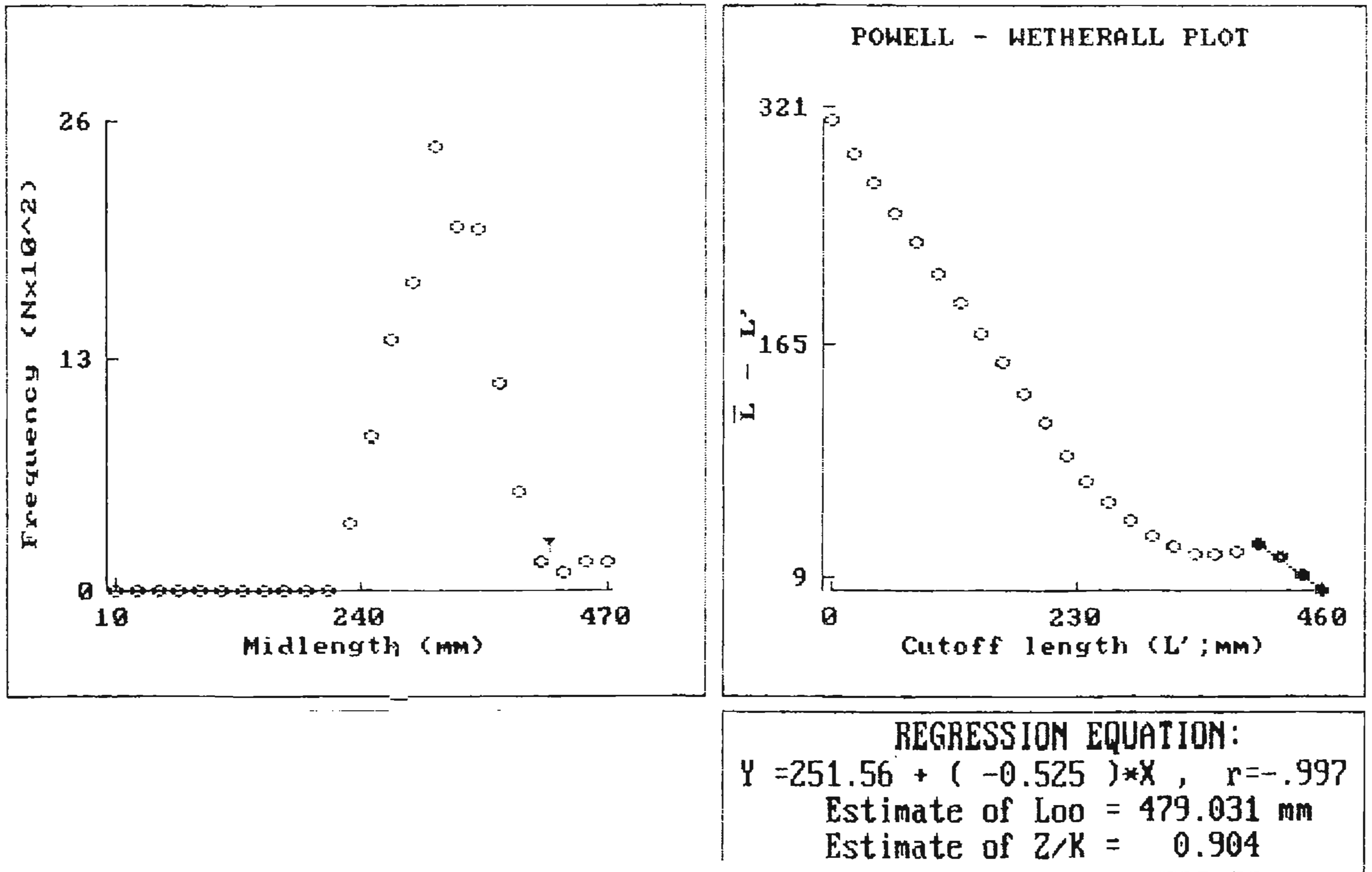
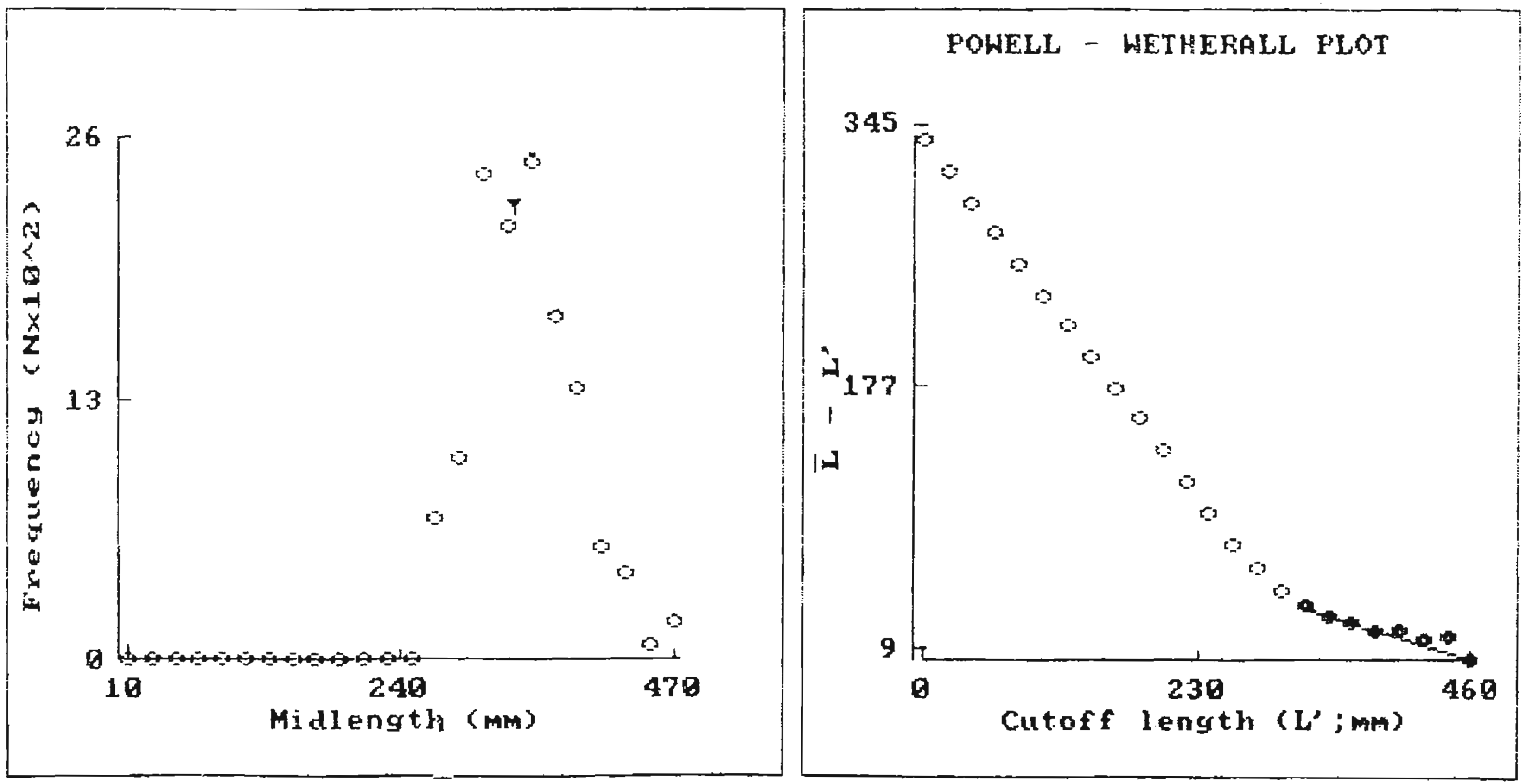


Fig.11.1.Powell – Wetherall plot for estimating Lα and Z/K of male population of

Puntius carnaticus



REGRESSION EQUATION:

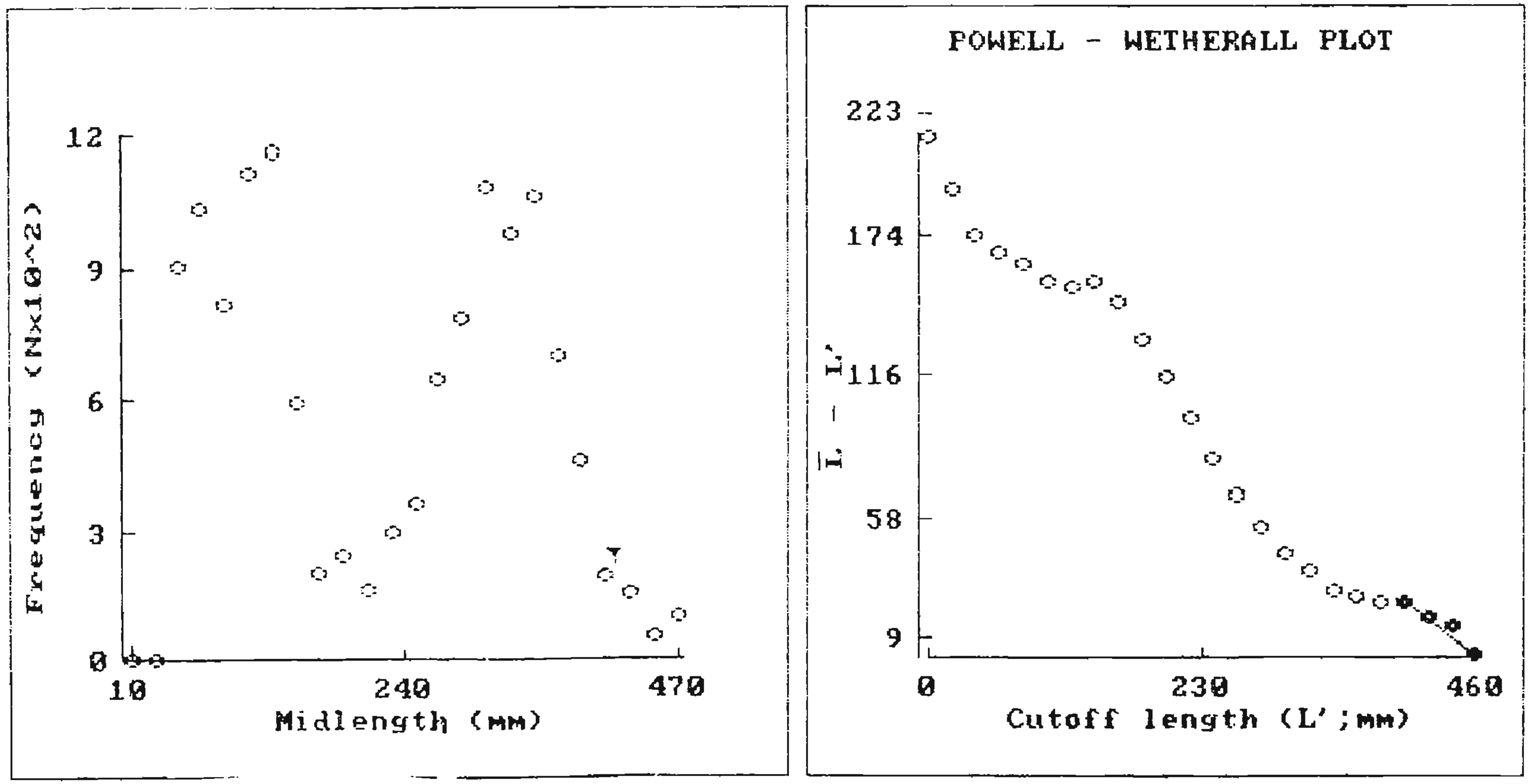
Y =120.92 + (-0.240)*X , r=-.960

Estimate of Loo = 504.611 mm

Estimate of Z/K = 3.173

Fig.11.2.Powell – Wetherall plot for estimating Lα and Z/K of female population of

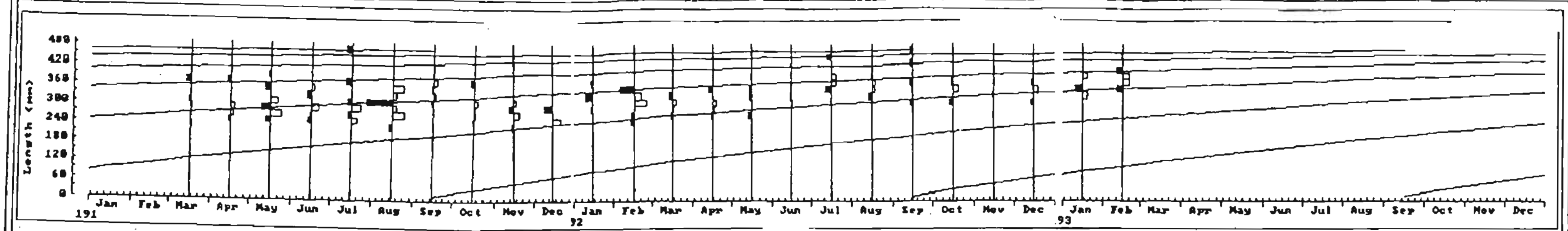
Puntius carnaticus



REGRESSION EQUATION:
Y =162.97 + (-0.325)*X , r=-.972
Estimate of Loo = 500.832 mm
Estimate of Z/K = 2.073

Fig.11.3.Powell – Wetherall plot for estimating Lα and Z/K of pooled population of

Puntius carnaticus



Loo ▶ 493.50
K ▶ 0.500
C ▶ 0.000
WP ▶ 0.000
SS ▶ 6
SL ▶ 310.00
Rn ▶ 0.181

Fig.11.4.Growth curve of male *Puntius carnatius* as estimated using the ELEFAN 1 programme

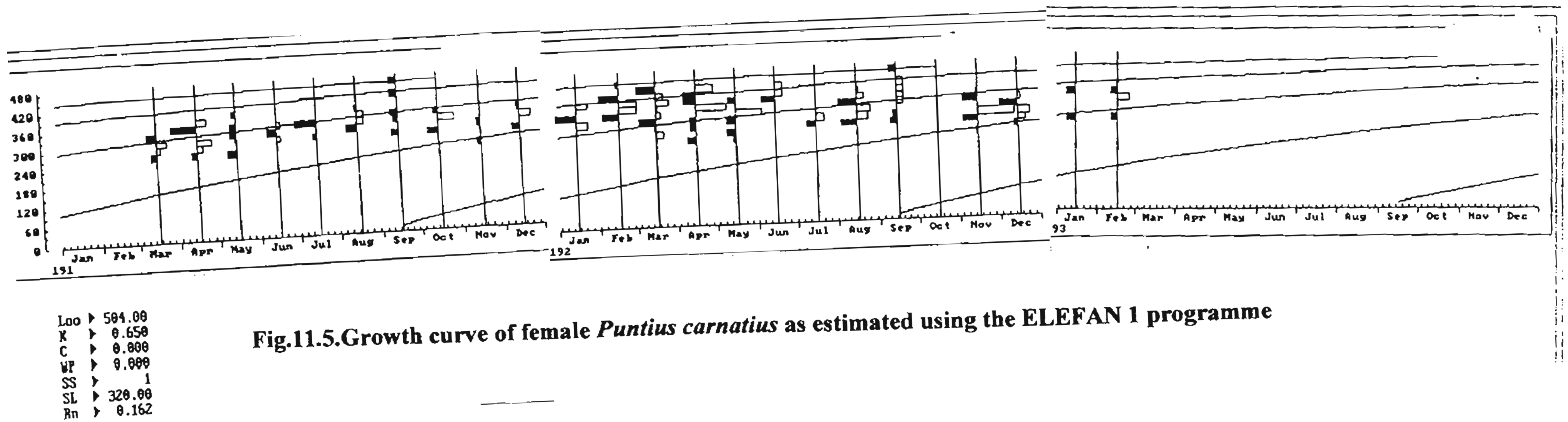
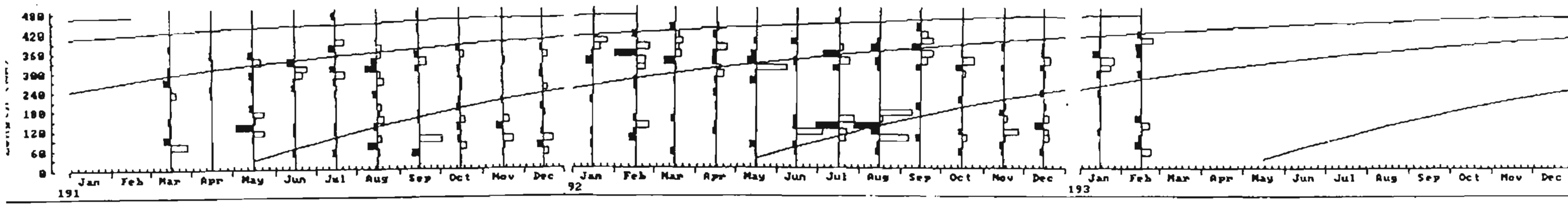
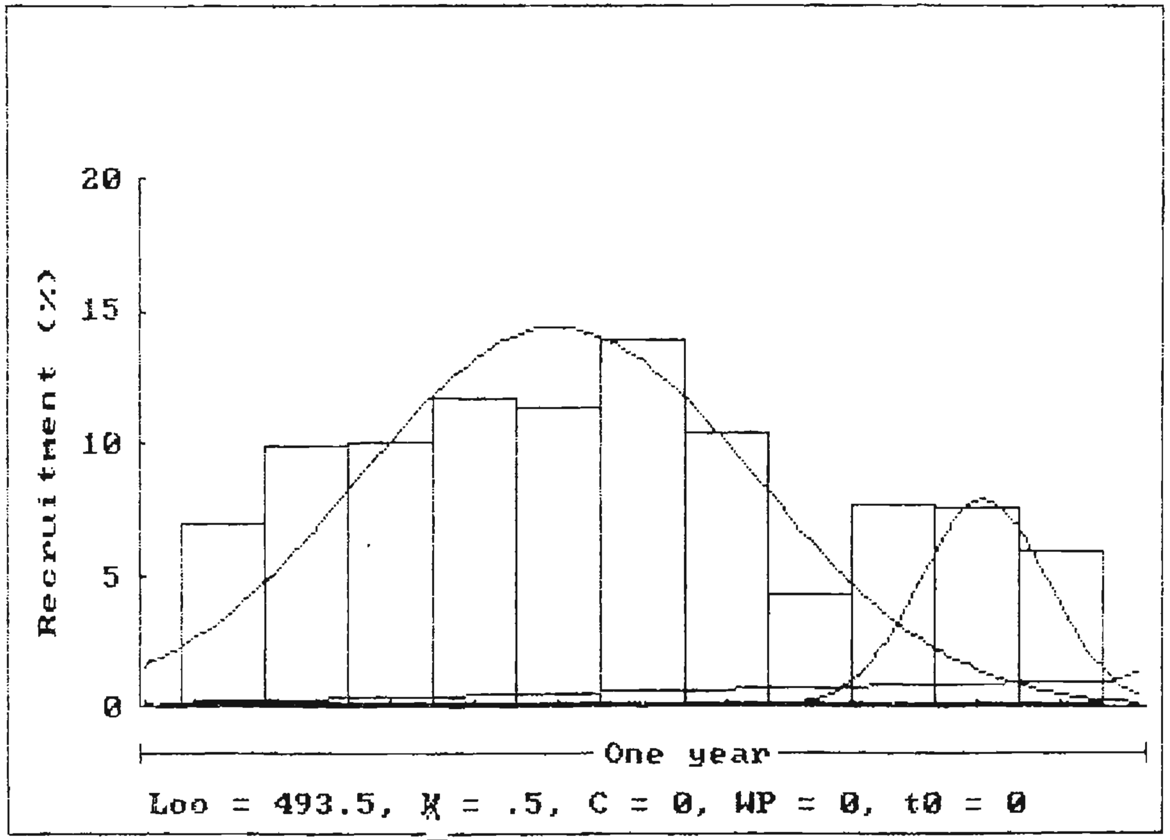


Fig.11.5.Growth curve of female *Puntius carnatius* as estimated using the ELEFAN 1 programme



Loo ▶ 500.83
K ▶ 0.970
C ▶ 0.000
WP ▶ 0.000
SS ▶ 15
SL ▶ 320.00
Rn ▶ 0.131

Fig.11.6.Growth curve of pooled population of *Puntius carnatius* as estimated using the ELEFAN 1 programme



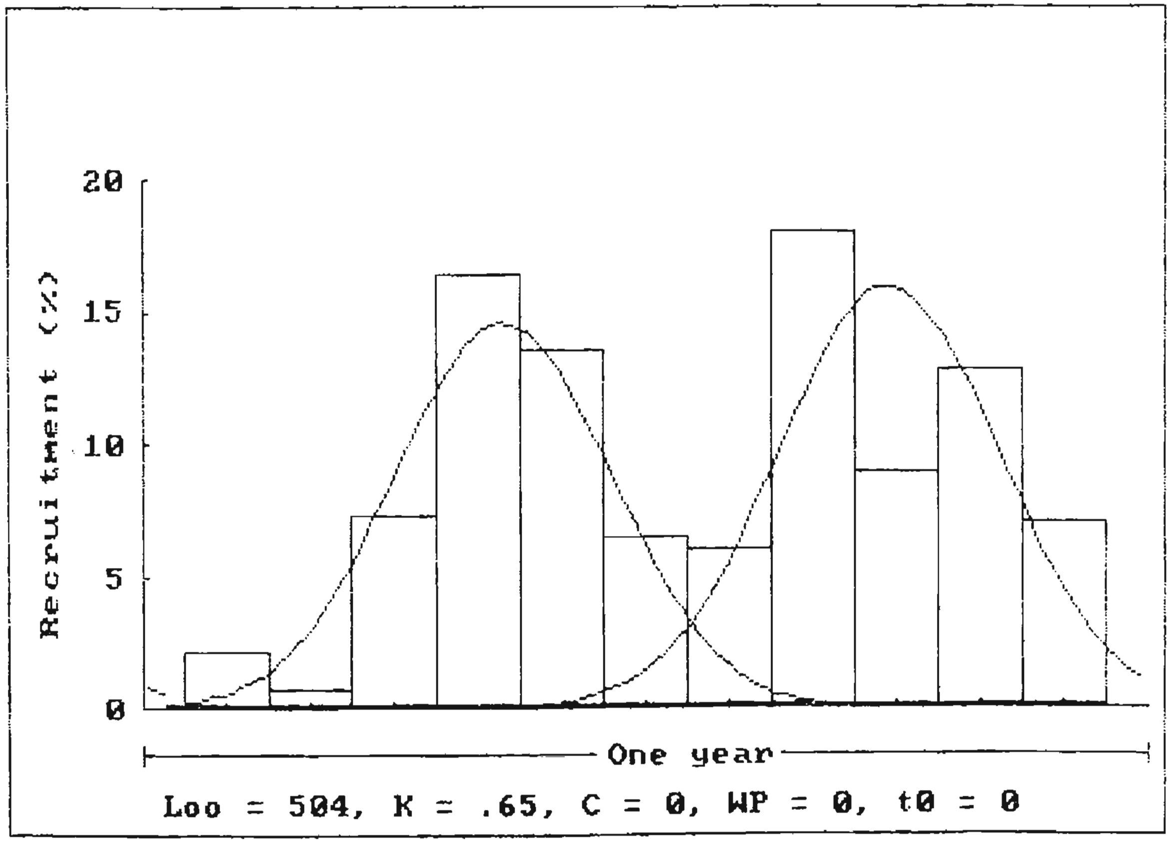
FILE: BRAISML
Wt. mode (2b)

Relative Time	Percent Recruitment
1	6.96
2	9.95
3	10.11
4	11.68
5	11.36
6	14.02
7	10.40
8	4.31
9	7.72
10	7.52
11	5.97
12	0.00

Group parameters:

Mean (1) :	4.50	Mean (2) :	9.59
S.D. (1) :	2.35	S.D. (2) :	0.78
N (%)(1) :	84.72	N (%)(2) :	15.28

Fig.11.7.Recruitment pattern of males of *Puntius carnaticus*



FILE: BARFMRS1
Wt. mode (2b)

Relative Time	Percent Recruitment
1	2.17
2	0.82
3	7.30
4	16.48
5	13.61
6	6.58
7	6.14
8	17.97
9	9.03
10	12.85
11	7.04
12	0.00

Group parameters:

Mean (1) :	3.80	Mean (2) :	8.41
S.D. (1) :	1.29	S.D. (2) :	1.32
N (%)(1) :	47.23	N (%)(2) :	52.77

Fig.11.8.Recruitment pattern of females of *Puntius carnaticus*

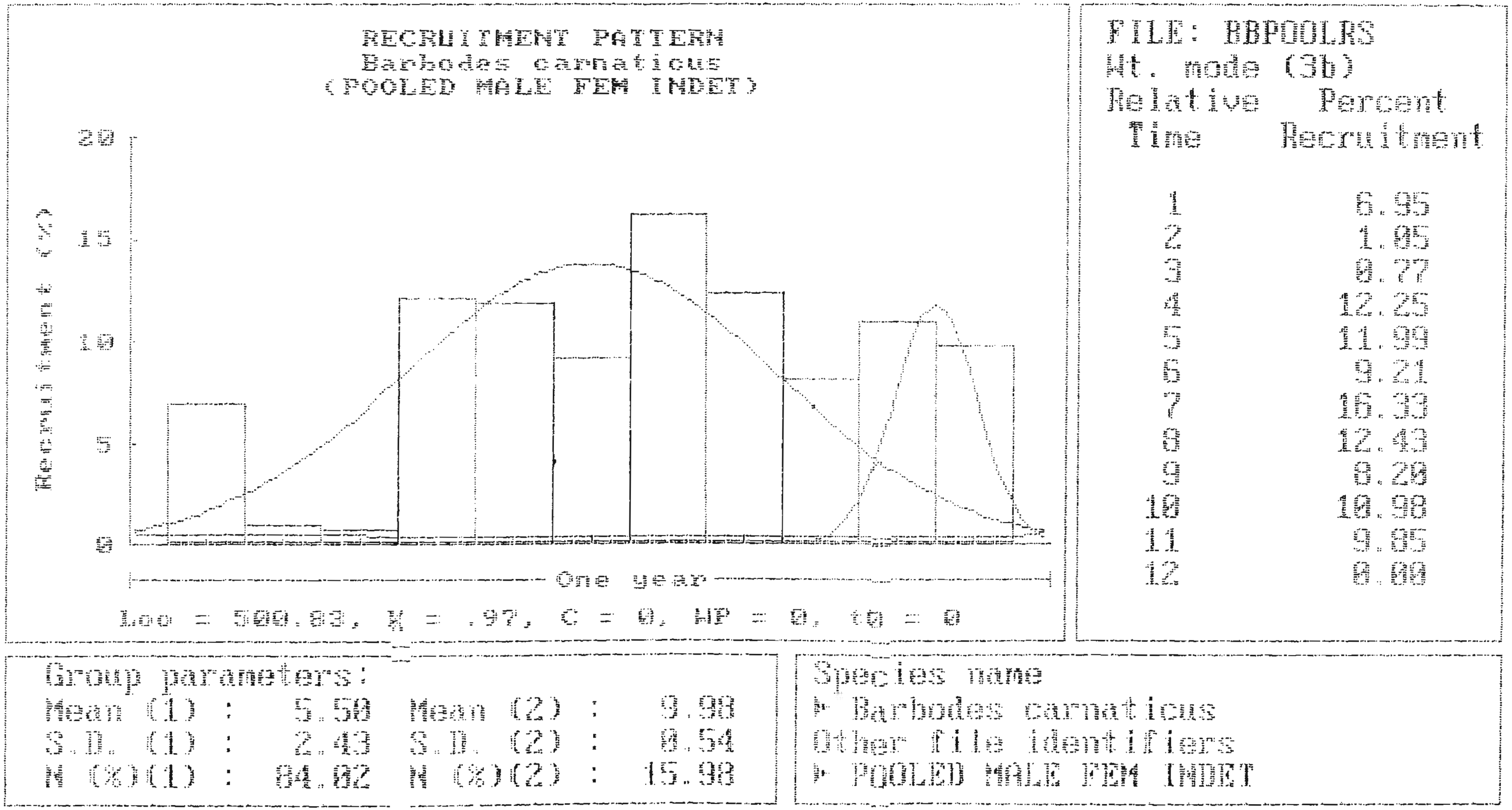


Fig.11.9.Recruitment pattern of pooled population of *Puntius carnaticus*

Chapter 12

Population Dynamics

12.1. Introduction

The fish population is highly dynamic due to various types of forces acting on it such as fishing and other fishery independent factors (Banerji, 1967). Successful management of this living resource is required for maintaining the balance of the stock between additive and destructive forces acting on the population. Fish exploitation has been increasing at a rapid rate to meet the growing demands of the rapidly multiplying human population which in turn has lead to a drastic decline in the abundance of many fish stocks. This situation calls for the development of suitable management strategies for the conservation of fishery resources for their rational use. Studies on population dynamics are essential to formulate fishing strategy to obtain the maximum sustainable yield without disturbing the equilibrium of fish stock. These studies help in evaluating both natural and human forces acting upon a population and fitting them into yield models so as to moderate the dynamic forces through management practices and thereby sustain benefits from the fish population on a long term basis (Bal and Rao, 1984).

Some of the important contributions on fish stock assessment in the tropics were those of Pauly(1980a, b; 1982a,b;1983 a,b; 1984a,b; 1987), Banerji and Chakraborthy(1973), Pauly and David(1981), Devraj(1983b), Sparre and Venema(1992) and Gayanilo and Pauly(1997). Miah *et al.* (1997) estimated the growth and mortality parameters of *Hilsa* from Bangladesh. Some of the recent works on the population dynamics of carps include those of Haroon *et al.* (1999, 2002) on major carps, Alam *et al.* (2000) on *Labeo calbasu*, Haroon *et al.* (2001) on *L. rohitha*, *L.calbasu* and *L.gonius* and Nurulamin *et al.*(2001) on *L.rohitha.*

Several studies on population dynamics of fishes from Indian waters are available, however, most of them pertain to marine fishes. Banerji(1967)highlighted the importance of fish population studies and reviewed the various methods available for such studies. The work of Sekharan(1974)on Oil Sardine and Mackerel, Krishnamoorthi(1976) on *Nemipterus japonicus*, Yohannan(1983) on Mackeral, Annigeri(1989)on *Sardinella gibbosa*, Karthikeyan *et al.*(1989) on *Leiognathus spp.*,Khan(1989)on *Harpodon nehereus*, Khan and Nandakumaran(1993) on *Cynoglossus sp.*,Reuben *et al.*(1994) on *Upeneus spp.*, Philip and Mathew(1996) on *Priacanthus hamur*, and Jaiswar *et al.*(2001) on *Decapterus russelli* are worth reporting. Goswami and Devaraj(1993)estimated the potential yield of *L. rohita* from a flood plain lake in Assam. Optimum yield assessment of *L. rohitha* and *Wallago attu* was carried out by Goswami and Devaraj(1994).The total mortality estimates of *W. attu* was done by the above authors(1996) from Bhramaputra basin of Assam region. Kurup (1998) studied the growth parameters, mortality, biomass recruitment pattern and exploitation rate of an indigenous endangered carp, *Labeo dussumieri* of river Pamba of Kerala (S. India).

P. carnaticus is an endemic vulnerable species of Kerala which requires protection and judicious exploitation of stock. Virtually, no information is available on any aspect of population dynamics of this endemic species. Therefore, present study is aimed at providing information on the mortality parameters and exploitation rate of *P. carnaticus* inhabiting Chalakudy river.

12.2. Materials and methods

882 specimens, comprising 262 males, 150 females and 470 indeterminates collected from Chalakudy river during April 2001 to March 2003 were used for the stock

assessment study. Assuming that the growth of this species follows von Bertalanffy growth formula (VBGF), growth parameters were estimated using FISAT (FAO-ICLARM Stock Assessment Tools) computer software package (Gayanilo and Pauly, 1997) as mentioned in Chapter 11 and results were used for the computation of various parameters given below:

12.2.1. Total mortality coefficient (Z)

Total mortality coefficient or instantaneous rate of total mortality expressed by Z, includes both natural mortality coefficient (M) and fishing mortality coefficient (F). Total mortality estimate was done by the methods of Beverton and Holt (1956), the cumulative catch curve method of Jones and Van Zalinge (1981), Ssentongo and Larkin method (1973), Pauly's pile up method (1983) and length converted catch curve method of Gayanilo *et al.* (1996).

12.2.1.1. Beverton and Holt method

Z was calculated from the mean length $\overline{L}$, L_α and K derived from the von Bertalanffy growth parameters.

$$Z = K \left[\frac{L_\alpha - \overline{L}}{\overline{L} - L'} \right]$$

where $\overline{L}$ = Mean length of fish

L' = Lower limit of the size group from which length upwards all lengths are under full exploitation.

12.2.1.2. Ssentongo and Larkin method (1973)

$$Z = K\left[\frac{n}{n+1}\right]\left[\frac{1}{\overline{Y} - Yc}\right]$$

$Y = -\ln(1 - l/l_{\alpha})$

$Yc = -\ln(l - lc/l_{\alpha})$

$\overline{Y} = \Sigma\, fy / \Sigma f$

where $n = \Sigma f$, $n+1 = \Sigma f + 1$

Yc = Corresponding to lc value

n = Number of fish caught from Yc onwards.

l = Mid length

12.2.1.3. Pauly's pile up method

$$\log_e (Nt/t) = a - b\, t^{*}$$

$$Z = -(-b),\ t^{*} = t_l + ½\, t$$

t = Time taken to grow from lower limit of the length class to upper limit.

$t = 1/K \log_e (L_{\alpha} - L_1) / (L_{\alpha} - L_2)$

$t_l = 1/K \log_e (1 - l/L_{\alpha})$

l = Lower limit of length class.

t_l = Relative age corresponding to lower limit of length class.

t^{*} = Relative age corresponding to the mid length of length-class.

N_t = Number of individual caught at time 't'.

12.2.1.4. Jones and van Zalinge method (1981)

Jones and van Zalinge found a linear relationship between catch and survivors. Following formula is applied:

$$\ln (C_{i,\alpha}) = a + \frac{Z}{K} \times \ln (L_{\alpha} - L_1)$$

where $C_{i,\alpha}$ = Cumulative catch corresponding to a given length.

i = Lower limit of that length class.

α = Indicates that the catch refers to a range from L_1 to all larger size.

12.2.1.5. Length converted catch curve method (Gayanilo *et al.*, 1996)

The length converted catch curve was computed using the following formula:

$$\ln (Ni / ti) = a + bti$$

where Ni = Number of specimens in length class i

ti = Relative age corresponding to length class i

12.2.2. Natural mortality coefficient

The methods of Sekharan (1974), Rikhter and Efanov (1976) and Pauly's empirical formula (Pauly, 1980 b) were used for calculating natural mortality coefficient.

12.2.2.1. Sekharan's method

This method is based on the assumption that 99% of fish would die if there was no exploitation when they reach t_{max}, which corresponds to L_{max}. L_{max} is the maximum observed length in the catch.

$$M = -(\log_e 0.01/t_{max})$$

where t_{max} = Age at L_{max} calculated from VBGF equation.

12.2.2.2. Rikhter and Efanov method (1976)

This method used the following formula:

$$M = (1.521 / t_m^{-0.72}) - 0.155$$

where t_m = Age at which 50% of the population is mature.

12.2.2.3. Pauly's empirical formula (1980)

Natural mortality is given by the following empirical formula:

$$\mathbf{Log_{10}\ M = 0.0066 - 0.279\ log_{10}\ L_\alpha + 0.6543\ log_{10}\ K + 0.4634\ log_{10}\ T}$$

where M = Natural mortality

$L\alpha$ and K = Growth parameters of VBGF

T = Annual mean temperature (^{0}C) of the water in which the fishes lives.

In the present study, T was taken as 25^0C.

12.2.3. Probabilities of capture

The probability of capture by length (Pauly, 1984b) of *P.carnaticus* was calculated by the ratio between the points of the extrapolated descending arm of the length –converted catch curve using the FISAT software.

12.2.4. Fishing Mortality Coefficient

Instantaneous rate of fishing mortality (F) was computed by subtracting natural mortality (M) from total mortality (Z).

$$\mathbf{F = Z - M}$$

12.2.5. Exploitation rate (U)

The rate of exploitation is defined as the fraction of fish present at the start of a year that is caught during the year (Ricker, 1975). This is estimated by the equation given by Beverton and Holt (1957) and Ricker (1975) as:

$$U = \frac{F}{Z}(1 - e^{-Z})$$

12.2.6. Exploitation ratio (E)

It refers to the ratio between fish caught and the total mortality (Ricker, 1975) or the exploitation rate or fraction of death caused by fishing (Sparre and Venema (1992). It is estimated by the equation:

$$E = \frac{F}{Z} = \frac{F}{M + F}$$

The ratio gives an indication of the state of exploitation of a stock under the assumption that the optimal value of E equals 0.5 ($E \approx 0.5$).

This, in turn, is under the assumption that the sustainable yield is optimised when $F \approx M$ (Gulland, 1971).

12.2.7. Virtual population analysis-VPA (Gulland, 1965)

The term virtual population means the part, by number, of a fish stock that is alive at a given time and which will be caught in future. In virtual population analysis the annual catch obtained from a single cohort during the exploited phase is used to calculate the abundance and fishing mortality rates of the cohort in each year. Managing a fishery by limiting effort requires estimates of annual abundance and total catch at different levels of fishing effort. VPA is a suitable method in such situations.

The basic equations used in this analysis are:

$$1.C\ (I, t, t+1) = N\ (i, t) \frac{F\ (i,t+1)}{M+F(i,t,t+1)} \exp\ [M+F\ (i,t,t+1)]$$

$$2. \frac{C\ (i, t, t+1)}{N\ (i+1,t+1)} = \frac{F\ (i, t, t+1)}{M+F(i,t,t+1)} \{\exp\ [M+F9i, t,t+1)]-1\}$$

3. N (i,t) = N(i+1,t+1) exp[M+F(I,t,t+1)]

(the notation exp (x) used in place of e^x)

The terms used in these equations have the following meanings:

C (I, t, t+1): Catch in number for year I with ages between t and t+1

N (i, t) : Number of fish (survivors) of age t in the sea at the beginning of year i

F (i, t, t+1): Instantaneous rate of fishing mortality during the year i for those between ages t and t+1

M : Instantaneous rate of natural mortality which is assumed to be the same for all age groups

Z (i, t, t+1) = M+F (I, t, t+1): Instantaneous rate of total mortality during year I for those between ages t and t+1.

The calculation for VPA starts from the bottom (highest age class in the catch, also known as the terminal class). With an initial guess of the fishing mortality for the terminal class (terminal F value), knowing the estimate of natural mortality M and catch for the terminal class, it is possible to estimate the number of survivors at the beginning of the year for this class from the first equation as:

M+F (i, t, t+1) C (i, t, t+1)

$$N(I, t) = \frac{\quad}{F(i, t, t+1)} \quad \frac{\quad}{\exp[M+F(i,t,t+1)]}$$

Since the number of survivors at the beginning of a year is same as the number of survivors at the end of the previous year, the estimation of the fishing mortality is also possible for the immediate previous age class from the second equation in which the only unknown factor will be F (i, t, t+1). The number of survivors for this class can be estimated using the third equation. This procedure can be repeated in this fashion starting from the last age class to estimate fishing mortality and number of survivors for each of the age classes.

12.2.8. Length based cohort analysis (Jones, 1984)

Cohort analysis is employed to estimate stock sizes and fishing mortalities. In this analysis, the number of fishes in the river that attain L, is given by

$$\mathbf{N\,(L_1) = [N\,(L_2)\,S\,(L_1, L_2) + C\,(L_1, L_2)]\,S\,(L_1, L_2)}$$

$$\text{Where } S(L_1, L_2) = [(L_\alpha - L_1) / (L_\alpha - L_2)]^{M/2K}$$

The exploitation rate is determined from the relationship

$$\mathbf{F/Z = C\,(L_1, L_2) / [N\,(L_1) - N\,(L_2)]}$$

The fishing mortality was calculated using the formula, $F = M\,(F/Z)/(1-F/Z)$. In the above expressions, L_α and K are growth parameters of VBGF. L_1 and L_2 are the lower and upper limits of a length group considered, N is the stock number, C is the number caught, F and M are the fishing and natural mortality coefficients respectively.

12.2.9. Relative yield per recruit (Y/R) and relative biomass per recruit (B/R)

Y/R and B/R values were determined as a function of Lc/Lα and M/K (Pauly and Soriano, 1986). The estimates were made using the FISAT software.

12.3. Results

The growth parameters used for the stock assessment studies were estimated using ELEFAN I programme of FISAT software (see chapter 11). Lα, K and t_0 computed in respect of males and females of *P.carnaticus* are 493.5,0.5 and –0.7448 and 504,0.65 and –0.7802 respectively.

12.3.1. Total mortality coefficient (Z)

Total mortality (Z) of males and females of *P.carnaticus*, estimated following different methods, are presented in Table 12.1.There exists variation in the values of Z calculated by different methods and therefore, further analysis was carried out based on the average values arrived at from various methods. The total mortality values calculated for males ranged from 1.9(Ssentongo and Larkin Method, 1973) to 3.64(Jones and Van Zalinge method, 1981). The average of the estimates by various methods was 2.01. In female population, the values of Z varied between 1.97(Pauly's pile up method, 1983) to 3.46(Jones and Van Zalinge method, 1981), the average being 2.78. The results of the catch curve analysis for male and female *P.carnaticus* are depicted in Figs.12.1 and 12.2 respectively.Fig.12.3 and Fig.12.4 represents the Jones and Van Zalinge plot for the estimation of total mortality of *P. carnaticus* in Chalakudy river.

12.3.2. Natural mortality coefficient (M)

The values of natural mortality coefficient worked out by different methods in males and females of *P.carnaticus* are given in Table 12.2.In males, the values of M were found to be 1.37 by Rikhter and Efanov method, 0.77 by Sekharan's method and 0.45 by Pauly's empirical formula. In the case of females, the natural mortality was estimated to be 1.37 by Rikhter and Efanov method, 0.99 by Sekharan's method and 0.54 by Pauly's empirical formula.

12.3.3. Probabilities of capture and length at first capture (l_c)

The results of the length converted catch curve method were used for the estimation of probabilities of capture and l_c .The values obtained by the probability of capture were L-25=278.19 mm, L-50=301.1mm and L-75 = 324.01mm in males (Table 12.3) and L-25=310.6mm,L-50= 334.15mm and L-75 = 357.7mm in females (Table 12.4) respectively.

12.3.4. Fishing mortality coefficient (F), exploitation rate (U) and Exploitation ratio (E)

Fishing mortality coefficient worked out for males and females were 1.15 and 1.81 respectively. The exploitation ratio (E) in male and female of *P.carnaticus* was 0.57 and 0.65 respectively. Similarly, the exploitation rate (U) was found to be 0.52 in males and 0.36 in females.

12.3.5. Virtual population analysis (VPA)

Results of the virtual population analysis of males and females are shown in Table 12.5 and 12.6 respectively. The F value increases to a maximum of 1.15 at 460-480mm and the maximum number of fishes were caught in the size group 300-320mm. In the case of females the maximum F value of 1.81 was observed in the 460-480mm size class and maximum numbers were caught in the size group 340-360mm.The average F value was 0.159 in males and 0.098 in females. The mean numbers, the length-wise catch and the steady state biomass pertaining to each length class of males (Table 12.7) show that the maximum catch (4116.6t) was obtained in the size class 300-320mm (Fig.12.5). Catch constituted mainly of 260-380mm length groups. The mean numbers, the length-wise catch and the steady state biomass pertaining to each length class of females is shown in Table 12.8. The maximum catch (9611 t) was observed in the size class 340-360mm (Fig.12.6). In the case of females the catch was mainly constituted by 300-400mm size groups.

In males, the biomass increased from 116.4 t in the size group 40-60 to the maximum of 6887.5t in 300-320mm length group and thereafter gradually declined to 712.9 in 460-480mm size group. In females, the biomass increased from 82.4t in 40-60mm size group to 8596.8t in 300-320mm length group. Thereafter, the biomass decreased to 930t in 460-480mm length class. The mean E was 0.103 in males and 0.14 in females.

12.3.6. Length based cohort analysis

The results of the length based cohort analysis of male population (Fig.12.7) revealed that the exploitation started at 200mm and increased up to 340mm and thereafter decreased. In females (Fig.12.8) the exploitation began from 240mm and gradually increased up to 380mm size, thenceforth a decline was noticed.

12.3.7. Relative yield per recruit model (Y'/R)

The relative yield per recruit (Y'/R) and biomass per recruit (B/R) of male and female populations of *P.carnaticus* are given in Table 12.9 and 12.10 respectively. In males the $L_C/L\infty$ and M/K used for the Y'/R analysis were 0.3 and 1.73 respectively. The yield per recruit reaches a maximum at an exploitation rate of 0.53 and as the exploitation rate increases the Y'/R decreases. Fig.12.9 depicts the relationship between present exploitation rate, relative yield per recruit and relative biomass per recruit, which revealed the present exploitation rate, E (0.52) was almost reached to the optimum exploitation rate(E_{max} =0.53). The $E_{-0.1}$ was estimated as 0.45 and $E_{-0.5}$ as 0.3.

In females the $L_C/L\infty$ and M/K used for the Y'/R analysis were 0.3 and 1.48 respectively. The yield per recruit reaches a maximum at an exploitation rate of 0.52 and as the exploitation rate increases the Y'/R decreases. The relationship between present exploitation rate, relative yield per recruit and relative biomass per recruit are shown in Fig.12.10.The results revealed that the present exploitation rate, E (0.36) is below the optimum exploitation rate (E_{max} =0.52). The $E_{-0.1}$ was estimated as 0.46 and $E_{-0.5}$ as 0.31.

12.4. Discussion

Progress on studies on fish population dynamics in tropical waters has been slow even though great strides have been made in temperate regions since 19^{th} century. The main hindrance in the study of population dynamics of tropical fishes are due to the well known problems such as the difficulty in the determination of age of fishes from their hard parts owing to the absence of clear cut annual markings on them and also due to the existence of large number of species supporting the fishery and variety of gears used for harvest. The stock assessment investigations from tropical waters gained momentum in the eighties due to the introduction of length based methods and models and also by the development of suitable computer soft wares like ELEFAN, LFSA and FISAT. In India most of the studies on population dynamics pertain to marine fishes. Non availability of required number of specimens belonging to different size classes has been the major factor hindering the progress of such studies in freshwater fishes in general and threatened fishes in particular. *P.carnaticus* is a vulnerable endemic fish of Western ghats. Virtually no information is available on the population dynamics of this species and hence the urgency of such a study was felt.

Mortality is caused by natural factors like diseases, predation, environmental change, senility etc. in the unexploited stock while in exploited stocks, in addition to natural causes, fishing is the major cause for mortality. Therefore total mortality of exploited stock comprises both natural and fishing mortalities. For estimating total mortality, five methods viz.,Beverton and Holt method(1956), Jones and Van Zalinge method(1981), Ssentongo and Larkin method(1973), Pauly's pile up method(1983)and length converted catch curve method(Gayanilo et al.,1996) were used. In male *P.carnaticus* , Z value was lowest in Ssentongo and Larkin method (1973) and highest in Jones and Van Zalinge method(1981). The estimate of Z was comparable in Pauly's pile up method and Ssentongo and Larkin method. The average value of mortality coefficient found from the five methods were 2.01 which was very close to the one estimated from catch curve method and Beverton and Holt method. In females, the values arrived at Ssentongo and Larkin method (1973) and catch curve method (1996) were almost comparable. Pauly's pile up method (1983) showed the lowest value while it was highest in Jone and Van Zalinge method (1981).

For estimating natural mortality coefficient (M), several simple methods are available and the best and easy method is regressing Z against effort (Sparre and Venema 1992). However, in the tropical multi-species system, apportioning of effort for a single species is difficult. Hence this method could not be attempted in this study. Moreover, as natural mortality is influenced by several biological and environmental factors, it is difficult to get an accurate estimate (Pauly, 1980b; Cushing 1981; Liu and Cheng, 1999). Further, it is also related to other growth parameters like Lα(Sparre and Venema, 1992), maturity (Rikhter and Efanov, 1976) and gonad weight (Gunderson and Dygert, 1988). The empirical equation of Pauly(1980b), Sekharan's method(1974) and the method of Rikhter and Efanov(1976) were used to derive natural mortality in the present study. In the case of males Pauly's empirical formula gave the lowest value while it was highest in Rikhter and Efanov method (1976). In females also, Pauly's empirical formula was the lowest while Rikhter and Efanov method showed the highest value. The low natural mortality arrived at in both the sexes of *P. carnaticus* was in compliance with the observation of Cushing(1981) who reported that the natural mortality is closely related to age and size and is low in larger fishes due to low predation rate. Therefore, M can be correlated to longevity of the fish and which in turn is correlated to growth coefficient K. M/K ratio can be used as an index for checking the validity of M and K values and the ratio usually ranged from 1 to 2.5 (Beverton and Holt, 1959). In the present study, the M/K ratios computed were 0.9(Pauly,s empirical formula,1980),1.54(Sekharan's method,1974) and 2.74(Rikhter and Efanov method,1976) in males and the same in females were 0.83,1.52 and 2.11 respectively. It was found that M/K ratio calculated using the M values estimated by all the three methods calculated in males except that using Rikhter and Efanov method falls under the limits proposed by Beverton and Holt (1959). The average M/K ratio obtained for male *P. carnaticus* was 1.72 while it was 1.5 in females. M/K ratio is found constant among closely related species and sometimes within the similar taxonomic groups (Beverton and Holt, 1959; Banerji, 1973). In the present study, the M/K ratios calculated in both males and females of *P.carnaticus* using three different methods were in compliance with that of *L.dussumieri*(Kurup,1998),*L.calbasu*(Alarm,*et al.*,2000)and *L.rohitha*(Nurulamin *et al.*,2001)

Estimation of the probabilities of capture showed that in males the exploitation starts at a lower size than in females. In males 25% of the total catch was less than 278.2 mm size, 50% was less than 301.1mm size and 75% of the total individuals were less than 324mm size. Whereas in females, the L-25, L-50 and L-75 were estimated to be 310.6mm, 334.2mm and 357.7mm respectively.

The fishing mortality co-efficient of females (1.81) was comparatively higher than in males (1.15) which justified the high exploitation ratio. Virtual population analysis showed the highest 'F' value of 1.15 in the 460-480 mm size class in males and the fishery was dominated by 300-320mm size class. While in females the highest 'F' value of 1.81 was also observed in 460-480mm length class and the maximum fishery was contributed by 340-360mm size group. Higher the average 'F' value in males, in contrast to females, revealed that males are more exploited in lower size group than females. This finding is also supported by the results of the length based cohort analysis which revealed that in males exploitation starts at 200mm and intensified up to 340mm followed by a decline. While in females exploitation begins from 240mm and gradually increased up to 380mm and thereafter showed a decrease.

In males, the present exploitation rate is 0.52, which is lesser than the E_{max} (0.53). In females, the exploitation rate and the E_{max} were 0.36 and 0.52 respectively. This implies that the stocks of *P.carnaticus* are not under excess fishing pressure and are well within the optimal level of exploitation. The higher exploitation of males of *P.carnaticus* may be attributed to three reasons 1) Due to the preponderance of males in the population (Sex ratio between males and females = 1:0.6), there is a possibility of its hiher exploitation.2) The commercial catch coming from the Peringalkuthu reservoir is mainly contributed by gill nets. Since males of this species are agile and inhabits in surface water in contrast to females which is characterised by a subsurface habitat preference, the former is more vulnerable to gillnet fishery.3) As evinced in the results of length based cohort analysis, in males, the exploitation starts in the lower length classes when compared to its female counterpart.

The result of the present study revealed that harvest of *P. carnaticus* could be kept at sustainable level by maintaining the present exploitation rate of male population. Even though this species belonged to vulnerable category, in Chalakudy river system, based on the present findings, it can be recommended that the fishing pressure of female can be improved by increasing the exploitation rate from 0.36 to 0.52 by way of excreting selective gillnet fishing effectively so that the production of *P.carnaticus* can be improved substantially.

Table 12.1.Estimation of total mortality coefficient(Z) of *Puntius carnaticus* collected from Chalakudy river system by different methods

Sl.no.	Method	Total mortality co-efficient(Z)	
		Males	Females
1	Beverton and holt method	2.09	2.99
2	Ssentongo and Larkin method	1.9	2.76
3	Pauly's pile up method	1.92	1.97
4	Jones and van Zalinge method	3.64	3.46
5	Length converted catch curve method	2.15	2.71
	Average	2.34	2.78

Table 12.2.Estimation of notal mortality coefficient(M) of *Puntius carnaticus* collected from Chalakudy river system by different methods

Sl.no.	Method	Natural mortality co-efficient(M)	
		Males	Females
1	Sekharan's method	0.77	0.99
2	Rikhter and Efanov method	1.37	1.37
3	Pauly's empirical formula	0.45	0.54
	Average	0.86	0.97

Table 12.3.Probabilities of captureof males of *Puntius carnaticus* collected from Peringalkuthu region of Chalakudy river

Midlength(mm)	Probabilities of selection	Smooth probability
230	0.0288	0.03200
250	0.0886	0.07940
270	0.197	0.18371
290	0.3477	0.36997
310	1.0000	0.60509
330	1.0000	0.79992
350	1.0000	0.91252
370	1.0000	0.96456
390	1.0000	0.98612
410	1.0000	0.99463
430	1.0000	0.99794
450	1.0000	0.99921
470	1.0000	0.99970
L-25 = 278.19	L_∞ = 493.500	
L-50 = 301.10	K = 0.50	
L- 75 = 324.01	t_0 = -0.75	
slope = 0.048		

Table 12.4.Probabilities of captureof femals of *Puntius carnaticus* collected from Peringalkuthu region of Chalakudy river

Mid length(mm)	Probabilities of selection	Smooth probability
270	0.0523	0.04776
290	0.0993	0.11308
310	0.3471	0.24478
330	0.4637	0.45174
350	1.0000	0.67686
370	1.0000	0.84190
390	1.0000	0.93121
410	1.0000	0.97176
430	1.0000	0.98870
450	1.0000	0.99552
470	1.0000	0.99823
L-25 = 310.601	L_∞ = 504.612	
L-50 = 334.151	K = 0.65	
L-75 = 357.700	t_0 = -0.78	
slope = 0.047		

Table 12.5.FISAT output of results of the length-structured VPA results for *Puntius-carnaticus* collected from Peringalkuthu region of Chalakudy river, Kerala, S. India

Length class(mm)	Catches(N)	Population(N*10^ 3	Fishing mortality
0 -20	0.00	2340608.5	0.0000
20 -40	0.00	2179843	0.0000
40 -60	0.00	2023894.13	0.0000
60 -80	0.00	1872820.38	0.0000
80 -100	0.00	1726683.63	0.0000
100 -120	0.00	1585549.63	0.0000
120 -140	0.00	1449488.38	0.0000
140 -160	0.00	1318574.63	0.0000
160 -180	0.00	1192888.25	0.0000
180 -200	0.00	1072515.25	0.0000
200 -220	0.00	957548.56	0.0000
220 -240	68530.00	848089	0.0570
240 -260	158200.00	737832.13	0.1415
260 -280	254860.00	625849.19	0.2507
280 -300	312390.00	512953.31	0.3478
300 -320	451780.00	404473.16	0.5976
320 -340	369190.00	294281.06	0.6099
340 -360	365970.00	205302.09	0.7976
360 -380	209620.00	129243.17	0.6302
380 -400	100820.00	79676.53	0.4136
400 -420	28570.00	48629.66	0.1543
420 -440	20000.00	29845	0.1426
440 -460	30960.00	15786.22	0.3501
460 -480	29090 (Ct)	5084.43 (Nt)	1.15 (Ft)

Table 12.6.FISAT output of results of the length-structured VPA results for female *Puntius carnaticus* collected from Peringalkuthu region of Chalakudy river, Kerala, S. India

Length class(mm)	Catches(N)	Population(N*10^ 2	Fishing mortality
0 -20	0.00	1708469	0.0000
20 -40	0.00	1608291	0.0000
40 -60	0.00	1510131	0.0000
60 -80	0.00	1414032	0.0000
80 -100	0.00	1320041	0.0000
100 -120	0.00	1228209	0.0000
120 -140	0.00	1138588	0.0000
140 -160	0.00	1051237	0.0000
160 -180	0.00	966217.81	0.0000
180 -200	0.00	883598.44	0.0000
200 -220	0.00	803453.31	0.0000
220 -240	0.00	725863.81	0.0000
240 -260	0.00	650919.81	0.0000
260 -280	131350.00	578721.44	0.1860
280 -300	181820.00	497069.28	0.2777
300 -320	144090.00	415382.47	0.7708
320 -340	394130.00	315088.75	0.8248
340 -360	455190.00	229322.25	1.2259
360 -380	313660.00	147786.44	1.1680
380 -400	246800.00	90371.46	1.3607
400 -420	104720.00	48098.27	0.8849
420 -440	79690.00	26147.81	1.0862
440 -460	14290.00	11062.25	0.3174
460 -480	34290	5266.64 (Nt)	1.81 (Ft)

Table 12.7.FISAT output of results of the length-structured VPA II results for male *Puntius carnaticus* collected from Peringalkuthu region of Chalakudy river, Kerala, S. India

VPA II	FEMALE				
ML(mm)	DELTA T(years)		Mean N	Catch(tonnes)	Steady state biomass
10	0.083		186936560	0.00	2688.91
30	0.086		181335952	0.00	31637.04
50	0.09		175667200	0.00	116426.33
70	0.094		169926400	0.00	276610.72
90	0.099		164109392	0.00	525236.06
110	0.104		158210672	0.00	870321.19
130	0.11		152225344	0.00	1315520.38
150	0.116		146146976	0.00	1860455.13
170	0.124		139968592	0.00	2500887.5
190	0.132		133682152	0.00	3228774.75
210	0.141		127278512	0.00	4032243.5
230	0.152		120237088	277842.91	4874802.5
250	0.164		111817336	804141.69	5683753.5
270	0.179		101639424	1596196.75	6365711.5
290	0.197		89815304	2375029.50	6828451
310	0.218		75597824	4116012.25	6887457.5
330	0.245		60534900	3985369.75	6534682.5
350	0.279		45886152	4634486.00	5810824.5
370	0.325		33261348	3086566.00	4897593
390	0.388		24377820	1712501.13	4140750.25

Table 12.8.FISAT output of results of the length-structured VPA II results for female *Puntius carnaticus* collected from Peringalkuthu region of Chalakudy river, Kerala, S. India

ML(mm)	DELTA T(years)		Mean N	Catch(tonnes)	Steady state biomass
10	0.062		103276464	0.00	1559.41
30	0.065		101196136	0.00	20700.63
50	0.068		99070944	0.00	82441.8
70	0.071		96897448	0.00	207717.23
90	0.074		94672752	0.00	413777.06
110	0.078		92392512	0.00	714664.56
130	0.082		90052816	0.00	1121381.38
150	0.087		87648720	0.00	1641899.88
170	0.092		85174560	0.00	2281088.5
190	0.098		82623864	0.00	3040562.5
210	0.105		79989176	0.00	3918459.5
230	0.112		77261856	0.00	4909135.5
250	0.121		74431336	0.00	6002725.5
270	0.132		70636208	1320130.63	7099278.5
290	0.144		65468884	2241815	8072221
310	0.159		57613136	6626530.5	8596798
330	0.177		47787120	7032929.5	8527223
350	0.2		37130896	9611792	7840552
370	0.23		26854784	7764700.5	6647942
390	0.271		18137770	7102841.5	5220004.5
410	0.329		11833654	3477508.25	3929682
430	0.418		7336653.5	3032741	2792090.5
450	0.576		4501660.5	619393.01	1951225.38
470	0.933		1894475.25	1683252.75	929973.94
Total		%	1513883904.00	50513620.00	85963104.00

Table 12.9.FISAT output of yield/ recruit from selection data for male *Puntius carnaticus* from Peringalkuthu region of Chalakudy river

Parameters : $L_c/L\alpha$ = .304, M/K = 1.7283

E	Y'/R	B'/R
0.05	0.0058153	0.9076060
0.10	0.0110788	0.8190400
0.15	0.0157783	0.7344400
0.20	0.0199028	0.6539460
0.25	0.0234429	0.5776970
0.30	0.0263913	0.5058320
0.35	0.0287436	0.4384850
0.40	0.0304987	0.3757860
0.45	0.0316598	0.3178540
0.50	0.0322359	0.2647940
0.55	0.0322425	0.2166940
0.60	0.0317036	0.1736140
0.65	0.0306536	0.1355830
0.70	0.0291391	0.1025810
0.75	0.0272216	0.7453500
0.80	0.0249797	0.0512970
0.85	0.0225115	0.0326320
0.90	0.0199353	0.0181950
0.95	0.0173880	0.0075170
1.00	0.0150181	0.0000000

Table 12.10.FISAT output of yield/ recruit from selection data for female *Puntius carnaticus* from Peringalkuthu region of Chalakudy river
Parameters : $L_c/L\alpha$ = .2976, M/K = 1.4995

E	Y'/R	B'/R
0.05	0.0072342	0.908536
0.10	0.0137944	0.820618
0.15	0.0196603	0.736402
0.20	0.0248129	0.656047
0.25	0.0292345	0.579715
0.30	0.0329097	0.507572
0.35	0.035826	0.439786
0.40	0.037975	0.376518
0.45	0.0393537	0.317931
0.50	0.0399661	0.264173
0.55	0.0398253	0.21538
0.60	0.0389563	0.171666
0.65	0.0373986	0.133109
0.70	0.0352108	0.099746
0.75	0.0324742	0.71551
0.80	0.0292982	0.048415
0.85	0.0258254	0.030124
0.90	0.0222344	0.01633
0.95	0.0187387	0.006519
1.00	0.0155741	0.000000

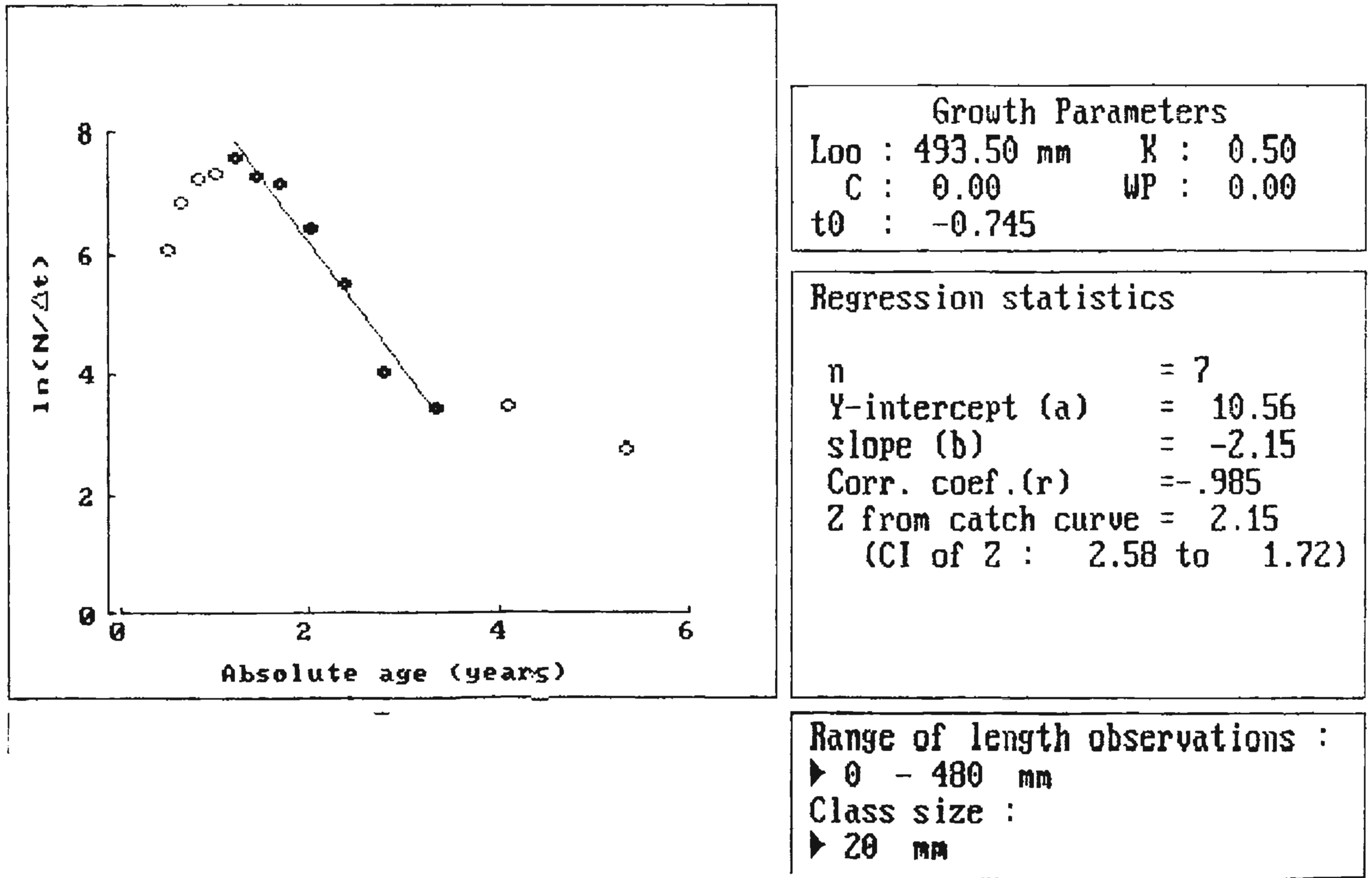
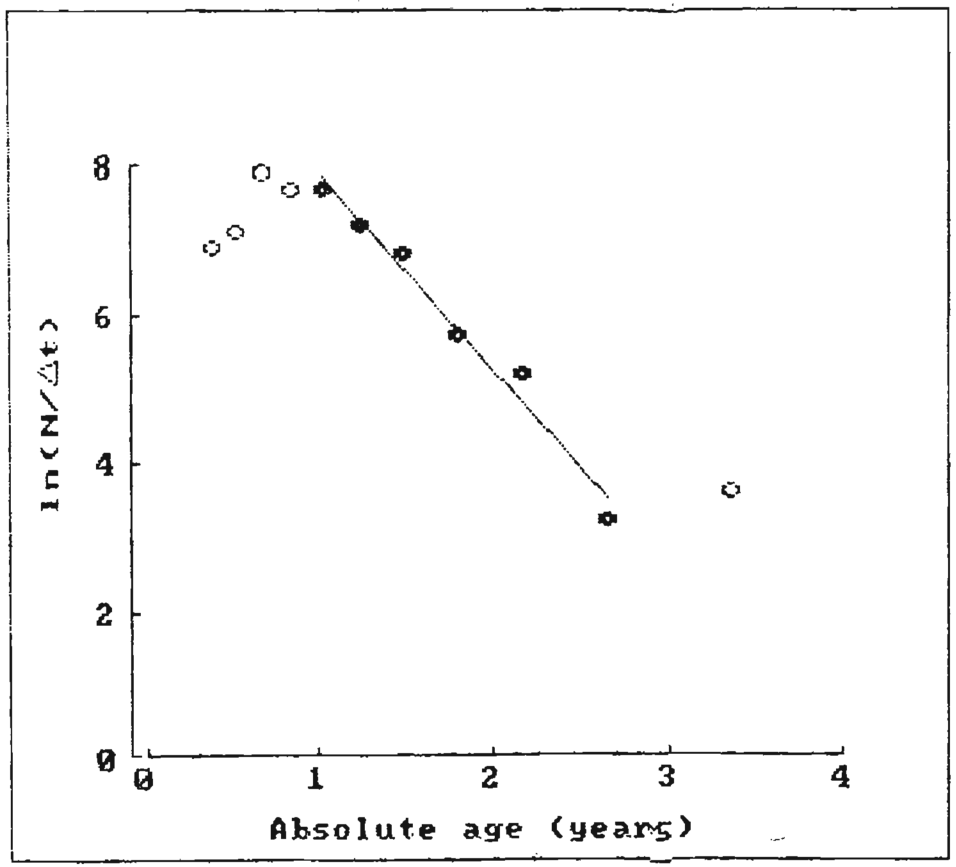


Fig.12.1.Results of the catch curve analysis of male *Puntius carnaticus*



Growth Parameters

Loo : 504.00 mm   K : 0.65
C : 0.00   WP : 0.00
t0 : -0.780

Regression statistics

n = 6
Y-intercept (a) = 10.71
slope (b) = -2.71
Corr. coef.(r) =-.987
Z from catch curve = 2.71
(CI of Z : 3.31 to 2.10)

Range of length observations :
▶ 0 - 480 mm
Class size :
▶ 20 mm

Fig.12.2.Results of the catch curve analysis of female *Puntius carnaticus*

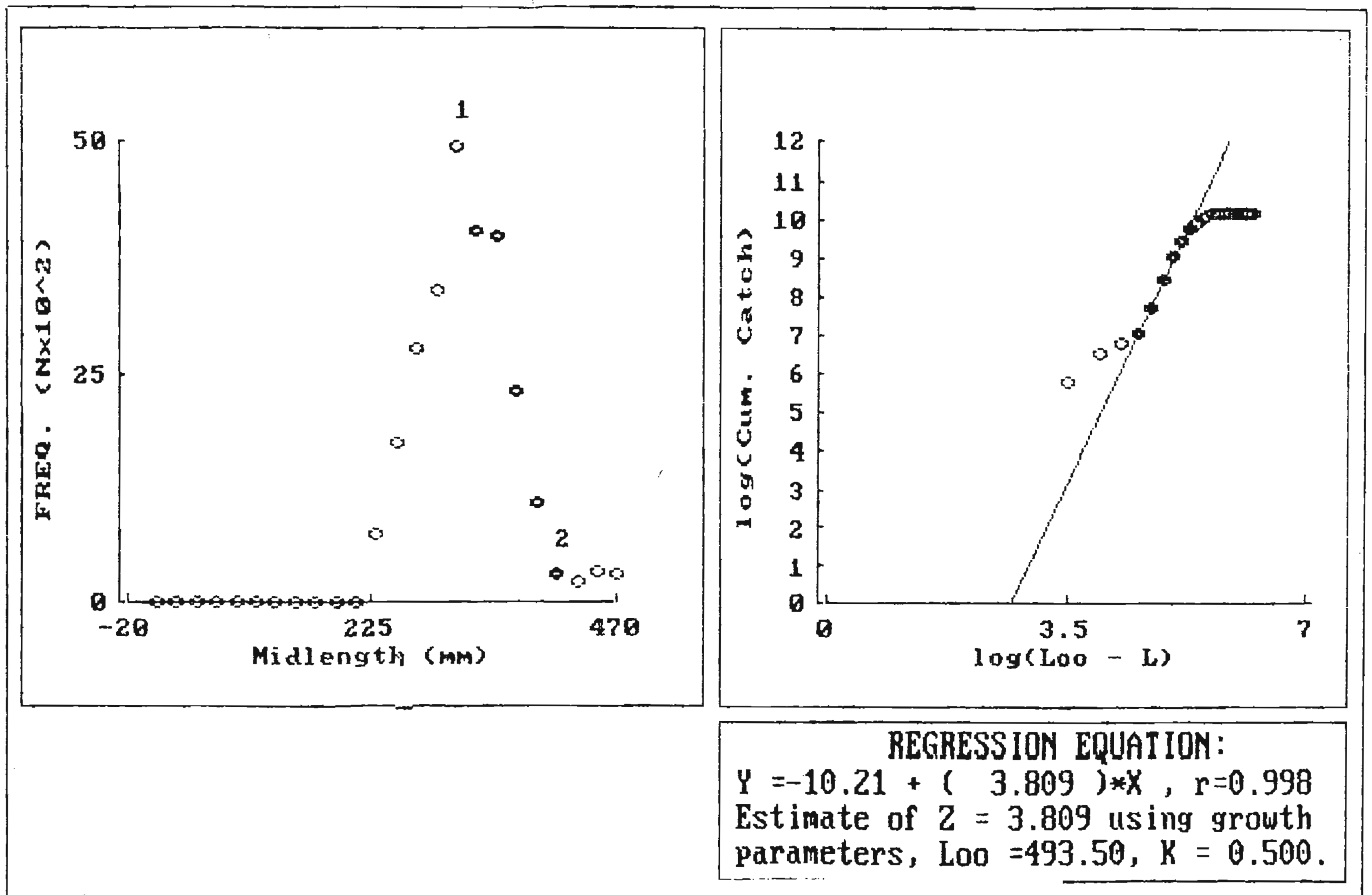


Fig.12.3.Jones and Van Zalinge plot for the estimation of total mortality of males of *Puntius carnaticus* in Chalakudy river

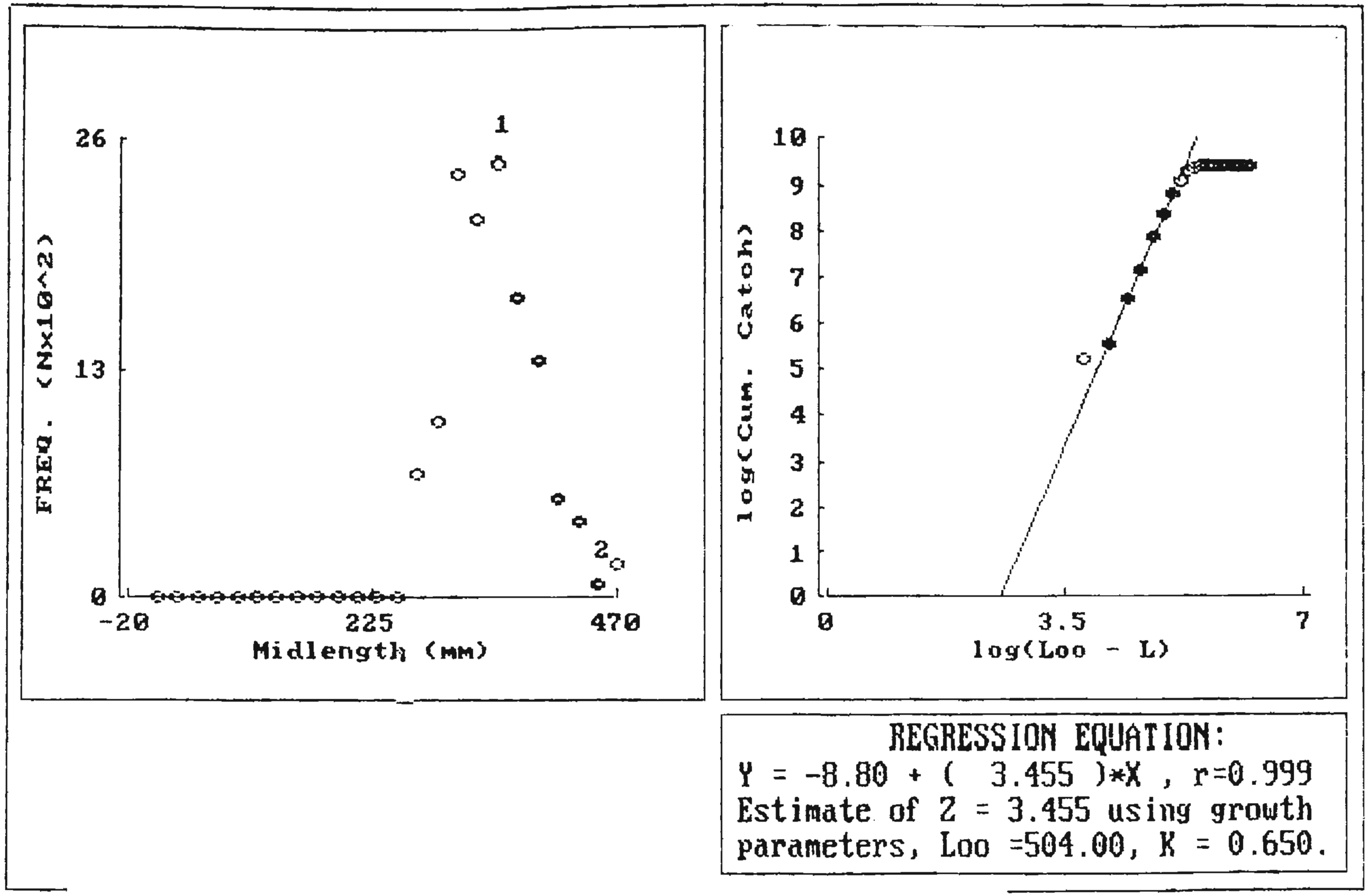


Fig.12.4.Jones and Van Zalinge plot for the estimation of total mortality of females of *Puntius carnaticus* in Chalakudy river

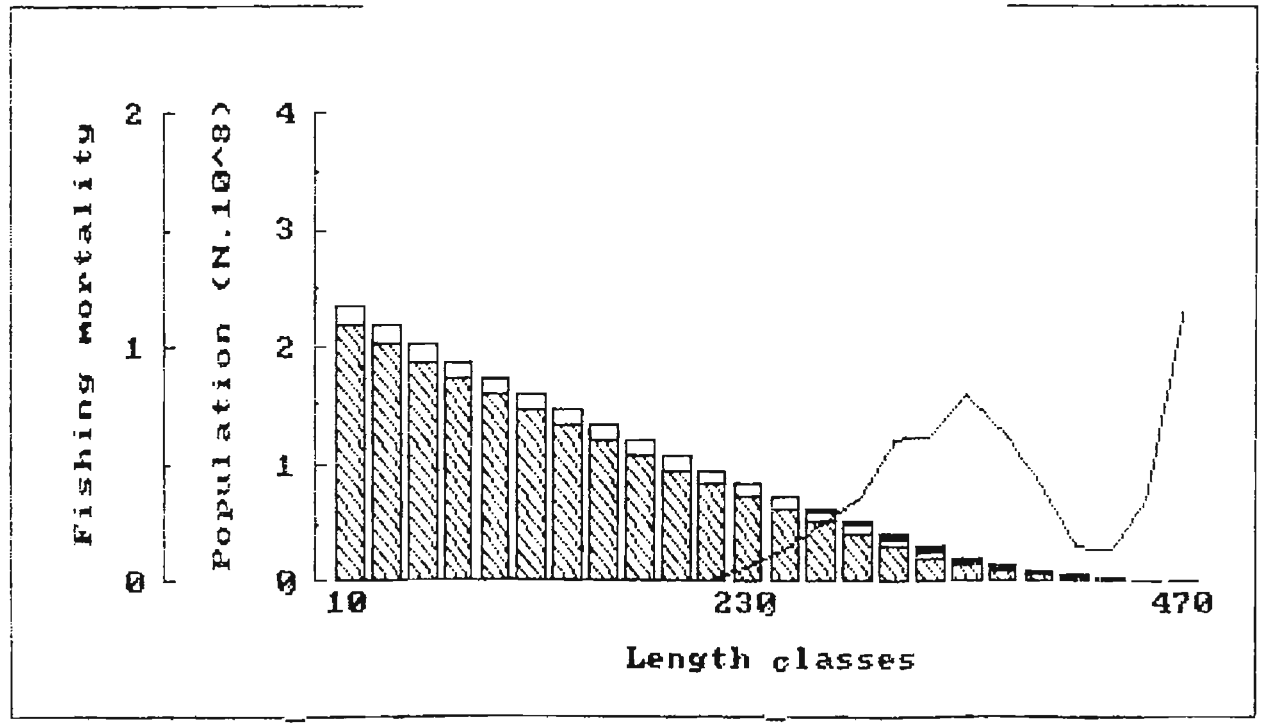


Fig.12.5.Length structured virtual population analysis of males of *Puntius carnaticus*

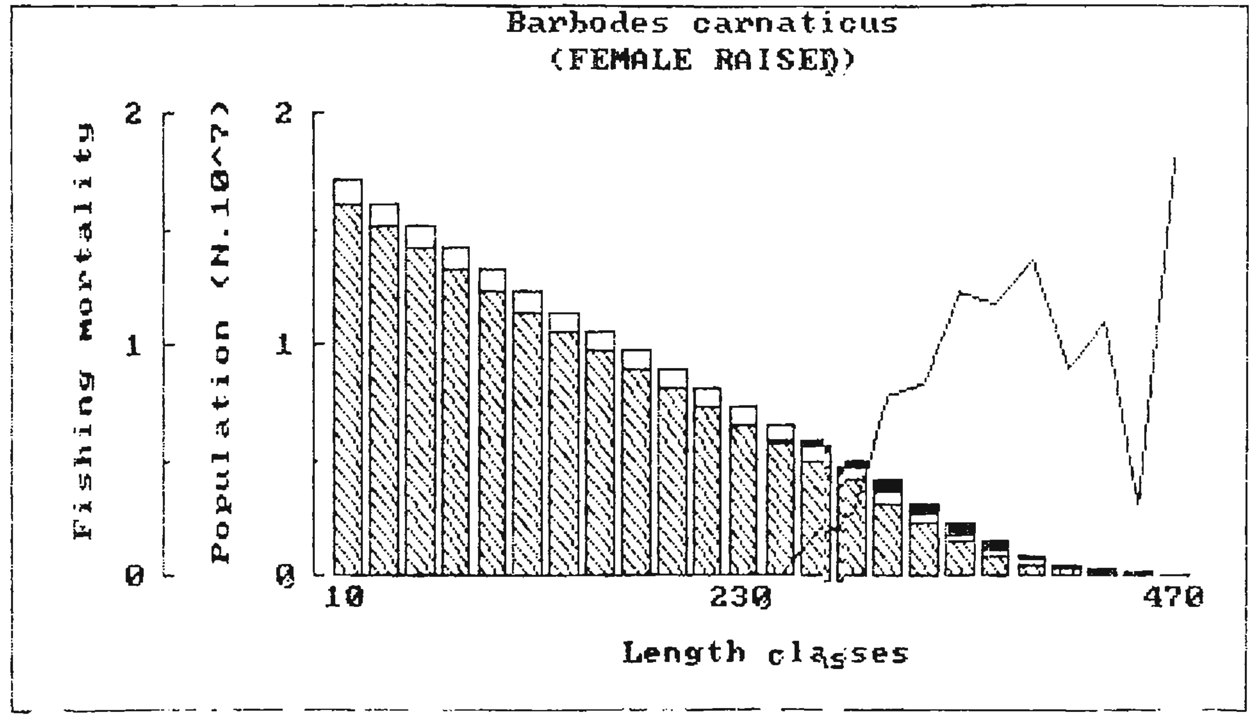


Fig.12.6.Length structured virtual population analysis of females of *Puntius carnaticus*

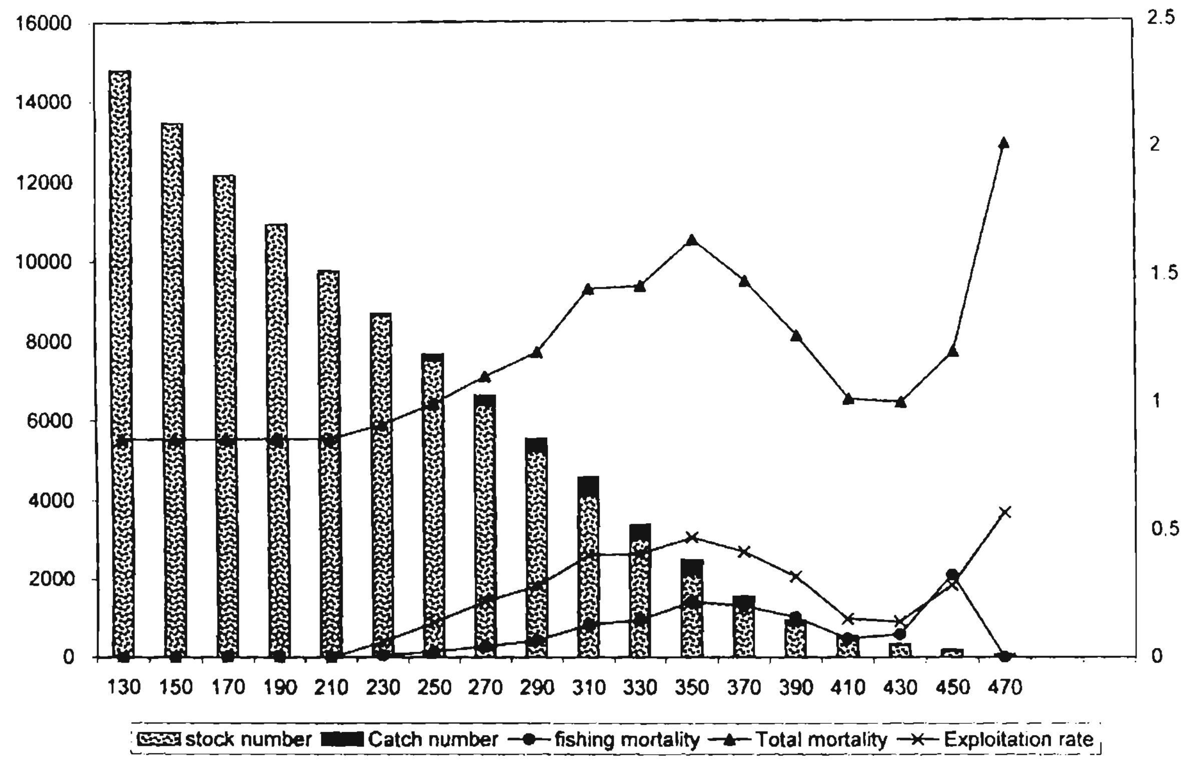


Fig.12.7.Length- cohort analysis of males of *Puntius carnaticus*

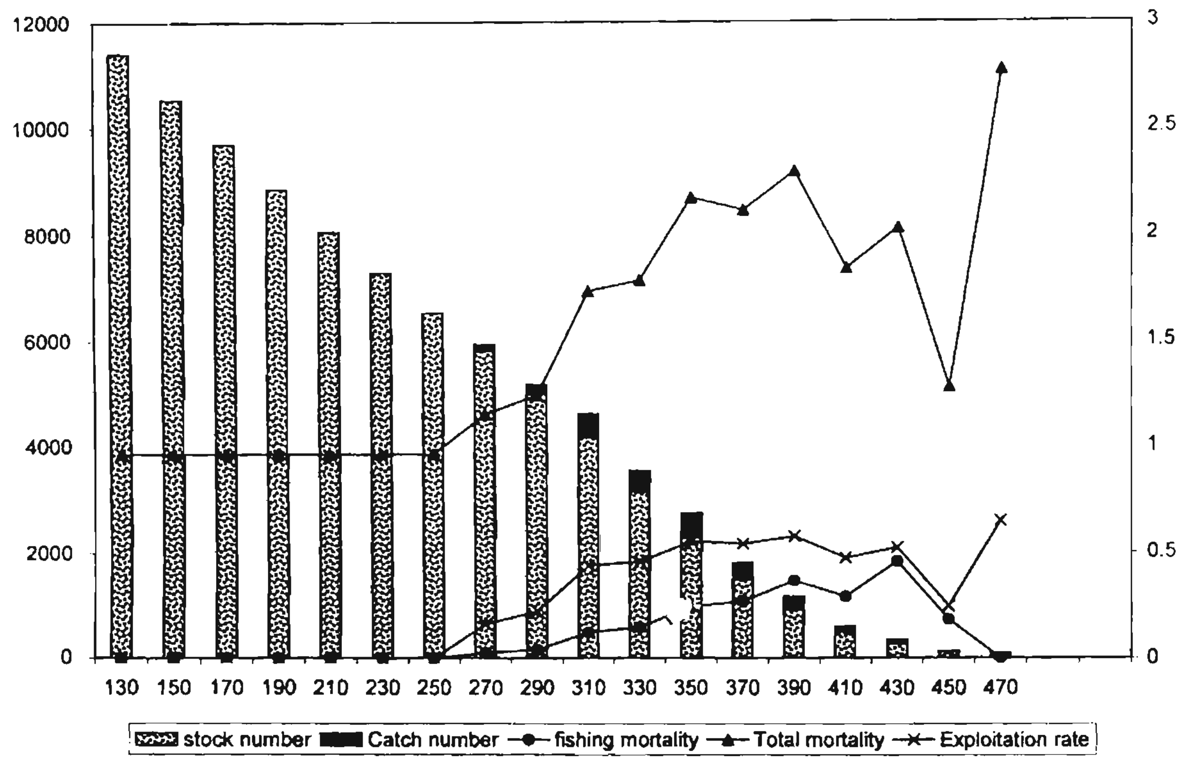


Fig.12.8.Length- cohort analysis of females of *Puntius carnaticus*

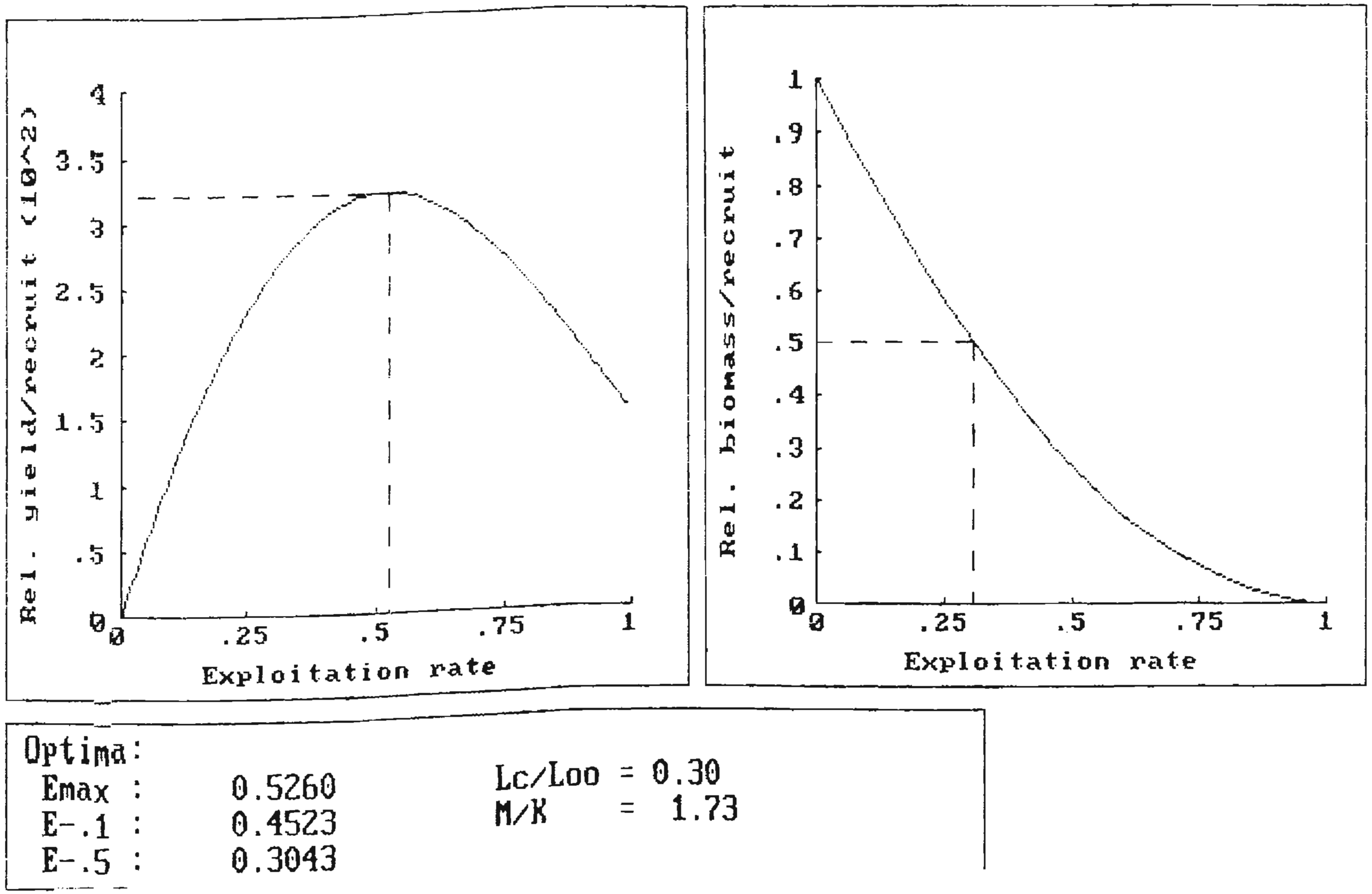


Fig.12.9.Relationship between present exploitation rate, relative yield per recruit and relative biomass per recruit in males of *Puntius carnaticus*

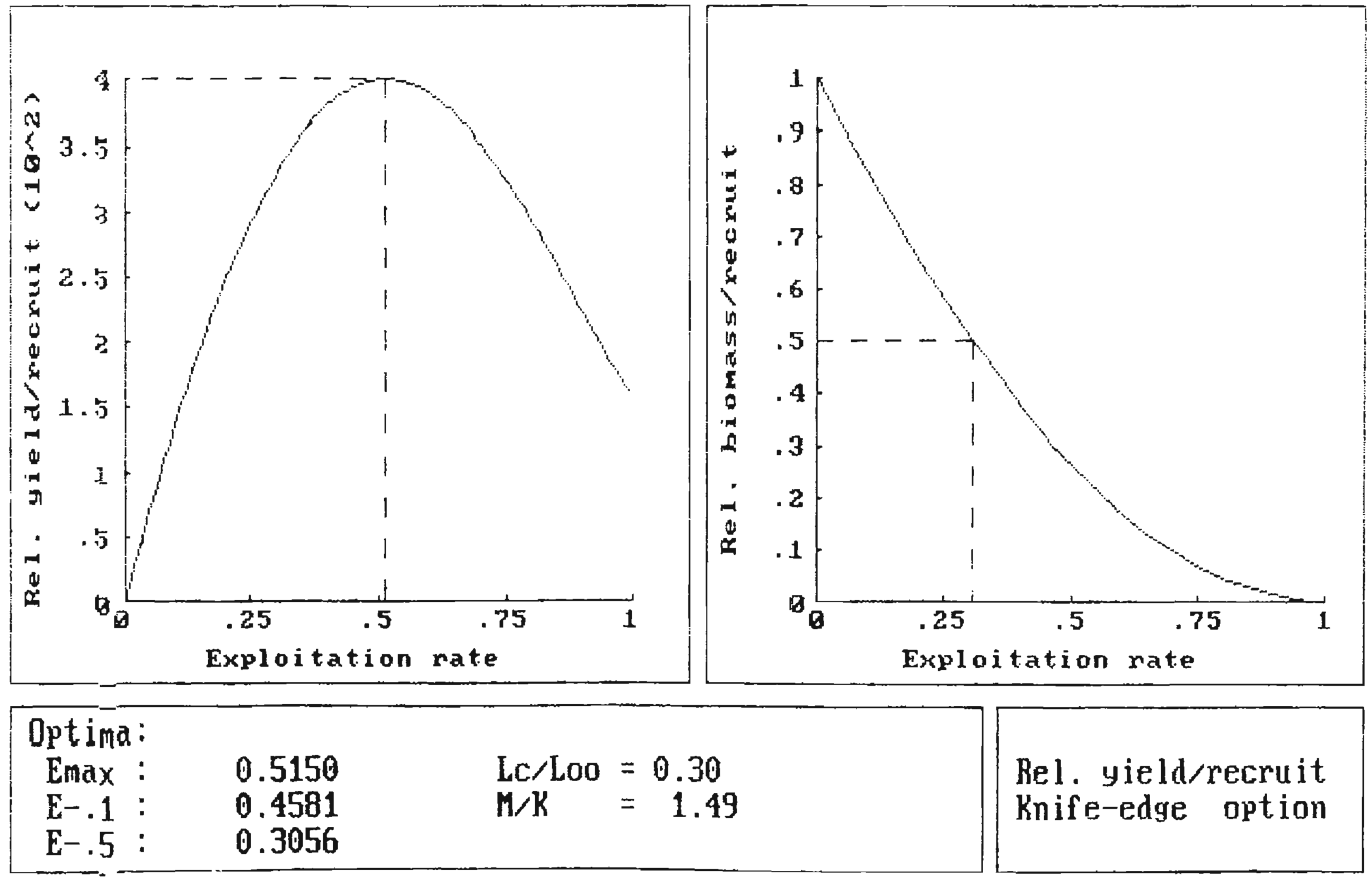


Fig.12.10.Relationship between present exploitation rate, relative yield per recruit and relative biomass per recruit in males of *Puntius carnaticus*

Chapter 13

Summary and Recommendations

13.1. Summary

Biodiversity refers to the variety within the living world. It manifests itself at all hierarchically related levels of biological organization from gene through cells, tissues, organs, individuals, populations, species, communities and life forms of ecosystems. The loss of biodiversity is a natural process, which takes many forms, but at its most fundamental and irreversible outcome it involves in the extinction of species. The convention of biodiversity signed by 156 countries at the Earth Summit in June 1992 in Rio de Janeiro thus shows that conservation of biodiversity currently regarded as a problem of worldwide scope. Scientists estimate that over the next 25 years more than a million species of plants and animals will become extinct. 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. The loss and impairment of natural habitats as well as pollution are universally recognized as the prime causes of loss of biodiversity. 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 human 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.

Seen from this perspective, scientists have a particular responsibility, a central role to play both in order to understand better the biodiversity phenomenon and to be able to draw up clear guidelines for careful resource management. In a review by WWF, IUCN and UNEP on the ways of conserving genetic diversity of freshwater fish it was recommended that the best way to conserve species diversity is to conserve habitats. 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. The habitat studies in freshwater ecosystems are very essential for the proper understanding and management of human impact on fish diversity, to study the relationship between habitat variables and fish species assemblage structure, quantification of ecosystem degradation, habitat quality and biotic integrity of the ecosystems, development of habitat suitability index (HSI) models and classification of river reaches based on their physico-chemical properties. Therefore in the present study an attempt was made to assess the biodiversity potential and the relationship between habitat variables and fish species assemblage structure in six major river systems of Kerala which would be very useful in impressing upon the seriousness of habitat degradation and biotic devastation undergone in the major river systems of Kerala. An attempt was also made to develop habitat suitability index models of 10 critically endangered and endemic freshwater fishes of Kerala, so enabling the administrations in adopting the relevant conservation and management plans for the sustenance of these fishes in our river systems for the years to come.

Kerala the land of rivers is endowed with 41 west flowing and 3 east flowing rivers with a total length of 3211km and having a basin area of 37884km^2.These rivers are originating from different regions of Western Ghats, even from an elevation as high as 2800m MSL, and harbouring 170 fish species belong to 12 orders and 28 families. Among the total 44 river systems, six major river systems such as Periyar, Bharathapuzha, Pamba, Chalakudy, Kallada and Periyar together constituted a basin area of 16942km^2 and supports 75% of the fish diversity known from Kerala rivers. Periyar, the largest river system in Kerala having a total length of 244km originating from the Sivagiri hills having an elevation of 1830m from the mean sea level(MSL). One of its major tributary originating from the Anamalai hills, having an elevation of 2800m MSL. Fish germplasm inventory conducted in this river system by various investigators so far identified a total of 76 species, among them 46 fish species were collected during the present study. Bharathapuzha river system has a total length of 209km, originating from the Anamalai hills is having an elevation of 1964m MSL. 63 fish species were reported by previous investigators while 58 species were collected now. Pamba river system has a total length of 176km originating from Pulachimalai having an elevation of 1650m MSL. 54 species were reported so far from this river system while in the present study 30 fish species could be collected. Chalakudy river system with a total length of 130km is originating from Anamalai is having an elevation of 1250m MSL. Earlier surveys reported 40 species of fishes while 40 species were collected and identified from Chalakudy river system. Kallada river system with a length of 121km, originating from Karimalai is having an elevation of 1524m MSL. 41 fish species were known from this river system while 23 species were identified from this water body now. Kabbini is one among the three east flowing river systems of Kerala is originating from Thondarmudi Malai having an elevation of 1500m MSL. 51 fish species were known from this river system. Whereas 54 fish species were collected from the Kerala part of Kabbini river system in the present study.

In the present study, in Kabbini river system 15 locations encompassing between 721-946m above MSL were surveyed. In Bharathapuzha river system 27 locations were studied including the main stretch, tributaries such as Gayathripuzha, Kunthipuzha , Kanjirapuzha and Chitturpuzha and I order streams above Malampuzha, Mangalam dam and Meenvallam region.All the stations were located between 18.4 –1001m above the MSL. In Kallada river system 11 locations were surveyed including the main stretch, tributaries such as Kulathupuzha, Kazhuthuruty Ar and Chenthuruny Ar. All the stations are located between 20.3 to 641m above MSL. In Pamba river system, 15 locations were surveyed from the main river stretch and tributaries such as Kakkiyar, Kochupamba and Azhutha. All the locations were situated 4.5-1000m MSL. In Chalakudy river system 20 locations encompassed between 40-996.4m above MSL were surveyed which include the main river stretch and major tributaries such as Sholayar, Parmbikulam and Karappara. In Periyar river system 29 locations embarking 20-1540m above MSL were surveyed which include the main river stretch and two major tributaries such as Neriyamangalampuzha and Pooyamkuttypuzha.57 habitat variables were collected from the selected locations in Periyar, Bharathapuzha, Chalakudy, Pamba, Kallada and Kabbini river systems following standard methods. For analyzing the species assemblage structure, sampling of fishes was done from all stations selected for habitat inventory. The fishing effort was made uniform at all the sampling stations. Based on the ratios such as sinuosity, entrenchment ratio, slope, width/depth ratio and dominant substrate the stream reaches were classified upto Rosgen's II level. The physical habitat quality (HQ) scoring and index of biotic integrity

(IBI) scoring of selected locations in each river system were done following Lyons (1992). The fish diversity in each river system were studied based on four diversity indices such as Shanon-Weiner diversity index, Simpson index, Pieoleu's evenness index and Margalef's index. The extent of ecosystem degradation undergone in each river system was studied by correlating Shannon- Weiner diversity index, index of biotic integrity score and fish abundance in each river system with the 57 habitat variables collected from each river system. The habitat suitability index (HSI) models of 10 endangered fishes were developed from the habitat parameters, which showed significant influence on the distribution and abundance of the respective species.

In the configuration of channel geomorphic units run was the dominant type in Kabbini river system. Whereas in all other west flowing river systems midchannel pool was the dominant microhabitat. Among instream cover, overhanging vegetation was the dominant type in Kallada and Kabbini river systems while in other river systems such as Bharathapuzha, Pamba, Chalakudy and Periyar depth was the dominant microhabitat. In the case of riverbed materials gravels were the dominant type in Kabbini and Kallada river systems whereas in all other river systems bedrock was the dominant substrate.

In Kabbini river system, among the 15 locations surveyed 1 location belonged to D4 class, 6 locations under A4 class, 1 location under DA6 class, 2 locations under n/a class, 1 location under A2 class, 3 locations under G6 class and 1 location under G5 class as per Rosgen's classification. In Bharathapuzha river system n/a class accommodated 10 locations, A1a+class 6 locations, A3 class 4 locations, A2 class 2 locations and DA5,DA6,D6,B6,C2b classes have 1 location each. In Kallada river system 5 locations comes under n/a class, 3 locations under A1a+ class while A2, G5 and A3a+

accommodated 1 location each. In Pamba river system, A1 class accommodated 5 locations, n/a class 4 locations, A3 class 3 locations and A2 and A1a+ classes having 2 and 1 locations respectively. In Chalakudy river system, of the total 20 locations studied 9 locations are coming under n/a class, 5 locations under A1 class, 2 locations under A2 class while G1e, Gde, A1a+ and B1 classes were represented by one location each. In Periyar river system 11 locations were coming under A1 class, 5 locations under n/a class, 3 locations under A1a+ class, 2 locations under F1b class. While classes such as C3, B5, A6, A4, B2, A2, G2e and A2a+ were represented by one location each.

During the present study the Habitat Quality Score (HQ) developed by the Ohio EPA was applied for the first time in India. To comply with the conditions prevailing in our river systems appropriate modifications were made in the scoring criteria. The Habitat Quality score (HQ) was found as ideal to measure the physical habitat quality of the river systems of Kerala. In Kabbini river system the habitat quality score varied from 14 to 56 with an average value of 33.4. Habitat quality score varied between 14 to 63(mean 39.6) in Bharathapuzha and 12 to 70(mean 40) in Kallada river systems. In Pamba river system the habitat quality score varied from 20 to 66 with a mean value of 41.9. Chalakudy river system showed the highest average habitat quality score of 57 and the location wise habitat quality score varied between 24 to 75.Habitat quality score varied from 10 to 77 with a mean value of 49.1 in Periyar river system.

Index of Biotic Integrity scoring (IBI), a technique used to study the biotic integrity and health of an ecosystem was applied for the first time in the rivers of Kerala. In U.S.A., Index of Biotic Integrity (IBI) is extensively used for bioassessment and biomonitoring programmes and interestingly, the Ohio EPA incorporated IBI scoring into Ohio water quality standards. In Kabbini river system IBI varied from 5 to 65 with a mean value of 38.4.Index of biotic integrity score in Bharathapuzha river system was in the range 0-60(Mean 21.7) and Kallada river system from 15-45(Mean 27.3). Biotic integrity was maximum in Chalakudy river system with a mean value of 44.1 and the location wise IBI ranged between 25-64.In Periyar river system IBI ranged between 0-52 with a mean value of 34.1.

The result of the present study revealed that, among various variables analysed, altitude has a very significant influence in deciding the fish diversity in six major river systems of Kerala. The fish diversity studied on the basis of Shanon-Weiner and Simpson diversity indices revealed that even though some minor variations occur with the suitability and complexity of habitats, the altitude showed inverse relationship with fish diversity. Shanon-Weiner diversity index showed maximum value in the 0-200m ranges in Bharathapuzha, Chalakudy and Periyar river systems. While in Kallada and Pamba river systems the maximum diversity recorded was in the range 200-400m and 400-600m. In Kabbini river system the survey was conducted only in the 600-1000m MSL.The highest diversity was observed in the stretch 600-800m. Simpson diversity index was maximum in 200-400m in Chalakudy and Pamba river systems, in contrast, it was highest in the 0-200m in Periyar, 600-800m in Bharathapuzha and Kallada river systems and 800-1000m stretch in Kabbini .

The species richness measured based on Margalef's index was highest at 0-200m in Bharathapuzha, Periyar, Chalakudy and Pamba river systems while in Kallada and Kabbini river systems it was respectively at 400-600m and 800-1000m. Species evenness measured based on Pieolu's evenness index was highest at 600-800m in Bharathapuzha, Chalakudy and Kallada river systems,400-600m stretch in Periyar and Pamba river systems and 800-1000m stretches in Kabbini river system.

The extent of ecosystem imbalance in each river system has been determined by comparing the fish species diversity, abundance and index of biotic integrity scores with the habitat variables in the respective locations in each river system. With the knowledge of these relationships, the stream restoration activities may successfully target on those features that are important to the stream fish community, which will helps to achieve the physical, chemical and biological integrity of our river systems. The study revealed that among the six river systems studied only Chalakudy river system showed the sign of a healthy ecosystem. On the other hand Bharathapuzha and Kallada river systems were prone to high degree of habitat degradationand if this ecosystem imbalance continues, there is every reason to anticipate that these river systems will become aqua deserts in the near future. The extent of relationship of habitat variables with fish abundance and tropic structure in Periyar and Pamba river systems revealed that even though the habitat alteration not severe as in the case of Bharathapuzha and Kallada river systems, habitat degradation were found very high in these river systems.

In the present study habitat suitability index models for 10 endemic threatened species such as *Lepidopygopsis typus,Gonoproktopterus micropogon periyarensis, Crossocheilus periyarensis, Neolissochilus wynadensis, Silurus wynadensis, Osteocheilus longidorsalis, Puntius jerdoni, Garra menoni, Homoleptera Pillai* and *Mesonemacheilus remadevi* were developed. Abundance of *Lepidopygopsis typus* showed a positive correlation with amount of bed rock substrate, chute type channel geographical unit, overhanging boulders, overhanging vegetation, total shade and tree cover and negative correlation with light intensity and slope. Optimum habitat of *Garra micropogon periyarensis* was found as midchannel pools with moderate depth, overhanging vegetation, less slope and excellent shade. *Crossocheilus periyarensis* is most abundant in scour out pools with enough woody debris , overhanging vegetation and tree cover. *Silurus wynadensis* can tolerate only a narrow range of habitat parameters and was found as a highly habitat specific species. Biomass of *Silurus wynadensis* showed a positive correlation with total instream cover, trench pool,water temperature and overhanging stream boulders. Optimum habitat of *Neolissocheilus wynadensis* was found as lateral and plunge pools with less channel width, low alkalinity and hardness. Distribution of *Osteocheilus longidorsalis* is positively correlated with abandoned channel, backwater pools, emergent vegetation, glide and overhanging stream boulders and is negatively correlated with channel width. *P. jerdoni* was found in abandoned channels with good channel width and rocky substratum and its abundance was negatively correlated with alkalinity and cascade type channel geomorphic unit. Occurrence of *Mesonemacheilus remadevi* showed negative correlation with bare ground, cobbles type substratum and depth. While the species showed positive correlation with bedrock type substratum, dissolved oxygen, riffle and glide type microhabitats, large and small woody debris. Occurrence of *Homoleptera pillai* showed positive correlation with bedrock, dissolved oxygen level, glide type microhabitat, large woody debris, small woody debris and shrub cover and negative correlation with cobble type substratum. Occurrence of *Garra menoni* showed positive correlation with bedrock, dissolved oxygen level, large woody debris and small woody debris and negative correlation with glide type microhabitat. The results of the present study were useful in forecasting the impact of proposed Pathrakadvu dam on the fish fauna of Silent valley. The HSI models of the three endemic fish species such as *Mesonemacheilus remadevi,Homoleptera pillai and Garra menoni* from Silent valley revealed that the distribution of these species showed high degree of correlation with rocky substratum, flowing water channel geomorphic units such as riffle and glide, presence of woody debris, dissolved oxygen level and vegetation on the stream bank. But once, the dam is commissioned, the level of bedrock type substratum, dissolved oxygen level, riffle and glide type channel geomorphic units, woody debris and vegetation cover on the river bank may be obliterated and this will become a malediction to this species. Based on the results of the present study it can be inferred that the construction of the proposed dam across Kunthi river at Pathrakadavu would bring about serious alterations in the fish habitat and species assemblage structure at Silent valley and such ecological transformation would not only ends up with the extermination of the above mentioned endemic threatened fish species but also the proliferation of many exotic fish species in the transformed lotic ecosystem. Moreover, hitherto no attempt was made to find out the reason of endemism in fishes related with HSI in the Indian context and therefore this subject was never surfaced while taking policy decisions on the fate of Indian rivers. The present study revealed that the National Policy on the interlinking of rivers would permanently alter the HSI indices of the above mentioned fish species, which are now solely protected by the individuality of the rivers where their limited occurrence was noticed. Any such interlinking would bring about severe alterations of habitat parameters such as flow velocity, nature of substratum, type of microhabitat and vegetation governing the presence of these fishes and consequently there is every possibility of extinction of these species from the universe. The present finding may be useful for the policy makers in dissuading from taking decisions in interlinking of those rivers which harbour such endemic fish habitat with other river systems, which would permanently damage such HSI factors and interalia the extermination of these species.

Puntius carnaticus(Jerdon), commonly known as Carnatic carp and locally known as Pachilavetti, belongs to the family Cyprinidae and subfamily Cypriniae. This species is endemic to Western Ghats and belongs to vulnerable category. *P.carnaticus* is a food fish with an excellent demand in local markets and fetches Rs.50-65 per kg at Peringalkuthu region of Chalakudy river basin. Besides being valued as a food fish, due to its voracious feeding nature on plant materials, prolonged breeding season and comparatively good growth rate when compared to other carps, this species has all the desirable traits of a candidate species for aquaculture, which can also substitute grass carp in polyculture. Hitherto, no information is available on the bionomics and resource characteristics of this species. Studies on detailed life history traits are indispensable for fishery management, captive breeding and conservation programmes. In the present study, a pioneer attempt was made to investigate the life history traits and resource characteristics of *P.carnaticus*.

The 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 were studied. The index of preponderance was used to assess the food preference of males,females and indeterminates. The study indicated that basic food of *P.carnaticus* was plant matter. The other major food items identified were filamentous algae, diatoms and animal matter in the order of their preference. Based on the feeding habitat males, females and indeterminates of *P.carnaticus* are coming under herbi-omnivore category.

Feeding intensity was very high and was found to be influenced by the reproductive cycle. It appeared that there exist a cyclic feeding rhythm in both males and females showing a period of higher feeding activity followed by a phase of lower one. Based on the diversity of the types of food consumed, this species can be categorized as stenophagic fish. Relative gut length and feeding intensity was comparatively less in indeterminates when compared to both the sexes. Gastrosomatic index (GSI)showed higher rate of feeding among sexually mature individuals than in indeterminates. Length group data of GSI revealed that females consuming more food than their male counterpart.

The various aspects of reproduction such as maturity stages of males and females, monthly percentage occurrence of fish with gonads in different stages of maturity, pattern of progression of ova during different months, gonado-somatic index, length at first maturity, sex ratio, fecundity and its relationship to various body parameters were studied in detail. The spawning season was delineated based on quantification of maturity stages, monthly percentage occurrence of fish with gonads in different stages of maturity, pattern of progression of ova during different months and the monthly variation of gonadosomatic index. The wide size range of ova with only one or two modes is the typical cyprinid character and is an indication of the prolonged spawning season with two distinct peaks. Males mature at a lower length (232 mm) than females (270mm).The spawning season of *P.carnaticus* is a prolonged one extending from April-August with a major peak during July-August in both the sexes and minor peak during April-May in females and May-June in males. The predominance of males were seen upto 310mmTL and thereafter the percentage occurrence of males become insignificant, on the contrary, females showed predominance in higher size groups in the fishery. Beyond 390mm TL, females dominated the fishery. Fecundity of *P. carnaticus* ranged from 2763(216.83mm TL) to 14071(445mm TL). Fecundity showed strong correlation to the weight of the ovary than to the other body parameters.

The length-weight relationship in males, females and indeterminates was established with the help of general linear equations. The value of regression co-efficient for indeterminates and males were 1.4243 and 2.7148 respectively, which showed significant departure from '3' indicating that the growth followed negative allometric pattern. On the contrary, the exponent value of 2.8618 in females is indicative of an isometric pattern of growth. The general well-being of the fish was ascertained from the relative condition factor (Kn). Monthly variation in relative condition factor (Kn) were found influenced by reproductive cycle, feeding intensity as well as some other unknown physiological or inexplicable environmental factors. Size-wise variation in Kn values could be related to maturation and spawning.

Age and growth of *P.carnaticus* was studied in detail. The $L\alpha$ of males is computed at 493.5mm and that of females at 504mm.The growth co-efficient (K) and Munro's PHI prime index were 0.5 and 5.08 in males and 0.65 and 5.22 in females respectively. The life span of *P.carnaticus* is 4-6 years and the male attains a length of 286.9mm, 368.2mm, 417.6mm 447.6mm and 465.9mm in the I, II, III, IV and V years respectively, while female attains 345.8mm, 421.1mm, 460.85mm and 481.7mm at the end of I, II, III and IVth years respectively. The growth rate of *P. carnaticus* is moderately fast when compared to other carps and attains marketable size in the first year of its life span, itself. Studies on the recruitment pulse revealed that *P.carnaticus* has a single long recruitment period extended from May-October in males and April- October in females, which is indicative of the long-term availability of brooders and fingerlings in the wild. The results of the age and growth are invaluable in recommending this species for aquaculture.

Total mortality, natural mortality, fishing mortality, exploitation rate, exploitation ratio, probabilities of capture and yield per recruitment were studied as part of resource charactrestics. The average total mortality co-efficient of males and females were 2.01 and 2.78 respectively. In males the average natural mortality was 0.86 and in females it was 0.97. Highest fishing mortality of 1.81 was recorded in the 460-480mm size group of females while it was 1.15 in males. Virtual population analysis revealed that the average 'F' value of different size classes were higher in males (0.16) when compared to females (0.098). In males exploitation starts at 200mm and fishery was dominated by 300-320mm length class. While in females exploitation starts at 240mm and fishery was dominated by 340-360mm length class. Studies on probabilities of capture also revealed that exploitation starts at a lower size in males and the L-25, L-50 and L-75 were 278.19mm, 301.1mm and 324.01mm respectively. While in females it was 310.6mm, 334.15mm and 357.7mm respectively. The exploitation rate and exploitation ratio of males and females were respectively 0.52 and 0.57 in males and 0.36 and 0.65 in females. Comparison of the present exploitation rate of males (0.52) with that of the E_{max} (0.52) revealed that the harvest of *P.carnaticus* could be kept at sustainable level by maintaining the present exploitation rate of male population. While the comparison of females exploitation rate(0.36) with that of its E_{max}(0.36) revealed that a slight increase in the fishing pressure through selective harvesting of female population up to an exploitation rate of 0.52 from the present 0.36 will help to increase the production without affecting the stock.

13.2. Recommendations

1. The fish habitat studies will provide adequate inputs for the proper management and restoration activities of river systems and therefore detailed habitat inventory surveys should carried out in all river systems of Kerala.

2. Develop a new stream of classification system of fish habitats exclusively for the streams and rivers of Kerala is required urgently.

3. Implementation of various action plans are required to maintain the Habitat Quality (HQ) and Index of Biotic Integrity (IBI) above 40 in the entire stretch of all the river systems of Kerala by improving the water quality parameters, instream cover, microhabitat diversity and quality of substrates.

4. Instream and stream side cover can be improved by boulder placement, placements of stumps, roots or debris, artificial undercut banks formed by overhanging cover structure, tree planting in banks and stop the removal of overhanging vegetation

5. In view of the fact that the pool-riffle reaches can be identified as most diversified macrohabitat it can be achieved by current deflectors, stream narrowing deflectors, installation of low weirs and mechanical construction of pools.

6. Substrate reinstatement by replacing the sediments with well-sorted gravels, cobbles or even with crushed rocks which will helps to improve the fish and invertebrate habitat.

7. In braided reaches improvement of current speed diversity possible through the installation of rapids by the construction of different types of low weirs. The weirs shall be placed over the full or partial width and at different angles to the riverbank. It may be straight, 'V' shaped in the upstream or downstream direction or with an irregular crest form. The weirs can built with boulders, cobbles, stone filled gabions or with concrete.

But maximum height of these weirs should not exceed 1.5m or it should be completely submerged in water.

8.Keep the longitudinal connectivity of rivers as intact not only to permit passage of migratory fish species but also for the free movement of all species within the maximum range; obstructions presented by dams and weirs may be bypassed by fish passes but the influence of water quality barriers must also be considered.

9. To maintain the lateral connectivity between the channel and river margin or flood plains in the middle and lower stretches, should not convert the flood plain ponds and backwaters associated with the river system to agricultural lands.

10. The micro invertebrates which form a good source of food to stream fishes can be motivated by increasing the concentration of woody debris, wet land vegetation and restoration of riffle type microhabitats in streams.

11. Due to the immense fish diversity prevailing at Athirappally to Vettilappara region in Chalakudy river system, Kulathupuzha to Thenmala dam in Kallada river system,Pooyamkutty to Thandamankuthu in Periyar river system and Begur to Baveli region in Kabbini river system, these regions may be declared as aquatic sanctuaries.

12. Develop the habitat suitability index (HSI) models of all the threatened and endemic fish species of Kerala for their effective insitu conservation and transplantation to similar habitats.

13. Ban the illegal sand mining activity in the rivers of Kerala

14. It is felt that there is inadequacy of appropriate legislation to curb the unethical and unscientific fishing methods such as dynamiting, fish poisions, electrofishing etc. which are very rampant in the rivers and rivulets of Kerala. By totally conceiving this,

immediate enactment of Kerala Inland Fisheries Regulation Act (KIFRA) is found indispensable for the conservation of the unique fish germplasm resources of Kerala.

15. The mesh size proposed in the acts and legislation shall be strictly implemented in various gears used for fishing.

16. Government of Kerala shall set up fish hatcheries exclusively for the breeding and propagation of critically endangered and endemic freshwater fishes in suitable locations, where brood stocks are available.

17. Introduction of exotic species should be permitted only after studying its biology, habitat specificity and potential threats to native fish species and environment.

18. It is mandatory to treat the effluents from the factories before its disposal to rivers.

19. The bionomics studies revealed that *P.carnaticus* have the potential of a good aquaculture species and also can use as a more effective substitute for grass carp in polyculture operations. Effort should be made to standardize the captive breeding technology of this species and introduce this species into the culture basket of Kerala.

20. Mass awareness programmes shall be organized among the public on aspects of habitat conservation of our river systems and implement location specific action plans for the restoration of riverine habitats.

21. Government should constitute an agency for periodic checking of the index of biotic integrity (IBI) scoring, Habitat Quality (HQ) scoring, Environmental Quality (EQ) scoring and water quality at lower, middle and upstream reaches of all the river systems. The results so compiled should publish in the medias at par with the daily temperature and cumulative rainfall

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