BIONOMICS, RESOURCE CHARACTERISTICS AND DISTRIBUTION OF THE THREATENED FRESHWATER FISHES OF KERALA

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DECLARATION

I, **Euphrasia C.J.**, do hereby declare that the thesis entitled **"BIONOMICS, RESOURCE CHARACTERISTICS AND DISTRIBUTION OF THE THREATENED FRESHWATER FISHES OF KERALA"** 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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30th July 2004

EUPHRASIA C. J.

CERTIFICATE

This is to certify that the thesis entitled **"BIONOMICS, RESOURCE CHARACTERISTICS AND DISTRIBUTION OF THE THREATENED FRESHWATER FISHES OF KERALA"** is an authentic record of research work carried out by **Mrs. Euphrasia C. J.** under my guidance and supervision in the School of Industrial Fisheries, Cochin University of Science and Technology in partial fulfilment 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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Euphrasia C. J.

THE EARTH IS FULL OF GOODNESS OF GOD, OUR LORD

"In the beginning the Lord did his work of creation,
and gave everything a place of its own.
He arranged everything in an eternal order
And decreed that it should be that way for ever".

Sirach 16 :26-27.

THE EARTH IS IN OUR HANDS, CONSERVE IT.

CONTENTS

CHAPTER I

GENERAL INTRODUCTION

1.1. Introduction

The basic characteristic of life is its unlimited diversity. Biodiversity is the outcome of natural evolution which had been going on for the last 3.5 billion years. It refers to the abundance and the variety within and among fauna and flora, as well as the ecosystems and ecological processes to which they belong to and is thus usually considered at ecosystem, species and genetic levels. Ecosystem diversity refers to the variety of habitats and species communities as well as the ecological processes within ecosystems whereas species diversity refers to the variety of living organisms and genetic diversity to the total genetic information contained in the genes of an individual species (Kottelat and Whitten, 1996). `Freshwater biodiversity' refers to the species and habitats within inland waters. Inland fisheries have the potential to provide good quality protein and their products can benefit the people without the need for complex and expensive harvesting, processing, marketing and transportation infrastructures. Potential fish yields vary from system to system and are a function of interacting abiotic and biotic factors. These fishery resources, upon which people depend on, are renewable when managed scientifically, on the other hand, when abused, they can become extinct. Unfortunately, the fishing sector seems to follow the latter path. Due to the increasing pressure from growing population and rapid modernization, ichthyobiodiversity is now getting depleted at an unprecedented rate. Fish habitats are destroyed as a consequence of many factors. Headwater regions of streams are altered by deforestation which, in turn, results in soil erosion, landslides and siltation, thereby destroying the breeding habitats of many species. Agricultural run-off, pesticides, fertilizers, sewage and chemical pollutants add additional stresses to the resident fish populations. Impoundments for water retention and electrical generation create barriers to the natural dispersal pathways of migratory fishes and eliminate opportunities for gene flow among populations of primary freshwater species. Canalization and diversion of streams have eliminated riparian zones and destroyed aquatic ecosystems that maintain water quality, nutrient recycling, etc., which contribute to the nurture of fish populations. Introduced exotic species is an additional threat to the native species as they compete with them for food as well as space and also transmit exotic diseases to the native ones (Vrijenhoek,1998). In order to prevent decline of biodiversity due to human intervention or otherwise, it is necessary to understand how the diversity of life is maintained under natural conditions. The assessment of biodiversity in an ecosystem by and large depends on making detailed inventories of species but this is a formidable task.

India is one among the 12 mega-diversity countries (Mc Neely *et al.*, 1990) with two globally recognized hotspots of biodiversity, the Western Ghats and Eastern Himalayas (Meyers, 1990). With respect to endemic fish taxa, Western Ghats is known as the richest region in India encompassing around 192 endemic species of the total 287 species of fishes (Shaji *et al.*, 2000). It forms a natural wall on the eastern side of the state of Kerala. Kerala is endowed with 41 west-flowing and 3 east-flowing rivers, which originate from Western Ghats and most of these rivers abound very rich, diversified, rare and endemic fish fauna. It is widely accepted that a majority of the freshwater fishes of Kerala are facing endangerment due to many reasons, among them the impact of human interventions are well documented. Habitat destruction due to mining of lakes and rivers, construction of dams across rivers and lakes, abstraction of water from rivers for agricultural purposes, pollution from industries and agriculture, application of destructive and indiscriminate fish catching methods, etc., are the common threats the fish population are prone to. However, among the 734 species of threatened fishes listed in the IUCN Red Data book from all over the world, only two species namely *Horaglanis krishnai* (Family: Claridae) and *Schistura sijuensis* (Family: Balitoridae) are included from India (IUCN, 1990). *Horaglanis krishnai,* a blind clarid fish, which is endemic to Kerala, is known only from the deep wells of its type-locality, Kottayam. None of the fish taxa from India is treated as being threatened in the Indian Red Data book of 1994 prepared by the Zoological Survey of India. Rather than indicating the population stability of freshwater fish fauna in India, by and large, it points towards the lack of information on the conservation status of Indian freshwater fishes. A perusal of the literature revealed that inadequacy of the database is found on aspects such as regional distribution and abundance pattern, resource characteristics, stock size, spawning season and time, fecundity and size at first maturity which are inevitable for the conservation and management plans of freshwater fishes of Kerala.

1.2. Review of Literature

An exhaustive review of the previous work carried out on the freshwater fishes of India especially that of Kerala is attempted. More than 400 relevant scientific papers were collected and screened which include the classical work by Hamilton (1822) and studies carried out till date. The literature pertains to taxonomy, distribution, resource characteristics, biology, conservation and management programmes. Desktop inventory of 237 freshwater fishes of Kerala together with their distribution and status as per IUCN criteria was prepared with a view to consolidate information hitherto available. Literature pertaining to biology and resource characteristics is given in the respective chapters of the thesis.

The first writer on Indian fishes, according to Day, was Bloch (1785-1795), followed by Lacepede (1800), Bloch and Schneider (1801), Hamilton (1822), McClelland (1839), Cuvier and Valenciennes (1828-1849), Sykes (1841), Jerdon (1849), Bleeker (1853), Blyth (1858) and Beavan (1877). Among them, the important contributions on the fresh water fishes are those of Hamilton (1822) who described 271 species of freshwater and estuarine fishes, McClelland (1839) (138 species of Indian Cyprinids) and Bleeker (1853) (162 fish species). An account of the fishes of Southern India was published by Jerdon (1849) in two parts, the first part contains 22 fishes and the second part 150 fishes. Another important contribution is that of Beavan (1877) who brought out

'Handbook on freshwater fishes of India' with description of 392 fish species. The most outstanding personality in the history of Indian ichthyology is undoubtedly Dr. Francis Day (1828-1889) who described 1340 species of freshwater and marine fishes in his monumental work *'The fishes of India, being a natural history of the seas and freshwaters of India, Burma and Ceylon'* Numerical strength of the primary freshwater fishes recorded in the book by him is 365. Even today this remains the most widely referred and monumental book on Indian fishes.

Adverting to the scenario of ichthyological studies in Kerala, *'The fishes of Malabar'* published by Day (1865) is perhaps the only book on the fishes of Kerala during the 19th century. He has described 66 freshwater fish species common in the hill streams, rivers, ponds, tanks and paddy fields of Malabar. After Day, the next work on freshwater fishes of Kerala was that of Pillay (1929), John (1936) and Hora and Law (1941) who studied the ichthyofauna of Travancore region. Homalopterid fishes *viz., Bhavania australis* and *Travancoria jonesi* were described from Wayand and Travancore by Hora (1941e). Two new Cyprinid fishes, *Barbus* (*Puntius*) *micropogon periyarensis* and *Barbus* (*Puntius*) *ophicephalus* and a new genus of schizothoracine fish, *Lepidopygopsis typus* were described from Periyar river system by Raj (1941a, b) while *Glyptothorax housei,* a sisorid catfish was newly reported from Puthuthottam estate in Kerala by Herre (1942).

Other notable works on freshwater fishes of Kerala during the period from 1945-1980 include those of Hora and Nair (1941), Mackay

(1945), Chacko (1948), Silas (1951, 1952, 1954), Menon (1951, 1952), Eapen (1965), Thobias (1973) and Antony (1977). *Horaglanis krishnai*, *Laubuca dadiburjori* and *Garra hughi* were the new descriptions from Kerala waters by Menon (1951, 1952) and Silas (1954) respectively. Rita *et al.* (1978) discovered a new species of loach, *Oreonectes keralensis* from Pampadampara while Indra and Remadevi (1981) described *Homaloptera Pillay* from Silent Valley. Remadevi and Indra (1984) added one more new species to the ichthyofauna of Kerala by discovering the cyprinid fish *Garra menoni* from Kunthi river and subsequently on the fishes of Silent Valley by the same authors (1986). Studies on the fish and fisheries of inland waters of Trichur district was carried out by Kader (1989).

A good deal of work had been done on the freshwater fishes of Kerala in the 1990s. Notable among them are Kurup (1990, 1994, 2000, 2002), Inasu (1991), Kurup and Kuriakose (1991), Remadevi and Menon (1992), Raghunathan (1993), Pethiyagoda and Kottelat (1994), Remadevi and Indra (1994), Easa and Shaji (1995, 1996, 1997), Easa and Basha (1995), Gopinathan (1995), Menon and Remadevi (1995), Shaji and Easa (1995a,b,c), Shaji *et al.* (1995), Arun *et al.* (1996), Gopi (1996), Menon and Jacob (1996), Remadevi *et al.* (1996), Remadevi *et al.* (1996), Shaji and Easa (1996), Shaji *et al.* (1996), Zacharias *et al.* (1996), Arun (1997), Menon (1977,1999), Bailey and Grans (1998), Gopi and Radhakrishnan (1998), Manimekalan and Das (1998), Thomas *et al.* (1998), Vairavel *et al.* (1998), Ajithkumar *et al.* (1999), Biju *et al.* (1999), Thomas and Abdul Aziz (1999), Thomas *et al.* (1999) and Zacharias &

Minimol (1999). The faunal status of Kerala waters was strengthened during this period with the description of a number of new species such as *Osteochilichthys longidorsalis, Travancoria elongata, Horabagris nigricollaris* (Pethiyagoda and Kottelat, 1994), *Nemacheilus pambarensis* (Remadevi and Indra, 1994), *Hypselobarbus kurali* (Menon and Remadevi, 1995), *Homaloptera menoni* (Shaji and Easa, 1995), *Garra surendranathani* (Shaji *et al.*, 1996), *Crossocheilus periyarensis* (Menon and Jacob, 1996), *Glyptohorax davissinghi* (Manimekalan and Das, 1998), *Monopterus roseni* (Bailey and Grans, 1998), *Nemacheilus menoni* (Zacharias and Minimol, 1999) and *Garra periyarensis* (Gopi, 2001). Remadevi and Menon (1992) described a subspecies *Horadandia attukorali brittani.* The most recent additions to the freshwater ichthyofauna of Kerala is that of Kurup and Radhkrishnan (2004) who discovered three new species of fishes *viz. Garra emarginata,Garra mlapparensis and Nemacheilus periyarensis* from Periyar river. *Salarias reticulates*, a new blenny from Chalakudy river, was also reported by Kurup *et al.* (2004).

Valuable contributions in the field of taxonomy of Indian freshwater ichthyofauna, which deserve special mention, are those of Misra (1962, 1976a,b), Jayaram (1981, 1999), Menon (1987, 1999) and Talwar and Jhingran (1991). These publications are widely referred to for the identification of Indian fish fauna by students as well as research communities. Shaji and Easa (2001) published a book 'Field guide- Freshwater fishes of Western Ghats', mainly concentrating on taxonomy and distribution of fishes from Kerala regions.

Recent years have focused considerable attention on the twin challenges of documenting fish biodiversity and evolving mechanisms for its conservation and sustainable utilization. The Convention on Biological Diversity (CBD) adopted in Nairobi in May 1992 and signed by more than 150 countries in June 1992 at Rio de Janeiro came into force in December 1993. The Rio declaration calls upon the signatories to CBD to draw National Biodiversity Action plans (NBA) to implement its provisions. The convention highlighted the importance of conserving the areas of megadiversity and giving priority to endemic species in culture practices. In the World Bank Technical paper on 'Freshwater biodiversity in Asia with special reference to Fish' (Kottelat and Whitten, 1996), the streams in Kerala have been identified as freshwater sites of exceptional biodiversities with high degree of endemism. India is a signatory to CBD and to fulfill India's commitment to the Rio convention, Biodiversity Conservation Prioritisation Project (BCPP) was implemented to prioritise species and sites and to develop strategies for conservation of biodiversity. The BCPP is a USAID sponsored project initiated by World Wide Fund for Nature (WWF), World Resources Institute and The Nature Conservancy. An endangered species prioritization working group at the BCPP planning meeting decided to use the IUCN criteria to assess the conservation status of the Indian species. The Conservation Assessment and Management Plan (CAMP) workshop process developed by the Conservation Breeding Specialist Group (CBSG), Species Survival Commission (SSC), IUCN was selected by BCPP as the methodology to be used for conducting the assessments. In India, the Zoo Outreach Organization, which hosts and drives CBSG, Indian Regional Network, was entrusted with the conduct of the CAMP workshops. The CAMP workshop on Freshwater fishes of India conducted from 22-26 September, 1997 was hosted by National Bureau of Fish Genetic Resources, Lucknow.

The CAMP workshop assessed a total of 327 fishes out of 650 freshwater fish taxa reported from India and this was mainly done on the basis of the available literature back up. Totally 227 taxa were included under threatened category which comprised of 47 critically endangered (CR), 98 endangered (EN), 82 vulnerable (Vu), 67 low risk nearly threatened (LR-nt), 13 low risk least concern (LR-1c), 18 data deficient (DD), 1 extinct ((EX) and 1extinct in the wild (EW) (Molur and Walker, 1998). The current status of these species needs revalidation based on recent database. Extensive survey and regular sampling is the need of the hour to collect data on the distribution, abundance, catch per unit effort (CPUE) and other resource and biological characteristics of the species for a precise assessment of the biodiversity status of fishes inhabiting Kerala waters. There is an on-going project on 'Germplasm Inventory Evaluation and Gene Banking of Freshwater Fishes', under the World bank aided National Agricultural Technology Project (NATP), which, in turn, was launched by Indian Council of Agricultural Research (ICAR) to generate data on similar lines and to revalidate the earlier assessments. NBFGR, Lucknow is the lead institution of the project and School of Industrial Fisheries, Cochin University of Science and Technology is one of the Cooperating centers with Dr. Madhusoodana Kurup as Principal Investigator. The present revalidation of the status of freshwater fishes of Kerala was on the basis of the exhaustive database generated as part of the above project.

1.3. Objectives of the study

While scanning the literature, it is evident that most of the previous faunistic studies were concentrated on the taxonomical and zoogeographical aspects. These studies contributed to many new additions to the fish fauna of Kerala meanwhile many species described earlier are reported missing in recent years. Many fish species were collected only once or twice by scientists. Detailed information on distribution, habitat, feeding habits, reproduction, population size, *etc.* are available only with regard to a very few fish species. A meaningful assessment on the biodiversity status of the majority of freshwater fishes cannot be done for want of sufficient data base and therefore, no suitable conservation and management programmes are forthcoming for the protection and preservation of the unique fish germplasm resources of Kerala. The present study was conceptualised and undertaken mostly aiming at bridging these gaps by generating an authentic data base on the distribution, resource characteristics and bionomics of the threatened fishes inhabiting the rivers of Kerala.

Osteobrama bakeri (Day) is an endemic fish having a very highly restricted and fragmented distribution in Periyar, Chalakudy, Kabini, Kallada and Meenachil rivers of Kerala. This belongs to vulnerable category and is locally known as Mullanpaval which is valued as food fish. Besides, due to its vibrant and attractive colouration and easiness for domestication, it has great potential for being propagated as an ornamental fish. 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, development of captive breeding technique and implementation of various conservation programmes. In the present study, a pioneer attempt is also made to investigate the life history traits, resource characteristics, proximate composition, etc. of *O.bakeri.*

The present investigation aims at

- ♣ Revalidation of the list of threatened freshwater fishes of Kerala following IUCN criteria.
- ♣ Generation of an authentic data base on threatened freshwater fishes of Kerala such as distribution pattern, stock size, river-wise catch per unit effort (CPUE), length weight relationship, food and feeding habits , maturation and spawning, etc.
- ♣ Identification of the threats these fish species are prone to, if any, in their regions of occurrence and factors leading to endangerment.
- ♣ Investigation on the bionomics and resource characteristics of *Osteobrama bakeri*, an endemic ornamental fish belonging to the vulnerable category under threatened fishes.
- ♣ To propose management plans for the conservation of endemic endangered fish germplasm resources of the state.

1.4. General organization of the thesis

The thesis is organized under ten chapters which begins with a general introduction of the topic vide chapter 1. Thenceforth, it is divided into two sections, while the former section gives a holistic account on the threatened fishes of Kerala waters whereas the latter section encompasses the findings of the bionomics and resource characteristics of *Osteobrama bakeri* (Day), an endemic ornamental fish belonging to the threatened category as per IUCN categorisation.

In the **first chapter**, the General Introduction, the importance of the present study is emphasized, works done on the freshwater fishes of Kerala have been reviewed, the objectives of present study are highlighted and the general organization of thesis is described. The **second chapter** deals with the threatened freshwater fishes of Kerala. Information regarding sampling stations, fishing methods practiced and application of IUCN criteria are illustrated in this chapter. A checklist of the 122 fishes collected and identified and a brief description of the 33 species of fishes categorised as 'threatened' together with information regarding stock size and availability, distribution, habitat, threats, river-wise catch per unit effort, length-weight relationship, food and feeding habits, sex and stage of maturity, etc. are furnished.

The salient features of *Osteobrama bakeri* together with its systematic position are described in the **third chapter**. The earlier reports of the fish species from Kerala are documented and the various biological aspects studied are highlighted. The **fourth chapter** evaluates the nutritive value of the species by analyzing the proximate composition, minerals and amino acids. Seasonal variations in protein, fat, ash and moisture contents were estimated. The concentration of minerals such as sodium, potassium, calcium and iron and the various amino acids present in the muscle tissue of *O. bakeri* are also included.

Information on the qualitative and quantitative aspects of food composition in relation to sex and season, seasonal variation in feeding intensity and gastrosomatic index are presented in the **fifth chapter**. The peculiarities of alimentary canal are described and its histological structures are illustrated. The **sixth chapter** deals with various aspects of reproduction. The processes of spermatogenesis and oogenesis of the fish species are illustrated with the help of the histological studies of ovary and testes in different stages of maturity. 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 are the various reproductive and biological aspects discussed in this chapter.

The **seventh chapter** brings out the relationship between total length (mm) and body weight (g) in both the sexes and indeterminates. This chapter also describes the relative condition factor (Kn) and ponderal index (K) of the fish along with seasonal and size-wise variation.

The results of age and growth studies worked out separately for male and female populations are given in **eighth chapter**. The growth parameters, life span and recruitment pattern are also presented.

Chapter nine deals with population dynamics. Total mortality coefficient (Z) and natural mortality coefficient (M) of male and female population estimated following different methods, results of exploitation ratio, exploitation rate and length converted cohort analysis are described in this chapter. **Chapter ten** embodies summary and recommendations. The salient findings of the present study are consolidated under summary. Based on results of the present study, a few management measures relevant for the conservation of the rare and unique fish germplasm of the rivers of Kerala are also proposed.

In general, each chapter is subdivided into brief introduction, materials and methods, results and discussion. Table, graphs and photographs are inserted at appropriate places. The list of references consulted is appended at the end of the thesis.

Section I

The Threatened Freshwater Fishes of Kerala

CHAPTER II

THE THREATENED FRESHWATER FISHES OF KERALA

2.1. Introduction

The state of Kerala, situated between 8º17'30" and 12º47'40"N lat. and 74º51'57" and 77º24'47"E long., is a small state occupying the southern extremity of India. The state, spreading over an area of 38,855 Sq. Km., is bordered by Western Ghats on the eastern side and Arabian sea on the western side. The altitude varies from below sea level to 2695 metres above MSL at Anamudi of Southern Kerala which is the highest peak in Western Ghats. The Western Ghats is recognized as one of the 18 global hotspots of biodiversity (Meyers, 1988, 1990). It is also one among the 24 hotspots recognized by Mittermeier *et al.* (1998). It is the watershed of the 44 rivers flowing through Kerala,41 west flowing and 3 east flowing rivers (Fig. 2.1) having a total waterspread of 85,000 ha. (Kurup, 1994). Rivers of Kerala are monsoon-fed and experience distinct flow seasonality with a marked wet season when flows peak alternating with a period of declining and low discharge. These rivers along with vast stretches of backwaters, lakes, reservoirs, ponds and tanks are enriched with a rich and diversified ichthyofauna, many of them are endemic to Kerala and Western Ghats. The threats faced by native fish fauna due to human intervention are manifold. Damming for irrigation and hydro-electric projects, habitat destruction, unethical and illegal fishing practices, pollution, epidemic diseases and introduction of exotic species are some of them (Kurup, 1994, 2002; Gopi, 2000). In order to ensure the conservation of available ichthyological diversity of the state more effectively, collection of basic data on the stock size, resource characteristics, distribution and abundance of diverse types of ichthyofauna are essential prerequisites which would enable prioritization of various water bodies for implementation of appropriate conservation and management measures for preserving the unique ichthyobiodiversity of Kerala.

Scanning of literature shows that the first account on the threatened fishes of Kerala river systems is that of Kurup (1994) who listed 25 fish species as threatened from Kerala waters comprising of 6 endangered, 10 vulnerable and 9 rare and endemic species. Among them, *Horaglanis krishnai*, a blind catfish of Kerala, is one of the 2 fishes from India which found a position in the red data book of IUCN (1990). Menon (1997) published a list of 18 fish species which were treated as rare and endangered fishes of Malabar, Kerala. As per CAMP report (Molur and Walker, 1998), about 650 freshwater teleost species are reported from India, out of which 327 species were evaluated for their conservation status, among them, 227 species were categorized as threatened in India. Of the 327 species evaluated, only 98 species belonged to Western Ghats and 92 to Kerala. Among the 92 species assessed from Kerala, 69 were categorized as threatened, 19 belonging to critically endangered, 29 endangered and 21 vulnerable species. CAMP report (Molur and Walker, 1998) revealed that 35 species of the total 92 species evaluated from Kerala were endemic to Kerala waters and among them, 32 were threatened. 13 species belonged to the Critically Endangered category while an equal number of species were found in the Endangered Category too whereas the remaining 6 species were Vulnerable. Recently there has been an upsurge in the publica-tions on freshwater fish fauna of Kerala. However, majority of these works are either compilation of the past work by scanning the available literature or covers only highly restricted locations. A consolidated list of 106 species of economically important fishes endemic to Western Ghats with informations on distribution, maximum size attainable, etc. was prepared by Gopalakrishnan and Ponniah (2000) while Shaji *et al.* (2000) catalogued 287 endemic, exotic, transplanted and widely distributed fishes found in Western Ghats. 165 freshwater fish species from Kerala together with their occurrence and relative abundance were reported by Gopi (2000) based on the faunistic survey programmes of Zoological survey of India, Calicut, during the period from 1993-1997 which also embodies the distribution and abundance of selected freshwater fishes seen very rarely in Kerala waters. 37 species, including 12 economically important cultivable species and 13 important ornamental fishes were recorded from rivers of Waynad district during May 1998 (Arunachalam *et al.*, 2000) and their current conservation status, habitat and ecology and the threats faced by these species are described. Ajith Kumar *et al.* (2000) documented 83 fish species from Chalakudy river and listed various threats faced by them. Mini (2000) discussed the conservation aspects of fish fauna of Periyar Lake stressing the importance of banning overfishing and dynamiting, eradication of introduced species and prohibition of fishing during closed season. 7 species of fishes were collected from Chaliyar river, Northern Kerala (Lal Mohan and Remadevi, 2000) and the authors also reported that many specimens of *Puntius* species were infected by Epizootic Ulcerative Syndrome

(E.U.S). Kurup (2000) proposed the mangement plans such as strengthening database on population size and distribution, generating precise information on migration, breeding season, behaviour and spawning grounds, developing captive breeding techniques etc. to arrest the declining freshwater fish diversity of Kerala. Gopalakrishnan and Basheer (2000) cautioned about the threats from gradual establishment of Indian major carps in rivers of Kerala.

Biju *et al.* (2000) surveyed 39 river systems of both northern and southern Kerala and reported a decline in the ichthyofaunal biodiversity in Kerala both in terms of species diversity as well as abundance, leading to their endangerment. The authors reported the presence of 7 critically endangered, 28 endangered and 28 vulnerable species from Kerala. In his well documented paper on 'Fish Biodiversity Hotspots of Kerala', Kurup (2002) enlisted 170 freshwater fishes, evaluated their biodiversity status as per IUCN red data list categories, listed out the various factors which aggravated the degree of threat and suggested relevant conservation and management measures required for the maintenance of the freshwater fish biodiversity of Kerala. Of the 170 species reported, 52 species were listed under threatened category by the above author and among them, 18 species belonged to the category of Critically Endangered fishes and 34 to Endangered while 31 were Vulnerable in their status. The impact of various human interventions on the aquatic ecosystem and bioresources of Periyar Lake was assessed by Kurup *et al.* (2002). Some other recent works on the freshwater fishes are those of Euphrasia and Kurup (2002), Jameela Beevi and Ramachandran (2002), Manoj Kumar and Kurup (2002), Mercy *et al.* (2002), Radhakrishnan and Kurup (2002) and Ramachandran (2002). It would thus appear that the status of the threatened fishes of Kerala require appraisal and revalidation regularly so as to implement location specific action plans for their conservation, wherever needed. It is against this background that the present study was conceptualized and undertaken to generate an authentic database on stock size, distribution and abundance, size composition of the catch, habitat preference and bionomics of the threatened freshwater fish species of Kerala.

2.2. Materials and Methods

The study was carried out during March 2000 to August 2003 as part of NAT-ICAR project on 'Germplasm inventory,evaluation and gene banking of freshwater fishes' being implemented at the School of Industrial Fisheries,Cochin University of Science and Technology with National Bureau of Fish Genetic Resources,Lucknow as the lead centre and Cochin University of Science and Technology as the co-operating centre. Extensive surveys and sampling were carried out in the 19 major river systems of Kerala (Table 2.1) to document the fish fauna with special reference to the threatened fishes. Among these rivers, Periyar is the largest one with a total length of 244 km, covering a basin area of 5284 km^2. The origin of the river is at Sivagiri having an elevation of 1830m from the mean sea level. The river has 4 major tributaries – (1) Muthirapuzha (2) Perinjankutty (3) Idamalayar (4) Mangalapuzha. Bharathapuzha, the second largest river in Kerala, has a total length of 209 km and has a total basin area of 6186 km^2 sharing both in Kerala and Tamil Nadu districts. The origin is from Anamalai hills with an elevation of 1964m. The main tributaries of the river are Gayathripuzha, Chithrapuzha, Kalpathipuzha and Thuthapuzha. Pamba river system has a total length of 176 km with a basin area of 2235 km^2. The origin of the river is from Pulachimalai having an elevation of 1650 m. The important tributaries of this river are Kakkiyar, Kochupamba, Azhutha and Kallar. Chalakudy River has a total length of 130 km having a basin area of 1404km^2. The origin is at Anamalai and Nelliampathy hill ranges with an elevation of 1250 m from the mean sea level and joins Periyar at Elanthikkara. The major tributaries of this river are Parambikulam, Sholayar, Kuriskutty and Karappara. Kallada river has a total length of 121km covering a basin area of 1699 km^2. The origin of the river from Karimalai is at an elevation of 1524 m from the mean sea level. The river has 3 tributaries (1) Kulathupuzha (2) Chedurni (3) Kalathuruthi. Chaliyar river has a total length of 169 km with a total basin area of 2923 km^2. The origin of the river is from Ilambani hills of Karnataka having an elevation of 2066 m. The important tributaries of this river are Karimpuzha, Cherupuzha, Kanjirapuzha, Kurumbanpuzha, Vadapuram-puzha and Iruthillypuzha. Achencovil River with a total length of 128 km and a basin area of 1484 km^2 originates at Pasukidamettu from an elevation of 700m from the mean sea level. Meenachil has a total length of 90 kms covering total basin area of 847km^2 and originates from Tatamala with an altitude of 1156m above the mean sea level. Manimala river has a length of 90km and covering a basin area of 847 km^2 The river has two branches, the Kochar and the Valiyar which join just below Kanjirappally. Kabini is one of the east flowing river in Kerala having wide range of diversity and endemism. The river has a total length of 56.6 km in Kerala with a basin of 1920 km^2. The origin of the river is from Tondarmudimalai having an elevation of 1500 m. The important tributaries of the river are Mananthavady, Panamaram, Bavelipuzha and Noolpuzha. Valapatnam River of Kannur district has a length of 110 km and around 2-3 km away from Irikkur joins Bavelipuzha, the main tributary of Kabini river, flowing through Wynad district. The river, Muvattupuzha, is 121km in total length and has a total basin area of 1554 km^2 It originates from Tarangamkanam with an elevation of 1094m from mean sea level. The major tributaries of this river are Kaliyar, Thodupuzha and Kothamangalam.Karuvannur river, with a total length of 48 km and basin area of 1054 km^2, originates from Pumalai having an elevation of 1100m. The river has 4 main tributaries-Manali, Kurumali, Chimoni and Muppili.Pambar is an inter-state river flowing to the east with a total length of 25 km in Kerala state.It has a total basin area of 384 km^2 and originates from Benmore with an altitude of 1950 m above the mean sea level.The major tributaries of the river are Iravikulam, Myladi, Thirthmala and Chengalar. The river Bhavani, another inter-state river flowing to the east, has a total length of 37.5 km in Kerala and total basin area of 562 km2. Originating from Bhavaniar Betta at an elevation of 2500m, the river has two major tributaries, Siruvani and Varayar. Tirur river has a total length of 48 km and basin area of 117 km^2 The origin of the river is from Atavanad at an elevation of 86 m. The main tributary of the river is Vallilapuzha. Keecheri and Puzhakkal rivers originate from Machadmalai, the former at an elevation of 365m while the latter at 525m. Keecheri river,with total basin area of 401 km^2, has a total length of 51km whereas Puzhakkal river is only 29 km in total length and has a basin area of 234 km^2.The main tributary of Keecheri river is Chundalthodu. Puzhakkal river has 4 tributaries *viz.*, Parathodu, Poomalthodu, Naduthodu and Kattachirathodu.

Fishes were collected from 402 locations of the 19 river systems surveyed. 100 m stretch in every 10km of each river system was fixed as a location for the fish species inventory surveys. The locations of the selected river systems from where sampling was done are given in Tables 2.2 to 2.17. Ichthyo-biodiversity was also assessed in protected areas and wildlife sanctuaries of Kerala such as Silent Valley National Park, Aralam Wildlife Sanctuary, Chinnar Wildlife Sanctuary, Muthanga Wildlife Sanctuary, Periyar Tiger Reserve and Angamoozhi Elephant Sanctuary. The habitat diversity was given due importance in the selection of locations within the river system. Sampling was done giving representation to pre-monsoon, monsoon and post-monsoon seasons of each year. The fishes were collected using diverse types of fishing gears such as cast nets (16mm, 18mm, 22mm), gill nets (32mm, 38mm, 64mm, 78mm, 110mm), drag net (4mm), scoop nets and other local contrivances like ottal, mada vala, etc. Visual observations were also carried out depending on the clarity of water to assess the distribution and abundance of the fishes. The sample size was fixed based on the number of specimens collected from each location. Colour pattern of the species and length-frequency measurements were recorded in the field itself while fishes for furthur detailed examination in the laboratory were preserved in 8% formalin. The fishes were identified mainly with the help of the most valid and authentic keys (Day, 1865, 1875-78; Jayaram 1981, 1991; Menon, 1987, 1999; Talwar and Jhingran, 1991). Length and weight measurements, sex-ratio, maturity stages and stomach fullness of fishes were determined following standard methods (Kurup, 1990). Food and feeding habits, reproduction and spawning, ova diameter studies, fecundity and length weight relationship were studied in detail depending on the availability of specimens of the threatened fishes, following standard methods (Hynes, 1950; Qayyum and Qasim, 1964; Clark, 1934; Le Cren, 1951; Kurup, 1990). The quantitative status of germplasm within a particular river system was examined by evaluating the abundance of the species based on catch per unit effort. The catch per unit effort was computed location-wise by dividing the total catch obtained of a species in the experimental fishing by the fishing hours executed. Since there is no proper methodology to standardize the fishing efforts of different gears used in the present study, the values recorded for different gears were pooled together and average was taken and presented. The size groups of the species represented in the exploited stock during various seasons were also recorded and this information is vital in assessing the stock recruitment relationships.

The biodiversity status of each species was assessed based on IUCN criteria (1994) (Table 2.18). In addition to the scientific data, informal or traditional knowledge was also applied to evaluate the conservation status of fishes. For this purpose, information was collected through interviews with experienced fishermen, fish vendors, local people and tribals.

2.2.1. IUCN Red List Categories

The New IUCN Red List categories (Walker and Molur,1997) are:

Extinct (Ex) - A taxon is Extinct when there is no reasonable doubt that the last individual has died.

Extinct in the wild (EW) A taxon is extinct in the wild when it is known only to survive in cultivation, in captivity or as a naturalized population well outside the past range. A taxon is presumed extinct in the wild when exhaustive surveys, throughout its historic range, have failed to record an individual.

Critically Endangered (CR) - A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future as defined by the criteria.

Endangered (EN) A taxon is Endangered when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future as defined by the criteria.

Vulnerable (Vu) A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium- term future as defined by the criteria.

Lower Risk (LR) - A taxon is lower risk when it has been evaluated and does not qualify for any of the threatened categories *viz.*, Critically

Endangered, Endangered or Vulnerable. Taxa included in this category are divided into 3 subcategories.

1. **Conservation Dependent (cd)** Taxa under a continuing taxon- specific or habitat-specific conservation programme, the cessation of which would result in the taxon qualifying for any of the threatened categories within a period of 5 years.
2. **Near threatened (nt)** Taxa which do not qualify for Conservation Dependent, but which are close to qualifying for vulnerable.
3. **Least Concern (LC)** Taxa which do not qualify for Conservation Dependent or Near Threatened.

Data Deficient (DD) A taxon is Data Deficient when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status.

Not Evaluated (NE) A taxon is Not Evaluated when it has not yet been assessed against the criteria.

All taxa listed as Critically Endangered, Endangered and Vulnerable together are described as 'threatened'. The schematic representation of the categories used by IUCN is given in Fig. 2.2.

2.3. Results

A total of 122 species of fishes were collected and identified as part of the NAT-ICAR project on 'Germplasm inventory, evaluation and genebanking of freshwater fishes' from 19 rivers of Kerala (Kurup *et al.*,2003) (Table 2.19). Of the 122 species, 33 fish species were threatened while 35 belonged to Lower risk- near threatened whereas 35 to Lower risk-least concern category. 16 species were listed as Data Deficient due to want of adequate data and 3 were not evaluated as they were introduced species. Among the threatened fishes, 8 species were considered critically endangered (CR) while 14 as endangered (EN). The remaining 11 species were grouped under vulnerable (Vu) category (Fig.2.3). The list of critically endangered, endangered and vulnerable fishes together with the river source, number of surveys conducted, locations from where the species was collected, number of occurrence and catch per unit effort is given in Tables 2.20, 2.21 and 2.22 respectively. The fishes belonging to critically endangered category (Table 2.20) were *Lepidopygopsis typus, Gonoproktopterus micropogon periyarensis, Crossocheilus periyarensis, Travancoria elongata, Balitora mysorensis, Channa micropeltes, Dayella malabarica and Silurus wynaadensis.* All the above fish species except *Silurus wynaadensis* were found restricted to a single location within a single river system while *Silurus wynaadensis* was restricted to three locations of a single river system. Out of the 14 endangered species (Table 2.21), 8 were found to inhabit a single river system each while 6 of them inhabit in two river systems each. 12 of the threatened fishes were strictly endemic to Kerala waters whereas 9 were endemic to Western Ghats region. A groupwise analysis showed that as high as 21 species belonged to order Cypriniformes while 6 species belong to Siluriformes. Numerical strength of other orders was 3 under Perciformes and one species each under Anguilliformes, Clupeiformes and Osteoglossiformes. A brief description of these rare fishes of this Universe together with information regarding stock size, river wise catch per unit effort, length - weight relationship, food and feeding habits, sex and stage of maturity, etc., are furnished species wise.

2.3.1. Threatened fishes of Kerala

2.3.1.1. Critically endangered fishes

1. *Balitora mysorensis* Hora (Plate 1a)

Common name Slender stone loach

Conservation status EN (Menon, 1993)

Systematic position:

Order Cypriniformes

Family Balitoridae

Identification:

D ii-iii 8-9; A ii 5; P viii-ix 10-11; V ii 9

Head and abdomen greatly depressed, lateral line complete with 64 -65 scales, six blotches on the dorsal region and a diffuse band along the lateral line.

Geographical distribution:

Endemic to Western Ghats (India): Cauvery and Thungabhadra river systems (Karnataka) and Kolhapur (Maharashtra) (Type locality–Sivasamudram, Mysore state).

Distribution in Kerala:

Earlier records

Bhavani river (Kerala part of Nilgiri Biosphere Reserve (Easa and Basha, 1995), Thippallikayam thodu of Bharathapuzha river system (Biju *et al.*, 2000), a small rivulet at Nadukani in Nilambur of Kabini river (Shaji and Easa, 2001).

Present collection site:

Kanayar of Achenkovil which unravels its extension range to southern Kerala.

Availability:

A single specimen was collected during the month of April 2002 during the present survey. No published information is available on its abundance from Kerala waters during early periods. Gopi (2000) treated it as a 'very rare' fish from Kerala waters.

Habitat

Fast flowing pool – riffle reaches with bedrock as the dominant substrate.

Bionomics:

The total length (TL) of the specimen collected was 87 mm. According to Talwar and Jhingran (1991) and Menon (1999), this species attains a length of 50 mm SL. Catch per unit effort (CPUE) was worked out as 0.01 Kg (Table 2.20).

Status as per present study and IUCN criteria:

Critically endangered (Regionally). $B_{1,\ 2a}$ (Restricted distribution in a single location, decline in the extent of occurrence).

Threats:

Lowering of water level or drying up of river due to water abstraction and diversion and hot spell in summer, change in habitat structure.

Remarks :

Talwar and Jhingran (1991) reported its occurrence from torrential streams and Biju *et al.*(2000) from streams of hilly areas with steep slopes with bed rocks and boulders forming the major substrate followed by sand, detritus and cobble.

2. *Channa micropeltes* (Cuvier) (Plate 1b)

Common name Malabar snakehead (English), Varaal, Cherumeen (Malayalam)

Conservation status C R (Molur and Walker, 1998; Kurup,2000)

Systematic position:

Order Perciformes

Family Channidae

Identification

D 43 – 46; A 27- 30; P 15; V 6

Body elongated, almost rounded in cross section, small scales on summit of head. Large mouth with several canines behind a single row of villiform teeth in lower jaw. Predorsal scales 22. Colour varies in young and adult. Adults with greyish brown head, back and flanks with small brown spots. In young ones, flanks orange- scarlet. Two black bands, one extending from the eye to the upper half of caudal fin and the other between angles of mouth and lower half of the fin. Vertical bars also present.

Geographical Distribution

India: Kerala; Burma; Thailand; Malay Penisula, Sumatra, Java. (Type-locality: Java).

Distribution in Kerala :

Earlier records:

Malabar (Day, 1875-'78); Travancore (Pillay, 1929; John, 1936; Hora and Law, 1941); Kerala state, Indian subcontinent (Talwar and Jhingran 1991); Pampa river (Kurup, 2000).

Present collection site:

Kallada River (Thenmala dam).

Availability:

Out of the 8 specimens collected during the present survey, 4 each were collected during October 2001 and July 2002. Hora nd Law (1941) treated it as a very uncommon fish. Kurup (1994) collected this species from Parumalakkadavu landing centre of Pampa river. Based on field studies conducted in Central Kerala during 1987-91, Kurup (2000) reported a decline of nearly 99% of the original population size of *C. micropeltes* due to EUS, unethical fishing activities, habitat alteration, poisoning and pollution.

Habitat :

Regime type microhabitat. Flow velocity negligible. Substratum is mainly dominated by fines.Depth is the major instream cover.

Bionomics:

Four each of specimens of *C. micropeltes* were collected during October 2001(131 to 145mm TL) and July 2002 (186 to 595 mm TL). Gut content analysis revealed that they are carnivores, mainly feeding on fishes and worms. CPUE varied from 0.0041 to 0.05 Kg/hr.

Status as per present study and IUCNcriteria:

CR. A $_{1a,c}$ (Observed population reduction due to decline in abundance, extent of occurrence), $B_{1,2a,}$ (restricted distribution, single location, decline in the extent of occurrence).

Threats

Damming, illegal fishing in prohibited areas of dams, pesticide application in paddy fields,exploitaton of brood fish during monsoon, fish diseases.

Remarks

Day (1875-'78) reported the occurrence of large number of *C.micropeltes* from Malabar and Canara regions. Day (1875-'78) and Talwar and Jhingran (1991) recorded the maximum length of this species as 3 feet and 1 metre respectively. The maximum size of the specimen collected during the present survey is 595 mm TL. Enquiries with local fishermen revealed that the large sized fishes, caught from Pampa and Kallada rivers during early eighties, had been dwindling gradually and have disappeared over these years and its availability became a rarity during recent years. Kurup (1994) reported about the total disappearance of Channa spp. from EUS stricken areas of Kerala, predominantly from Kuttanad and Trichur and suggested the replenishment of the stock by resorting to artificial propagation as a conservation measure.

3. *Crossocheilus periyarensis* Menon & Jacob (Plate 1c)

Common Name	Periyar latia (English), Karimbachy, Kariachy (Malayalam)
Conservation Staus	Vu (Molur and Walker,1998)

Systematic position:

Order	Cypriniformes
Family	Cyprinidae
Sub-family	Garrinae

Identification:

D iii 8; A iii 5; P i 12; V i 7

Body moderately elongate, somewhat compressed, dorsal and ventral profiles convex. Mouth wide and covered by papillated upper lip and fleshy lower lip. 34 – 36 scales in lateral line. A pair of rostral and maxillary barbels. Prominent tubercles on snout and cheek of males. Upper half of body brownish black and lower yellowish.

Geographical distribution:

India: Kerala: Western Ghats: Periyar river. (Type locality: Thannikkudy, Periyar river)

Distribution in Kerala:

Earlier reports :

Jayaram (1999); Remadevi *et al.* (2000).

Present collection sites:

Periyar river system (Thannikkudy and above Pulikkayam, Inchippara, Moolavaika).

Availability:

The original description of the species by Menon and Jacob (1996) was based on 4 specimens measuring 98 to 130mm SL. Since then, there is no published information on its availability. 36 specimen were collected during the present investigation (71-145 mm TL), among them20 were brought to the laboratory for detailed analysis and the others were released back into the water body from where it was collected.

Habitat

Pools found in cascade reaches. This species is abundant in lateral and scour out pools with enough woody debris, overhanging vegetation and tree cover (Manojkumar and Kurup, 2002).

Bionomics:

Among the 20 fishes examined, 14 were males, 4 females and 2 indetermates. During the present study, 5 specimens (71 -120mm TL) were collected in March 2001, 4 (96 – 135mm TL) in May 2001, 5 (96 – 135mm TL) in September 2001, 11 (111 – 145mm TL) in February 2002, 3 (116 – 125mmTL) in April 2002 and 8 specimens (91 – 130 mm TL) in May 2002. Fishes were in the 2nd and3rd stages of maturity. A female (140mm TL and 30g W) with light yellow ovary containing mature eggs was collected on the 25th of February 2002. Fig. 2.4 depicts the size composition of the exploited population. Maximum numbers of fishes belonged to the 130 – 135mm size group. Males and females ranged from 113mm to 138mm and 133 to 145mm in total length and 12 – 30g and 27.26 – 31.32g in weight respectively. Indeterminates measured 97 – 100mm in TL and 9.42 – 10g in body weight. Length – weight relationship (Fig. 2.5) was worked out and represented as follows:

$$\log w = -5.4509 + 3.2213 \log l.$$

The exponential value of 3.2213 was not significantly different from 3, thereby indicating that the weight increases at a rate almost equal to the cube of length (t value = 0.75462, df = 19). The correlation coefficient 'r' between log length and log weight was worked out to be 0.9328.CPUE ranged from 0.001 to 0.099 Kg/hr (Table 2.20).

Status as per present study and IUCN criteria:

CR. $B_{1, 2a,b}$(Restricted distribution, known to exist at only a single location, continuing decline in the extent of occurrence, area of occupancy).

Threats:

Lowering of water level during summer weather.

Remarks :

The survey during 2003 revealed marked decline in the availability as well as the extent of occurrence of the fish species. Apart from that, it is distributed only in a single location of a single river system globally and hence, this species deserves priority in *in-situ* and *ex-situ* conservation programmes. According to Menon (1999), *C. periyarensis* is found in fast flowing streams with rocky bed. Zacharias *et al.* (1996) have reported it to be a rare species usually found in the upper streams above Thannikkudy and are adapted to lotic torrential waters. Shaji and Easa (2001) have recorded its presence in stagnant portions of streams.

4. *Dayella malabarica* (Day) (Plate 1d)

Common name Day's round Herring (English)

Conservation status : CR (Molur and Walker, 1998), Vu (Kurup, 1994), LR – lc (Biju *et al.*, 2000).

Systematic position

Order Clupeiformes

Family Clupeidae

Subfamily Pellonulinae

Identification

D iii 10 – 11, A iii 15 – 16, P i 12, V i 7

Slender body with rounded belly having 1 – 4 thin irregular scutes hidden by scales. Pelvic scutes with vertical arms. Pointed snout with somewhat prominent lower jaw. Dorsal fins inserted slightly anterior to the pelvic fins. Lateral line absent. Body light yellowish-green above, silvery abdomen and a silvery stripe along the flank.

Geographical distribution:

Endemic to South-Western India (Type locality : Malabar, Kerala, India)

Earlier reports

Day (1873); Talwar and Whitehead (1971); Misra, (1976); Jayasree *et al.* (1993); Kurup (1982, 1994);Remadevi *et al.*(1996); Biju *et al.*(2000).

Present collection site

Chalakudy river (Thumburmuzhi)

Availability :

During the present survey, only six specimens were collected from the downstream of Chalakudy river. According to the past records, this monotypic genus was considered to be a common fish in the rivers and estuaries of western coast of India (Day, 1873). Jayasree *et al* (1993) collected this species from Shertallai, central coastal region of Kerala in limited numbers. Kurup (1994) included it under the category of 'vulnerable' fishes owing to its sporadic and sparse occurrence. Remadevi *et al.* (1996) has mentioned about four specimens of *D. malabarica* which were collected from Kumarakom Fish landing centre, Vembanad lake during December 1987 and from a ditch near Kottayam Railway station during the same period. Biju *et al.* (2000) recorded it from low and mid land areas of many rivers of Kerala and assessed it as a non-threatened fish. Since this species exactly resembles *Ehirava fluviatilis*, which also coexist in the same habitat and the latter species is also very abundant, the assessment made by the authors may be due to the incorrect identification of *D. malabarica*. This is further confirmed by the CAMP report (Molur and Walker, 1998) which strongly corroborates that only very few specimens of *D. malabarica,* which were procured from two locations of Kuttanad region of Kerala, were collected since its first description.

Habitat :

Regime reach dominated by muddy or sandy substratum.

Bionomics

The length of six specimens collected during the present study ranged between 71 and 85 mm TL. Three of them belonged to 71 – 75mm size group, two to 76 – 80mm and one to 81 – 85mm group. All were males in II and III stages of their maturity. Remadevi *et al.* (1996) reported specimens in the range 40 to 50mm SL. According to

Talwar and Jhingran (1991), the species attains a total length of about 60mm. It may be pointed out that all the specimens collected now are higher in size compared to the previous reports. CPUE varied between 0 and 0.025 Kg/hr (Table 2.20).

Status as per present study and IUCN criteria:

CR. $B_{1,2a}$ (Restricted distribution, severely fragmented, decline in extent of occurrence).

Threats

Destructive type of fishing practices such as poisoning of fish applying plant based as well as chemical poisons, dynamiting, electrocution,sand mining, habitat alteration, bund construction, Industrial and pesticide pollution, water abstraction,intensive agriculture along the banks affecting bank stability.

Remarks

The close rescemblence of *D. malabarica* to *Ehirava fluviatilis,* which is abundant in Kerala waters, often lead to erroneous identification and erroneous conclusion. Hence the listing of *D. malabarica* under Lr-lc by Biju *et al.* (2000) needs revalidation.

5. *Gonoproktopterus micropogon periyarensis* Raj (Plate 2a)

Common name	Periyar barb (English), Kariyan (Malayalam).
Conservation status	EN (Menon, 1997, Molur and Walker, 1998)

Systematic position :

Order : Cypriniformes

Family : Cyprinidae

Subfamily : Cyprininae

Identification:

D iv 9 ; A iii 5 ; P i 16 ; V i 8 – 9

Body elongated and fairly deep. Mouth sub terminal. Barbels two pairs, rostral and maxillay. Lateral line complete with 42 – 43 scales. Last unbranched ray osseous, strong and smooth. Body slaty colour.

Geographical distribution

Endemic to Kerala (India): Periyar lake and connected streams (Type locality : Periyar lake,Kerala).

Earlier reports:

Periyar lake and associated streams (Chacko 1948; Arun,1997; Zacharias *et al.*, 1996; Shaji and Easa ,2001); Vandiperiyar river close to Arnakal estate, Peermade hills (Silas , 1952).

Present collection sites

Upstreams of Periyar river system (Thannikkudy and above- Pulikayam, Aladi, Inchipara, Moolavaika).

Availability :

During the present investigation, a total of 65 specimens were collected, out of which 14 were procured from the landing centre at Thekkady. Silas (1952) collected a single specimen, measuring about 76mm in length from Vandiperiyar river. Talwar and Jhingran (1991), considering the fish species as a synonym of *G. micropogon*, recorded it as the commonest fish in Periyar lake Zacharias *et al.* (1996) described it as a common species found in the upper streams of Periyar.

Habitat

Pool-riffle reaches with good riparian vegetation, substratum dominated by bedrock.

Bionomics

65 specimenes ranging from 124 – 355mm TL and weight 15.86 – 500g were collected (Table.2.23). Among them, males predominated constituting 67.69% of the total catch while females and indeterminates contributed 20% and 12.31% respectively. Major size group was represented by 240 – 249 mm TL group followed by 220 – 229 mm group (Fig. 2.6). Both males and females collected were in the Ist and IInd stages of maturity. Length-weight relationship (Fig.2.7) could be expressed as follows:

$$\log w = -5.5589 + 3.2356 \log l$$

The 't' test on 'b' value revealed significant deviation of the exponential value from '3' (t = 2.97096, df = 64), thereby indicating an increase in weight at a rate grater than the cube of length.The correlation coefficient 'r' was 0.9816 disclosing a strong relationship between the two variables. As evidenced from the analysis of gut contents and RLG values, *G. micropogon periyarensis* was found to be a herbivore. Macrovegetation constituted the main food of this species followed by diatoms and insects (Fig.2.8). RLG values ranged between 1.6 and 3. CPUE varied between 0.109 and 0.355 Kg/hr (Table.2.20).

Status as per present study and IUCN criteria

CR. B $_{1,\ 2a}$ (restricted distribution, a single location, decline in the extent of occurrence).

Threats

Pollution and overexploitation in Periyar lake.

Remarks:

Talwar and Jhingran (1991) treated this as a synonym of *G. micropogon*. The reports of Jayaram (1999) on the occurrence of this species only from Dakshin Kannada, Karnataka and Cardomom hills, Tamil Nadu, are very much doubtful.

According to local fishermen, this is a delicious species which had been harvested frequently from the Periyar lake in large numbers as food fish, however, its occurrence became very sparse and sporadic during the recent years which is indicative of its drastic decline in Periyar lake. Pollution of lake through the discharge of sewage from Kumily and also by regular plying of boats due to heavy tourist influx, invasion and establishment of exotic fish species such as *Cyprinus carpio, Oreochromis mossambicus,* etc. (Kurup *et al.*, 2002) could be the contributing factors for the decline of the species in the lake.Being reported only from a single location globally and having understood the threat faced by the species in the type locality, *G.micropogon periyarensis* deserves the status and protection of the critically endangered category.

***6. Lepidopygopsis typus* Raj** (Plate 2b)

Common name	Periyar trout (English), Brahmanakendai, Brahmanakanda (Malayalam).
Conservation status	CR (Molur and Walker, 1998), EN (Menon, 1993).

Systematic position:

Order	Cypriniformes
Family	Cyprinidae
Sub-family	Schizothoracinae

Identification:

D iv 7; A iii 5; P i 13-15; V i 8

Body elongate and compressed with inferior mouth. Two pairs of barbels, rostral and maxillay. Lepidosis irregular and scattered with a few scales at base of dorsal spine and a patch of scales on scapular region. A continuous row of enlarged scales along lateral line, elongated tile like scales in the vent and anal fin region. Lateral line complete with 53 – 59 scales.

Geographical distribution:

Endemic to Kerala (India) :Upstreams of Periyar river (Type - locality: Periyar lake, Kerala)

Earlier records:

Periyar lake (Raj, 1941; Hora and law, 1941; Chacko, 1948; Tilak, 1987; Talwar and Jhingran, 1991; Arun, 1997; Jayaram, 1999; Menon, 1999; Shaji and Easa, 2001).

Present collection sites:

Thannikudy, Pulikkayam, Moolavaika, Inchipara, Koovala-kayam and Aaladi. All these sites are closely situated within a periphery of 40 Km of Periyar Tiger Reserve.

Availability:

Sixty one specimens were collected during the present investigation, 14 in February 2001with TL from 109 to 271mm while 6 in September 2001, with size range 147-238 mm TL ,22 (124 – 207mm TL) in February 2002 and 19 (85-176mm TL) in May 2002. After measuring length and weight, more than half of the number were released back into their habitat. Chacko (1948), Kurup (1994), Zahcharias *et al.,* (1996) and Menon (1999) included this endemic species in the category of 'rare' fishes.

Habitat:

Mainly bedrock reach, abundant in areas with chute type microhabitat. According to Manojkumar and Kurup

(2002),*L.typus* is abundant in chute type microhabitat with bedrock substrate,overhanging boulders, overhanging vegetation and shady areas with tree cover.

Bionomics :

61 fishes ranging in length from 85-271 mm and weight from 8 -181.82 g were collected. Majority of them belonged to 120-150 mm size group (Fig.2.9). Length – weight relationship of the species (Fig.2.10) can be expressed as follows:

$$\log w = -5.5735 + 3.1985 \log l$$

The 't' test on 'b' value revealed that there was no significant deviation from '3' (df = 60, t =1.986)', thereby indicating the fish follows isometric pattern of growth. Correlation coefficient 'r' was found to be 0.9724, revealing strong correlation between the two variables.Gut contents mainly consisted of diatoms, plant matter and insects (Fig. 2.11). Algae, crustaceans and fine gravel were also encountered. Relative gut length values ranged from 2.5 to 4.15 which indicate herbivorous mode of feeding. Four female fishes ranging in length 200-271mm and weight 69.96-181.82 g were analysed for estimating fecundity. The absolute fecundity varied from 3034 to 10228 eggs in this species (Table 2.24). Maximum diameter of ova was found to be 1.46mm. CPUE varied from 0.002 to 0.5258 Kg/hr (Table 2.20).

Status as per present study and IUCN criteria:

CR.B $_{1,2b}$ (Restricted distribution, single location, decline in area of occupancy).

Threats:

Pollution in Periyar lake, overexploitation, unauthorized fishing in the streams, lowering of water level in streams.

Remarks:

In some specimens of *L.typus*, the lateral line was found to be discontinuous. Lateral line curves downwards and extends up to the anal fin region where it disappears at the 42 nd scale. Just behind the beginning of anal fin, the lateral line appears again in the centre of the caudal peduncle region and the number of scales in this region is 17.

L. typus, which was recorded from Periyar lake by many earlier workers,has totally disappeared from the lake waters limiting their distribution to the streams in the uppermost reaches of Periyar river *viz.* Thannikkudy (829 m above msl) and above. The Periyar lake might have become inhospitable for this species due to pollution from the discharge of sewage from Kumily and diesel spillage due to plying of boats for sight seeing purposes of tourists, invasion and establishment of population by exotic fishes such as *Cyprinus carpio, Oreochromis mossambicus,* etc. (Kurup *et al.*, 2002). This species is known to exist only in Periyar river system globally and needs to be protected by implementing *in-situ* and *ex-situ* conservation measures.

7. *Travancoria elongate* Pethiyagoda and Kottelat (Plate 2c)

Common name	Travancore loach (English), Kallotty (Malayalam)
Conservation status	CR (Molur and Walker, 1998; Shaji *et al.* 2000)

Systematic position :

Order	Cypriniformes
Family	Balitoridae
Subfamily	Balitorinae.

Identification

D iii 7-8; A iii 5 ; P vii 10; V ii 10.

Head and greater part of body strongly depressed. Mouth inferior, fleshy upper lip continuous around corners of mouth, lower lip not continuous with the upper lip, restricted to a median pad barely covering lower jaw and followed posteriorly by two prominent, fleshy antrorse papillae. Barbels 3 pairs, 2 pairs of rostral and one pair of maxillary. Rostral cap with three inconspicuous lobes which are not developed into barbels and are separated from the upper lip by a deep groove. Lateral line complete with 74 -77 scales. Head, except rostrum, dotted with small widely spaced tubercles. Body greenish-brown, with dark brown spots, arranged in 3 rows. Ventral side creamy white. Pectoral fin with 5 series, pelvic with 4 series, dorsal and anal with 2 series of dots.

Geographical distribution:

Endemic to Kerala (India): Chalakudy river (Type-locality- Chalakudy river, near Vettilappara).

Distribution in Kerala:

Earlier reports

Chalakudy river (Shaji and Easa, 1996-97; Gopalakrishnan and Ponniah, 2000; Gopi, 2000; Shaji *et al.,* 2000).

Present collection sites:

Periyar (Pooyamkutty).

Availability :

A single specimen from Periyar river was examined in July 2002.Pethiyagoda and Kottelat (1994) collected 23 specimens from the type- locality of Chalakudy river. Gopi (2000) treated this species as 'very rare'.

Habitat:

Cascade reaches with high flow velocity.

Bionomics

During the present survey, one specimen of 68 mm TL was examined. Pethiyagoda and Kottelat (1994) collected 23 specimens ranging in standard length between 43.7 and 114.3 mm, 10 specimens (79.3-114.3mm SL) in April 1992, 2 (83.8-90.6 mmSL) in November 1992 and 11 (43.7- 112.8 mm SL) in September 1993. CPUE was found as 0.0027 Kg/hr.

Status as per present study and IUCN criteria:

Vu. B $_{1,\,2a}$ (Restricted distribution, single location, decline in the extent of occurrence).

Threats:

Dynamiting, poisoning and other destructive type of fishing methods.

Remarks:

So far, T. *elongata* was reported only from its type-locality, Chalakudy river. The present record from Periyar river reveals the extension of its distribution to another river system in Kerala.

8. *Silurus wynaadensis* Day (Plate 3a)

Common name Malabar silurus (English), Thonnivala, Wynadan mushi (Malayalam).

Conservation status: CR (Molur and Walker, 1998; Kurup, 2000, 2002; Shaji *et al.*, 2000), Rare (Menon, 1999)

Systematic position

Order Siluriformes

Family: Siluridae

Identification:

D 4; A ii 58 – 62 ; P I 10; Vi 7

Elongated body with small head and terminal mouth. Vomerine teeth in two separate batches. 2 pairs of mandibular and one pair of maxillary barbels present, small dorsal fin inserted anterior to the origin of the ventral. Adipose dorsal fin absent. Anal fin separated from the rounded candal fin by a distinct notch.

Geographical distribution:

India: Western Ghats: Kerala: Wynaad; (Cauvery drainage); Karnataka: Jagger Valley (Thungabadhra drainage) (Menon, 1999) (Type-locality: Wynaad, Kerala).

Distribution in Kerala:

Earlier reports:

The fish species, endemic to Western Ghats globally, is known to occur in Wynaad in Kerala. Day (1873, 1875-'78) reported it from a stream of Wynaad, about 3000 ft. above mean sea level (Cauvery drainage). Hora (1936), Talwar and Jhingran (1991) and Jayaram (1999) reported it as a species from Kerala region of Western Ghats. Misra (1976b) recorded its occurrence from Wynaad, Bhavani river, Western Ghats. *S.wynaadensis* was collected from a hillstream at Ranipuram (760m above msl) which forms the headwaters of Chandragiri river, Kasargod district by Gopi (1996). Gopi and Radhakrishnan (1998) reported its occurrence from Ranipuram as well as Theerthakundu of Thirunelli aar (Kabini river), Wynaad District. Shaji *et al.* (2000) described it as a species of Wynaad hills, Kerala. Apart from Kerala, *S.wynaadensis* has been reported from Jaggar valley associated with Thungabadhra drainage in Karnataka (Bhimachar and Rau, 1941). Rajan (1955) reported the species from headwaters of Bhavani river, a tributary of Cauvery.

Present collection sites:

Kabini river (Aranagiri, Kattikunnu, C. C. puzha)

Availability :

During the present survey,18 specimens were collected, 7 in October 2000, 5 in November 2001, 4 in January 2002 and 2 in April 2003.No previous data available. ZSI survey reports of 1993 - '97 included it under very rare to rare category. Gopi (1996) collected two specimens in 1993 from Ranipuram.

Habitat:

Pool-riffle reaches predominated by sandy substrate.

Bionomics:

Total length of the specimens collected during October 2000 and November 2001 ranged from 56-80 mm while those collected in January 2002 and April 2003 were within the range of 56mm to 70mm TL. The fishes examined by Gopi (1996) were 60 – 61.5mm SL. According to Talwar and Jhingran(1991) and Menon (1999), these fishes grow to a size of 30cm TL. CPUE values ranged from 0 to 0.006 (Table 2.20)

Status as per present study and IUCN criteria:

CR. $B_{1,\ 2a,b}$ (Restricted distribution, severely fragmented, decline in extent of occurrence and area of occupancy).

Threats:

Dynamiting, use of plant based and chemical poisons and other destructive fishing methods, agricultural pesticides, water abstraction and encroachment for agricultural purposes, drying up of streams during summer.

Remarks

A steady decline in the availability as well as occurrence of this species was clearly evident over the three years of survey. They are found in fast flowing streams with gravelly and sandy bed (Menon, 1999).

2.3.1.2. Endangered fishes of Kerala

9. *Cirrhinus reba* (Hamilton - Buchanan) (Plate 3b)

Common name Reba carp (English), Kaverikanni(Malayalam)

Conservation status Vu (Nationally), D D (Globally) (Molur and Walker, 1998)

Systematic position :

Order : Cypriniformes

Family Cyprinidae

Subfamily Cyprininae

Identification

D ii – iii 8; A iii 5 ; P i15; V i 8.

Body fairly elongate,snout slightly projecting beyond mouth. Dorsal fin less than body height. Lateral line with 34 – 38 scales. Body dark grey dorsally and silvery on flanks and belly. Tips of anal and pelvic fins orange coloured.

Geographical distribution:

Endemic to Indian subcontinent (Gopi, 2000): India; Pakistan; Nepal; Bangladesh (Type-locality: Rivers and ponds of Bengal and Bihar).

Distribution in Kerala:

Earlier reports:

Waynad and hill ranges of Nilgiris (Hora, 1941), Kabini (Shaji and Easa, 2001).

Present collection sites:

Kabini river (Kuruvadeep,Kunnumbatta, Noolpuzha).

Availability :

Eight specimens were collected during the present survey, 2 in April 2001 and 6 in October 2003. Earlier data on abundance of *C.reba* not available. Gopi(2000) treated this as a rare fish.

Habitat:

Regime reach predominated by mud and sand substrate.

Bionomics:

In April 2001, two specimens of 158 mm and 179 mm TL were collected while 6 specimens ranging between 146 – 170mm TL were collected in October 2003. According to Talwar and Jhingran(1991) and Menon(1999), this species attains 30cm TL. CPUE together with the number of surveys conducted, locations from where the species was collected and the number of occurrence of the species are given in Table 2.21.

Status as per present study and IUCN criteria:

EN. B $_{1,\ 2a,\ 2b}$ (Restricted distribution, continuing decline in the extent of occurrence, area of occupancy)

Threats:

Dynamiting, poisoning and other destructive type of fishing methods,water abstraction and encroachment for agricultural purposes, agricultural pesticides, drying up of streams during summer period

10. *Garra periyarensis* Gopi (Plate 3c)

Common name : Oortha, Kalvarayan (Malayalam)

Conservation status No previous report available on evaluation.

Systematic position:

Order	Cypriniformes
Family	Cyprinidae
Subfamily	Garrinae

Identification:

D ii 8 ; A ii 5 ; P i 14 ; V i 7

Body elongated and slender, a prominent flexible tuberculated knob like protuberance on snout. Barbels two pairs, rostral shorter than eye and maxillary rudimentary. Scales absent on breast and belly, post pelvic region scaly. Lateral line scales 37-39, Predorsal scales 10-11. Upper half of body brownish black, lower yellowish brown, an indistinct mid lateral band from behind the gill opening to the base of caudal fin.

Geographical distribution:

Endemic to Kerala(India): Periyar river (Type – locality Thannikkudy, Periyar Tiger Reserve).

Distribution in Kerala:

Earlier reports :

Thannikkudy, Periyar Tiger Reserve (Gopi ,2000); Mlappara, Periyar river(Shaji *et al.*,2000).

Present collection sites:

Periyar river (Thannikkudy and above - Mlappara, Mullakkudy, Pulikkayam, Pillakkayam, Moolavaika, Inchippara).

Availability:

During the present study, 102 specimens were collected. Among them, 24 were caught in September 2001, 21 in February 2002, 48 in May 2002 and 9 in February 2003. No previous data is available on the abundance of this species.The original description of the species was based on two specimens of 156 and 124.5 mm SL.

Habitat :

Cascade and pool riffle reaches with bedrock as the dominant substrate.

Bionomics

A total of 102 specimens comprising of 49 males, 27 females and 26 indeterminates were collected during the present survey. 24 specimens, caught in September 2001, ranged in length 115-220 mm TL. Fishes collected in February 2002 varied from 123 to 184mm in TL while those of May 2002, from 67-204 mm TL. In February 2003, 9 specimens were collected which ranged in TL between 132 and 183mm. Length composition of the fishes collected is presented in Fig.2.12. Length-weight relationship of the species (Fig.2.13) was worked out and can be expressed as follows:

$$\log w = -3.9405 + 2.4877 \log l$$

The 't' test on 'b' value revealed that it deviated significantly from cubic value of '3' (t = 8.7445, df = 101), thereby indicating that the weight increases at a rate lesser than the cube of length. The correlation coefficient 'r' value of 0.9734 showed strong correlation between length and weight. Out of the 5 females collected in February 2003, 4 were mature and 1 was in the 2^{nd} stage of maturity. Males dominated the population except in February 2003. The CPUE values were found to fluctuate during the three years of study. The maximum CPUE recorded during 2001 was 0.156 while during 2002, it was 0.472 and in 2003, 0.022 Kg/hr.

Status as per present study and IUCN criteria:

EN. $B_{1,3a}$ (Restricted distribution, Single location, fluctuation in the area of occurrence).

Threats:

Unprecedented dry spell in summer leading to either lowering of water level or drying up of streams and forest fires.

Remarks:

Flctuations in CPUE values can be taken as an index of the endangerment of the species.This is a newly described species, known to exist only in upstreams of Periyar river globally and hence there is every need to protect it with utmost care.

11. *Glyptothorax lonah* (Sykes) (Plate 4a)

Common name — Deccan sucker fish (English).

Conservation status — EN (Biju *et al.,* 2000), LR-nt (Molur and Walker, 1998).

Systematic position:

Order	Siluriformes
Family	Sisoridae

Identification:

D I 6 ; A iii 8 – 10 ; P I 9 ; V i 5

Body elongate, head depressed, mouth inferior. 4 pairs of barbels, maxillary barbels extend posteriorly to the middle of the pectoral fin, adipose fin inserted opposite to the origin of anal fin. Adhesive thoracic apparatus well developed. Skin minutely granulated on head and body. Body yellowish brown above and lighter below. A light streak present along the lateral line. Fins yellowish, dorsal, anal and caudal fins with black bands.

Geographical distribution

Endemic to India Deccan plateau, Godavari, Krishna river systems (Type-locality Deccan).

Distribution in Kerala:

Earlier reports :

This fish was first reported from Kerala by Biju *et al.* (1999) while surveying Chalakudy river. It was collected from Karappara tributary of Chalakudy river and Nelliampathy area (Ajith kumar *et al.* (1999).

Present collection sites

Chalakudy river (Vazhachal).

Availability :

A single specimen of 113 mm total length was collected on 12.8.2000 during the present survey. Six specimens of *Glyptothorax lonah* were collected from Pararnbikulam area of Chalakudy river system by Ajithkumar *et al.* (1999), who considered it as a 'very rare' species.

Habitat :

Pool-riffle and cascade reaches with high to moderate flow velocity, substratum dominated by bedrock followed by boulders.

Bionomics

The total length of *Glyptothorax lonah* examined was 113 mm. According to Talwar and Jhingran (1991), it attains a length of about 150 mm.The maximum CPUE during the present study was computed as 0.01 Kg/ hr (Table 2.21).

Status as per present study and IUCN criteria:

EN. $B_{1,2a}$ (Restricted distribution, severely fragmented, continuing decline in the extent of occurrence).

Threats

Pollution associated with heavy tourist inflow, lowering of water level during summer months.

Remarks :

There are many locations in Godavary and Krishna rivers from where the fish is available (Molur and Walker, 1998). The fish closely resembles the Gangetic goonch, Bagarius bagarius and is strikingly beautiful when alive (Talwar and Jhingran, 1991). According to Biju *et al.* (2000), the fish prefers foot hill rivers and mountainous swift running streams with bed rock, cobble, boulders and detritus as the main substrate. The location was reserve forest with eucalyptus plantation on one bank and thick evergreen forest on the other. Though only a single specimen was examined in the laboratory during the year 2000, this species was observed in the field in very limited numbers during the surveys of Chalakudy river in the subsequent years and hence included in the endangered category.

12. *Gonoproktopterus dubius* (Day) (Plate 4b)

Common name	Nilgiris barb (English), Kozhi-meen (Tamil)
Conservation status	EN (Molur and Walker, 1998; Menon, 1999; Shaji *et al.,* 2000).

Systematic position

Order	Cypriniformes
Family	Cyprinidae
Subfamily	Cyprininae

Identification

D iv 9 ; A ii 5 ; P i 16 ; V i 8

Body robust, snout somewhat elevated. Barbels two pairs, the short rostrals almost equal to half the diameter of the orbit and the maxillary a little longer. Dorsal fin inserted nearer to snout tip, last unbranched ray of dorsal osseous, strong and smooth. Lateral line complete with 42 – 45 scales. Predorsal scales 14. 4 ½ to 5 scales between lateral line and pelvic fin base. Colour of body silvery with a bluish tinge in males and red tinge in females.

Geographical distribution

India Tamil Nadu Cauvery, Bhavani and Manimuthar (Type - locality : Bhavani river at base of Nilgiri hills, Tamil Nadu)

Distribution in Kerala :

Earlier reports

Data not available.

Present collection sites :

Kabini (Baveli, Noolpuzha, Vythiri).

Availability

9 specimens were collected during the present survey. There is no previous information available on the abundance of this species from rivers of Kerala.

Habitat

Pool – riffle reaches of mountain streams with moderate flow velocity. Substrate is dominated by gravel.

Bionomics

The fishes collected belonged to 181 – 210mm TL size group. 5 specimens ranging in total length 181-210 mm were procured in April 2001 while 3 specimens (186 – 210mmTL) were collected in January 2002. A single female fish of 209 mmTL was obtained in March 2003. According to Gopalakrishnan and Ponniah (2000), the fish grows up to a size of 610mm TL whereas Talwar and Jhingran (1991) stated it to be 250mm TL. Males dominated the sample population with 8 numbers. CPUE varied between 0 and 0.84 Kg/hr (Table 2.21).

Status as per present study and IUCN criteria:

EN, B $_{1,\ 3a}$ (Restricted distribution , severely fragmented, fluctuation in the extent of occurrence).

Threats

Destructive type of fishing practices using plant based as well as chemical poisons, dynamiting, electrocution lowering of water level and dryiny up of streams during summer weather, deterioration of water quality during summer due to littoring of leaves and stagnation of water,water abstraction and encroachment for agricultural purposes,pollution from pesticides and insecticides.

Remarks

G.dubius forms a fishery in Cauvery river system (Talwar and Jhingran, 1991). However,according to CAMP report

(Molur and Walker,1998), 70 – 80% decline has been observed in the population of this carp during the past 10 to 20 years nationally. Menon (1999) reported that this species is found in the deeper parts of large streams and rivers below the Ghats.

13. *Horabagrus nigricollaris* Pethiyagoda and Kottelat (Plate 4c)

Common name : White collared imperial catfish (English),
Manjetta, Manjaletta, Manjakoori (Malaylam).

Conservation status: CR (Molur and Walker,1998; Shaji *et al.*,2000).

Systematic position

Order Siluriformes

Family: Bagridae

Identification

D 1 5 ; A iii 23-26 ; P1 8; V i 5

Body elongate, head depressed and broad, mouth sub terminal and crescentic. Occipital process distinct, extending to predorsal plate. Barbels four pairs, maxillary barbel extends beyond the base of pectoral fin, others shorter. The dorsal profile of adipose fin continuous with the dorsal profile of the dorsum anterior to it. Caudal fin lobes short and rounded. Head and body greyish brown, darker above, belly white. A large saddle shaped band edged in white or pale yellow, extends from the humeral region of each side over the nape. Caudal fin light yellow, edged in black.

Geographical distribution

Endemic to Kerala (India) Chalakudy river (Type -locality Chalakudy river, near Vettilappara).

Distribution in Kerala

Earlier reports

Chalakudy river (Gopalakrishnan and Ponniah, 2000; Shaji and Easa, 2001)

Present collection sites:

Chalakudy (Vettilappara, Thumboormuzhi).

Availability:

During the present study, 8 specimens were collected, 5 in March 2001 and 3 in February 2003.Pethiyagoda and Kottelat (1994) collected 12 specimens from Chalakudy river, the type-locality,among them, 3 each in March 1993 and June 1993 and six in September 1993, ranging in length from 72.7-173 mm SL. Gopi (2000) treated it as a rare fish.

Habitat

Found in regime reaches with fines as the dominant substrate and also in bedrock reaches.

Bionomics

The fishes collected at present ranged from 101–180 mm TL. Those collected in March 2001 were 106-180mm in TL whereas those obtained in February 2003 were of smaller size (101-170 mmTL). According to Menon (1999), this species attains a size of 27cmTL while Gopalakrishnan and Ponniah(2000) reported it to be 17 cm TL. The CPUE varied from 0 to 0.24 Kg/hr in the year 2001 while it was between 0 and 0.021 in 2003.The reduction in CPUE can be indicative of declining trend in the availability of the species.

Status as per present study and IUCN criteria

EN. B $_{1,2a}$ (Restricted distribution to 2 locations, continuing decline in the extent of occurrence).

Threats:

Overexploitation for trade as ornamental as well as food fish.

Remarks:

H. nigricollaris is an attractive endemic species which can be easily acclimatized for ornamental purposes and is very hardy.This species is exported from India and fetches US $ 5 per piece (Ramachandran , 2002).

14. *Neolissocheilus wynaadensis* (Day) (Plate 5a)

Common name South Indian barb (English) Kadanna, Manipparal (Malayalam)

Conservation status CR (Molur and Walker, 1998; Shaji *et al.* 2000); Rare (Menon 1999).

Systematic position

Order Cypriniformes

Family Cyprinidae

Sub-family :Cyprininae.

Identification

D iv 9; A iii 5 ; P i 16 ; V i 8.

Body elongated with broad head, mouth smoothly rounded, lower labial fold interrupted. Barbels two pairs, maxillary barbels as long or longer than the orbit, the rostrals shorter. Dorsal fin inserted a little anterior to the insertion of ventral. Lateral line complete with 26-28 scales. Predorsal scales 10. Body grayish silvery along the back. A dark coloured band extending from the eye to the middle of the base of caudal fin, sometimes ending in a round black blotch. Belly light orange in colour.

Geographical distribution:

Endemic to Western Ghats (India). Wynaad (Kerala) and headwaters of Cauvery river (Talwar and Jhingran, 1991). (Type- locality : Vythiri, Wynaad, Kerala).

Distribution in Kerala:

Earlier reports :

Day (1875-'78); Pillay (1929); Hora and Law (1941); Jayaram (1981,1999); Talwar and Jhingran (1991);Easa and Basha (1995); Menon (1999); Gopi(2000); Shaji *et al.* (2000) and Shaji and Easa (2001) reported the occurrence of this fish from Vythiri, Wynaad. Shaji and Easa (2001) collected juveniles from a rivulet passing through Periya (Wynaad). Remadevi *et al.* (1996) reported about juveniles collected from Pambar river at border of Chinnar Wildlife Sanctuary in April 1990.

Present collection sites

Kabini river (Aranagiri, Kunnumbatta, Kattikunnu, C.C. puzha and Appenkappa).

Availability

A total of 18 specimens were collected during the present investigation, 3 each in October 2000 and September

2001, 4 each in October 2001, November 2002 and August 2003. Day (1875-'78) reported it as common in larger streams while Gopi (2000) considered it as 'very rare'. 14 juveniles ranging in size between 13 and 31 mm TL were collected from Pambar river (Remadevi *et al.*, 1996). Studies conducted during 1985 and 1995 by Zoological Survey of India showed its distribution to be sporadic, stray and scanty (Gopi, 2000).

Habitat:

Pool–riffle reaches, dominated by sandy substrate, flow velocity is moderate.

Bionomics:

Out of the 18 specimens examined, 7 were males, 4 females and 7 indeterminates. Among them,3 specimens collected in October 2000, belonged to the 161-165mm TL size group. Three smaller fishes falling within the range of 61-80 mm TL were procured in September 2001 while in October 2001, four large specimens in the length range 141-235 mm TL were collected. Total length of the 4 specimens obtained in November 2002 ranged from 81-85 mm and those of August 2003 measured 141-145 mm. According to Talwar and Jhingran (1991) and Menon (1999), it grows upto a total length of 250 mm. Maximum size of this species collected during the present survey was 235 mm. Gonads were in the 1st stage of maturity in August. Fishes collected in September and November were immature whereas in October they were in the 2nd and 3rd stages of maturity. This fish species is a herbi - omnivore, showing preference to plant matter especially leaves (51.2%) followed by insects (35.8%). Diatoms and filamentous algae were encountered in small amounts (Fig.2.14). CPUE from the various locations ranged from 0 to 0.43 Kg/hr (Table 2.21).

Status as per present study and IUCN criteria:

EN. $B_{1,\ 2b}$ (Restricted distribution, severely fragmented, continuing decline in the extent of occurrence).

Threats:

Destructive fishing methods such as application of plant based as well as chemical poisons, dynamiting, illegal fishing especially by the vagrant fishermen from Karnataka, erection of temporary barriers across streams and rivulets for fishing, water abstraction and encroachment for agricultural purposes.

Remarks

According to Menon (1999), *N. wynaadensis* is found in fast flowing streams and rivers with rocky bottom.

15. *Osteochilichthys longidorsalis* Pethiyagoda & Kottelat (Plate 5b)

Common name	Long finned barb (English), Modon, Macchan (Malayalam)
Conservation status	CR (Molur and Walker, 1998), EN (Biju *et al.*, 2000; Thomas *et al.*, 2002).

Systematic Position

Order	Cypriniformes
Family	Cyprinidae
Subfamily	Cyprininae

Identification

D iv 10 ; A iii 5 ; P i 13 ; V i 8

Head and body compressed, snout with tubercles which form a patch in front of the eyes and about the level of their lower rim, the rostral fold overhangs the upper lip medially. Lower lip adnate with the jaw. Barbels absent. Last simple dorsal ray markedly elongate, longer in adults than in juveniles and its tip reaches beyond all the others. Lateral line complete with 39 – 40 scales, 12 predorsal scales. Body greenish yellow on flanks and black dorsally.

Geographical distribution

Endemic to Kerala (India): Chalakudy river (Type-locality: Chalakudy river, near Vettilappara)

Distribution in Kerala

Earlier reports:

Chalakudy river (Pethiyagoda and Kottelat, 1994; Shajj and Easa, 1996-97; Ajithkumar *et al.,* 1999; Biju *et al.,* 2000; Shaji and Easa, 2001; Thomas *et al.,* 2002).

Present collection sites:

Chalakudy river [Malakkapara, Athirappilly, Parambikulam (Orukombankutty)]

Availability:

During the present study, 19 specimens were collected from Chalakudy river. Pethiyagoda and Kottelat (1994) collected 69 specimens from the type-locality during April 1992-'93 and September and November 1993. The second report was that of Ajithkumar *et al., (*1999) who collected only a single specimen from the Parambikulam tributary of Chalakudy river, 2 Km away from Orukombankutty. Thomas *et al.* (2002) considered it as a very rare species.

Habitat :

Pool-riffle reaches dominated by bed rock substrate.

Bionomics :

8 specimens of this fish species, ranging from 71 - 130mm TL, were collected in March 2001, 7 specimens (71 – 120mm TL) in July 2001 and 4 specimens (111 – 185mm TL) in February 2003. Majority of fishes belonged to 71 – 80mmTL group (Fig.2.15).Specimens collected by Pethiyagoda and Kottelat (1994) ranged between 66.8 and 220mm SL. Gopalakrishnan and Ponniah (2000) recorded it as 300 mm TL, while Shaji and Easa (2001) reported139 mm SL. The CPUE varied from 0 to 0.19 Kg/hr (Table 2.21).

Status as per present study and IUCN criteria:

EN. $B_{1,2a}$ (Restricted distribution, exist in less than 5 locations , decline in the extent of occurrence).

Threats:

Collection for ornamental purposes, unethical fishing methods, construction activities associated with tourism development and increasing tourist inflow in Athirappilly, lowering of water level during summer.

Remarks :

O. longidorsalis could not be collected from its type-locality, Vettilappara during the present survey. The fish was caught only from upper streams, indicating a shift in the distribution of the species to higher reaches of the river. Habitat destruction due to human intervention associated with heavy tourist inflow could be a contributing factor for the migration of these fishes to upstreams. Biju *et al.,* (2000) collected *O. longidorsalis* from deep running waters of hilly areas with sand, gravel, cobble, boulders and bed rock as substrate

16. *Osteochichthys nashii* (Day) (Plate 5c)

Common name	Nash's barb (English), Machal, Mamal, Modon (Malayalam)
Conservation status	EN (Thomas *et al.,* 2002), Vu (Menon, 1999; Shaji *et al.,* 2000).

Systematic position

Order	Cypriniformes
Family	Cyprinidae
Subfamily	Cyprininae

Identification

D iv 11 ; A iii 5 – 6 ; P i 14; V i 8

Body oblong and compressed, mouth broad, inferior and overhung by snout which in adults is covered by papillae. Lips continuous at angles of mouth, no barbels. Dorsal fin without osseous ray, ventral arises about the middle of the dorsal, lateral line complete with 40 – 43 scales. Body golden yellow in colour with a broad black lateral band extending from eye to caudal fin. Dark band on dorsal and anal fins.

Geographical distribution

Endemic to Western Ghats (India) Karnataka and Kerala. (Type-locality Fraserpet river, Coorg District, Karnataka).

Earlier reports

Wayanad (Day, 1875-'78; Hora, 1941); Aralam Wildlife Sanctuary, Kabini and Chaliyar (Easa and Basha, 1995; Shaji *et al.,* 1995); Chandragiri, Periyar, Chaliar, and Valapattanam rivers (Biju *et al.,* 2000).

Present collection sites :

Kabini (Begur, Aranagiri, Noolpuzha, Baveli, Kunnumpatta, Pookode lake).

Availability

22 specimens comprising of 16 males and 6 females were collected during the present survey. Shaji *et al.* (1995) collected 10 specimens, three from Cheenkannipuzha, 4 from Valayamchal and 3 from Narikadavu. Gopi (2000) treated it as a rare species.

Habitat

Pool-riffle reaches of mountain streams with moderate flow velocity, substratum dominated by fines and gravels.

Bionomics

The fishes collected during the present study ranged between 121 and 180 mm TL. In January 2001 only two males were obtained (144 and 168mm TL) while in April 2001, 9 males and 2 females were captured (121 – 180mm TL). During May 2001, 5 males and 4 females ranging in size between 121 and 180mm TL were collected. In January 2001, the males possessed light pink testis and were in the first stage of maturity. In May 2001, the ovary was yellow coloured and was in the third stage of maturity while testis was cream coloured and in the second stage of maturity. The specimens collected by Shaji *et al.* (1995) belonged to 75 – 137mm SL. According to Talwar and Jhingran (1991) and Menon (1999), the species attains a length of 180 mm .The maximum size of the fish collected during the present study is 180mm. CPUE from the various locations was estimated to be between 0 and 0.32 Kg/hr (Table.2.21).

Status as per present study and IUCN criteria:

EN. B $_{1,2b}$ (Restricted distribution, severely fragmented, decline in the area of occupancy).

Threats

Destructive type of fishing practices such as killing of fish by applying plant based as well as chemical poisons, dynamiting, electrocution, water abstraction and encroachment for agricultural purposes,agricultural pesticides, change in water flow in rivers and streams due to severe draught in summer periods, heavy fishing pressure from vagrant fishermen from neighbouring states like Karnataka.

Remarks

According to Biju *et al.* (2000), *O. nashii* inhabits hilly areas while Menon (1999) reported it as inhabiting large hill streams and rivers.

17. *Anguilla bicolor bicolor* McClelland (Plate 6a)

Common name — Short fin eel (English), Malinjeen, Karuthamalinjeen, Vilangu, Mlanjil (Malayalam).

Conservation status — EN (Biju *et al.,* 2000).

Systematic position

Order — Anguilliformes

Family — Anguillidae

Identification

D 220 – 245 ; A 200 – 220 ; P 18

Body elongate, head flattened dorsally, angle of mouth extends to the posterior margin of eye. Small teeth form broad continuous bands on jaws and vomer. Dorsal fin begins above the anus or slightly before or behind it. Body with plain colouration. Dark olive above becoming yellowish below.

Geographical distribution :

East Africa to Pakistan, India, Sri Lanka. (Type-locality :India) (Talwar and Jhingran, 1991).

Earlier reports

Travancore (John, 1936; Hora and Law 1941), Periyar lake (Chacko, 1948); Sherthallai, Alleppey (Jayasree *et al.,*1993), Chalakudy River (Ajithkumar *et. al.,* 1999), Chalakudy and Periyar river systems (Biju *et al.,*2000), Bharathapuzha (Bijukumar and Sushama, 2001).

Present collection sites:

Periyar (Pooyamkutty), Puzhayakkal (Puzhayakkal).

Availability

Two specimens were only examined during the present study, one each from Puzhaykkal and Pooyamkutty during August 2001 and February 2003 respectively. Ajithkumar *et al.* (1999) and Biju *et al.*(2000) treated *A. bicolor bicolor* as a 'rare' eel in fresh waters of Kerala while Shaji and Easa (2001) considered it as fairly common in low land water bodies and rivers. Noticing considerable reduction in its population during the recent years, Bijukumar and Sushamma (2001) evaluated it as a 'rare' fish.

Habitat

Pool-riffle and regime reaches with moderate flow velocity.

Bionomics

The total length of the fishes collected from Puzhaykkal and Pooyamkutty were 43mm and 72 mm respectively. Both specimens were immature. Maximum CPUE was estimated as 0.21 Kg/hr from Puzhaykkal and 0.32 from Periyar (Table 2.21).

Status as per present study and IUCN criteria :

EN. B $_{1,2a}$ (Restricted distribution, severely fragmented, decline in area of occupancy).

Threats:

Pooyamkutty –Destructive type of fishing activities using fish poisons, dynamiting and electrocution, construction of bunds and barriers. Puzhaykkal-Regular and indiscriminate fishing leading to overexploitation of stock.

Remarks:

Anguilla bicolor bicolor, in one or two numbers, were observed in the local markets occasionally. According to local fishermen,their abundance has declined drastically during recent years.Only two specimens were brought to the laboratory for further studies during the present survey.

18. *Barilius bendelisis* (Hamilton-Buchanan) (Plate 6b)

Common name	Hamilton's barb (English), Paral, Thuppalkothiparal (Malayalam).
Conservation status	LRnt (Nationally) (Molur and Walker, 1998); Vu (Kerala) (Biju *et al.,* 2000).

Systematic position

Order	Cypriniformes
Family	Cyprinidae
Subfamily	Rasborinae

Identification:

D ii 7; A ii – iii 7 – 8; P i 14; V i 8

Body shallow. Barbels two short pairs, the rostral pair occasionally absent. Dorsal fin inserted in front of the origin of anal and commences nearer the base of the caudal fin than the snout. Lateral line complete with 40 – 45 scales. Pre-dorsal scales 18 – 20. Body silvery with 8 – 12 dark bands descending from back to lateral line. In adults, these bands become indistinct as spots.

Geographical distribution

India, Pakistan, Bangladesh, Nepal, Srilanka (Type–locality Vidawati stream, head waters of Krishna river, Mysore).

Earlier reports

Periyar lake (Chacko,1948) Pambar river at border of Chinnar Sanctuary (Remadevi *et al.*,1996; Easa and Shaji, 1996); Thekkadiar tributary of Chalakudy river, flowing through Parambikulam Wildlife Sanctuary (Ajith-kumar *et al.*,1999); Chalakudy river, Bharathapuzha, Pambar, Bhavani rivers (Biju *et al.,* 2000); Bharathapuzha and Chalakudy river (West flowing), Chinnar and Pambar (East flowing) rivers (Shaji *et al.,* 2001).

Present collection sites

Chalakudy river (Malakkapara, Athirappally and Kuriyarkutty); Bharathapuzha (Cheruthuruthy and Cholagu).

Availability :

During the present study, 11 specimens were caught, 6 from Bharathapuzha and 5 from Chalakudy river. Remadevi *et al.* (1996) reported that 70 specimens of *Barilius bendelisis,* comprising of 54 juveniles and 16 adults, were collected from Pambar river. 6 specimens were procured from Chalakudy river by Ajithkumar *et al.* (1999).

Habitat :

Abundant in cascade reach, sparse and sporadic occurrence in braided reach with moderate flow velocity.

Bionomics :

The fishes collected belonged to the size group of 86 – 134 mm TL. During March 2001, 3 specimens (93, 102 and 134 mm TL) were obtained from Chalakudy river whereas in February 2003, 2 specimens (93 and 99 mmTL) were collected from the same river. Collection from Bharathapuzha included 4 specimens (111–120 mm TL) obtained in December 2001 and two fishes (86 – 95mm TL) in August 2002. All specimens were males and none of them was in mature or ripe condition. Remadevi *et al.* (1996) collected 70 specimens in April 1990 and were 13 – 59 mm in TL. According to Shaji and Easa (2001), it attains a length of 110mm SL whereas Talwar and Jhingran (1991) opined it as 155mm TL. The maximum size of the fish caught during the present study was 134 mm TL. CPUE from Chalakudy river ranged from 0 to 0.05 Kg/hr while the values from Bharathapuzha varied between 0 and 0.01 (Table 2.21).

Status as per present study and IUCN criteria

EN. $B_{1,\ 2a,\ 2b}$ (Restricted distribution, severely fragmented, continuous decline in the extent of occurrence, area of occupancy)

Threats

Bharathapuzha -Overexploitation, Sand mining, habitat destuction, siltation,construction of check dams, pollution mainly caused by Industrial effluents, unethical fishing practices. Chalakudy–construction works as part of tourism promotion , tourist influx , pollution from domestic wastes.

Remarks :

According to Talwar and Jhingran (1991), this species was fairly common all over India except in Kerala. However, as early as in (1948), Chacko reported its presence from Periyar Lake.

19. *Gonoproktopterus kolus* (Sykes) (Plate 6c)

Common name	Kolus (English); Kooral, kariyan (Malayalam)
Conservation status	EN (Molur and Walker, 1998 ; Shaji *et al.,* 2000); Vu (Biju *et al.,* 2000 ; Thomas *et al.,* 2002)

Systematic Position:

Order	Cypriniformes
Family	Cyprinidae
Subfamily	Cyprininae

Identification:

D iv 9 ; A iii 5 ; p i 14 ; V i 8

Body compressed, a moderate ascend in the profile from the occipital to the dorsal fin. Mouth slightly subterminal. Barbels one pair. Dorsal fin inserted anterior to pelvic fins, its last unbranched ray osseous and weak. Lateral line with 40 – 43 scales. Body silvery with a tinge of yellow.

Geographical distribution:

Endemic to India : Cauvery, Godavari and Krishna river systems (Jayaraman , 1999); Kerala (Vairavel *et al.,* 1998)

Distribution in Kerala:

Earlier reports:

Thunnacadavu reservoir, Chalakudy river at Malakkapara (Vairavel *et al.,* 1998); Chalakudy river, Periyar, Muvattu-puzha and Karamana (Biju *et al.,*2000); Chalakudy river (Gopalakrishnan and Ponniah, 2000); Chalakudy Periyar (Euphrasia and Kurup, 2002).

Present collection sites

Periyar (Anakkayam, Thannikudy); Chalakudy (Karapara, Kuriarkutty, Parambikulam).

Availability :

During the present faunistic survey, 63 specimens of *G.kolus* were collected. According to Talwar and Jhingran

(1991), this is commonest in Poona waterways. No data is available from Kerala regarding abundance of this species. Ajithkumar *et al.,* (1999) treated it as 'very rare', inhabiting an altitude of 76-500m above msl. Thomas *et al.,* (2002) reported it as a rare fish.

Habitat :

Pools distributed in the pool- riffle reach with moderate flow velocity. Substratum dominated by bedrock and mud.

Bionomics

A total of 63 specimens were collected during the present survey. Out of these, 59 fish were caught from Chalakudy river and four from Periyar (Table.2.25).Highest frequency of fishes was noticed in the 211-220 mm TL group (Fig.2.16).The maximum size of the fish collected during the present study was 225 mm. According to Talwar and Jhingran (1991), the fish attains a length of 30cm while Gopalakrishnan and Ponniah (2000) reported it to be >60cm. The length-weight relationship of G. *kolus* (Fig.2.17) can be expressed as follows:

$$\log w = -5.3765 + 3.1621 \log l$$

The regression coefficient on 't-test' showed that it is significantly higher than '3', indicating that the weight of fish increases at a rate greater than the cube of length. The correlation coefficient was 0.9845. Out of the 59 fishes examined in the laboratory, 29 were males, 23 females and 7 indeterminates. Fishes collected during the month of

March 2001 were in the 2nd and 3rd stages of maturity. The gut content analysis of *G.Kolus* revealed that it mainly feeds on vegetable matter (38.21%) and crustaceans (26. 27%). Diatoms, insect larvae, algae and molluscs were the other food items encountered in the gut (Fig. 2.18). Thus the species was found to be a herbi-omnivore. The CPUE from Chalakudy ranged from 0 to 1.495 Kg/hr while the values from Periyar river varied between 0 and 0.17 (Table 2.21).

Status as per present study and IUCN criteria:

EN. $B_{1,2a}$ (Restricted distribution, severely fragmented, continuing decline in the extent of occurrence)

Threats:

Pesticide pollution from neighbouring coffee plantations (Karappara), domestic wastes (Kuriarkutty), lowering of water level during summer altering the flow rate, unethical fishing practices.

Remarks:

Menon (1999) consider *G.kolus* under the genus *Hypselobarbus* as a synonym of *H.curmuca*. Females of *G.kolus* put on gaudy colours to attract males during breeding season which is from June to August (Talwar and Jhingran, 1991).

20. *Gonoproktopterus thomassi* (Day) (Plate 7a)

Common name Red Canarese barb (English), Chakkali (Malayalam).

Conversation status EN (Molur and Walker, 1998; Biju *et al.* 2000 ; Shaji *et al.*, 2000), Very rare (Gopi, 2000), Rare (Shaji and Easa,2001).

Systematic position

Order : Cypriniformes

Family : Cyprinidae

Sub-family Cyprininae.

Identification:

D iii-iv 9; A iii 5 ; P i 16 ; V i 9.

Body elongate, dorsal and ventral profiles of body equally convex. Mouth subinferior, lower labial fold interrupted. Barbels two pairs, rostrals shorter than maxillary. Dorsal fin inserted midway between the tip of snout and base of caudal fin, last unbranched ray osseous and weak.Caudal fin deeply forked, the upper lobe longer. Anal fin separated from the rounded candal fin by a distinct notch. Lateral line with 31-34 scales. Body silvery along the back, each scale with a red lunule.

Geographical distribution:

Endemic to Western Ghats (India): Karnataka, Dakshin-kannada (South Canara); Kerala: Chalakudy river, Cardamom hills (Menon, 1999) (Type-locality: South Canara).

Distribution in Kerala:

Earlier reports

Chalakudy river (Thobias,1973) Pooyamkutty and Kalady areas of Periyar river (Biju *et al.*, 2000)

Chendurni wildlife Sanctuary, Kallada river (Gopi,2000) Kabini (Shaji and Easa , 2001) ; Kallada river (Euphrasia and Kurup, 2002).

Present collection sites

Kallada river (Meenmutti, Thenmala dam), Periyar (Pooyamkutty).

Availability :

During the present survey, 20 specimens were examined. A total of 5 and 10 specimens were collected from Kallada river during October 2001 and July 2002 respectively. From Periyar river, 5 fishes were recorded in February 2003. Based on Zoological Survey of India 1997 reports, Gopi (2000) attributed to this species the status of very rare fish. Shaji and Easa (2001) considered it as a rare fish as they could collect only 2 specimens from Kabini river during their faunistic survey carried out during 1995-'97. A single specimen collected from Periyar river is exhibited in the museum at Thattekkad Bird Sanctuary. 2 specimens were obtained during the survey from May 2000 to April 2001 (Euphrasia and Kurup,2002).

Habitat:

Regime and pool-riffle reaches with bedrock as dominant substratum.

Bionomics:

20 specimens ranging in total length between 206 and 355 mm TL were procured. Among them, 5 fishes in the length

group of 231 -340 mm TL were caught in October 2001 while in July 2002,10 specimens measuring 206 to 315mm TL were obtained.The five fishes collected during February 2003 belonged to 256 -355 mm TL group. Maximum number of fishes was in 251-260 mm and 281-290 mm TL group (Fig.2.19). According to Talwar and Jhingran (1991) and Gopalakrishnan and Ponniah (2000), the fish attains a total length of 100 cm. Menon (1999), recording the size of this species as 23 cm, added that it is known to grow to a length of 100 cm as Red mahseer. Maximum CPUE from Kallada and Periyar rivers were estimated as 0.21 and 0.015 Kg/hr respectively (Table 2.21).

Status as per present study and IUCN criteria:

EN.$B_{1,2a}$ (Restricted distribution, known to exist at less than 5 locations, severely fragmented, continuing decline in the extent of occurrence).

Threats:

Dynamiting, application of poisons, gill netting and other destructive types of fishing methods.

Remarks :

In Kulathupuzha Temple Sanctuary, this species enjoys the privilege of conservation due to religious sentiments. According to Menon (1999), *G. thomassi* is distributed in large streams and rivers below the ghats. Biju *et al.* (2000)opined that this species prefers running waters of highland areas. They collected the fish from (a) the reserve forest area of Pooyamkutty with sand, gravel and cobble as substrate and bamboos and trees as riparian vegitation and (b) Kalady, a settlement area with agricultural lands, the dominant substrate being sand.

21. *Nemacheilus semiarmatus* Day (Plate 7b)

Common name Loach (English), Koima (Malayalam)

Conservation status EN (Biju *et al.*, 2000), Vu (Molur and Walker, 1998).

Systematic position

Order	Cypriniformes
Family	Balitoridae
Subfamily	Nemacheilinae

Identification:

D ii-iii 8 ; A ii 5 ; P i 10; V i 6

Body fairly elongate, barbels well developed and thread like, as long as eye diameter. Lateral line complete. Dorsal fin inserted near to tip of snout than base of caudal fin. Caudal fin slightly forked. Body and sides of head with irregularly scattered but conspicuous black dots. Young possess 12 or 13 bands instead of dots, anal fin with a row of dots, ventral and caudal fins with multiple rows of dots.

Geographical distribution

Endemic to Western Ghats (India): Cauvery basin in Waynad, Nilgiri and Mysore Silent valley (Bharathapuzha basin).(Type – locality Bowany and Seegoor river at base of Neilgherry)

Distribution in Kerala:

Earlier reports: Bhavani and Kabini rivers (Easa and Basha, 1995); Pambar river, Chinnar Wildlife Sanctury (Biju *et al.,* 2000; Thomas *et al.,* 2002).

Present collection sites :

Kabini (Sugandhagiri), Chinnar (Chinnar)

Availability:

Two specimens were collected during the present survey. No published information on its abundance. Gopi (2000) and Thomas *et al.* (2002) considered it as a rare fish.

Habitat :

Found in pools of bedrock reaches with moderate flow velocity.

Bionomics:

Two specimens were examined in the laboratory, one each from Kabini (January 2001) and Chinnar (August 2003).The specimen from Kabini river was 53mm while the one from Chinnar was 74mm in TL. According to Talwar and Jhingran (1991) and Menon (1999), they attain standard length of about 56mm. The CPUE from Kabini was found to be 0.0035 while it was 0.0009 Kg/hr from Chinnar (Table 2.21).

Status as per present study and IUCN Criteria:

EN. $B_{1,\ 2b}$ (Restricted distribution, Severely fragmented, Continuing decline in area of occupancy).

Threats:

Sugandhagiri: Agricultural pesticides, destructive type of fishing by using chemical and plant based poisons.

Remarks

The fish species was found at the bottom of the streams in moderate numbers during the surveys in the year 2001, but a conspicous declining trend was observed in the frequency of occurrence as well as the area of occupancy during the subsequent years and hence the species was included in the endangered category. According to Menon (1999), *N.semiarmatus* is seen in small streams with gravelly bed. On the other hand, Biju *et al.*(2000) collected it from cool, fast flowing streams in the reserve forest with shrubs and trees as riparian vegetation and with sand, gravel and cobbles as the main substrate.

22. *Travancoria jonesi* Hora (Plate 7c)

Common name Travancore loach (English); Kallotty, Kalsravu, Kalleppatti (Malayalam)

Conservation status CR (Biju *et al.*, 2000); EN (Menon,1993; Molur and Walker, 1998; Shaji *et al.*, 2000; Thomas *et al.*, 2002)

Systematic position

Order	Cypriniformes
Family	Balitoridae
Subfamily	Balitorinae

Identification

D ii 7-8 ; A i 4-5 ; P vi 9-10 ; V ii 6-7.

Head and anterior part of the body depressed, tail somewhat compressed, head broadly pointed anteriorly, covered with series of short hard spine like growths. Mouth small and inferior, well developed lips free from jaws, 7 rostral and 2 maxillary barbels. Lateral line with 75-77 scales. Paired fins broad, wing like and horizontal. Body dark above and pale below, the dorsal surface with a series of 8 to 10 broad, saddle shaped spots; head and sides of body mottled with black spots of different sizes and pattern.

Geographical distribution

Endemic to Western Ghats (India): High ranges of Northern Travancore and Anamalai hills. [Type-locality: Pampadampara, Peermed, Kerala (Periyar river basin)]

Distribution in Kerala :

Earlier reports

Travancore (Hora, 1941; Hora and Law, 1941; Gopi, 2000; Shaji *et al.*, 2000) ; Cochin section of Anamalai and Nelliampathi hills (Silas, 1951); Pasuparai estate, Peermed hills (Silas, 1952); Kerala high ranges and Anamalai hills (Menon, 1987, 1999); rivers of Kerala (Kurup, 1994); Periyar river (Arun *et al.,* 1996; Zaccharias *et al.,* 1996); Chalakudy river (Ajithkumar *et al.*, 1999; Biju *et al.*, 1999); Chalakudy and Periyar rivers (Thomas *et al.*, 2002); Pampa, Periyar, Kallar, Neyyar (Shaji and Easa, 2001); Chalakudy (Radhakrishnan and Kurup, 2002).

Present collection sites :

Chalakudy [Nelliampathi (Karappara), Thekkady ar]

Availability

5 specimens were examined during the present study. A single specimen was collected in May 2002 from Chalakudy river. The remaining 4 were caught during the month of January 2003 from the same river.Silas (1952) collected a single specimen from a stream close to Pasuparai estate, Peermed hills. Several authors listed it under `very rare' (Ajithkumar *et al.*, 1999; Gopi, 2000; Thomas *et al.*, 2002) and `rare' (Kurup, 1994; Arun *et al.*, 1996; Zacharias *et al.*, 1996; Radhakrishnanand Kurup, 2002) category.

Habitat :

Pools in the bedrock reach.

Bionomics

During the month of May 2002,a single fish of 48mm TL was caught. Total length of the 4 specimens obtained in January 2003 ranged from 61-75 mm. SL of *T.jonesi* was recorded as 80mm by Talwar and Jhingran (1991),84mm by Menon (1999) and 90mm by Silas (1952).CPUE ranged between 0.0015 and 0.0073 Kg/hr (Table 2.21).

Status as per present study and IUCN criteria

EN. $B_{1,2a}$ (Restricted distribution, severely fragmented, decline in the extent of occurrence)

Threats :

Karappara-bank erosion, intensive agricultural practices, pollution due to pesticides and insecticides. Thekkedy aar drying up of stream during summer, bank erosion, construction of three check dams leading to alteration of habitat and prevention of fish migration, temporary bund construction for fishing and destructive fishing methods.

Remarks:

Biju *et al.* (2000) collected *T.jonesi* from a rocky area of Thekkady ar which is a subtributary of Chalakudy river and the stream was found to be partially dried up being summer season.

2.3.1.3.Vulnerable fishes of Kerala

23. *Garra hughi* Silas (Plate 8a)

Common name Cardamom garra (English),
Kallunthi, Kallotti (Malayalam).

Conservation status EN (Biju *et al.,* 2000; Shaji *et al.,* 2000; Thomas *et al.,* 2002).

Systematic position

Order Cypriniformes

Family Cyprinidae

Subfamily : Garrinae

Identification

D ii 7; A i – ii 5; P i 11 – 13; V i 7 – 8.

Body elongate and slender, head broad, snout broadly rounded and smooth. Barbels 2 pairs, maxillary short and stumpy. Dorsal fin inserted almost midway between tip of snout and base of caudal fin. Lateral line scales 36 – 38. Upper half of the body grayish , a dark lateral band from gill opening to base of caudal fin. Another band on the mid-dorsal region.

Geographical distribution :

Endemic to WesternGhats (India): Cardamom and Palani hills; Kerala (Type-locality: Streams in lower Vauguvarrai Estate, High range, Travancore).

Distribution in Kerala :

Earlier reports :

Pambar river (Thomas *et al.,* 1999, 2002); Pambar river, Eravikulam National Park, Chinnar, Periyar (Shaji and Easa, 2001).

Present collection sites

Achenkovil (Kanayar, Kallar); Pamba (Kochupamba, Moozhiyar); Periyar (Thannikudy); Chinnar (Chinnar); Pambar (Chambakkad).

Availability :

During the present survey, 19 specimens were collected. 2 specimens were collected from Achenkoil in May 2001, a single one from Pampa in July 2001, 3 from Pambar in January 2002, 1 from Periyar in April 2002, 10 from Pampa in August 2003 and 2 from Chinnar in August 2003. Gopi (2000) and Thomas *et al.* (2002) treated it as a very rare fish.

Habitat :

Pool-riffle reaches, dominant substrate bedrock followed by boulders.

Bionomics

The total length of *G.hughi* in the present collection varied from 81 to 90 mmTL. The single fish collected from Pampa in July 2001 was 84 mm TL while those of August 2003 were in the range 42-90 mm TL.Specimens collected from Periyar were 81mm, 88mm and 90 mm in TL in January 2002 and 74 mm in April 2002. Specimens from Achenkoil and Chinnar belonged to 81-85 mm and 41-45 mm TL respectively. According to Menon (1999), this species reaches standard length of 155mm. CPUE worked out for various river systems from where the species was collected are given in Table 2.22.

Status as per present study and IUCN criteria :

Vu. $B_{1, 2b}$ (Restricted distribution, severely fragmented, exist in less than 10 locations, continuing decline in the area of occupancy)

Threats

Drying up of streams and lowering of water level during summer, unauthorized fishing in the sanctuaries.

Remarks

According to the original description by Silas (1954), the mid-dorsal streak of *G.hughi* is devoid of scales. But scales were noticed in the mid-dorsal region of specimens collected during the present survey. Remadevi and Indra (1999) reported that the arrangement of scales in *G.hughi* is a highly variable character and they may be partially present or absent on the back, belly and post pelvic region of the fish. Similar observations were reported by Biju *et al.* (2000) and Shaji and Easa (2001). According to Menon (1999), *G.hughi* is found in mountain streams. Biju *et al.* (2000) reported its occurrence in high elevated areas, characterised by the presence of sand, gravel, cobbles and bedrock and surrounded by typical grassland ecosystem.

24. *Glyptothorax annandalei* Hora (Plate 8b)

Common name Annandale's sucker catfish (English), Parayotti (Malayalam)

Conservation status : En (Biju et al., 2000; Thomas et al., 2002).

Systematic position

Order Siluriformes

Family: Sisoridae

Identification

D 1 6; A iii 7; P 1 9 ; V i 5.

Body elongated, head greatly depressed. Barbels 4 pairs, maxillary extend beyond the base of pectoral fins, nasals do not reach orbit. Adhesive thoracic apparatus well developed and longer than broad, devoid of a central pit. Skin on head and body minutely tuberculated.

Body dark with two longitudinal bands, one along lateral line and the other above.

Geographical distribution

Endemic to Indian subcontinent. India: Western Ghats and the Vindhyas; Nepal (Type-locality: Bhavani river at base of Nilgiri Hills).

Distribution in Kerala

Earlier reports

Bhavani river (Hora, 1923); Periyar (Remadevi and Indra, 1986; Arun *et al.,* 1996); Kabini and Kunthi (Easa and Basha, 1995; Gopi and Radhakrishnan, 1998); upstreams of Kothamangalam and Thodupuzha tributaries of Muvattupuzha river (Biju *et al.*, 2000); Muvattupuzha river (Thomas *et al.,* 2002).

Present collection sites:

Periyar (Pooyamkutty, Kunthrapuzha, Anakulam), Chinnar (Chinnar), Chaliyar (Mayiladipotti, Mancheri, Meenmutty).

Availability :

9 specimens were examined during the present study. 3 specimens were caught in June 2002 while 2 in September 2002 from Periyar river, 3 from Chaliyar in September 2002 and 1 from Chinnar in August 2003.No previous data available on the abundance of this fish in Kerala. Gopi (2000) reported it to be abundant in Kerala waters. On the contrary, Thomas *et al.,* (2002) treated it under 'very rare and endangered' category.

Habitat

Pool-riffle reaches with bedrock and boulders as dominant substratum and moderate flow velocity.

Bionomics

Nine specimens ranging from 136 – 165mm in TL were collected during the present survey. TL of specimens collected in June 2002 from Periyar was 138 mm, 154 mm and 165 mm while those obtained in September 2002 were 144 mm and 159 mm in TL. The fishes collected in September 2002 from Chaliyar measured 123mm, 138 mm and 140mm TL while that from Chinnar was 124 mm in TL. According to Talwar and Jhingran (1991) and Menon (1999), the fish attain a length of 115mmTL. CPUE from Periyar varied between 0 and 0.1702 Kg/hr while from Chaliyar, It was between 0 and 0.024 Kg /hr (Table 2.22).

Status as per present study and IUCN criteria

Vu. $B_{1, 2a}$ (Restricted distribution, severely fragmented, decline in the extent of occurrence).

Threats

Application of fish poisons, dynamiting and other destructive types of fishing methods.

Remarks

This species, which were not uncommon in their habitats, showed sporadic and sparse occurrence during the recent surveys, which can be indicative of their endangerment. Hence the species was considered as vulnerable. According to Biju et *al.,* (2000), *G.annandalei* is a bottom dwelling fish inhabiting beneath the stones and rocks as well as swift running streams. They are found in typical hill streams with detritus, sand, cobble, boulders and bedrock as the major substrate.

25. *Glyptothorax madraspatanam* (Day) (Plate 8c)

Common name	South Indian / Travancore sucker catfish, Clown cat fish (English), Parayotti (Malayalam).
Conservation status	EN (Biju *et al.,* 2000); Vu (Molur and Walker,1998; Shaji *et al.* ,2000).
Systematic position	
Order	Siluriformes
Family	Sisoridae

Identification

D 1 6 ; A ii–iii 8 ; P 1 9–10 ; V i 5

Body elongate, head depressed and broadly pointed in front. Mouth inferior, barbels four pairs, maxillary barbels extended posteriorly to the base of pectoral fin. Adhesive thoracic apparatus longer than broad without a central pit. Dorsal spine strong and serrated near apex on both edges, pectoral spine generally almost as long as head. Skin smooth on head and body. Body yellowish with dark bands.

Geographical distribution

Endemic to western Ghats (India): Anamalai, Nilgiri Hills and Cauvery River (Type–locality Bhavani river at base of Nilgiri hills).

Distribution In Kerala :

Earlier reports :

Travancore (Hora, 1941; Hora and Law, 1941; Silas, 1952) Periyar lake and upstreams (Chacko, 1948; Zaccharias *et al.,* 1996; Arun, 1997); Anamalai hills of Ponnani drainage system (Silas,1951a) rivers of Kerala (Kurup, 1994) Chaliar and Kabini rivers (Easa and Basha, 1995) Periyar, Chaliyar, Kabini rivers (Shaji and Easa, 2001).

Present collection sites :

Achenkovil (Kanayar), Muvattupuzha (Thommankuthu), Chalakudy, (Nellimpathy, Athirappilly), Kabini (Noolpuzha, Kuruvadweep).

Availability

6 specimens were examined during the present survey, one each from Achenkovil (May, 2001) and Muvattupuzha (July, 2002) and 2 each from Chalakudy (June, 2001) and Kabini (April, 2003). Silas (1951a) collected two specimens from Ponnani drainage system and in 1952, 4 specimens from Peermed hills. Kurup (1994) considered it as rare and endemic fish. Gopi (2000) treated it as rare.

Habitat :

Cascade reach with high flow velocity.

Bionomics :

Fishes collected ranged from 64 to 113 mm in total length. The total length of fishes from Achenkovil and Muvattupuzha were 113 and 107mm respectively while those collected from Chalakudy (86-90 mm TL) and Kabini (61-65 mm TL) were smaller in siize. Silas (1951a) collected 2 specimens of 50.25 and 63.25mm SL from Anamalai hills of Ponnani drainage system. The same author (1952) collected 4 specimens (111 – 166mm SL) from Peermed hills. According to Talwar and Jhingran (1991), the fish attains a length of 115mm TL. The highest CPUE of 0.021 Kg /hr was recorded from Kuruvadweep of Kabini river system (Table 2.22).

Status as per present study and IUCN criteria :

Vu. B $_{1,2\ a}$ (Restricted distribution, severely fragmented, exist at not more than ten locations,decline in the extent of occurrence).

Threats

Destructive fishing methods using poisons, dynamiting, soil erosion in Noolpuzha, pollution associated with tourist inflow.

Remarks :

This species were observed in the streams often during early surveys, but a decline in the frequency of occurrence as well as extent of occurrence was evident during the subsequent surveys. According to Zacharias *et al.* (1996), this fish species are distributed in upper streams with lotic torrential waters, usually found clinging to the substratum by its adhesive apparatus. Menon (1999) reported it as inhabiting mountain rapids.

26. *Labeo dussumieri* (Valenciennes) (Plate 8d)

Common name　　Malabar labeo (English), Thooli, Pullan (Malayalam)

Conservation status　　EN (Kurup, 1994; Molur and Walker, 1998; Shaji *et al.,* 2000); Vu (Menon, 1999).

Systematic position

Order　　Cypriniformes

Family　　Cyprinidae

Subfamily　　: Cyprininae

Identification

D iii 12-13; A ii 5; P i 16; V i 8

Body elongate and compressed. Snout slightly projecting beyond mouth. Mouth somewhat inferior, lips fleshy and fringed, with a distinct inner fold above and below. 2 pairs of minute barbels. Caudal fin very deeply forked. Lateral line with 53-55 scales. Body greyish, lighter beneath, scales with a reddish centre edged with a darker shade. Usually with a dull dark spot on either side of the base of caudal fin, fins dusky.

Geographical distribution

India Western ghats upto north Canara and Sri Lanka (Talwar & Jhingran, 1991; Menon, 1999). (Type locality: Alleppy, Kerala state).

Distribution in Kerala

Earlier reports

Travancore (Pillay, 1929; John, 1936; Hora and Law, 1941); Malabar (Hora,1942; Menon, 1993) upstream reaches of Vembanad lake (Kurup,1982); Meenachil, Pampa, Manimala, Achenkovil, upstream reaches of Vembanad lake (Kurup,1990), Rivers of Kerala (Gopalakrishnan and Ponniah, 2000; Gopi, 2000; Shaji and Easa , 2001).

Present collection sites

Achenkovil (Prayikkara, Vettor, Parumalakadavu, Payippad), Pampa (Pavukkara landing center, Payippad, Neerettupuram).

Availability

During the present study, 21 specimens were collected, 8 from Achenkovil in June 2000, 9 specimens from Pamba river in June 2001 and a single specimen from Achenkovil in June 2001.Earlier *L. dussumieri* was reported to be very common in Karuvanoor and Manali rivers of Trichur district (Day,1865); rivers of central Travancore (John, 1936), upstream part of Vembanad lake (Kurup,1982) and rivers of south Kerala (Talwar and Jhingran, 1991;

Shaji and Easa, 2001). Extensive fish sampling surveys conducted in 18 rivers of Kerala by Kurup (1990) revealed the occurrence of this species only in 4 rivers *Viz.,* Pamba, Meenachil, Manimala and Achenkovil. Chalakudy and Periyar river which had sustained fishery of this species no longer serve as fishing grounds of *L.dussumieri* (Kurup, 1990). CAMP report (Molur and Walker, 1998) recorded 50% reduction in the population of the fish species over the last 10years. Gopi (2000) and Shaji and Easa (2001) reported it as 'very rare' species now.

Habitat

Regime reaches with muddy and sandy substratum.

Bionomics :

The fishes collected ranged in size between 221 – 430 mm TL in June 2000 while in June 2001, they were in the size range of 216 – 375 mmTL. Maximum number of fishes belonged to 311 – 320mm TL (Fig.2. 20). According to Talwar and Jhingran (1991) and Menon (1999), the fish attains a total length of 350 mm. Kurup (1990) collected fishes in the size range of 90-454 mm TL from Meenachil, Pampa, Manimala and Achenkovil. During the present study, three specimens having total length of 428, 367 and 373mm with fully ripe gonads were collected and the absolute fecundity was enumerated to be 2,11,068 ova, 1,69,743 ova and 1,52,946 ova respectively. Ova diameter ranged from 1.2 – 1.8 mm. Studies on the feeding habits revealed that detritus and mud formed the major portion of the gut contents (Fig. 2.21). Diatoms and Chlorophyceae were the next dominant items. Kurup (1990, 1994, 1998) has studied in detail the bionomics, resource characteristics and distribution of *L. dussumieri* in the rivers of Kerala. CPUE from Achenkoil river varied between 0 and 1.12 Kg/hr while the values from Pampa ranged from 0 to 1.6 (Table 2.22).

Status as per present study and IUCN criteria :

Vu. A $_{1c}$, B $_{1,2a}$ (Population reduction of 20% over the last 10 years due to decline in the extent of occurrence, restricted distribution , exist at not more than ten locations, decline in the extent of occurrence).

Threats

Damming, overexploitation, dynamiting, poisoning and other destructive fishing methods, recruitment overfishing during monsoon, insecticide and pesticide pollution,sand mining , siltations, trade.

Remarks

Kurup (1992b) made a pioneer attempt to ranch *L.dussumieri* in Pampa river of Kerala in 1989 and the follow up studies indicated encouraging results.

27. *Macrognathus guentheri* (Day) (Plate 9a)

Common name	Malabar spiny eel, Tire track spiny eel (English); Arakan, Aaron, Pazhukkamundi, Kal-aural (Malayalam)
Conservation status	Vu (Molur and Walker,1998; Shaji *et al.* 2000); LR-nt (Biju *et al.*, 2000)

Systematic position :

Order	Perciformes
Family	Mastacembilidae
Subfamily	Mastacembilinae

Identification

D xxviii- xxx 58-74; A iii 59-75; P 17-21; C 11-13

Body eel like and slightly compressed. Preopercle with 2 or 3 spines, preorbital spine present. Dorsal fin inserted behind tip of pectoral fin, dorsal and anal confluent with caudal fin. Body olive or greenish brown, dull yellow below. Some black bands, radiating from the eye, cross the under surface of the jaws, a light band along upper edge of lateral line, short oblique bars on body.

Geographical distribution

Endemic to Kerala (India). (Type- locality: Trichoor, Kerala)

Distribution in Kerala

Earlier reports :

Travancore (Pillay, 1929; John, 1936; Hora and Law, 1941); Southern part of Vembanad lake (Kurup, 1982); Vembanad lake, Cannannore, Cheenkannipuzha river, Trichur, Kodanad (Molur and Walker, 1998); 20 rivers of northern and southern Kerala (Biju *et al*; 2000); Periyar and northwards (Shaji and Easa, 2001),Muvattupuzha (Jameela Beevi and Ramachandran,2002).

Present collection sites :

Chalakudy river (Thumboormuzhi), Periyar river (Pooyamkutty)

Availability:

Two specimens were collected for laboratory study, one each from Chalakudy and Periyar in July 2002 and April 2003 respectively during the present survey. Gopi (2000) treated it as a 'very rare' species. On the contratry, Biju *et al.* (2000) reported the distribution of *M.guentheri* throughout Kerala and listed it under non- threatened category of fishes.

Habitat :

Pool- riffle reach with moderate flow velocity.

Bionomics

The specimen collected from Periyar was 369mm in total length while the one from Chalakudy river was 210mm. Talwar and Jhingran (1991) and Menon (1999) recorded the maximum total length of the fish as 260mm and commonly about 200mm.Maximum CPUE was estimated as 0.072 and 0.10 Kg/hr from Chalakudy and Periyar rivers respectively (Table 2.22).

Status as per present study and IUCN criteria

Vu. B $_{1,\ 2a}$ (Restricted distribution, severely fragmented, decline in the extent of occurrence)

Threats

Agriicultural pesticides, unethical fishing practices, reclamation of paddy fields, nibbling of perpetual bunds of paddy fields,habitat destruction.

Remarks:

M.guentheri was available in less numbers during most of the present surveys. Enquiry with local fishermen revealed the occurrence of this species occasionally in the catches from Chaliyar, Muvattupuzha, Kabini and Bharathapuzha.

28. *Notopterus notopterus* (Pallas) (Plate 9b)

Common name : Grey featherback (English), Ambattanvallah (Malayalam)

Conservation status Vu (Biju *et al.,* 2000; Thomas *et al.,* 2002), LR-nt (Molur and Walker, 1998).

Systematic position

Order : Osteoglossiformes

Family Notopteridae

Identification

D 7 – 9 ; P 17 V 5 – 6 ; A + C 100 -110.

Body strongly compressed laterally, preopercle serrated. Mouth moderate, maxilla extends to below the middle of the orbit. Dorsal fin commences nearly mid way between the snout and end of the caudal fin.

Scales minute, much larger on opercles than on body. Body silvery with numerous fine grey spots, dark on back.

Geographical distribution

Oriental region: Pakistan, India, Nepal, Myanmar, Bangladesh, Thailand, Malaya and Indonesia (Molur and Walker, 1998). [Type-locality: Ponds and rivers of Bengal (Menon, 1999)]

Distribution in Kerala:

Earlier reports :

Periyar lake (Chacko, 1948); Kerala part of Nilgiri Biosphere Reserve (Easa and Basha, 1995); Kabini (Shaji and Easa; 1996); Karuvannur river, Chaliyar, Bharatha-puzha and Kadalundi (Biju *et al.*, 2000)

Present collection sites

Kabini (Begur, Kuruvadeep, Panamaram, Puthusseri-kadavu, C.C.puzha); Bharathapuzha (Yakkara).

Availability :

6 specimens were procured during the present study. 4 fishes were caught from Kabini during the month of April 2001 and May 2002. The remaining 2 fishes were obtained from Bharathapuzha (December 2002) and Kabini (April 2003). No published information is available on the abundance in earlier days. Thomas *et al.* (2000) listed *N.notopterus* in the 'very rare' category of fishes. According to Talwar and Jhingran (1991), this species is common throughout the greater parts of India.

Habitat :

Regime reaches with moderate flow velocity, substratum dominated by fines.

Bionomics

4 specimens, caught from Kabini in April 2001 and May 2002, belonged to 16-30 and 131-140 mm TL group respectively while the one collected in April 2003 was 30 mm TL. Total length of the fish procured in December 2002 from Bharathapuzha was 144mm. Shaji and Easa (2001) recorded the maximum standard length of *N.notopterus* as 230mm. Talwar and Jhingran (1991) documented its maximum total length as 610mm but the common size as much smaller. In North Bengal, it attains a total length of 250mm while in Tamil Nadu, 460mm TL. One of the specimens obtained in May 2002 during the present study was a ripe female with yellowish ovaries, indicating that the fish breeds in the early monsoon period. Talwar and Jhingran (1991) reported that the fish breeds in rainy season and the fingerlings of this species are noticed in the upper reaches of Cauvery in July-August. *N.notopterus* is a carnivore, feeding manily on insects followed by shrimps, fishes, crustaceans, mollusks, etc. CPUE from Kabini ranged between 0 and 0.07 while it was between 0 and 0.02 Kg/hr from Bharathapuzha (Table 2.22).

Status as per present study and IUCN criteria :

Vu. B $_{2a, 2b}$ (restricted distribution, severely fragmented, continuing decline in extent of occurrence)

Threats

Overexploitation, use of fish poisons, water abstraction, pesticides, enchroachment for agricultural purposes, habitat alteration.

Remarks:

This species was often observed during the field surveys in limited numbers. According to local fishermen, recently the abundance of the species has declined significantly.It prefers lowland areas (fresh or brackish) and breeds in stagnant or running water in the rainy season (Talwar and Jhingran, 1991; Biju *et al.*, 2000). Shaji and Easa (2001) reported that this species is normally found in the stagnant pools in the river course with low flow rate.

29. *Osteobrama bakeri* (Day) (Plate 9c)

Common name — Malabar osteobrama (English), Mullanpaval, Mullanparal (Malayalam)

Conservation status — EN (Molur and Walker, 1998; Shaji *et al.*, 2000; Radhakrishnan and Kurup, 2002); Vu (Biju *et al.*, 2000; Thomas et al., 2002).

Systematic position

Order	Cypriniformes
Family	Cyprinidae
Subfamily	Cyprininae

Identification

D iii 8; A iii 12-13; Pi 12-14; V i 10

Body compressed considerably. Abdominal edge rounded in front of pelvic fins but sharp and trenchant between bases of pelvic and anal fins.Two small pairs of barbels. Dorsal spine weak and serrated posteriorly. Lateral line with 43-44 scales. (Detailed description, refer Section 2, Chapter 3)

Geographical distribution

Endemic to Kerala (India). (Type-locality: Kottayam in Tranvancore)

Distribution in Kerala :

Earlier reports :

Travancore (Pillay, 1929; Hora and Law, 1941); Manimala river, Kottayam, Travancore (John, 1936); Chaliyar, Nilgiri Biosphere Reserve area (Easa and Basha, 1995); Chalakudy (Ajithkumar *et al.*,1999); Lowland areas of Periyar, Chalakudy, Karuvannur, Muvattupuzha, Meenachil, Manimala, Chandragiri, Chaliyar, Bharathapuzha (Biju *et al.*, 2000); Chalikkal tributary of Chaliyar river, Nilambur, Malappuram district; Kottayam (Gopi, 2000); Kottayam, Chaliyar, Periyar (Shaji *et al.*, 2000); Kottayam, Thattekkad (Periyar basin), Chaliyar (shaji and Easa, 2001); Kallada, Achenkoil (Radhakrishnan and Kurup, 2002); Chalakudy, Periyar, Karuvannur, Muvattupuzha, Meenachil, Manimala, Chaliyar, Bharathapuzha (Thomas *et al.*, 2002)

Present collection sites:

Periyar (Pooyamkutty, Kaipra); Chalakudy (Kanakkan-kadavu, Pillappara, Vettilappara); Kallada (Meenmutty); Kabini (Noolpuzha); Meenachil river (Kattachira, Kidangur check dam)

Availability :

1118 specimens of *O.bakeri* were examined during the present survey .Among them, 2 specimens were collected from Noolpuzha in November 2000, 2 from Kallada river during October 2001, 2 from Meenachil during December 2001 and 4 from Chalakudy river during the month of February 2003. The remaining 1108 specimens were collected from Kaipra and adjoining areas of Periyar river during the period from June 2001 to May 2003.

Habitat

Regime reach with sand, gravel and mud as dominant substratum.

Bionomics

1118 specimens comprising of 572 males, 333 females and 213 indeterminates were collected during the study. Bionomics and resource characteristics of *O.bakeri* are dealt with in detail in Chapters from 111 to 1X of the thesis. CPUE from Periyar river for the year 2001 was worked out to be 0.0868 to 0.1861 Kg/hr. Slight improvement was noticed in 2002 and the values ranged from 0.1743 to 0.3828 Kg/hr while it was between 0.0722 and 0.1314 Kg/hr in 2003 (Table 2.22).

Status as per present study and IUCN criteria :

Vu. B $_{1,2a,3a}$ (Restricted distribution, severely fragmented, decline in the extent of occurrence, extreme fluctuation in the extent of occurrence ,area of occupancy).

Threats

Habitat alteration, sand mining, saline water intrusion, intensive agriculture, agricultural pesticides,pollution from domestic wastes,electrocution and other destructive type of fishing methods,damming.

Remarks :

O.bakeri generally inhabits the subsurface waters in the middle stretches of rivers. During rainy season, they are found moving in shoals along the margin of rivers. According to Biju *et al.* (2000), this species prefers mud and sand as substrates though it was also collected from moderate hilly areas of Chandragiri river with sand, gravel, cobble and boulders as main substrata.

30. *Puntius conchonius* (Hamilton - Buchanan) (Plate 9d)

Common name — Rosy barb, Red barb (English), Vattathiparal, Vattapparal, (Malayalam).

Conservation status — Vu (Molur and Walker, 1998; Biju *et al.,* 2000; Ramachandran,2002) LR- nt (Thomas *et al.,* 2002)

Systematic position

Order	Cypriniformes
Family	Cyprinidae
Subfamily	Cyprininae

Identification

D iii 7- 8; A ii – iii 5; P i 18; V i 8

Body deep and compressed. Barbels absent. Last unbranched ray of the dorsdal fin osseus, strong and finely serrated. Lateral line incomplete with 10 – 13 scales, 24 – 26 scales in the longitudinal series. Body olive green on back, Flanks and belly silvery, a black blotch on the caudal peduncle at the posterior region of the anal fin. This species is most impressively coloured during the breeding season, the silvery male assumes a rich claret flush while the female becomes more luminous.

Geographical distribution

India: Ganga, Brahmaputra, Mahanadi and Cauvery river systems; Afganistan; Pakistan; Bangladesh; Nepal.(Type-locality ponds of North-East Bengal and Kosi and Ami rivers).

Distribution in Kerala

Earlier reports

Travancore (Pillay, 1929; John,1936; Hora and Law, 1941); Kerala part of Nilgiri Biosphere Reserve (Easa and Basha, 1995); Bharathapuzha, Chandragiri and Manimala (BIju *et al.*, 2000); Wayanad (Shaji and Easa, 2001); rivers of Southern Kerala (Thomas *et al.*, 2002).

Present collection sites:

Kabini (Kuruvadweep, Pozhuthana, Muthanga, Puthusseri-kadavu, Meenangadi, Begur, Baveli); Bharathapuzha (Yakkara check dam, Tamrachalla).

Availability

25 specimens of *P. conchonius* were examined during the present study. Three fishes were collected in October 2001 from Bharathapuzha.13 and 3 specimens were obtained from Kabini during December 2001 and January 2002 respectively. 6 specimens were caught from Bharathapuzha during March 2003. In Kerala, *P. conchonius* is found abundantly in streams and rivers of Waynad (Shaji and Easa, 2001). Thomas *et al.* (2002) treated it as a 'rare' species from Kerala. Gopi, (2000) recorded it as an abundant species in India while Talwar and Jhingran (1991) recorded its abundance in the Cauvery water shed.

Habitat

Pool-riffle reaches with moderate flow velocity and gravel as dominant substratum.

Bionomics

Three specimens of *P.conchonius,* collectd in October 2001 from Bharathapuzha were 61 – 90mm in total length whereas those of March 2003 were smaller in size (51-65 mmTL). 13 specimens obtained during December 2001 from Kabini ranged between 46 and 85mm TL while the three specimens of January 2002 were 51-55 mm in TL.

The fish is reported to attain a length of 140mm TL and mature at 60mm (Talwar and Jhingran, 1991), 125mmTL (Menon, 1999) and 66.5mm SL (Shaji and Easa, 2001). It is omnivorous in feeding habit. CPUE from Kabini ranged from 0 to 0.016 while Bharathapuzha recorded a maximum value of 0.0012 Kg/hr (Table 2.22).

Status as per present study and IUCN criteria

Vu. $B_{1,2a}$ (Restricted in distribution, limited to less than 10 locations, continuing decline in the extent of occurrence).

Threats :

Pollution from agricultural pesticides, water abstraction and encroachment for agricultural purposes, construction of check dam, destructive fishing methods such as dynamiting and use of fish poisons, indiscriminate exploitation for ornamental fish trade.

Remarks

According to Talwar and Jhingran (1991), *P. conchonius* generally inhabits lakes and streams and are more abundant in the hills than the plains. Menon (1999) reported its presence from fast flowing hill streams. Ramachandran (2002) reported that this species is marketed within India for a price of Rs. 1 – 5 per fish within the size range of 10 – 35mm TL. It is also exported from India for 0.18 US $ per fish.

31. *Puntius ophicephalus* (Raj) (Plate 10a)

Common name	Periyar barb, Channa barb (English), Eettilakanda, Eechathalaikendal (Malayalam)
Conservation status	CR (Thomas *et al.* 2002); EN (Molur and Walker, 1998; Shaji *et al.*, 2000; Ramachandran, 2002)

Systematic position

Order	Cypriniformes
Family	Cyprinidae
Subfamily	: Cyprininae

Identification :

D iii 7; A ii-iii 5; P i 13-15; V i 8

Body elongate. Head broad and depressed. Mouth moderate and sub inferior, 2 pairs of barbels, rostrals equal to orbit, maxillary much longer. Last unbranched ray of dorsal fin weak, smooth and articulated in its upper part. Lateral line scales 40-42, predorsals 15-17. Body rich golden brown above, flanks and abdomen silvery brown. A broad dark band along the lateral line from behind the head to middle of the base of caudal fin.

Geographical distribution

Endemic to Kerala (India): Pambiyar river and its tributary (Talwar and Jhingran,1991). (Type-locality: Kallar near Periyar lake, Kerala).

Distribution in Kerala :

Earlier reports

Periyar lake (Chacko, 1948); Mundakayam (Manimala river) at the foot of Peermed Hills (Silas, 1952); Periyar river: Mlappara, Ummikkuppanthodu and above (Zaccharias *et al.*, 1996); Kallar, a tributary of Periyar river, south of Pachakani estate adjoining Periyar lake (Menon, 1999); Pambiyar river and its tributary, Headwaters of Periyar river, Manimalayar, Peermed Hills, Kerala (Gopi, 2000); Periyar lake and upstreams (Shaji *et al.*, 2000); Kallar and Periyar above Mullaperiyar dam (Shaji and Easa, 2001); Periyar river (Thomas *et al.*, 2002).

Present collection sites

Periyar (Ummikkuppanthodu and above).

Availability

71 specimens were examined during the present ichthyofaunistic survey. During September 2001, 38 specimens comprising of 30 males, 5 females and 3 indeterminates were caught while during February 2002, ten specimens (4 males, 4 females and 2 indeterminates) were collected. The 23 specimens examined in March 2003 comprised of 17 males and 6 females. Silas (1952) collected a single specimen from a large stream close to Mundakayam at the foot of Peermed hills. Zacharias *et al.* (1996), Menon (1999) and Shaji and Easa (2001) reported

this species as 'rare' barb while Gopi (2002) considered it as 'very rare'.

Habitat :

Pool- riffle reaches with good instream cover, negligible flow velocity and sandy substrate.

Bionomics :

71 fishes ranging in length 91-180mm and weight 7.84-45g were analysed during the present study. Highest frequency of fishes was noticed in the 126-130mm TL group (Fig. 2.22). Males varied from 103-150mm in total length and 8.96 - 30g in body weight while females were 127-180mm in TL and 18.12 – 45 g in weight. Total length and weight of indeterminates were 91-107mm and 7.84 - 10g respectively. The length of the fish recorded was 128mm SL by Silas (1952), 196mm TL by Menon (1999) and 122mm SL by Shaji and Easa (2001). The maximum size recorded during the present study was 180mm TL. Length-weight relationship of the species was worked out (Fig. 2.23) and can be expressed by the following equation:

$$\log w = -4.6083 + 2.798 \log l$$

The 't' test on regression coeffecient 'b' did not show significant difference at 5% level from the expected value of 3 indicating isometric growth in this species. (t-value = 1.3188, df=70). The correlation coefficient was found to be 0.9103. Males outnumbered females in September 2001 as well as March 2003 while in February 2002, the distribution of the sexes was found to be almost equal. Out of the total 71 fishes collected, 51 were males and 15 females, thereby clearly indicating the clear-cut preponderance of males over their female counterpart. Three males (130-150mm TL) collected in March 2003 were mature whereas one female (150mm TL) was in the maturing stage with yellowish ovary extending into three-fourth of the abdominal cavity. In September 2001, one mature male (150mm TL) was obtained. All other fishes were in the first and second stages of maturity. Gut content analysis revealed that insects, especially adult beetles, insect larvae and nymphs constituted the basic food of this species (>60%) followed by diatoms, algae, crustaceans and semidigested animal matter. CPUE was worked out to be between 0.0001 and 0.5942 Kg/hr (Table 2.22).

Status as per present study and IUCN criteria :

Vu. $B_{2a,\ 3a}$ (Restricted distribution, decline in the extent of occurrence , fluctuation in the extent of occurrence)

Threats

Lowering of water level during summer weather.

Remarks:

P.ophicephalus was fairly abundant in the streams of Periyar, but recent surveys revealed fluctuation in its abundance and hence included under vulnerable category.

32. *Sicyopterus griseus* Day (Plate 10b)

Common name: Hillstream goby, Clown goby (English), Poozhipoolan (Malayalam)

Conservation status: EN (Thomas *et al.,* 2002); Vu (Biju *et al.,*2000)

Systematic position

Order: Perciformes

Family: Gobbidae

Subfamily: Sicydiaphiinae

Identification

D_I VI; D_2 1 10 ; P i 16 ; A i 10

Body anteriorly cylindrical, posteriorly compressed. Upper surface of head flat. Mouth nearly horizontal and bordered by thick lip continuous at the angle of the mouth, upper lip with papillae along its lower margin. Scales of head and nape cycloid, about 80 scales along longitudinal series, predorsals 25. Pelvic fins united, round in appearance and are closely adherent to the body. Body brownish with 7 – 8 rings on the body which are prominent over the dorsum. Fins dark.

Geographical distribution

India: South Canara and Madras (Talwar and Jhingran, 1991); South Canara, Madras, SriLanka (Jayaram,1999). (Type-locality South Canara).

Distribution in Kerala :

Earlier report :

Travancore (Hora and Nair, 1941) ; Chalakudy (Shaji and Easa, !996-97); Valapattanam, Chandragiri, Mahe, Periyar, Kuttiadi (Biju *et al.,* 2000); South Canara and Travancore (Shaji *et al.,* 2000); Bharathapuzha (Bijukumar and Sushama, 2001); Chaliyar, Cheenkannipuzha, Chalakudy, Periyar and Pampa (Shaji and Easa, 2001); Chalakudy and Periyar (Thomas *et al.,* 2002).

Present collection sites

Chaliyar (Areekode); Periyar (Pooyamkutty); Bharathapuzha (Cheruthuruthy),Chalakudy (Vettilapara).

Availability :

6 specimens of *S.griseus* were obtained during the present study. A single specimen was collected from Chaliyar during the month of July 2001, 2 from Periyar in April 2002, 2 from Chalakudy in February 2003 and 1 from Bharathapuzha in March 2003.Shaji and Easa (2001) reported this species as fairly common in the five rivers from where they could collect this species. Bijukumar and Sushama (2001) listed it under 'very rare' category of fishes from Bharathapuzha. Thomas *et al.* (2002) also included this species under 'very rare' category of fishes collected from rivers of South Kerala.

Habitat

Pool-riffle reaches with moderate flow velocity, substratum dominated by bedrock.

Bionomics

Total length of fishes collected during the present study ranged from 9 mm to 19 mm.The fishes obtained from

Chaliyar and Bharathapuzha were 19 and 16 mm TL respectively. Specimens collected from Periyar were 12 and 14 mm while those from Chalakudy were 9 and 15 mm in TL. Talwar and Jhingran (1999) reported the maximum standard length of *S.griseus* to be 65mm while Menon (1999) recorded 97mm TL. The maximum size of the specimen collected during the present survey is 19 mmTL. Maximum CPUE from Chaliyar was estimated as 0.00156 Kg/hr while It was 0.0035, 0.00242 and 0.0012 Kg/hr from Chalakudy, Periyar and Bharatha-puzha respectively (Fig. 2.22).

Status as per present study and IUCN criteria :

Vu B $_{1,2a,2b}$ (Restricted distribution,severely fragmented , decline in the extent of occurrence, area of occupancy).

Threats

Habitat destruction due to sand mining, soil erosion, scarcity of water during summer.

Remarks

This species, in very limited numbers, were found distributed in Chaliyar, Periyar, Chalakudy and Bharathapuzha most of the time during the present study. According to Talwar and Jhingran (1991), this species is common in Madras backwaters. Jayaraman (1999) reported *S. griseus* to be a species found in backwaters while Menon (1999) stated that it inhabits fresh water predominantly migrating up to torrential streams. They are common in the waters along the margins of streams where the flow is somewhat slower and probably breeds in fresh water (Menon, 1999). According to Biju *et al.* (2000), this species is distributed in high altitude as well as low land areas.

33. *Wallago attu* (Schneider) (Plate 10c)

Common name Freshwater shark, Boal (English) Attuvala, Vallaha, Manjavala (Malayalam)

Conservation status Vu (Kurup,1994), Lr – nt (Molur and Walker, 1998 ; Biju *et al*.,2000).

Systematic position :

Order Siluriformes

Family Siluridae

Identification

D 5; A iii 74 – 93; P 1 13 – 15; Vi 7 – 9.

Elongated, laterally compressed body with head depressed, 2 pairs of barbels, maxillary pair long and extend beyond the origin of anal fin. Adipose dorsal fin absent, dorsal fin inserted above half of the pectoral fin. Caudal fin lobed, the upper lobe longer. Upper surface of the body olive with golden gloss, sides and abdomen silvery white.

Geographical distribution:

India, Pakistan, Bangladesh, Myanmar, Srilanka, Thailand, Indonesia, Vietnam, Java and Sumatra (Type – locality: Malabar).

Distribution in Kerala:

Earlier reports:

Schneider(1801), Hamilton–Buchanan (1822), Jerdon (1849), Valenciennes (1839), Bleeker (1862), Gunther (1864), Day (1875-78), Beaven (1877), Raj (1916), Hora(1939, 1942), Hora and Law(1941), Chacko and Kuriyan (1948), Menon (1974, 1999), Jayaram(1981, 1999), Talwar and Jhingran (1991), Biju *et al.* (2000), Shaji and Easa (2001), Jameela Beevi and Ramachandran (2002).

Present collection sites :

Achenkovil river (Payippad), Kabini (Pookode lake, Begur), Bharathapuzha (Cheruthuruthy), Muvattupuzha (Muvattupuzha).

Availability:

11 specimens were collected during the present survey, 2 in September 2000 from Bharathapuzha, 6 in April2001 from Kabini, 1 in June 2001 from Achenkoil and 2 in October 2001 from Muvatupuzha. Day (1865) assigned it to the category of common fishes from rivers of Kerala. According to Talwar and Jhingran (1991), the fish species thrives well in rivers and tanks and are caught in large numbers as food fish. Kurup (1994) reported its presence from 10 rivers of Kerala. Biju *et al.* (2000) recorded it from 24 rivers of Kerala. However, Jameela Beevi and Ramachandran (2002) opined that this erstwhile common

fish species has become very rare in Muvatupuzha river system of Kerala recently.

Habitat:

Regime reaches, substratum dominated by fines and flow velocity negligible.

Bionomics:

The fishes collected during the survey ranged from 81-450 mm TL. Specimens collected in September 2000 were in the length range 301-320 mm TL while those of April 2001 belonged to the 81-450 mm TL group. The single specimen obtained in June 2001 was 304 mm in total length. Those collected in October 2001 were smaller fishes (186-195mm TL). Kurup (1994), while discussing about the distribution of this fish species in Kerala, drew attention to the size reduction of this species over the years from 100-120 cm in the earlier landings (Day,1865) to 40-70 cm TL. Maximum CPUE from Bharathapuzha was estimated as 0.23 while that from Achenkoil river was 0.09 Kg/hr.The value was higher from Kabini river (1.5657) and lower from Muvattupuzha (0.0021) (Table 2.22).

Status as per present study and IUCN criteria:

VU.A $_{1c,d}$ (Suspected reduction of population of at least 50% based on a decline in area of occupancy, extent of occurrence and quality of habitat, overexploitation)

Threats:

Overexploitation for food/ ornamental trade, unethical fishing methods such as poisoning, dynamitig, industrial and pesticide pollution, sand mining, siltation.

Remarks :

Eventhough *W.attu* was reported from 24 rivers by Biju *et al.*, the population is observed to have reduced drastically during the present study. According to local fishermen, this species was very common in most of the rivers during early days and their availability became very sparse and sporadic during recent days. Besides being used as food fish, it is highly priced and in demand in ornamental fish market(Jameela Beevi and Ramachandran, 2002).

2.4. Discussion

Of the 122 fish species collected from 19 Kerala rivers, 33 were categorized as threatened. Out of the 33 fish species, 8 species were critically endangered, 14 endangered and 11 vulnerable. Among threatened fishes, 12 were exclusively endemic to Kerala while Western Ghats was the homeland of the remaining 9 species. An endemic fish is the fish species found exclusively in a country or a drainage system where it is native and described and endemism enhances the conservation value of the species (Molur and Walker, 1998). According to Musick (1999), species that are endemic or restricted in range to some relatively small, contiguous geographic entity (*i.e.,* island, archipelago, river system etc.) in which the habitat is or may be under threat of degradation or destruction should be classified at least as vulnerable. Maitland (1993) stated that in the case of fish, the actual numbers of individuals in the population are less important than the number of sites because fish are often so confined within their habitat that one incident (eg: a poisoning, land-slide) is likely to destroy every fish present. According to the same author, it would be much safer to have 100 fish in each of 10 lakes than 10,000 or more fish in one lake. Incidentally, the distribution of 7 of the 8 critically endangered species collected during the present study was found well confined to a single location of a single river system while the remaining one was found distributed in a single river system. 4 of them are exclusively endemic to Kerala while 3 of the above 4 *viz. L.typus, G.micropogon periyarensis and C. periyarensis* are strictly endemic to the same river system, Periyar and are confined to the upper reaches of the river system.The remaining species, *S. wynaadensis*, was found distributed only in Kabini river system. *Travancoria elongata* was reported so far only from its type-locality of Chalakudy river. Though the species was not collected from Chalakudy river during the present survey,the record of *Travancoria elongata* from Periyar river revealed the extension of its distribution to the particular river system. Among the 14 endangered fishes, 8 species were encountered in only a single river system of Kerala while 6 in 2 river systems. 5 of them are endemic to Kerala and 4 endemic to Western Ghats. 11 vulnerable fishes include 3 species endemic to Kerala and 2 endemic to Western Ghats. Periyar river harboured the highest number of threatened fishes (14) followed by

Kabini (11) and Chalakudy (11). Among them, 8 species from Periyar, 2 from Kabini and 5 from Chalakudy were found to be endemic to Kerala.

The results of the present study clearly revealed that over the years, the rich and diversified ichthyofauna of Kerala has undergone drastic depletion due to natural and man made reasons. The rivers of Kerala are monsoon- fed and the erratic and deficient showers have caused havoc to the riverine ecosystem during the recent past. The annual rainfall of the state is 2,963 mm (Ipe *et al.*, 1991) of which the South-West monsoon contributes to around 60% and North-East monsoon 40%. During 2003, the rainfall dipped to 2270 mm (The Week, magazine, March 21, 2004) and the state received 26% less rainfall than normal, Wayanad recording the highest deficiency of precipitation (The Hindu, Daily Newspaper, 3rd October 2004, page 4). The state was reeling under severe drought condition from beginning of the year 2004. The unprecendented dry spell has been blamed for the forest fires that ravaged the Western Ghats region of the state causing incalculable damage to the ecosystem. In Wayanad Wildlife Sanctuary, during this long spell of drought like condition, a number of waterholes and usually perennial streams dried up, adding to the misery of wildlife in the area (The Hindu, Daily Newspaper, 26th March 2004, p5). Bharathapuzha river too has dried up at several places and shrubs are found to grow on the sand bed of their tributaries. The dry river allows plundering sand miners to carry truckloads of sand. Similar are the cases of Manimala and Pamba rivers. Varattar, an eleven km long tributary of Manimala has already vanished (The Week, magazine, March 21, 2004). The dry situation adversely affects the ichthyofauna in the streams.

In addition to the effects of natural processes, human perturbations such as deforestation, hydro-electric projects, destructive fishing practices, pollution, encroachment and water abstrction for agricultural purposes, etc. highly alter the riverine ecosystem. The protected areas of many rivers are threatened by deforestation which leads to soil erosion, landslides and habitat destruction. Very recent media exposure on the destruction of 35 acres of pristine forests in Kakkivani Malavaram, at the Silent Valley National Park has shocked environmentalists who warned of the drying up of Nillipuzha, a tributary of Bharathapuzha, originating from the Kakkivani-Poonchola forest area as one of the consequences of this deforestation act (The Hindu, Daily newspaper November 18, 2003. p.1). Commisioning of hydro-electric projects, other dams and barrages changes habitat drastically by regulating streamflow, changing turbidity and sedimentation pattern and transforming lotic ecosystem to a lentic one. Migratory fishes are particularly threatened by these constructions and hindrance to spawning migration may soon lead to their endangerrment. Fishes of Periyar river (Hydroelectric projects at Idukki, Lower Periyar, Sengulam, Idamalayar, Neriamangalam and Panniar, Bhoothankettu barrage), Chalakkudy (Parambikulam, Thunakadavu, Peruvaripallam, Poringal-kuthu, Sholayar,Malakkapara), Bharathapuzha (Malampuzha and Pothundy dams, Yakkara check dam, Mangalam,Cheerakuzhi, Valayar dam),Pamba river (Sabarigiri) and Kallada river (Thenmala dam) are prone to these problems. In such cases, fish passes, fish ladders, etc. should be provided for the free movement of fishes without any hindrance.

Pollution of water mainly from industries, sewage and pesticides has been responsible for major decline in the population of fishes. Fishes inhabiting Periyar river (especially Periyar lake and lower stretches), Kabini, (Pookode lake and Kunnumbotta), Meenachil (Teekoi), Muvattupuzha, Pamba, Achenkovil, Chaliyar, Chalakudy (Karappara tributary), and Bharathapuzha were subjected to the impact of pollution. Pookode (Wynaad) and Periyar lakes were faced wirh the problems related to tourism development and introduction of exotic species. Invasion of exotic species were observed in most reservoirs of dams.

Sand mining is slowly marking the death of Kerala's waterbodies and its biotic resources.Effect of sand mining was observed in most of the river systems such as Bharathapuzha, Manimala, Periyar, Chalakudy, Meenachil, Pamba, Achenkovil and Muvattupuzha.River bank erosion, habitat destruction and lowering of river bed leading to intrusion of saline water were some of the consequences evident in these water bodies. At Kootakadavu, where the tributary Thotapuzha meets Bharathapuzha, there is no more sand left to mine. Indiscriminate killing of juveniles, adults and broodfishes by use of dynamite, electric shocks and plant based and chemical poisons was found to be very rampant in all river systems surveyed.

The present study shows that in majority of the river systems surveyed, many of the threats mentioned above causing imperilment of fishes occur in combination aggravating the situation. Immediate efforts are to be made to protect and conserve the threatened species, according to the order of priority. In conservation programmes, utmost priority should be given to the species that are endangered throughout their range and to species that are the sole representative of the family or genus and also families and genera that are monotypic should receive priority over polytypic ones(Singh and Sharma,1998). Endemic species deserves priority over the other fish species (Molur and Walker, 1998). On the basis of present study, *Lepidopygopsis typus*, the only representative of the genus and restricted to a single location globally should be given the highest priority followed by *Gonoproktopterus micropogon periyarensis, Crossocheilus periyarensis, Silurus wynaadensis* and *Dayella malabarica.* Conservations strategies should be developed for the five endangered endemic species *viz. Neolissocheilus wynaadensis, Osteochilichythys longidorsalis, Horabagrus nigricollaris, Garra periyarensis* and *Travancoria jonesi.* Conservation can be done either through *in-situ* or *ex-situ* methods. In the former the threatened fish species is conserved by protecting the ecosystem in which it occurs naturally. Such ecosystems are declared as national parks, biosphere reserves and sanctuaries. In *ex-situ* conservation, the fish species is conserved outside its natural habitat. This includes (1) Live Gene Bank where the threatened species is reared in captivity and bred there in and (2) Gamete / Embryo Bank where cryopreservation of milt, eggs and embryos is carried out

(Pandey and Das, 2002). Habitat inventory of the prioritized water bodies where prioritized fish species are available is essential to find out the critical environmental parameters, governing their restricted availability so that these fishes can be conserved in the system itself (Basheer and Singh, 2002). Habitat Suitability Index (HSI) for a number of threatened fishes of Kerala has been worked out by Manoj and Kurup (2004). These indices can be effectively applied to implement the *ex-situ* and *in-situ* conservation of critically endangered species such as *Lepidopygopsis typus, Gonoproktopterus micropogon periyarensis, Crossocheilus periyarensis, Silurus wynaadensis* and endangered species such as *Neolissocheilus wynaadensis, Osteochilichythys longidorsalis, Horabagrus nigricollaris* and *Garra periyarensis.* Identification of ideal habitats and translocation of critically endangered species which are restricted to a single location to new locations would also be worth undertaking. Similarly, development and standardization of captive breeding technology of the threatened endemic species are inevitable for their rehabilitation as a tool for the sustenance of stock. Kurup *et al.* (1993) achieved success in induced breeding of *Labeo dussumieri*, an endangered carp of Kerala, using pituitary extrct and other hormones. National Bureau of Fish Genetic Resources, Lucknow standardized techniques for induced spawning of captive golden mahseer (*Tor putitora*) and *Labeo dussumieri* (Pandey, 2000). Cryopreservation of milt of endangered as well as commercially important fishes like *Tor putitora*, *Tor khudree, Labeo rohita, Hilsa ilisha, Cyprinus carpio* var. *Communis* and *Salmo gairdneri gairdneri* has been achieved by NBFGR, Lucknow (Pandey and Das, 2002).

Works on similar lines can be adopted with respect to the threatened fishes of Kerala waters too. A fish hatchery exclusively for the breeding and propagation of critically endangered and endemic freshwater fishes should be setup under the auspices of Government of Kerala.

Data on the freshwater fish fauna of Kerala is deficient at present. Systematic and extensive surveys and samplings in the 44 rivers of Kerala should be intensified in order to strengthen the available database and regular monitoring of existing threatened populations must be done along with their stock assessment. Sanctuaries, reserves and national parks of Kerala should be protected and the unethical and unscientific fishing methods and practices which are very rampant in the rivers and rivulets of Kerala should be curbed by strict legislation. Immediate enactment of Kerala Inland Fisheries Regulation Act (KIFRA) on a war footing is found indispensable for the conservation of threatened fishes of Kerala. Awareness programmes regarding the importance of conservation of fish fauna shall be organized at local body level through group discussions, seminars and training camps and implementation of location specific conservation programmes giving due representation to inland fishermen at local body level is also found very necessary for the protection of the fast depleting freshwater germplasm resources of the state.

It is known from Darwin's time that species become rare before becoming extinct and rare species are fast vulnerable to disappearance. Hence we should not ignore *rarity*. Future efforts to protect species and to prevent the extinction of rare ones will depend on a deeper understanding of the biology of rarity and a sense of how human interactions with the biosphere affect them (Narain, 2000). Without effective initiatives, the fate of most of the ichthyofauna of Kerala will be to become a part of the past. Jnanpeeth winner and noted Malayalam writer, Sri.M.T.Vasudevan Nair, laments about Bharatha-puzha that the river, once a source of a vibrant physical and cultural life in Valluvanadu, is no longer a river but just a pale memory of what it once was (The Week, magazine, March 21, 2004). Unless we act now, time may not be far when Keralites will get to know about the state's rivers and their rich and diversified ichthyodiversity only from related articles and writings. Timely and apt conservation measures adopted now will ensure that our future generations inherit at least some proportion of extant freshwater ichthyofauna and they can see the fishes swimming in their own habitats rather than among permanently preserved fish collections.

Table 2.1. Details of river systems surveyed in Kerala during 2000-2003

Sl. No.	Name of river	Length (km)	Number of locations surveyed	Catchment area (km^2)
1	Valapattanam	110	28	1321
2	Chaliyar	169	26	2535
3	Thiroor	48	9	117
4	Bharathapuzha	209	45	4400
5	Keecheri	51	3	401
6	Puzhakkal	29	6	234
7	Karuvannur	48	17	1054
8	chalakudy	130	34	1404
9	Periyar	244	63	5284
10	Muvattupuzha	121	15	1554
11	Meenachil	78	24	1272
12	Manimala	90	2	847
13	Pamba	176	38	2235
14	Achenkovil	128	24	1484
15	Kallada	121	21	1699
16	Pambar	25	2	384
17	Kabini	56.6	33	562
18	Chinnar	78	9	-
19	Bhavani	64	3	562

Table 2.2. Locations surveyed in Valapattanam River

Sl. No.	Location	Sl. No.	Location
1	Aralam	15	Karimbam
2	Iritti	16	Kottiyoor
3	Kurukkathode	17	Manathana
4	Kuppam	18	Baveli
5	Malappattam	19	Peravoor
6	Meenmutty	20	Nadukani
7	Narikkadavu	21	Kanichar
8	Parassinikkadavu	22	Kappithode
9	Paripputhodu	23	Chottavalathode
10	Pazhassi dam site	24	Karimkappu
11	Pazhayangadi	25	Moonamthode
12	Srekandapuram	26	Kootupuzha
13	Karingalkuzhi	27	Keezhpally
14	Kattampilly	28	Pemboor

Table 2.3. Locations surveyed in Chaliyar River

Sl. No.	Locations	Sl. No.	Locations
1	Appankappu	14	Mancheri
2	Areekkode	15	Mayiladippotti
3	Chalikkal	16	Meenmutty
4	Cherukulam	17	Mukkam
5	Chunkatahra	18	Munda
6	Edakkara	19	Munderi
7	Kallankode	20	Muttikkadavu
8	Kannappankundu	21	Nedumkayam
9	Kannar	22	Panangayam
10	Karimpuzha	23	Vallakktta
11	Kathiroor estate	24	Vallikuthukadavu
12	Kinaloor	25	Vazhikkadavu
13	Kunduthodu	26	Veedukuzhi

Table 2.4. Locations surveyed in Tirur River

Sl. No.	Location	Sl. No.	Location
1	Anakkayam	6	Pattamadakkavu
2	Atavanadu	7	Pazhoor
3	Kalloopalam	8	Tirur
4	Kunduthodu	9	Velliar
5	Olipuzha		

Table 2.5. Locations surveyed in Bharathapuzha River

Sl. No.	Location	Sl. No.	Location	Sl. No.	Location
1	Aaliyar	17	Kannadi	33	Palakkayam
2	Atla water falls	18	Kavalakkadavu	34	Pallavoor
3	Ayiloor	19	Kawa	35	Pampady
4	Cheerakuzhi	20	Kawarakkundu	36	Poochippara
5	Cheriyawalakkad	21	Kodambu	37	Pothundy
6	Cheruthuruthy	22	Koottilakkadavu	38	Sarkkarpuzha
7	Chittor	23	Mailadippuzha	39	Syrendri
8	Cholagu	24	Malampuzha dam	40	Thamrachalla
9	Choorapara	25	Mangalam dam	41	Thathamangalam
10	Chulliar dam site	26	Mannarkkadu	42	Thippilikkayam
11	Dhoni	27	Meenkara dam	43	Walakkad
12	Irumbakachola	28	Meenvallam	44	Walayar
13	Kaliyara	29	Mukkali	45	Yakkara
14	Kalpathypuzha	30	Neelickal		
15	Kanjirappuzha	31	Nellipuzha		
16	Kanjirappuzha dam	32	Nenmara		

Table 2.6. Locations surveyed in Puzhakkal and Keecheri Rivers

	Puzhakkal River		Keecheri River
Sl. No.	Location	Sl. No.	Location
1	Kunduthodu	1	Chundalthodu
2	Mupliyam	2	Keecheri
3	Palappilly	3	Pazhoor
4	Puzhakkal		
5	Puzhakkal coal lands		
6	Vazhani		

Table 2.7. Locations surveyed in Karuvannur River

Sl. No.	Location	Sl. No.	Location
1	Bikkode	10	Marottikavu
2	Canolithode	11	Moorkkinikavu
3	Chimoni	12	Muppilithode
4	Chimoni dam site	13	Peechi
5	Kainoor	14	Pillathode
6	Kallazhi	15	Puthukkad estate
7	Kannara	16	Puthoor
8	Kurumalipuzha	17	Valakkavu
9	Manali		

Table 2.8. Locations surveyed in Chalakudy River

Sl. No	Location	Sl. No.	Location	Sl. No.	Location
1	Adichili	14	Malakkappara	27	Thellikkal
2	Anakkayam	15	Nelliampathy	28	Thumburmuzhi
3	Athirappally	16	Nooradi	29	Upper sholayar
4	Chalakkudy	17	Orukombankutty	30	Valparai
5	Illikal	18	Padikkutty	31	Vanchikkadavu
6	Kanakkankadavu	19	Padippara check dam	32	Vazhachal
7	Kaipra	20	Pannimala	33	Vetti ar
8	Kanjirakuthu	21	Poringal	34	Vettilappara
9	Karapara	22	Pillappara		
10	Krishnankotta	23	Pulikkalkadavu		
11	Kulappady plantation	24	Pulikkayam		
12	Kunjiarvathi	25	Puliyala		
13	Kuriarkutty	26	Sholayar		

Table 2.9. Locations surveyed in Periyar River

Sl. No	Location	Sl. No.	Location	Sl. No.	Location
1	Aanakkallankayam	23	Kunjuthanni	45	Perunda
2	Aanakkulam	24	Lower periyar	46	Pillakkyam
3	Aladi	25	Mandrappara	47	Pindippara
4	Bhoothathankettu	26	Mankulam	48	Pooyamkuuty
5	Charupara	27	Meenmutty	49	Pulikkayam
6	Chembakavallithodu	28	Mlappara	50	Pulinkuthu
7	Cheruthoni	29	Moolavaika	51	Pulimkuzhi allu
8	Chokkanpettythodu	30	Mukkar	52	Purakkal
9	Edamalayar	31	Mullakkodi	53	Santahnpara
10	Idukki	32	Mundiyeruma	54	Thandumankuthu
11	Injippara	33	Munnar	55	Thannikkudy
12	Injipparathaodu	34	Narakathumthodu	56	Thannimoodu
13	Kaipra	35	Neriyamangalam	57	Ummikuppanthodu
14	Kalloli	36	Pachankuthu	58	Vandipperiyar
15	Kallar	37	Padincharkutty	59	Vagalalaaynthodu
16	Karimanal	38	Pallippara	60	Valiyaparakutty
17	Karimban	39	Pampadumpara	61	Vazhukkappara
18	Katamadithodu	40	Pangappara	62	Venkalakkallu
19	Koombanpara	41	Parayadi	63	Vellathuval
20	Koondrappuzha	42	Parisakuthu		
21	Koovalakkayam	43	Pathinalammile		
22	Kundenkallu	44	Periyar lake		

Table 2.10. Locations surveyed in Moovattupuzha River

Sl. No.	Location	Sl. No.	Location
1	Kadumpidi	9	Malankara
2	Kaliyar	10	Moovattupuzha
3	Kalloor	11	Muttom
4	Kavana	12	Piravam
5	Kothamangalam	13	Thodupuzha
6	Kozhippally	14	Thommankuthu
7	Kuruvithode	15	Vakkakkayam
8	Madakkathanam		

Table 2.11. Locations surveyed in Meenachil and Manimala Rivers

Meenachil River				Manimala River	
Sl. No.	Location	Sl. No.	Location	Sl. No.	Location
1	Adivaram	13	Kulathukadavu	1	Manimala
2	Al-manarkadavu	14	Kumarakom	2	Kanjirapilly
3	Aryakunnumudi	15	Melukavu		
4	Bharanamghanam	16	Muzhayammavu		
5	Chathanpuzha	17	Nallathanni		
6	College Padi	18	Palai		
7	Eerattupetta	19	Peringalam		
8	Elappara	20	Poonjar		
9	Ettilakkadavu	21	Theekoyi		
10	Kallamthodu	22	Thottumukku		
11	Kolahalamedu	23	Vagamon		
12	Kudamurutty	24	Vattolikkadavu		

Table 2.12. Locations surveyed in Pamba River

Sl. No.	Location	Sl. No.	Location	Sl. No.	Location
1	Angamoozhi	14	Kochupamba	27	Perumthenaruvi
2	Aranmula	15	Kozhanchery	28	Prayikkara
3	Athikkayam	16	Maniyadippalam	29	Puthankavu
4	Attathode	17	Mannar	30	Puthiyakavu
5	Azhutha	18	Moozhiyar	31	Randattinkara
6	Chakkulam	19	Mundakkayam	32	Ranni
7	Chengannur	20	Neerettupuram	33	Seethathode
8	Edathuva	21	Nilakkal	34	Tiruvillapuram
9	Edayaranmula	22	Pachakkanam	35	Vadasserikkara
10	Gavi	23	Pambavalley	36	Vallakkadavu
11	Kakki	24	Parumala	37	Veliyankadavu
12	Kalaketti	25	Pavukkara	38	Viyyapuram
13	Kinadi	26	Payippad		

Table 2.13. Locations surveyed in Achenkoil River

Sl. No.	Locations	Sl. No.	Locations
1	Achenkoil	13	Palappara
2	Aruthalakkayam	14	Pandalam
3	Chuttippara	15	Parumalakkadavu
4	Edathua	16	Pathanamthitta
5	Kallar	17	Payippad
6	Kalleli	18	Prayikkara
7	Kanayar	19	Pulikkayam
8	Konni	20	Thura
9	Konnimoozhi	21	Vallakadavu
10	Kozhanchery	22	Vazhapperiyar
11	Kumbazha	23	Vettoor
12	Omallur	24	Valanchuzhi

Table 2.14. Locations surveyed in Kallada River

Sl. No.	Locations	Sl. No.	Locations
1	Aryankavu	12	Palaruvi below water falls
2	Chankili	13	Palaruvi downstream
3	Edappalayam	14	Pallivasal
4	Kazhuthurutti	15	Punalur
5	Kulathupuzha	16	Rose mala
6	Lookout	17	Thenmala
7	Meenmudy	18	Thenmala dam
8	Mukkadavu	19	Umayar
9	Neduvannurkkadavu	20	Urukunnu
10	Ottakkal	21	Venkalappara
11	Palaruvi upper stream		

Table 2.15. Locations surveyed in Bhavani and Pambar rivers

Bhavani River		Pambar River	
Sl. No.	Location	Sl. No.	Location
1	Agali	1	Chambakkad
2	Anakkatti	2	Koottar
3	Mukkali		

Table 2.16. Locations surveyed in Kabini River

Sl. No.	Location	Sl. No.	Location	Sl. No.	Location
1	Achoor	13	Kunnumpotta	25	Pookode lake
2	Aranagiri	14	Kurlode lake	26	Pozhuthana
3	Arattuthura	15	Kuruvadeep	27	Puthusserikkadavu
4	Banasurasagar dam site	16	Makkilayam	28	Sugandagiri
5	Baveli	17	Mananthavadi	29	Thalippuzha
6	Begur	18	Meenangadi	30	Tholpetty
7	C.C.Puzha	19	Niravilpuzha	31	Tirunelli
8	Chembrapeak	20	Noolpuzha	32	Valliyoorkavu
9	Kalloor	21	Padincharethara	33	Vythiri
10	Kattikunnu	22	Palvelicham		
11	Kolavalli	23	Panamaram		
12	Koyleri	24	Ponkuzhi		

Table 2.17. Locations surveyed in Chinnar River

Sl. No.	Locations	Sl. No.	Locations
1	Chinnar	6	Mlarev
2	Chinnar checkpost	7	Muthukanalai
3	Koottar	8	Periyaparathurai
4	Kovilkadavu	9	Thoovanam
5	Marayoor		

Table 2.18. IUCN categories and criteria, 1994 (Walker and Molur, 1997)

Use any of the A-E criteria	**Critically Endangered (CR)**	**Endangered (En)**	**Vulnerable (Vu)**
A. Population reduction Population reduction measured over 10 years or 3 generations whichever is longer in the form of either of the following:			
1. Population decline observed estimated, inferred or suspected in the past: OR	80%	50%	20%
2. Population reduction projected or suspected in the future: based on any of the following a. direct observation b. an index of abundance appropriate for the taxon c. a decline in area of accupancy, extent of occurrence and/or quality of habitat d. actual or potential levels of exploitation e. the effects of introduced taxa, hybridization, pathogens,pollutants, competitors or parasites.	80%	50%	20%
B. Restricted distribution			
Extent of occurrence OR	< $100Km^2$	<$5000Km^2$	<$20,000Km^2$
Area of occupancy AND	<$10Km^2$	<$500Km^2$	<$2000Km^2$
Any 2 of the following 3: 1. Severely fragmented (isolated subpopulation with a reduced probability of recolonisation, if once extinct)			

OR Known to exist at a definite number of locations	1	<5	<10
2. Continuing decline, observed, inferred or projected in any of the following: a. extent of occurrence b. area of occupancy c. area, extent and/or quality of habitat d. number of locations or subpopulations e. number of mature individuals			
3. Extreme fluctuations in any of the following a. extent of occurrence b. area of occupancy c. number of locations or subpopulations d. number of mature individuals			
C. Population estimates			
Number of mature individuals AND Either of the following	<250	<2500	<10000
1. An estimated continuing decline rate	25% within 3 years or 1 generation whichever is longer	20% within 5 yrs or 2 generations whichever is longer	10% within 10 years or 3 generations whichever is longer
2. Continuing decline observed, projected or inferred in number of mature individuals and population structure in the form of either: a. severely fragmented: Number of mature Individuals in a subpopulation.	Not more than 50	Not more than 250	Not more than 1000
b. All individuals are in a single subpopulation			
D. Restricted population Either of the following			
1. Number of mature individuals	<50	<250	<1000
2. Population is susceptible	(not applicable)	(not applicable)	Area of occupancy <100km^2 or number of locations <5
E. Probability of extinction Quantitative analysis showing the probability of extinction in the wild to be at least.	50% in 10 years or 3 generations whichever is longer	20% in 20 years or 5 generations whichever is longer	10% in 100 years

Table 2.19. List of freshwater fishes collected and identified from Kerala during 2000-2003(Source : Kurup *et al.*, 2003).

Sl. No.	SPECIES	STATUS
1	*Ambassis gymnocephalus*	LR-lc
2	*Amblypharyngodon melettinus*	LR-nt
3	*Amblypharyngodon microlepis*	LR-nt
4	*Anabas testudineus*	LR-nt
5	*Anguilla bicolor bicolor*	EN
6	*Anguilla bengalensis bengalensis*	LR-nt
7	*Aplocheilus blochii*	DD
8	*Aplocheilus lineatus*	LR-lc
9	*Awous gutum*	LR-nt
10	*Balitora brucei*	DD
11	*Balitora mysorensis*	CR
12	*Barilius bakeri*	LR-lc
13	*Barilius bendelisis*	EN
14	*Barilius canarensis*	LR-nt
15	*Barilius gatensis*	LR-lc
16	*Batasio travancoria*	LR-nt
17	*Bhavania australis*	LR-nt
18	*Catla catla*	NE
19	*Channa marulius*	LR-nt
20	*Channa micropeltes*	CR
21	*Channa punctatus*	LR-nt
22	*Channa striatus*	LR-nt
23	*Chela fasciata*	LR-lc
24	*Cirrhinus reba*	EN
25	*Cirrhinus mrigala*	LR-lc
26	*Clarias dussumieri*	LR-nt
27	*Crossocheilus periyarensis*	CR
28	*Cyprinus carpio*	DD
29	*Danio malabaricus*	LR-lc
30	*Danio aequipinnatus*	LR-lc
31	*Dayella malabarica*	CR
32	*Eleotris fusca*	DD
33	*Esomus theramoicois*	LR-nt
34	*Etroplus maculatus*	LR-lc
35	*Etroplus suratensis*	LR-lc

Sl. No.	SPECIES	STATUS
36	*Garra hughi*	Vu
37	*Garra gotyla stenorhynchus*	LR-nt
38	*Garra mcClellandi*	LR-nt
39	*Garra menoni*	DD
40	*Garra mullya*	LR-lc
41	*Garra periyarensis*	EN
42	*Garra surendranathanii*	LR-nt
43	*Glossogobius giuris*	LR-lc
44	*Glyptothorax anamalaensis*	DD
45	*Glyptothorax annandalei*	Vu
46	*Glyptothorax lonah*	EN
47	*Glyptothorax madraspatanam*	Vu
48	*Gonoproktopterus curmuca*	LR-lc
49	*Gonoproktopterus dubius*	EN
50	*Gonoproktopterus kolus*	EN
51	*Gonoproktopterus micropogon periyarensis*	CR
52	*Gonoproktopterus thomassi*	EN
53	*Heteropneustes fossilis*	LR-nt
54	*Horabagrus brachysoma*	LR-nt
55	*Horabagrus nigricollaris*	EN
56	*Kantaka brevidorsalis*	DD
57	*Labeo dussumieri*	Vu
58	*Labeo fimbriatus*	NE
59	*Labeo kontius*	DD
60	*Labeo rohita*	NE
61	*Lepidocephalus thermalis*	LR-lc
62	*Lepidopygopsis typus*	CR
63	*Macrognathus guentheri*	Vu
64	*Macropodus cupanus*	LR-lc
65	*Mastacembelus armatus*	LR-lc
66	*Microphis cuncalis*	DD
67	*Mystus armatus*	LR-lc
68	*Mystus bleekeri*	DD
69	*Mystus cavasius*	LR-lc
70	*Mystus gulio*	LR-lc

Sl. No.	SPECIES	STATUS
71	*Mystus oculatus*	LR-nt
72	*Nandus nandus*	LR-nt
73	*Nemacheilus botia*	LR-lc
74	*Nemacheilus denisoni denisoni*	LR-nt
75	*Nemacheilus guentheri*	DD
76	*Nemacheilus keralensis*	LR-nt
77	*Nemacheilus menoni*	DD
78	*Nemacheilus monilis*	LR-nt
79	*Nemacheilus pambarensis*	DD
80	*Nemacheilus semiarmatus*	EN
81	*Nemacheilus triangularis*	LR-lc
82	*Neolissocheilus wynaadensis*	EN
83	*Notopterus notopterus*	Vu
84	*Ompok bimaculatus*	LR-lc
85	*Ompok malabaricus*	DD
86	*Oreochromis mossambicus*	LR-lc
87	*Osteobrama bakeri*	Vu
88	*Osteochilichthys longidorsalis*	EN
89	*Osteochilichthys nashii*	EN
90	*Osteochilichthys thomassi*	DD
91	*Parambassis dayi*	LR-lc
92	*Parambassis thomassi*	LR-lc
93	*Pristolepis marginatus*	LR-lc
94	*Puntius amphibius*	LR-lc
95	*Puntius arulius*	LR-nt
96	*Puntius bimaculatus*	LR-nt
97	*Puntius carnaticus*	LR-nt
98	*Puntius chola*	LR-nt
99	*Puntius conchonius*	Vu
100	*Puntius denisonii*	LR-nt
101	*Puntius dorsalis*	LR-nt
102	*Puntius fasciatus*	LR-lc
103	*Puntius filamentosus*	LR-lc
104	*Puntius jerdoni*	LR-nt
105	*Punius ophicephalus*	Vu

Sl. No.	SPECIES	STATUS
106	*Puntius parrah*	LR-nt
107	*Puntius sarana subnasutus*	LR-lc
108	*Puntius ticto*	LR-lc
109	*Puntius vittatus*	LR-lc
110	*Pseudotropius mitchelli*	LR-nt
111	*Rasbora daniconius*	LR-lc
112	*Salmostoma acinaces*	LR-lc
113	*Salmostoma boopis*	LR-lc
114	*Salmostoma sardinella*	LR-nt
115	*Sicyopterus griseus*	Vu
116	*Silurus wynaadensis*	CR
117	*Tetradon travancorius*	LR-nt
118	*Tor khudree*	LR-nt
119	*Tor putitora*	DD
120	*Travancoria elongata*	CR
121	*Travancoria jonesi*	EN
122	*Wallago attu*	Vu

CR = Critically endangered
EN = Endangered
Vu = Vulnerable
LR-nt = Low risk near threatened
LR-lc = Low risk least concern
DD = Data deficient
NE = Not evaluated.

Table 2.20. List of critically endangered species, river sources and catch/unit effort

Sl. No	Species	River source	Number of surveys conducted	No. of locations surveyed and repeatedly surveyed	Name of the location from where the species was collected	Number of occurrence of the species	Catch/Unit Effort(CPUE) (Kg)		Endemism
							Min	Max	
1. Species restricted to a single location									
1	***Balitora mysorensis***	Achenkovil	9	24	Kanayar	1	0	0.01	EWG
2	***Channa micropeltes***	Kallada	6	21	Thenmala dam	2	0.0041	0.05	-
3	***Dayella malabarica***	Chalakudy	10	34	Thumburmuzhi	1	0	0.025	EWG
4	***Crossocheilus periyarensis***	Periyar	17	63	Thannikkudy and above	6	.001	.099	EK
5	***Gonoproktopterus micropogon periyarensis***	Periyar	17	63	Thannikkudy and above	9	.109	.355	EK
6	***Lepidopygopsis typus***	Periyar	17	63	Thannikkudy and above	4	.002	.5258	EK
7	***Travancoria elongata***	Periyar	17	63	Pooyamkutty	1	0	.0027	EK
2. Species restricted to a single river system									
8	***Silurus wynaadensis***	Kabini	17	33	Aranagiri, Kattikunnu, C.C Puzha	4 1 1	.00012 0 0	.006 0.0015 0.0013	EWG

EK = Endemic to Kerala.
EWG = Endemic to Western Ghats

Table 2.21. List of Endangered fishes, river sources and catch/unit effort

Sl. No.	Species	River source	Number of surveys conducted	No. of locations surveyed and repeatedly surveyed	Name of the location from where the species was collected	Number of occurrence of the species	Catch/Unit Effort (CPUE) (Kg)		Endemism
							Min	Max	
1. Species restricted to a single river system									
1	***Cirrhinus reba***	Kabini	17	33	Kuruvadeep, Kunnumbatta, Noolpuzha	1 1 1	0 0 0	0.14 0.06 0.08	-
2	***Garra periyarensis***	Periyar	17	63	Thannikkudy and above	4	.002	.472	EK
3	***Glyptothorax lonah***	Chala-kudy	10	34	Vazhachal	1	0	.01	-
4	***Gonoproktopterus dubius***	Kabini	17	33	Baveli, Noolpuzha, Vythiri	3 3 1	0.01 0.03 0	0.13 0.84 0.02	-
5	***Horabagrus nigricollaris***	Chala-kudy	10	30	Vettilappara, Thumbormuzhi	1 1	0 0	0.24 0.021	EK
6	***Neolissocheilus wynaadensis***	Kabini	17	33	Aranagiri, Kunnumbatta, Kattikkunnu, C.C. puzha Appenkappa	3 1 2 1 2	0.002 0 0.001 0 0.11	0.43 0.002 0.20 0.31 .01	EK
7	***Osteochilichthys nashii***	Kabini	17	33	Aranagiri, Kunnumbatta, Baveli, Noolpuzha, Begur, Pookode	3 1 1 3 3 1	0.005 0.002 0 .04 .04 0	0.32 0.12 .06 .09 0.13 0.08	EWG
8	***Osteochilichthys longidorsalis***	Chala-kudy	10	34	Malakkapara, Athirapilly, Orukombankutty	3 2 1	0.01 .06 0	.133 .14 0.19	EK
2. Species restricted to two river systems									
9	***Anguilla bicolor bicolor***	Periyar Puzha-ykkal	17 1	63 6	Pooyamkutty Puzhaykkal	1 1	0 0	0.32 0.21	
10	***Barilius bendelisis***	Chala-kudy Bharatha-puzha	10 12	34 45	Malakkapara , Kuriyarkutty, Athirapilly Cheruthuruthi, Cholagu	1 1 1 1 1	0 0 0 0 0	0.05 0.01 0.02 0.01 0.01	
11	***Gonoproktopterus kolus***	Periyar Chala-kudy	17 10	63 34	Anakkayam, Thannikkudy Kuriyarkutty, Parambikulam Karappara	1 1 2 3 1	0 0 0.11 0.013 0	0.08 0.17 1.0223 1.495 0.11	EWG
12	***Nemacheilus semiarmatus***	Kabini Chinnar	17 4	33 9	Sugandagiri Chinnar	1 1	0 0	.0035 .0009	EWG
13	***Gonoproktopterus thomassi***	Kallada Periyar	5 17	16 38	Meenmutty, Thenmala dam Pooyamkutty	2 1 1	0 0 0	0.12 0.21 0.015	EWG
14	***Travancoria jonesi***	Chala-kudy	10	34	Nelliampathi (Karappara)	2	0.0015	0.0073	EK

Table 2.22. List of Vulnerable fishes, river sources and catch/unit effort

Sl. No.	Species	River source	Number of surveys conducted	No. of locations surveyed and repeatedly surveyed	Name of the location from where the species was collected	Number of occurrence of the species	Catch/Unit Effort(CPUE) (Kg)		Endemism
							Min	Max	
1	*Garra hughi*	Pamba	7	38	Kochupamba Moozhiyar	2 1	0.001 0	0.023 .016	EWG
		Periyar	17	63	Thannikkudy	1	0	0.06	
		Pambar	2	2	Chambakkad	1	0	0.003	
		Chinnar	4	9	Chinnar	1	0	0.001	
		Achen-kovil	9	24	Kanayar Kallar	1 1	0 0	0.0012 0.0141	
2	*Glyptothorax annandalei*	Periyar	17	63	Pooyamkutty, Kunthrapuzha, Anakulam	2 1 1	.0012 0 0	0.1702 0.0123 0.0012	-
		Chinnar	4	9	Chinnar	1	0	0.0103	
		Chaliyar	2	26	Mancheri,	1	0	0.003	
					Meenmutty,	1	0	0.0238	
					Mayiladipotti	1	0	0.024	
3	*Glyptothorax madras-patanam*	Achen-kovil	9	24	Kanayar	1	0	.001	EWG
		Kabini	17	33	Noolpuzha, Kuruvadeep	1 1	0 0	0.01 0.021	
		Muvattu puzha	5	15	Thommankuthu	1	0	0.0018	
		Chala-kudy	10	34	Nelliampathy, Athirapilly	1 1	0 0	0.006 0.008	
4	*Labeo dussumieri*	Achen-kovil	9	24	Prayikkara, Vettor, Parumalakadavu, Payippad	1 1 2 1	0 0 0.042 0	.09 0.232 1.12 0.025	-
		Pamba	7	38	Pavukkara	1	0	0.27	
					Payippad,	1	0	1.6	
					Neerettupuram	1	0	0.159	
5	*Macrognathus guentheri*	Chala-kudy	10	34	Thumbormuzhi	1	0	0.072	EK
		Periyar	17	63	Pooyamkutty	1	0	0.10	

6	*Notopterus notopterus*	Kabini	17	33	Kuruvadeep, Puthusserikadavu, Begur, Panamaram, C.C.puzha	1 1 1 1 1	0 0 0 0 0	0.02 0.03 0.07 0.024 0.03	-
		Bharatha-puzha	12	45	Yakkara	1	0	0.02	
7	*Osteobrama bakeri*	Periyar	17	63	Pooyamkutty, Kaipra(240 times sampled)	1 160	0.001 .0722	0.008 0.3828	EK
		Chalakudy	10	34	Kanakkankadavu, Pillapara, Vettilapara	1 1 1	0 0 0	0.002 0.0048 0.01	
		Kabini	17	33	Noolpuzha	1	0	0.0054	
		Kallada	5	21	Meenmutty	1	0	0.026	
		Meenachil	3	24	Kattachira, Kidangoor check dam	1 1	0 0	0.056 0.014	
8	*Puntius conchonius*	Kabbini	17	33	Kuruvadeep, Pozhuthana, Muthanga, Puthusserikadavu, Meenangadi, Begur, Baveli	1 2 1 1 1 2 2	0 0.001 0 0 0 0.0012 0.001	0.006 0.004 0.004 0.001 0.012 0.016 0.0132	-
		Bharatha-puzha	12	45	Yakkara Tamrachalla	1 1	0 0	0.001 0.0012	
9	*Puntius ophicephalus*	Periyar	17	63	Ummikku-ppanthode	3	.0001	0.5942	EK
10	*Sicyopterus griseus*	Chaliyar	7	26	Areekode	1	0	0.00156	
		Periyar	17	63	Pooyamkutty	1	0	0.00242	
		Bharatha-puzha	12	45	Cheruthuruthy	1	0	0.0012	
		Chalakudy	10	34	Vettilapara(check)	1	0	0.0035	
11	*Wallago attu*	Achenkovil	9	24	Payippad	1	0	0.09	-
		Kabini	17	33	Begur, Pookode lake	1 1	0 0	1.5657 0.0052	
		Moova-ttupuzha	5	15	Moovattupuzha	1	0	0.0021	
		Bharatha-puzha	12	45	Cheruthuruthy	1	0	0.23	

EK = Endemic to Kerala
EWG = Endemic to Western Ghats

Table 2.23. Details of *G.micropogon periyarensis* collected during survey

Date of collection	Number of specimens collected	Length group (mm)
16.02.2001	11	130-223
26.09.2001	9	195-310
30.11.2001	2	246-285
15.12.2001	3	231-272
25.02.2002	2	313-355
05.05.2002	13	124-263
06.08.2002	18	201-290
08.10.2002	1	270
09.01.2003	6	188-243

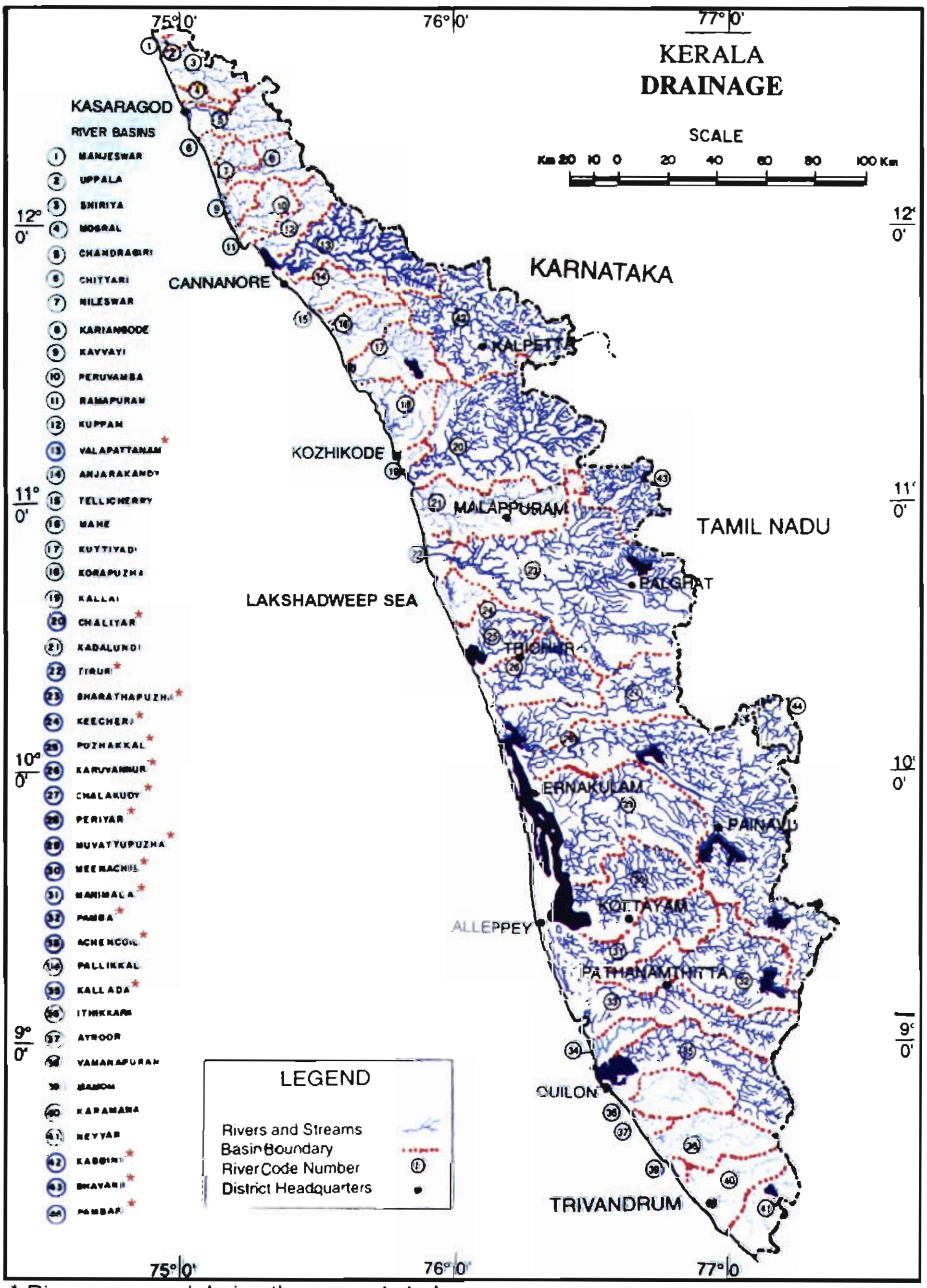
Table 2.24. Fecundity indices in *L. typus*

Sl. No.	Total length (mm)	Body weight (g)	Ovary length (mm)	Ovary weight (g)	Fecundity		Absolute fecundity
					Per gram fish weight	Per gram body weight	
1	271	181.82	100	13.76	37.74	743.31	10,228
2	262	164.6	87	9.7	37.01	999.69	9697
3	207	77.26	67	4.52	17.77	813.94	3679
4	200	69.96	62	3.18	15.17	954.09	3034

Table 2.25. Details of *G. kolus* collected during the survey

River source/location	Date of collection	Number of fish obtained	Length-group(mm)
Chalakudy (Karappara, Parambikulam)	30-3-2001	17	125-225
Chalakudy (Kuriarkutty, Parambikulam)	18-11-2001	12	139-152
Periyar (Anakayam, Thannikudy)	04-02-2002	4	124-202
Chalakudy (Parambikulam)	15-11-2002	23	108-161
Chalakudy (Kuriyarkutty)	03-02-2003	7	130-175

Fig. 2.1. Rivers of Kerala



* Rivers surveyed during the present study

Source: Centre for Water Resources Development and Management, Kozhikode, 1995.

Fig.2.2. Schematic representation of IUCN categories, 1994 (Walker and Molur, 1997)

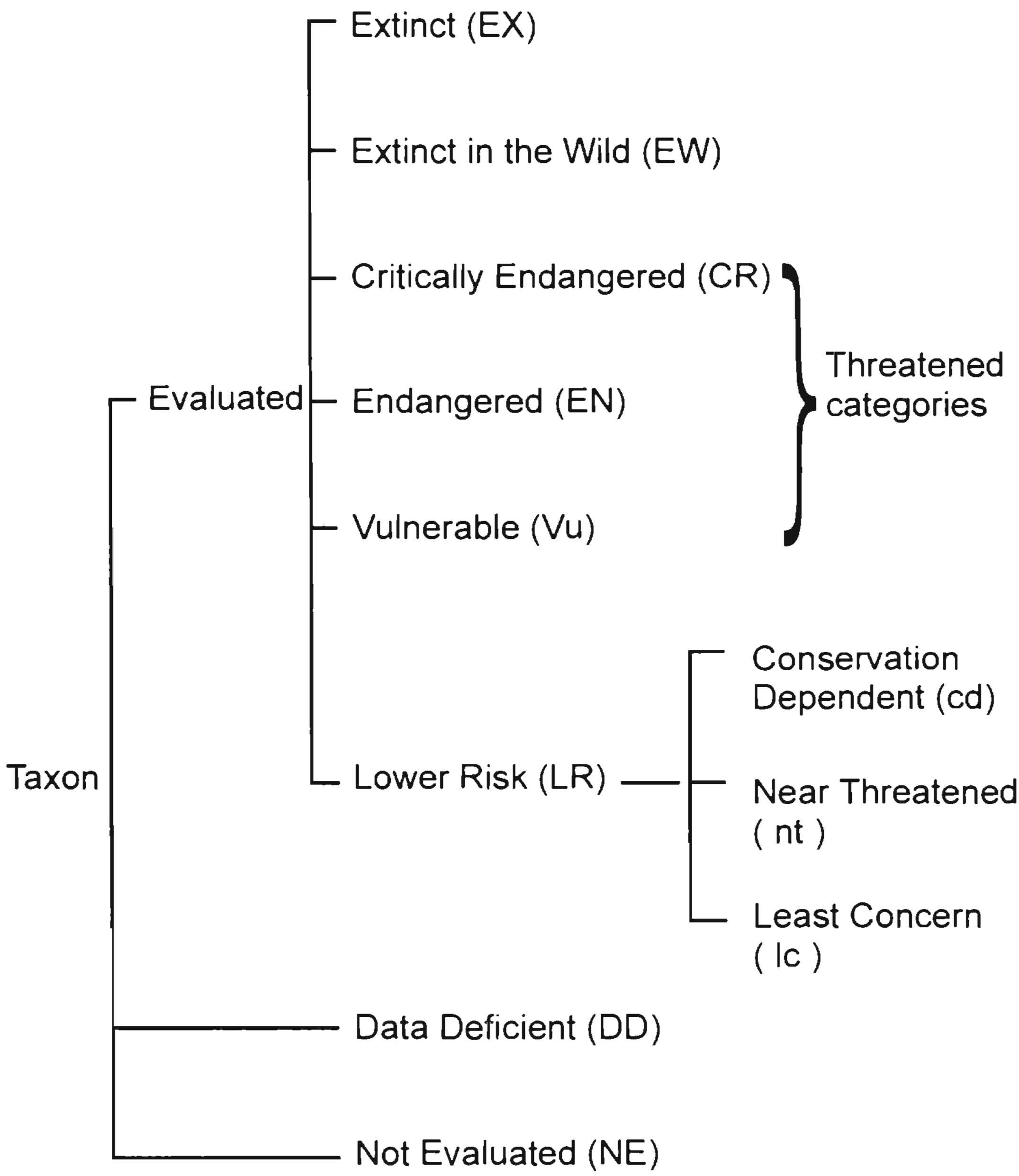


Fig. 2.3. Biodiversity assessment of 122 fish species collected from Kerala waters

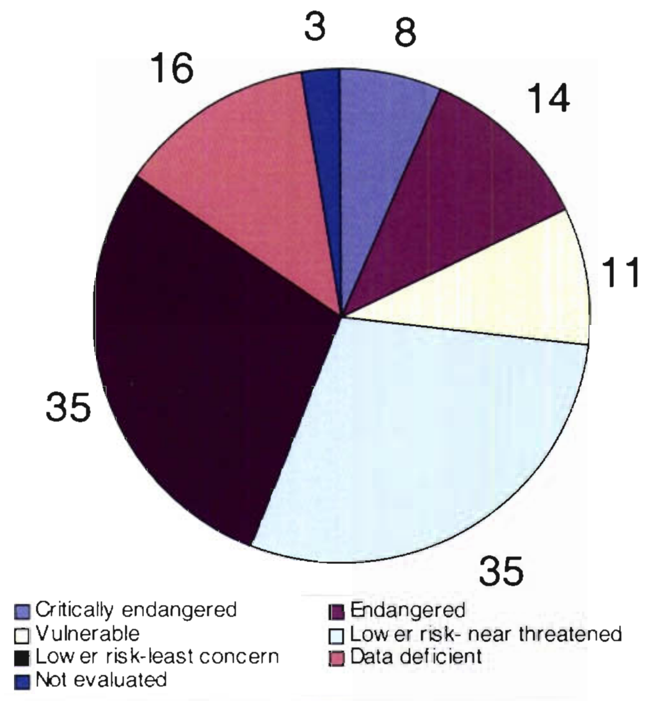


Fig. 2.4. Size composition of *Crossocheilus periyarensis*

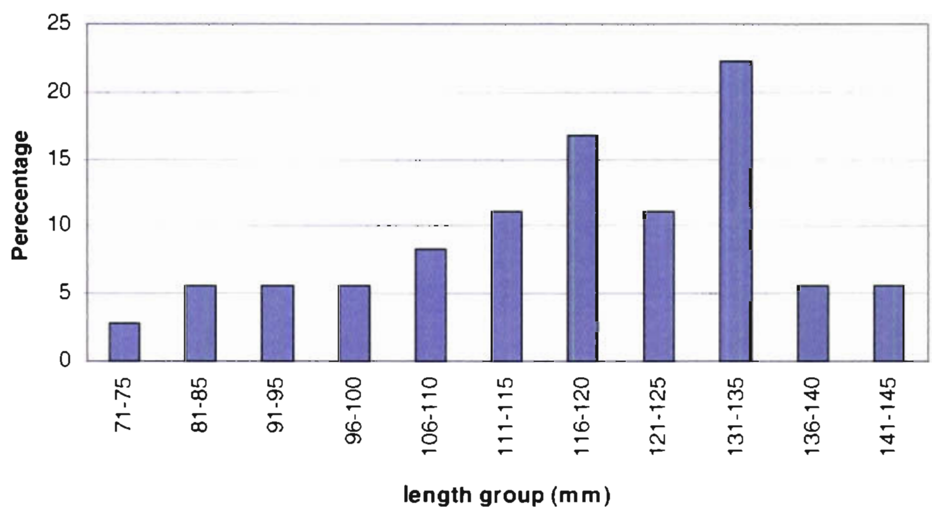
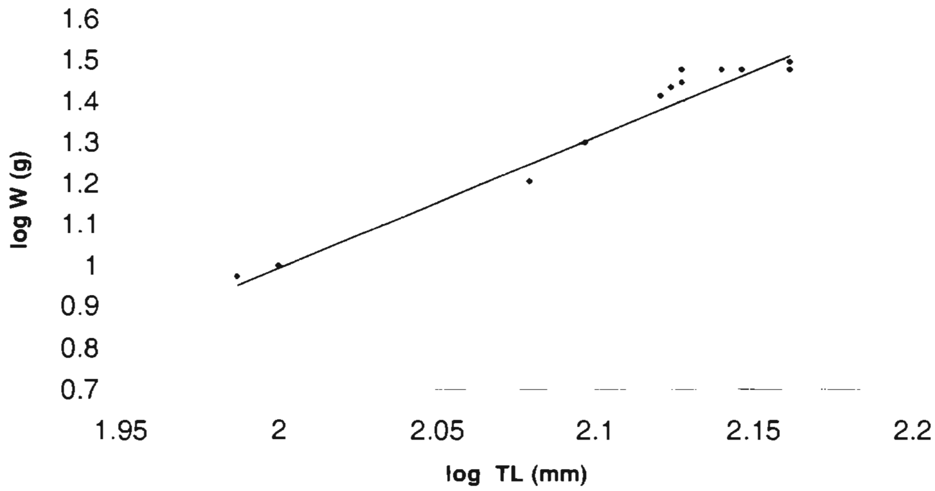


Fig.2.5. Length- weight relationship in
Crossocheilus periyarensis



log w = -5.4509 +3.2213 log l   r = 0.9328

Fig.2.6. Size composition of
Gonoproktopterus micropogon periyarensis

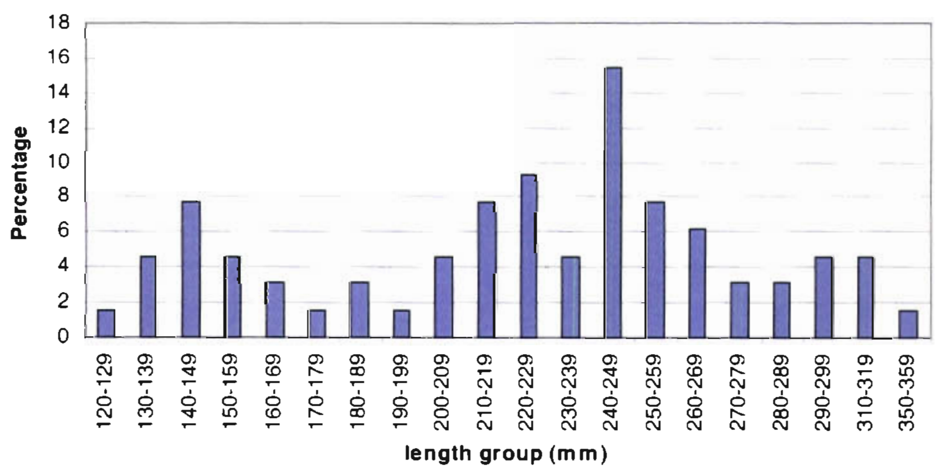
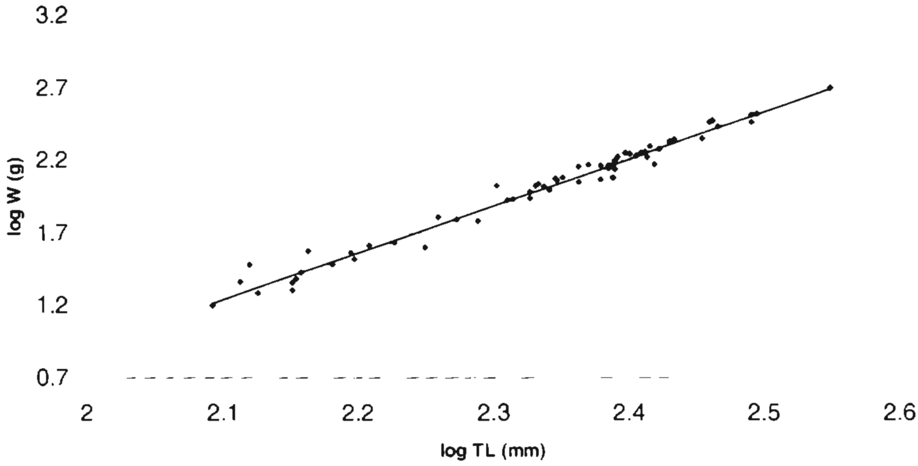


Fig.2.7. Length-weight relationship in *Gonoproktopterus micropogon periyarensis*



log w =-5.5589 +3.2356 logl r = 0.9816

Fig.2.8. Percentage composition of food items in *Gonoproktopterus micropogon periyarensis*

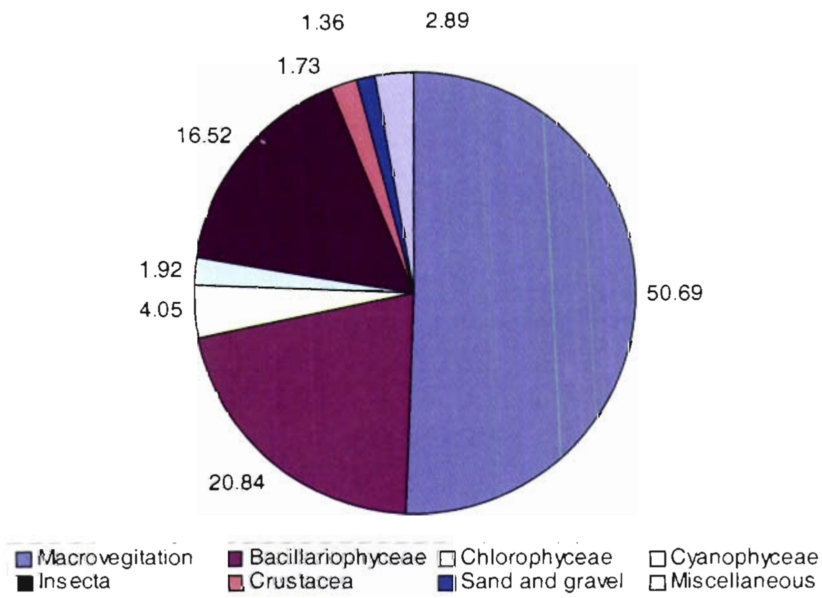


Fig.2.9. Size composition of *Lepidopygopsis typus*

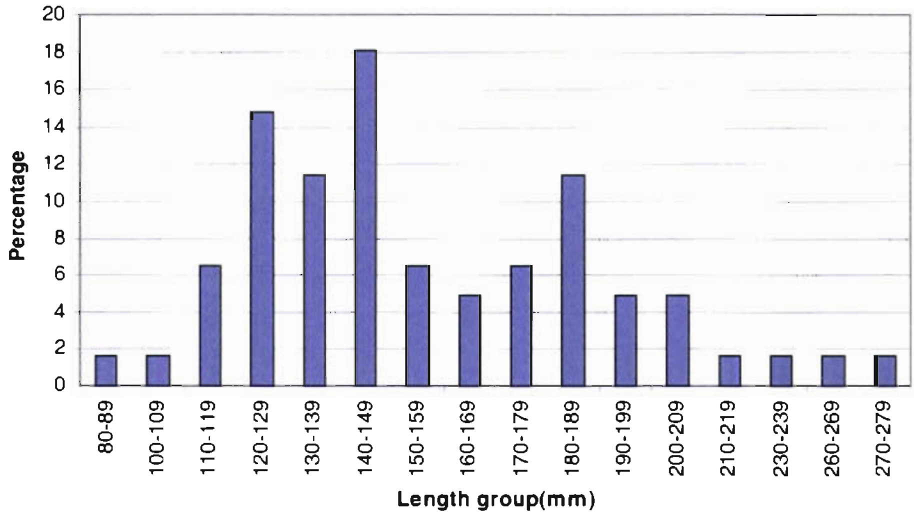
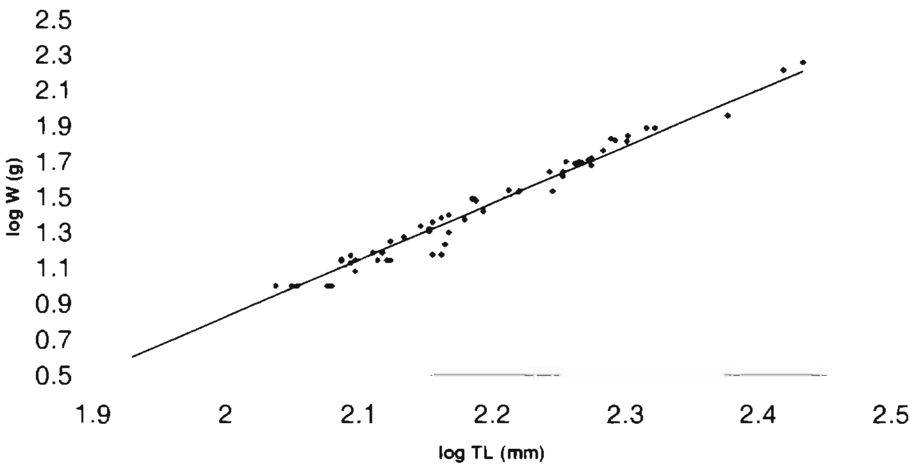


Fig.2.10. Length-weight relationship in *Lepidopygopsis typus*



log w = -5.5735 + 3.1985 log l   r = 0.9724

Fig.2.11. Percentage composition of food items in *Lepidopygopsis typus*

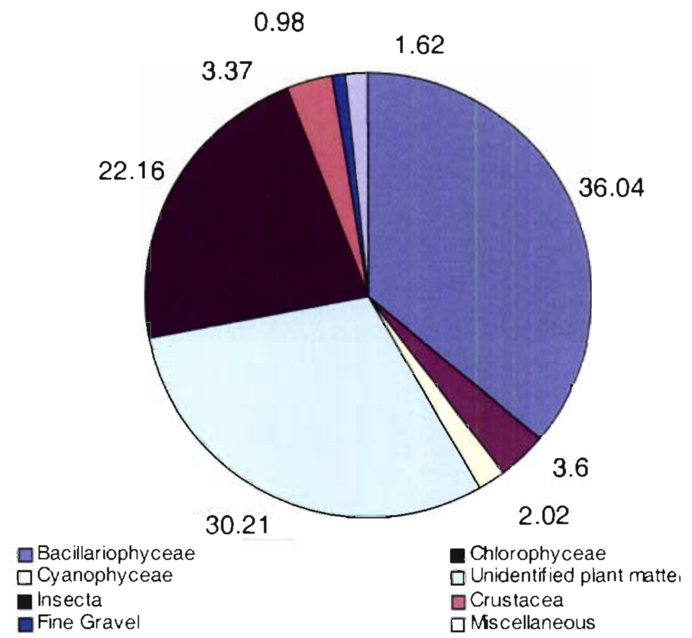


Fig. 2.12.Size composition of *Garra periyarensis*

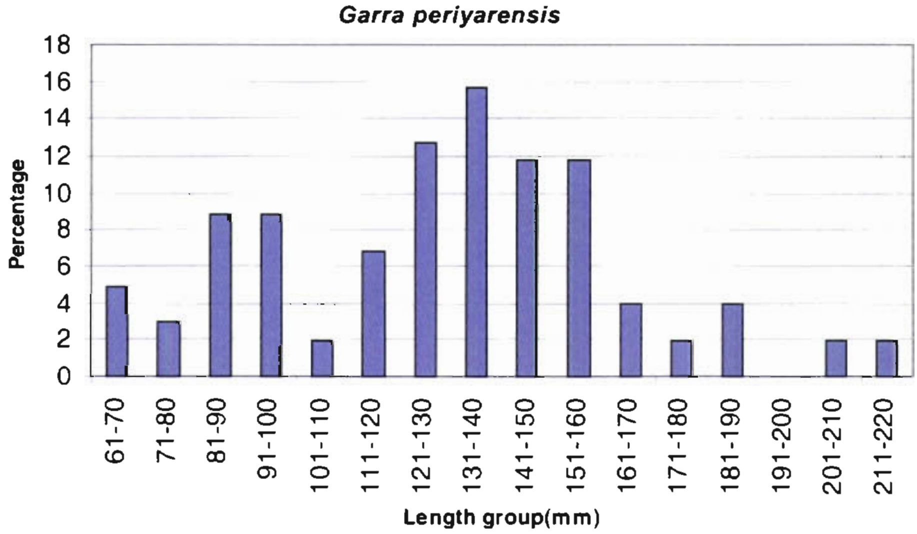
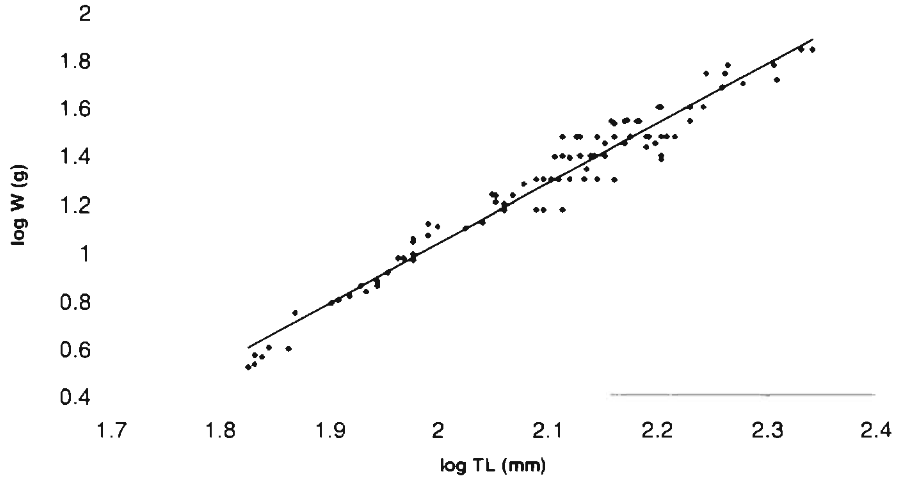


Fig.2.13. Length weight relationship in *Garra periyarensis*



log w =-3.9405 +2.4877 log l   r =0.9734

Fig. 2.14. Percentage composition of food items in *Neolissocheilus wynaadensis*

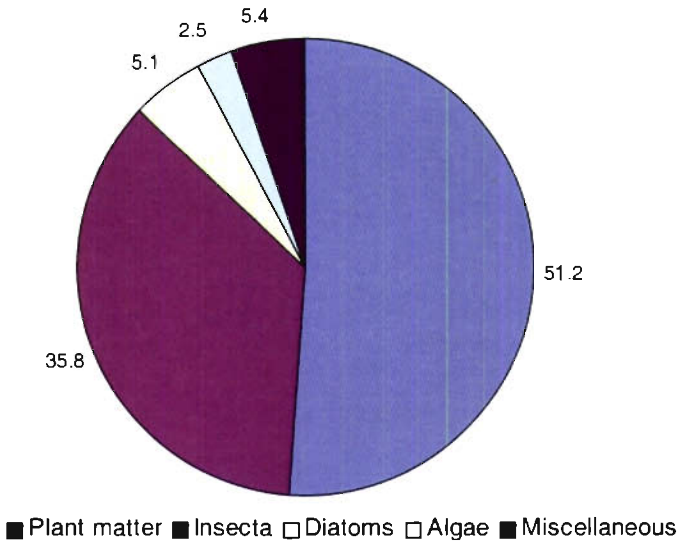


Fig.2.15. Size composition of
Osteochilichthys longidorsalis

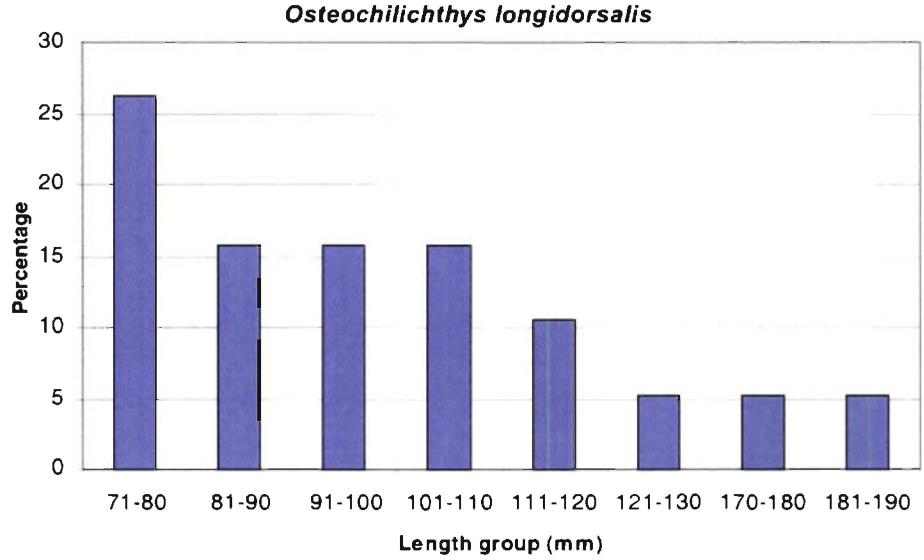


Fig.2.16. Size composition of
Gonoproktopterus kolus

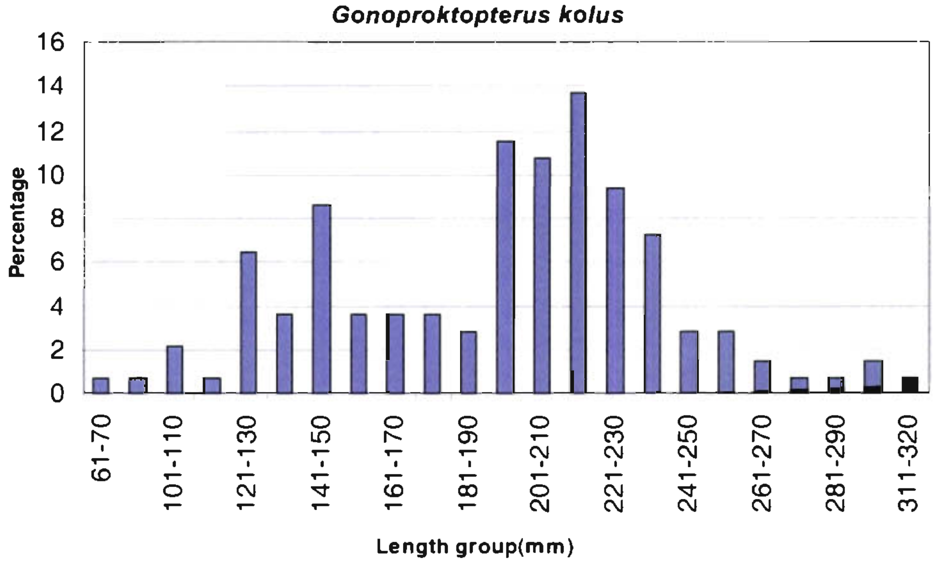
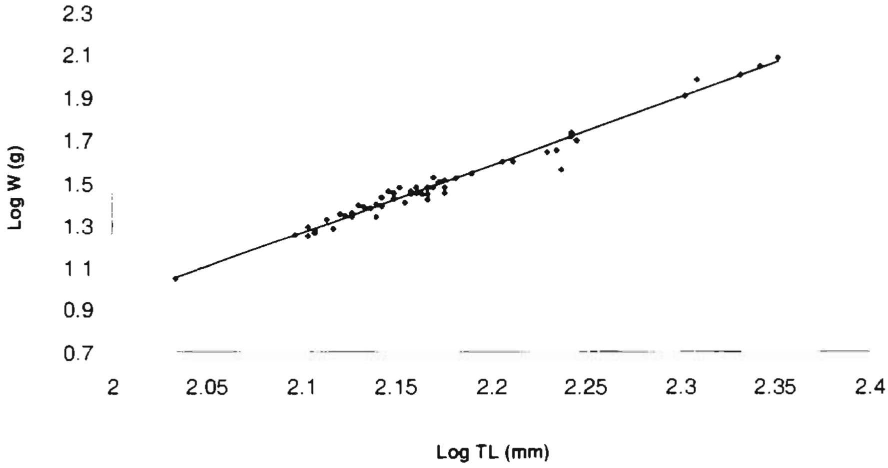


Fig.2.17. Length-weight relationship in *Gonoproktopterus kolus*



log w = -5.3765 + 3.1621 logl   r = 0.9845

Fig.2.18. Percentage composition of food items in *Gonoproktopterus kolus*

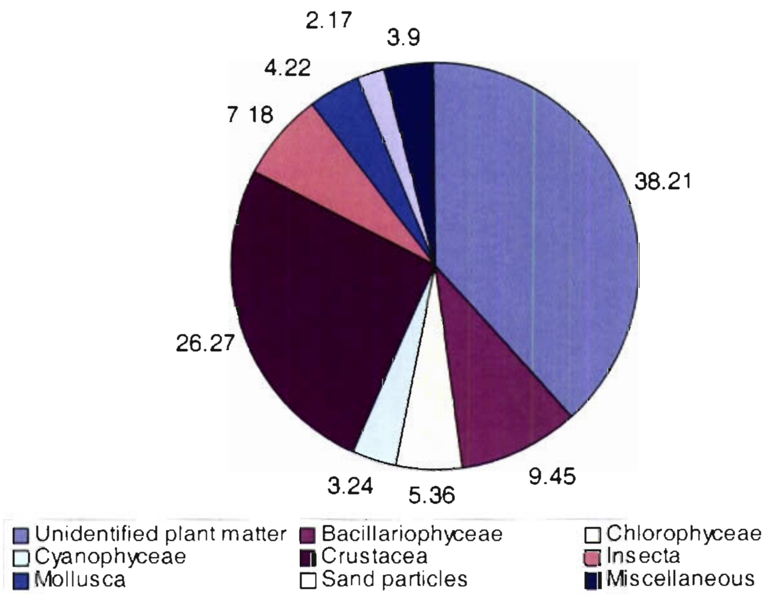


Fig.2.19. Size composition of *Gonoproktopterus thomassi*

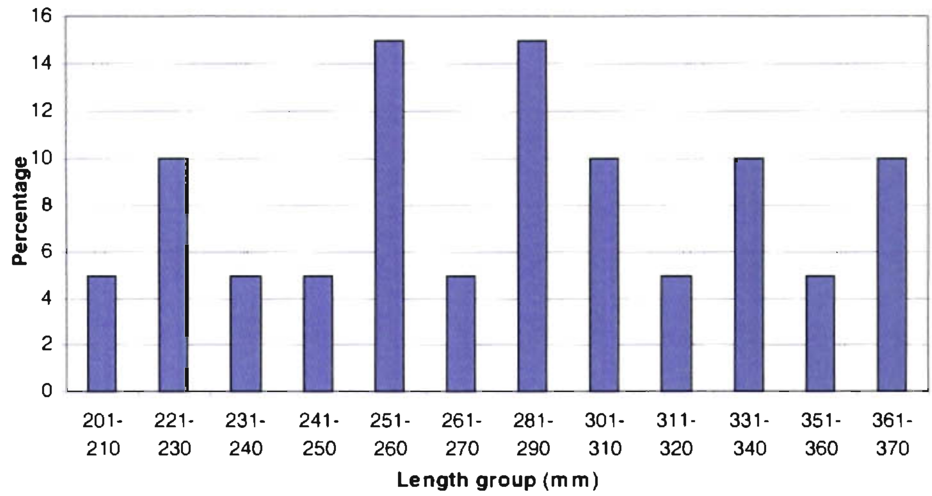


Fig. 2.20. Size composition of *Labeo dussumieri*

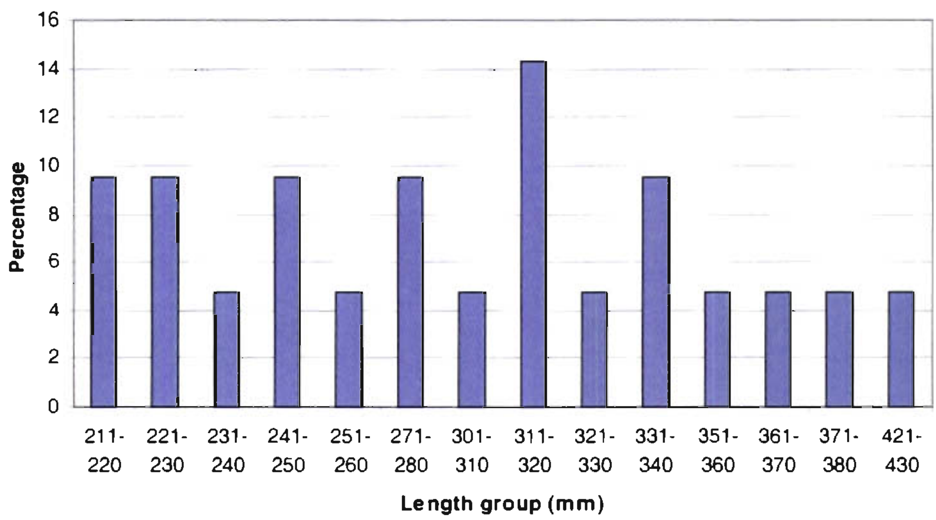


Fig.2.21. Percentage composition of food items in *L. dussumieri*

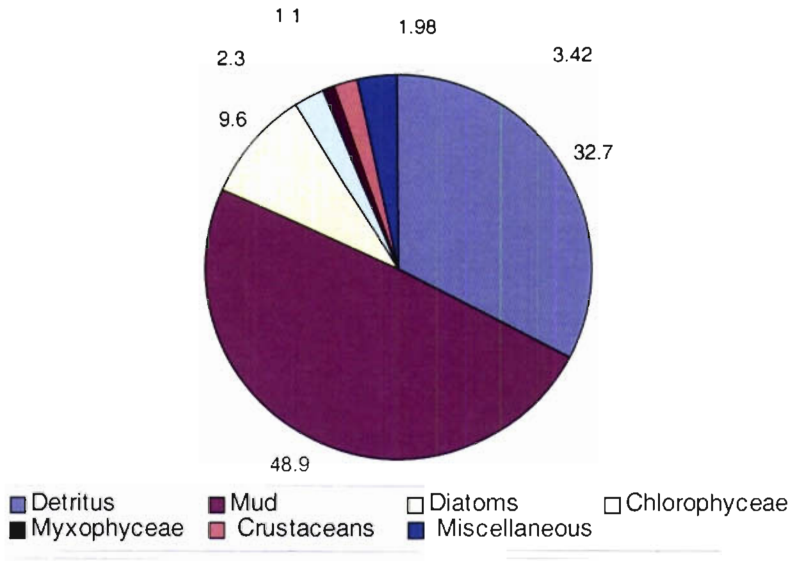


Fig.2.22. Size composition of *P. ophicephalus*

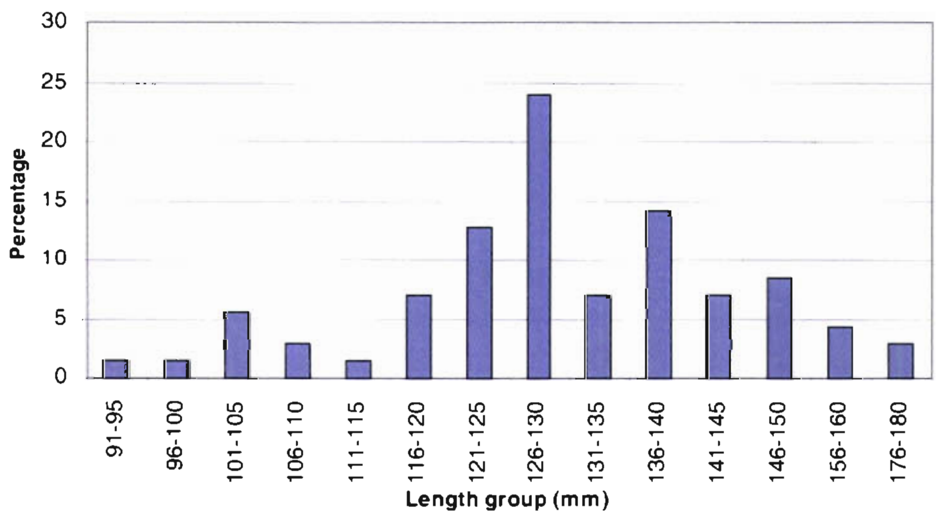
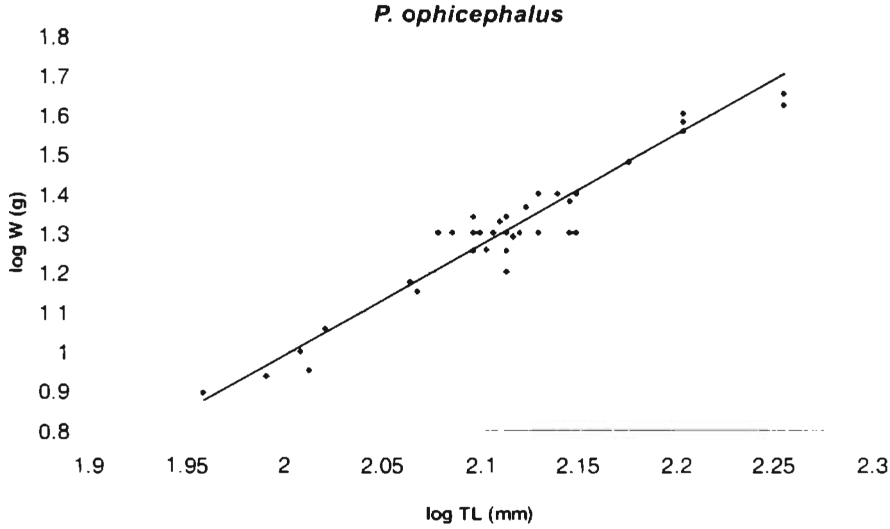


Fig.2.23. Length - weight relationship in *P. ophicephalus*



log w = -4.6083 + 2.7980 log l   r = 0.9103

Plate 1

a. *Balitora mysorensis* Hora

b. *Channa micropeltes* (Cuvier)

c. *Crossocheilus periyarensis* Menon & Jacob

d. *Dayella malabarica* (Day)

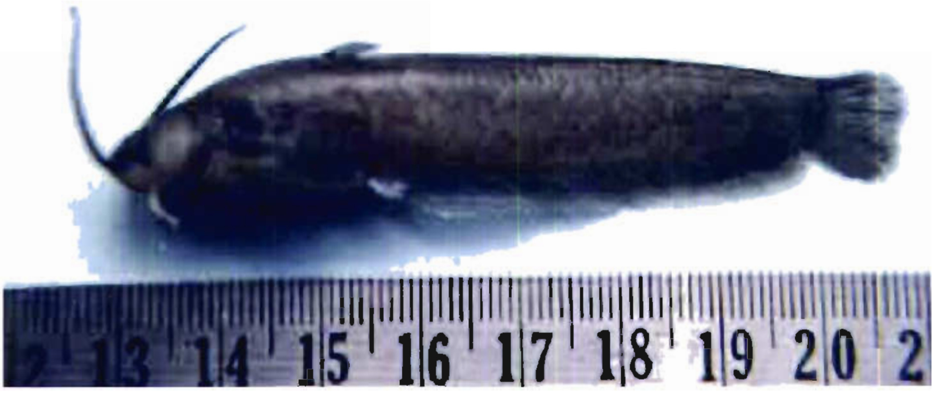
Plate 2

a. *Gonoproktopterus micropogon periyarensis* Raj

b. *Lepidopygopsis typus* Raj

c. *Travancoria elongata* Pethiyagoda and Kottelat

Plate 3

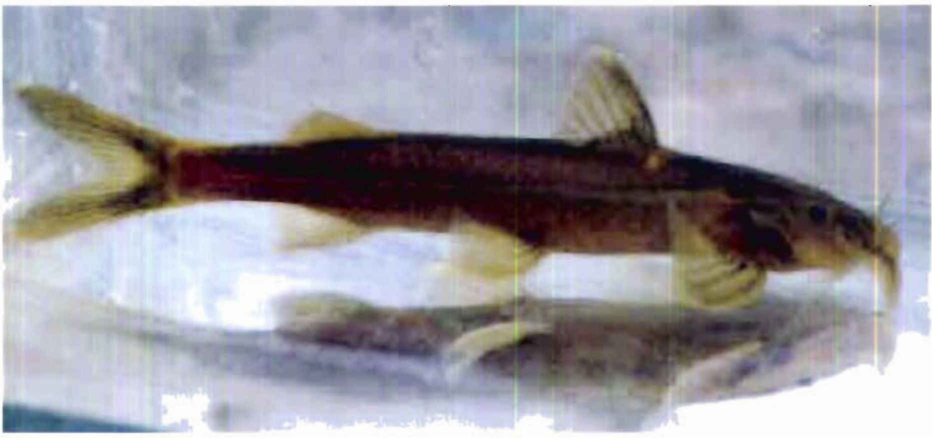


a. ***Silurus wynaadensis*** **Day**

b. ***Cirrhinus reba*** **(Hamilton - Buchanan)**

c. ***Garra periyarensis*** **Gopi**

Plate 4



a. *Glyptothrax lonah* (Sykes)

b. *Gonoproktopterus dubius* (Day)

c. *Horabagrus nigricollaris* Pethiyagoda and Kottelat

Plate 5

a. *Neolissocheilus wynaadensis* (Day)

b. *Osteochilichthys longidorsalis* Pethiyagoda and Kottelat

c. *Osteochilichthys nashii* (Day)

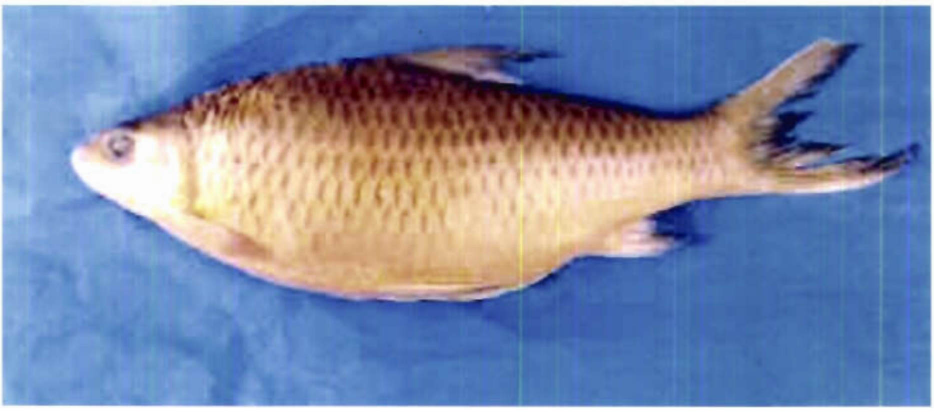
Plate 6

a. *Anguilla bicolor bicolor* McClelland

b. *Barilius bendelisis* (Hamilton - Buchanan)

c. *Gonoproktopterus kolus* (Sykes)

Plate 7



a. *Gonoproktopterus thomassi* (Day)

b. *Nemacheilus semiarmatus* Day

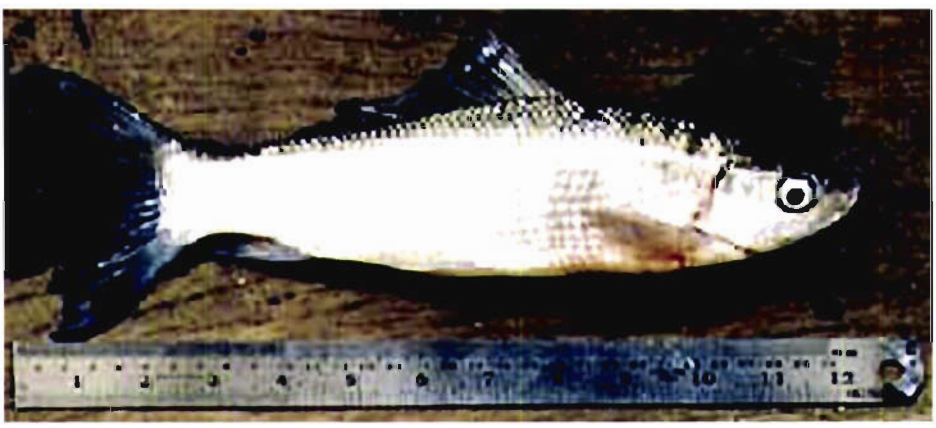
c. *Travancoria jonesi* Hora

PLate 8

a. *Garra hughi* Silas

b. *Glyptothorax annandalei* Hora

c. *Glyptothorax madraspatanam* (Day)



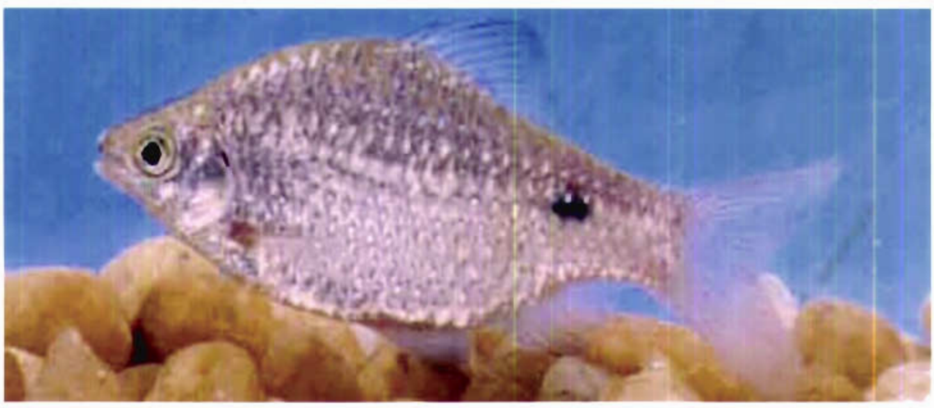
d. *Labeo dussumieri* (Valenciennes)

Plate 9

a. ***Macrognathus guentheri*** **(Day)**

b. ***Notopterus notopterus*** **(Pallas)**

c. ***Osteobrama bakeri*** **(Day)**



d. ***Puntius conchonius*** **(Hamilton - Buchanan)**

Plate 10

a. ***Puntius Ophicephalus*** **(Raj)**

b. ***Sicyopterus griseus*** **Day**

c. ***Wallago attu*** **(Schneider)**

Section II

Bionomics and Resource Characteristics of *Osteobrama bakeri* (Day)

CHAPTER III

SYSTEMATICS OF

Osteobrama bakeri (Day)

3.1. Introduction

The state of Kerala, situated on the South-West coast of India, with its varied geographical and climatic features, has been blessed with rich and diversified fisheries resources. The state abound with extensive inland water spread which are suitable for fish culture, extending over 3.61 lakhs ha, including backwaters (2.43 lakhs ha), reservoirs (0.30 lakh ha), tanks and ponds (0.03 lakh ha) and rivers (0.85 lakh ha) (FRMS, 2002). In spite of having immense scope and potential for the development of 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 protein requirements of the human being and also to meet the emergency demands for the indigenous fishes in the ornamental fish trade industry in recent years, studies on freshwater fishes are gaining momentum in Kerala and other states of India. According to Kurup (2002), of the 170 species of fishes collected from the rivers and streams of Kerala, 66 species are food fishes and 104 species are having all the desirable qualities for propagating as ornamental fishes. The contribution of Kerala to the international fish trade is almost negligible at present when the turn out from the world ornamental fish trade is estimated to be approximately US$ 4.5 billion (Kurup, 1999; Ramachandran, 2002). With judicious tapping of the freshwater fishery resources, Kerala could become one of the leading states in India in ornamental fish trade, thereby generating employment opportunities and *inter alia* increasing export earnings considerably.

Sustainable utilisation of fishery resources calls for rational exploitation of the resources together with the implementation of appropriate conservation and rehabilitation programmes. A scientific database on resource characteristics and bionomics of fishes is indispensable for any programme designed for the management and conservation of fish species of commercial importance.

The fish species selected for the present study, *O.bakeri,* is an endemic species, belonging to the vulnerable category of threatened fishes. It is locally used as food fish and has all the desirable traits of an ornamental fish.

3.2. Description of the species

O. bakeri is a cyprinid fish, which is commonly known as Malabar Osteobrama and locally known as Mullanpaval or Mullanparal (Fig. 3.1).

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	*Osteobrama*
Species	*bakeri*

An endemic species of Kerala, *O.bakeri* exhibits the following diagnostic characteristics.

D iii 8; A iii 12 – 13; P i 12 – 14; V i 10; C 20.

Trapezoid and compressed body with the abdominal edge rounded in front of pelvic fins and trenchant between bases of pelvic and anal fins. Mouth small, subterminal and protrusible; lips thin, lower lip adnate to lower jaw. Jaws moderate, teeth absent on jaws and palate. Pharyngeal teeth in 3 rows. Two small pairs of barbels. Dorsal spine weak and serrated posteriorly. Scales small; lateral line with 43–44 scales. Scale rows $5^1/_2$ between lateral line and pelvic fins. Predorsal scales 15.

Very attractive fish with silvery and iridescent body. Scarlet tinge on dorsal and anal fins. Highly compatible and peaceful in community tanks.

According to earlier reports, the anal fins of this fish possess only 11 branched rays and pectoral fins 12 rays (Day 1875-'78, Talwar and Jhingran, 1991; Jayaram, 1999). However, Shaji and Easa (2001) reported 13 anal fin rays in this species. In the present study, the presence of 12-13 rays in anal fin and 12-14 rays in pectoral fin was encountered. The fish attains a total length of about 110 mm (Talwar and Jhingran 1991; Menon, 1999). In contrast, males measuring a total length of 150 mm and females of 163 mm could be collected during the present investigation.

O.bakeri is generally seen in the middle stretches of rivers, inhabiting the subsurface waters. They were present in shoals along the margin of rivers especially during the monsoon season. They were mainly collected from settlement areas with some crop fields. According to Biju *et al.* (2000), it prefers mud and sand as substrates. However, they also collected it from the moderate hilly areas of Chandragiri River where sand, gravel, cobble and boulders were present as main substrates.

3.3. Earlier reports

A perusal of available literature revealed that genus *Osteobrama* was diagnosed and described by Heckel (1842).

Osteobrama Heckel, 1842. *Ichth. Russegger's Reisen in Europa, Asien and Africa, etc.* 1(1):1033 (type-species, *Cyprinus cotio* Hamilton-Buchanan); Silas, 1952, *Proc. nat. Inst. Sci. India*, 18(5):430 (Status discussed).

Rohtee (*nec* sykes) Hora and Misra 1940, *Rec. Indian Mus.* 42(1):155-172 (Revision).

The previous reports of *O.bakeri* are as follows:

Rohtee bakeri	Day, 1873. *Proc. Zool. Soc.*, 240 (Type-locality: Kottayam in Travancore). Day, 1878. *Fish. India.*, p.586 pt. 147, fig.1(Kottayam in Travancore). Day, 1889. *Faun. Brit. Ind. Fish,* 1:340. Pillay, 1929. *J. Bombay nat. Hist. Soc.*, 33:357 (Travancore). John, 1936. *J. Bombay nat. Hist. Soc.*, 38(4):707 (Manimala River, Kottayam, Travancore). Hora and Law, 1941. *Rec. Indian Mus.*, 43:237 (Travancore).
Osteobrama bakeri	Jayaram, 1981. *Handbook of freshwater fish, India.*, p.113 (Kottayam, Kerala). Talwar and Jhingran, 1991. *Inland fishes of India and adjacent Countries*, 1:237 (Kerala). Easha 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. Ajithkumar *et al.*, 1999. *J. Bombay nat. Hist. Soc.*,96 (2) :251. Jayaram, 1999. *The freshwater fishes of the Indian region,* p.101 Menon, 1999. *Rec. Zool. Surv. India,* Occasional paper No: 175. p.63. Biju *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. Radhakrishnan and Kurup, 2002. *Riverine and Reservoir Fisheries of India*, Society of Fisheries Technologists (India), Cochin.p.165. Thomas *et al.*, 2002. *J. Bombay nat. Hist. Soc.*,99 (1):49.

The genus *Osteobrama* is represented by 7 species in India (Jayaram, 1999) *viz., O. bakeri* (Day), *O. belangeri* (Valenciennes), *O. bhimensis* Singh & Yazdani, *O. dayi* (Hora & Misra), *O. neilli* (Day), *O. vigorsii* (Sykes) and *O. cotio* represented by 3 subspecies, *O. cotio cotio* (Hamilton-Buchanan), *O. cotio cunma* (Day) and *O. cotio peninsularis* Silas. Only two species *viz., O. bakeri* and *O. cotio peninsularis* are recorded from the rivers of Kerala. *O. cotio peninsularis* is the commonest form of Osteobrama in Peninsular India (Talwar and Jhingran, 1991) but its first and the only record from Kerala is that of Biju *et al.* (1999) who collected the fish species from Aluva region of Periyar river. According to Shaji and Easa (2001), *O.bakeri, O.bhimensis, O.cotio peninsularis, O.dayi, O.neilli* and *O.vigorsii* are available in Indian waters. Among them, *O.bakeri* was considered as a rare endemic species of Kerala, known only from the streams of Kottayam, Thattekkad (Periyar Basin) and Chaliyar River. Talwar and Jhingran (1991) described 8 species of *Osteobrama* from India *viz. O.bakeri, O.belangeri, O.cotio cotio, O.cotio cunma, O.cotio peninsularis, O.dayi, O.neilli* and *O.vigorsii.* Except *O.dayi*, all the above seven species were reported by Menon (1999). Among them, *O.bakeri* was treated as a rare fish whose distribution is only known from Kerala. Other species reported so far include *O.brevipectoralis* (Tilak and Hussain, 1989. synonym: *O.belangeri* by Talwar and Jhingran, 1991 and Menon, 1999), *O.alfrediana* (Beavan, 1877. synonym: *O.cotio cunma* by Menon, 1999), *O.microlepis* (Blyth, 1860. synonym: *O.belangeri* by Menon, 1999) and *O.rapax* (Gunther, 1868. synonym: *O.vigorsii* by Menon, 1999).

Ever since the description of *O.bakeri* in 1873 by Day as *Rohtee bakeri*, 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 knowledge on this very rare species having immense ornamental potential, thus has prompted to undertake the present investigation on *O. bakeri* in order to unravel life history traits, resource characteristics and nutritive value of this species. During the period of study from June 2001 to May 2003, the following aspects were dealt with:-

1. Biochemical analysis to understand the nutritive value of fish.

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

3. Reproductive biology to observe the process of gametogenesis, spawning season, sex ratio, fecundity and other related aspects.

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

5. Age and growth to understand the age composition of the exploited stock, age at maturation and life span of the species.

6. 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 undertaken and this knowledge is essential for its judicious exploitation and management.

Fig. 3.1. ***Osteobrama bakeri*** **(Day)**
Monospecies aquarium

CHAPTER IV

BIO-CHEMICAL COMPOSITION

4.1. Introduction

The unique value of fish as an important source of easily digestible, high quality food rich in protein, minerals, vitamins and other organic substances which can supplement the nutritional requirements of man's diet, is well documented. Consumption of 100g of fish per day could provide about 25% of our daily requirement of protein, 10% of fat, half of vitamins and most minerals (Kandoran, 1976). Nutritional studies have proved that fish proteins, besides ranking in the same class as chicken protein (Srivastava, 1985), are better than beef or egg protein (Beveridge, 1947) and are superior to casein in promoting growth (Drummond, 1918). Fish protein is an excellent source of essential aminoacids (Stansby and Olcott, 1963) which are of nutritional significance to adults as well as children. Besides protein, fish form an important source of minerals like calcium, magnesium, potassium, sodium, phosphorous, iron, sulphur and iodine (Srivastava, 1985). The importance of fish oils as the richest known source of vitamins A, B and D is also well established.

Biochemical studies of fish tissues are of considerable importance as they help in evaluating the nutritive value as well as the physiological needs of fishes at different periods of life. The normal composition of an animal is useful in establishing the health and nutritional state of an animal (Hurvitz and Plavnik, 1986). To a commercial aqua-culturist, knowledge of the physiological condition and consequently the health status of fish at different stages can be helpful in reckoning the quality and quantity of feed to be given (Shearer *et al.*, 1994). According to Basimi and Groves (1985) and Dygert (1990), harvest strategies could be planned in such a way that the harvesting is done at a time when the protein is at its highest levels and yield is substantial without being detrimental to the stock. Besides these, the data on the composition of fish is necessary in order to standardise the technology of processing fish and fishery products.

The chemical composition and nutritive values of food fishes were studied by Atwater as early as in 1892. Milroy (1908) made the first careful study on the variation in fat and water content of various tissues and correlated these changes to feeding and spawning cycles of a given population of fish. Drummond (1918) initiated the systematic investigations on the nutritive value of fishes and he isolated the proteins of herring, cod and salmon. Since then a number of works have been published on the proximate composition of several species of fishes. Notable among them from abroad are those of Bruce (1924), Lovern and Wood (1937), Wilson (1939), Hart *et al.* (1940), McBride *et al.* (1959), Thurston (1961), Mannan *et al.* (1961), Love (1970), Love *et al.* (1973), Elliott (1976), Craig (1977), Bird and Potter (1983) and Shearer *et al.* (1994). Works on similar line were carried out extensively in India too. Basu and De (1938) and Saha and Guha (1940) have published an account of the proximate and mineral composition of freshwater fishes of Bengal. Chari (1948) studied the nutritive value of some of the marine food fishes of Madras Province.

The fat variations in mackerel were investigated by Chidambaram *et al.* (1952). Natarajan and Sreenivasan (1961) analysed the chemical composition of 36 species of freshwater fishes of Madras state while Sreenivasan and Natarajan (1961) selected two catfishes *Wallago attu* and *Mystus aor* and a cyprinid *Barbus dubius* for studying the chemical constituents. Other important studies on the chemical composition of freshwater fishes are those of Jafri *et al.* (1964), Khawaja (1966), Jafri and Khawaja (1968), Banerjee and Bagchi (1969), Sharma and Simlot (1971), Siddiqui *et al.* (1973), Bano (1975), Pandey *et al.* (1976), Somavanshi (1979,1983), Masurekar and Pai (1979), Nair and Gopakumar (1981), Bhagowati and Ratha (1982), Sivakami *et al.* (1986), Vijayakumar (1987), Vishwanath and Sarojnalini (1988), Lilabati *et al.* (1993) and Pandey *et al.* (1996). Seasonal changes in the muscle composition and energy contents of male and female fishes of *Tor putitora* were examined with regard to their spawning cycle by Basade *et al.* (2000). Kosygin *et al.* (2001) reported the nutritive value of six economically important hill stream fishes of Manipur. Details on the chief body constituents and the various amino acids and fatty acids present in the muscles of Indian major carps were reported by Sankar and Ramachandran (2001). However, hitherto no information is available on the biochemical composition of *O.bakeri.* Hence a pioneer investigation on the biochemical components of this species was taken up to evaluate its nutritional quality.

4.2. Materials and Methods

Live fishes of *O.bakeri* were collected from Periyar river during the period from June 2001 to May 2002. The muscle tissue was removed immediately from males and females separately. Care was taken to ensure that the muscle was free of bones. Muscle was kept in hot air oven maintained at a temperature of 60-70°C to obtain constant weight and ground into powder using mortar and pestle. Powdered tissue was stored in a desiccators until further analysis.

Moisture and ash contents were determined according to the official methods of AOAC (1990). For evaluation of protein content, nitrogen value was estimated using microKjeldal distillation method (Cutting, 1962). Corresponding values of protein were calculated by multiplying the value of nitrogen by Kirk's conversion coefficient 6.25. Fat was extracted by soxhlet method using solvent ether as the extracting medium (AOAC, 1990). Fat thus extracted was dried and weighed and the results were expressed on wet weight basis. Analysis of variance (ANOVA) was employed to find out significant differences, if any, in the protein, fat and ash contents between males and females of *O. bakeri*. Sodium, potassium and calcium were estimated by flame photometry (Vogel, 1969). Iron was estimated by the method of Wong (1972).

HPLC (High pressure liquid chromatography) analysis was employed for characterisation of amino acid profile. The muscle tissue for amino acid analysis was prepared following the method of Ishida *et al.* (1981). The sample thus prepared was filtered through a membrane filter of 0.45μm to completely remove all the impurities that hinder the chromatographic separation. After appropriate dilution, the filtrate was subjected to HPLC analysis following Ishida *et al.* (1981). 20μl of the sample was injected into a Shimadzu HPLC-LC10AS, fitted with a packed column (ISC-07/S 1504-Na). The column material was a strongly acidic cation exchange resin i.e. styrene divinyl benzene copolymer sulfinic group. The elution buffers used were as described in the HPLC manual. Oven temperature was kept at 60°C. The amino acid identification was done by non-switching flow method and fluorescence detection after the post column derivatisation of amino acids with O-pthalaldehyde. Tryptophan was estimated as per the method of Sastry and Tummuru (1985) after alkali hydrolysis of the sample using 5% sodium hydroxide at 110°C for 24 hours.

4.3. Results

The proximate composition of males, females and indeterminates of *O.bakeri* is given in Table 4.1. The average values of moisture content were highest in indeterminates (77.56%) and lowest in females (75.7%). Protein content of males and females were estimated to be 17.97% and 18.32% respectively while in indeterminates, it was comparatively low with 17.55%. Fat and ash contents were highest in females with 1.6% and 1.4% respectively while it was lowest in indeterminates with 0.6% and 1.2% respectively. Sodium, potassium and iron showed similar trend, being highest in females and lowest in indeterminates. Sodium, potassium and iron concentration were 340, 260 and 1.38mg/100g in females while indeterminates showed 302, 233 and 0.97mg/100g respectively. Highest calcium content was observed in males (31.41 mg /100g) while it was lowest in indeterminates (29.32 mg /100g).

Table 4.2 summarises the monthly variations in the composition of the chief body constituents of males and females of *O.bakeri*. The moisture content of muscle tissue ranged from 74.47 to 77.85% and 74.42 to 76.86% in males and females of *O.bakeri* respectively. Protein content was in the range of 17.12 to 18.89% in males and 17.23 to 19.72% in females. Fat was found to vary from 0.81% in October to 1.16% in April in males and from 1.4% (June) to 1.83% (April) in females. Ash content in males ranged from 1.29% to 1.37% and in females it was from 1.36% to 1.44%. The results of ANOVA test (Tables 4.4, 4.5 and 4.6) showed significant difference in fat and ash contents between males and females of *O.bakeri*. On the other hand, protein content did not vary significantly between the sexes of this species.

Amino-acid composition of muscle tissue of *O.bakeri* is given in Table 4.3. Glutamic acid contributed the major share among the aminoacids with 17.1% followed by Aspartic acid (11.64%). All the essential aminoacids like threonine, valine, methionine, isoleucine, phenylalanine, lysine and trypophan were present in the muscle tissue. In addition, infants require two more essential aminoacids, arginine and histidine and these amino acids were also available in this species. 44.49% of the total amino-acids were contributed by these essential aminoacids. Among them, leucine was present in the highest concentration (8.16%) while tryptophan was the lowest (1.39%). Cysteine was not detected in the muscle tissue of this species.

4.4. Discussion

The concentration of major body constituents of *O.bakeri* compares favourably with other freshwater fishes of India. Natarajan and Sreenivasan (1961) determined the chemical composition of 36 species of freshwater fishes. The moisture content in general varied between 75 and 80%, protein content between 17 and 18%, fat content between 0.17 and 3% and ash content between 1 and 1.5%. Sharma and Simlot (1971) recorded 75-80% moisture, 16-17% protein, 0.97-1.69% fat and 1.08 -1.5% ash in different species of *Labeo* and *Cirrhinus reba*. The values obtained for *O.bakeri* were found to be within the above range except for protein, the values of which were higher ranging between 17.12 and 19.72%. In *Barbus dubius*, Sreenivasan and Natarajan (1961) reported moisture and protein values comparable to that of *O.bakeri* but fat content was slightly higher. The average values of protein in males (17.97%) and females (18.32%) of *O.bakeri* during the present study are in agreement with the observation of Khawaja (1966) who recorded the protein content of muscle tissue of carps as an average of 18%. Sivakami *et al.* (1986) recorded very high moisture content (78.78-87.74%), high fat values (3.06-4.43%) and comparatively low protein concentration (6.38-14.61%) in *Cyprinus carpio*. Protein content of *Puntius filamentosus* was estimated to be low (9.18-15.14%) and fat content slightly higher (1.8-3.52%) (Vijayakumar, 1987). Gopakumar (1997) published the biochemical composition of major freshwater, brackish water, marine and deep sea fish and shellfish species of India. 22 species of freshwater fishes were analysed for their normal composition during the study. The author summarised the normal composition of fish as 65-80% moisture, 15-20% protein, 5-20% fat and 0.5-2% ash. The estimated values for the respective constituents of *O.bakeri* fall within the above range with the exception of fat. However, the same author reported very low fat content for freshwater fishes like *Labeo potail* (0.19%), *Barbus* sp. (0.19%), *Labeo rohita* (0.2%), *Cirrhinus reba* (0.22%), *Labeo calbasu* (0.6%) and *Cirrhinus mrigala* (1%) and slightly higher values of 1.3% and 1.96% for *Catla catla* and *Tor mussullah* respectively. High fat content of 3.15% was reported only in *Cyprinus carpio* and *Puntius sarana*. The fat values registered in males (1%), females (1.6%) and indeterminates (0.6%) of *O.bakeri* in the present study strongly corroborate with that of Gopakumar (1997).

According to Sreenivasan and Natarajan (1961), freshwater fishes with protein content of 16.65-17.93% can be treated as having fairly high nutritive value. Kleiminov (1971) listed some of the table fishes as highly nutritive due to their high protein content ranging between 18.2 and 21.3%. In compliance with the above, *O.bakeri* with protein values between 17.2-19.72% can well be fitted into the group of highly nutritive fishes.

Fat content in the muscle of *O.bakeri* was low throughout the year in both the sexes. Similar findings have been reported earlier by Swift (1955) and Watanabe (1963). According to Srivastava (1985), based on the fat content, fish may be classified into 3 groups : (a) oily or fat with more than 8% fat content, (b) average fat with values between 1% and 8% and (c) lean with less than 1%. It would thus be more appropriate to include *O.bakeri* in the third category of lean fishes since it possesses very low fat values of 0.6 %, 1 % and 1.6 % in indeterminates, males and females respectively.

The results of the present study revealed variations in the fat and protein contents among males, females and indeterminates of *O.bakeri*. Fluctuations in fat content on the basis of feeding habits of fishes have been reported by many researchers. Hornell and Nayudu (1924) correlated the maximum fat deposit in *Sardinella longiceps* to the dinoflagellate and infusorian rich food intake. Venkataraman and Chari (1951) opined that a plankton rich food increases the fat content in fishes. Supporting this view, Sreenivasan and Natarajan (1961) added that the predatory and carnivorous fishes have a lower fat content than the plankton feeding fishes. Venkataraman *et al.* (1968) stated that the quantity of fat in fish is dependent on the nature of their diet. Anney (1988) reported lower values of fat in the carnivorous fish *Megalops cyprinoides* when compared to *Scatophagus argus*, an omnivore. The results of the present study corroborate the above findings as the female *O.bakeri*, an omnivore, showed higher fat content when compared to indeterminates which are carnivorous in their feeding habit.The carni-omnivorous males too registered a lower fat content than the females (Refer Chapter V).

The fat content in the muscle of *O.bakeri* was found to fluctuate seasonally and these variations were more pronounced in female fishes. The fluctuations in fat content have been related to the amount of fat available in the diet and feeding activity of the fish (Hornell and Naydu, 1924; Lovern and Wood, 1937; Venkataraman and Chari, 1951; Chidambaram *et al.*, 1952; Jafri, 1968) as well as gonadal maturation and spawning (Lovern, 1938; Wilson, 1939; Sekharan, 1949). According to Hickling (1947), Idler and Bitners (1960) and Pandey *et al.* (1976), fat reserves stored in muscle, liver and intestine are transferred to the gonads during maturation. Lovern and Wood (1937) stated that in *Clupea harengus*, there is depletion of fat in the lateral muscles during the maturation of gonads. On the other hand, Bruce (1924) and Channon and Saby (1932) stated that there is an increase in fat concentration of herrings during maturation for utilisation in ripe and spawning stages. Durairaj (1962) made similar observations in *Cirrhinus reba*. Jafri (1968) found that the ripening of gonads in *Cirrhinus mrigala* was accompanied by a rapid increase in fat, the highest values being observed during the period of peak ripeness. Similar observations were reported in *Garra mullya* (Somavanshi, 1983), *Trichogaster pectoralis* (Hails, 1983) and *Tor putitora*

(Basade *et al.,* 2000). According to Masurekar and Pai (1979), in females of *Cyprinus carpio*, the increase in fat content in the late maturation stage was followed by a decline to reach the lowest level in the spent stage which is indicative of its utilisation in spawning activity. The fat content decreases during breeding season probably due to high metabolic and physical activity of the animal during this period (Banerjee and Bagchi, 1969 and Pandey *et al.*, 1976). These earlier findings lend support to the present observation on *O.bakeri* in which maximum lipid concentration was noticed in both the sexes during the month just prior to breeding season followed by a sudden decrease during the breeding months of the fish. The lowest fat values recorded in spent stages may manifest that the stored lipids might have been utilised as a source of energy at the time of spawning. It is, however, probable that liver, visceral and mesenterial fat contribute more towards the demands of ovarian maturity than the muscle fat in *O.bakeri* as reported in *Pseudosciaena aneus* and *Johnius carutta* by Rao (1967).

According to Love (1970), an increase in the proportion of any one of the three body constituents *viz.* water, lipid or protein leads to a corresponding decrease of the remaining two constituents, however, the sum remains approximately constant. An inverse relationship between water and fat in the tissues of fishes has been documented by many authors (McBride *et al.*, 1959; Natarajan and Sreenivasan, 1961; Sreenivasan and Natarajan, 1961; Rao, 1967; Jafri and Khawaja, 1968; Venkataraman *et al.*, 1968; Solanki *et al.*, 1976; Vinayak and Neelakantan, 1980; Vijayakumar, 1987; Kingston and Venkataramani, 1994). Love (1970) reported that fatty fishes have lower moisture values. However, such a relationship was not observed in *O.bakeri* in the present study. On the other hand, an inverse relationship was found to exist between water and protein in females (Fig. 4.1) whereas males did not show any such trend (Fig. 4.2). This observation agrees with the views of Sreenivasan and Natarajan (1961), Solanki *et al.*(1976), Ayyappan *et al.* (1976), Somavanshi (1983) and Sivakami *et al.* (1986).

The ash content in general, was found to vary from 1 to 1.5% in many species of fishes (Natarajan and Sreenivasan, 1961; Radhakrishnan *et al.*, 1972; Solanki *et al.*, 1976; Rifaat, 1984; Gopakumar, 1997). In the present study, ash content varied from 1.2-1.4% which falls within the range as reported by the above authors. In general, the high percentage of ash observed in females coincided with the highest percentage of organic constituents and low percentage of water as reported by Somavanshi (1983) in *Garra mullya*.

Mineral content of 19 species of freshwater fishes was estimated by Gopakumar (1997). Potassium content in *O.bakeri* was comparable to those of *Tor mussullah* (250.22mg/100g) and *Barbus* sp. (244.93mg/100g). In all other cyprinids investigated by the above author, except *Labeo calbasu* (310mg/100g), the values were below 170 mg/100g. The calcium value of 30.32 mg/100g recorded in *Cyprinus carpio* and *Puntius sarana* are comparable with that of *O.bakeri* while all other carps were reported to have higher values. Iron content of *Cirrhinus reba* (1.24mg/100g), *Cirrhinus mrigala* (1.1mg/100g), *Catla catla* (1mg/100g) and *Labeo rohita* (1.4mg/100g) corroborated with the values reported in *O.bakeri*. In contrast, the value for sodium in *O.bakeri* was found to be much higher than in all the 19 species reported by Gopakumar (1997). However, it is comparable with the values reported in some of the marine fishes by Ayyappan *et al.* (1976).The calcium content in *Osteobrama belangeri*, collected from Manipur, was reported as 20.7 mg/100g (Viswanath and Sarojnalini, 1988) and this is on a lower side when compared to *O.bakeri*, on the other hand, the iron content reported in the above fish (20.8mg/100g) is on a higher side than *O.bakeri*. Moisture and ash contents were comparable in both species while protein and fat contents were higher in *O.belangeri*, the values being 21.31% and 9.5% respectively. Kosygin *et al.* (2001) suggested that the high protein and fat values in the hill-stream fishes of Manipur may be due to peculiar ecological conditions prevalent in hill-streams especially high velocity of water, high dissolved oxygen and abundant food availability which may enhance the internal metabolism of these fishes. The influence of sex, size, season, age, maturity stages, food and feeding activities, localities and environmental factors on the biochemical composition of fishes had also been reported by many workers (Lovern and Wood, 1937; Rao, 1967; Zinevici, 1970; Dygert, 1990; Geetha *et al.*, 1991; Patil and Kulkarni, 1994; Shearer *et al.*, 1994; Pandey *et al.*, 1996; Basade *et al.*, 2000).

The results of the present study on aminoacid composition of *O.bakeri* revealed that glutamic acid formed the major aminoacid component which is in agreement with that of Gopakumar (1997) and Sankar and Ramachandran (2001). The occurrence of Aspartic acid as the second dominant aminoacid and the concentration of essential aminoacids observed in *O.bakeri* is in accordance with the earlier report for catla, rohu and mrigal by Sankar and Ramachandran (2001). Lysine content in *O.bakeri* was higher than in the freshwater fishes listed by Gopakumar (1997) and also higher than those of rohu and mrigal but comparable to that of catla (Sankar and Ramachandran, 2001). In *O.bakeri,* proline content was higher than in most of the freshwater fishes reported by the above authors. The concentration of essential aminoacid tryptophan in *O.bakeri* was found to be higher than all the 16 freshwater fishes analysed by Gopakumar (1997) and lesser than *L.rohita* and *C.mrigala* (Sankar and Ramachandran, 2001). Cysteine was reported in insignificant amounts in all the fishes investigated by the above authors except in *L.rohita*. The present study revealed the absence of cysteine in *O.bakeri* as in *L.rohita* cited above. Other aminoacids are within comparable range as suggested by Gopakumar (1997) and Sankar and Ramachandran (2001).

The results of the present study on the biochemical composition of *O.bakeri* strongly unfold that the nutritive value of the fish species is high when it is evaluated from the point of view of protein content. The low fat content and high protein content along with the occurrence of all the essential aminoacids make *O.bakeri* a good table fish too.

Table 4.1. Proximate composition in males, females and indeterminates of *O. bakeri*								
	Moisture %	Protein %	Fat %	Ash %	Na mg/100g	K mg/100g	Ca mg/100g	Fe mg/100g
Males	76.07	17.97	1	1.33	324	254	31.41	1.26
Females	75.70	18.32	1.60	1.40	340	260	31.08	1.38
Indeterminates	77.56	17.55	0.6	1.2	302	233	29.32	0.97

Table 4.2. Seasonal variations in proximate composition of male and female *O. bakeri*								
MONTHS	MALES				FEMALES			
	Moisture %	Protein %	Fat %	Ash %	Moisture %	Protein %	Fat %	Ash %
June	76.22	18.72	0.83	1.35	75.48	18.64	1.4	1.39
July	75.42	18.48	1.02	1.34	74.55	18.96	1.49	1.42
August	77.85	17.91	0.9	1.3	76.8	17.72	1.58	1.39
Sept.	76.44	18.14	1.14	1.31	74.45	19.72	1.82	1.44
October	77.23	18.43	0.81	1.34	74.42	19.25	1.56	1.4
Nov.	76.64	17.47	1	1.29	76.7	17.56	1.59	1.36
Dec.	75.82	18.89	1.12	1.34	76.72	17.33	1.48	1.43
January	74.8	17.12	0.96	1.32	76.86	17.23	1.52	1.38
February	74.47	18.06	1.02	1.36	75.81	18.29	1.63	1.4
March	75.81	17.82	1.03	1.37	75.45	18.32	1.71	1.41
April	76.26	17.33	1.16	1.34	75.22	18.89	1.83	1.39
May	75.85	17.25	1.04	1.33	75.92	17.91	1.61	1.38

Table 4.3. Amino acid composition of muscle tissue in *O. bakeri*

Aminoacid	Quantity g/100g protein
Aspartic acid	11.64
Threonine	4.6
Serine	3.9
Glutamic acid	17.1
Proline	5.5
Glycine	4.6
Alanine	6.3
Cysteine	0
Valine	4.3
Methionine	2.1
Isoleucine	4.04
Leucine	8.16
Tyrosine	2.2
Phenyl alanine	4.2
Histidine	3.4
Lysine	7.3
Arginine	5
Tryptophan	1.39

Table 4.4. Analysis of variance on protein content in the muscle tissue of male and female *O.bakeri*						
Source of Variation	**SS**	**df**	**MS**	**F**	**Significance F**	**P**
Between Groups	0.735	1	0.735	1.499898	0.233639415	Non significant
Within Groups	10.78073333	22	0.4900333			
Total	**11.51573333**	**23**				

Table 4.5. Analysis of variance on fat content in the muscle tissue of male and female *O.bakeri*						
Source of Variation	**SS**	**Df**	**MS**	**F**	**Significance F**	**P**
Between Groups	2.154004167	1	2.154004167	144.12802	3.94182E-11	P<0.05
Within Groups	0.328791667	22	0.014945076			
Total	**2.482795833**	**23**				

Table 4. 6. Analysis of variance on ash content in the muscle tissue of male and female of *O.bakeri*						
Source of Variation	**SS**	**df**	**MS**	**F**	**Significance F**	**P**
Between Groups	0.026666667	1	0.026666667	49.230769	4.84783E-07	P<0.05
Within Groups	0.011916667	22	0.000541667			
Total	**0.038583333**	**23**				

Fig.4.1.Relationship between moisture and protein content in female *O. bakeri*

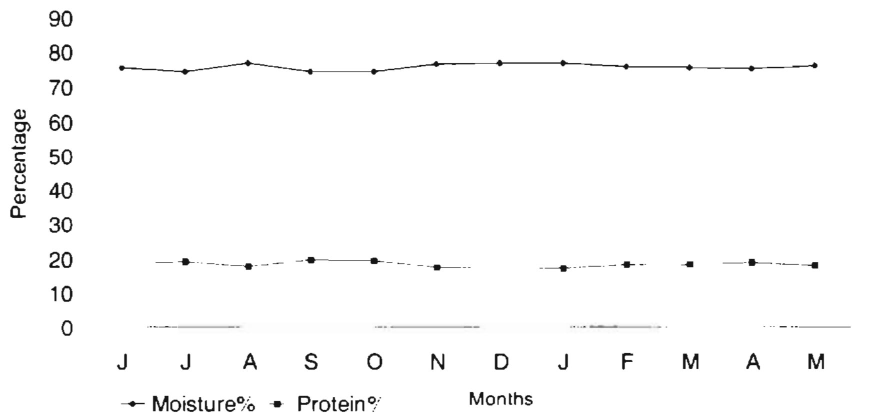
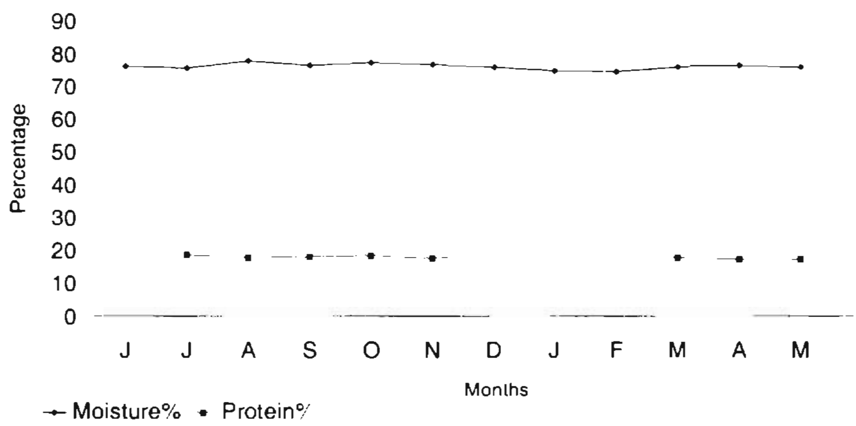


Fig.4.2.Relationship between moisture and protein content in male *O. bakeri*



CHAPTER V

FOOD AND FEEDING HABITS

5.1. 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 its potential use for culture (Royce, 1987). Assessment of the food items and feeding habits is 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 these information, compatibility of different fish species with least inter-specific competition for natural food can be ascertained for farming purposes. It would also be helpful 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 waterborn 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); 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); Nautiyal and Lal (1984); Biswas (1985, 1986); Dasgupta (1988, 1990, 1991); Sharma *et al.* (1992); Nath (1994), Kohli and Goswami (1996), Kishor *et al.* (1998); Basuda and Vishwanath (1999) and Singh and Subbaraj (2000). Nevertheless,reports on the feeding habits of fishes inhabiting the rivers and streams of Kerala are few. Antony (1977) reported the feeding habits of hill-stream fishes of Trichur District while Ritakumari (1977) studied the diets of loaches, *Lepidocephalus thermalis* and *Noemacheilus triangularis*. The food preferences, seasonal and lengthwise fluctuations in the food items and variations in the feeding intensity of *Puntius sarana subnasutus* were analyzed 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 informations 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 the evaluation of this species as a cultivable fish. Mercy *et al.* (2002) described the food and feeding habits of *Puntius melanampyx*, an endemic ornamental fish of Western Ghats. Food and feeding habits of *Osteobrama bakeri* (Day) is hitherto unknown, albeit there are reports on the nutritional aspects of related species. Alikunhi (1957) has stated that the carp minnow, *Osteobrama cotio* was in the habit of scooping the bottom silt along the margins of ponds while feeding. Parameswaran *et al.* (1971), while studying the biology of *O.cotio*, also examined the food and feeding habits. Food and feeding relationships of some commercial fishes of the Tungabhadra reservoir including that of *Osteobrama vigorsii* were analyzed by David and Rajagopal (1975). Nath (1994) has mentioned about the feeding habits of *O.cotio* in his studies on the feeding ecology of fishes of Jammu Province. Basudha and Viswanath (1999) investigated the food composition of various size groups of *O.belangeri*, an endemic carp of Manipur and explained how the anatomical features of the alimentary canal were modified in relation to the food and feeding habits of the fish. The present investigation was undertaken with a view to study in detail the preferred food items of *O.bakeri* belonging to different size groups and sex, their seasonal variations in dietary preference and feeding intensity, if any, and also examine the morphological peculiarities of the digestive system, commensurate with the mode of feeding in this species.

5.2. Materials and Methods

Specimens for the study were collected from Periyar River using gill net during the period from June 2001 to May 2003. A total of 725 specimens comprising of 398 males (100–150 mm TL), 287 females (105–163 mm TL) and 40 indeterminates (89–117 mm TL) were examined. After recording the total length (mm) and weight (g), the fishes were dissected to determine the sex and fullness of stomach. The entire gut was preserved in 5 % formalin for detailed examination.

The extent of feeding can be judged by the degree of fullness of stomach or from the amount of food contained in it. The degree of distension of gut was expressed as gorged (50 points), full (40 points), ½ full (20 points), ¼ full (10 points), trace (5 points) and empty (0 points), following Kurup and Samuel (1988). The gut was considered 'gorged' when it was packed with food and stretched fully with thin, transparent walls, 'full' when filled with food but the walls thick and intact and '¾ full' when the gut was partly collapsed and with thick walls. Depending on the amount of food present and the collapsed nature of the gut wall, it was further designated as ½ full, ¼ full, trace and empty.

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

$$GSI = \frac{\text{Weight of the gut}}{\text{Total weight of the fish}} \times 100$$

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

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

The contents of the intestinal bulb and intestinal proper were taken out separately for the analysis of food components. The percentage composition of the diet was determined following the occurrence method as described by Hynes (1950). The 'Index of Preponderance' (Natarajan and Jhingran, 1961), which accounts both the frequency of occurrence of food items as well as its size into consideration, was employed to assess the food preferences of males, females and indeterminates. The Index of Preponderance was resolved by the formula:

$$I = \frac{V_iO_i}{\sum ViOi} \times 100$$

where I = Index of preponderance of the food item.

V_i = Percentage of volume index of the food item

O_i = Percentage of occurrence index of the food item.

The points (volumetric) method, described by Pillay (1952) was used for estimating the volume index. The fullness of stomach was also taken into account in the allotment of points (Frost, 1943). The points gained by each food item altered proportionally to the total points allocated for the stomach. The food components were identified upto the generic level or group depending on the state of digestion.

Standard fixatives and staining techniques were used for histological studies. Small pieces of intestinal bulb, intestinal proper, rectum and liver from freshly killed fishes were fixed in Bouin's fluid. Serial sections cut at 4 – 6 µm were stained with Harri's haematoxylin followed by eosin counterstain.

5.3. Results

The mouth of *O.bakeri* is sub terminal and protrusible in nature. Lips are thin and the lower lip is adnate to lower jaw. The moderately built jaws and palate are devoid of teeth. Pharyngeal teeth, which are very small, are the only teeth present in the fish. The floor of the buccal cavity has a muscular raised portion, analogous to the tongue of other vertebrates. The pharyngeal cavity is bounded laterally by the gill arches. Gill rakers are moderately long. Posteriorly pharynx constricts to form a short muscular oesophagus which opens into the intestinal bulb. *O.bakeri*, being a cyprinid, lacks the conventional stomach and the anterior part of the intestine is dilated to form the intestinal bulb. The intestinal proper is coiled around the bulb, thus concealing it from view. The intestinal proper can be divided into 4 sections. Soon after its origin from the intestinal bulb, the first section proceeds anteriorly parallel to intestinal bulb and on reaching the middle of the intestinal bulb deviates to the left to continue forward. Anteriorly it curves and extends posteriorly as section II. At the level of the 1st section turning left, the 3rd section commences. It is in the form of an inverted 'U' shaped loop and lies within the space between the 1st and 2nd sections. This loop is connected to a tapering rectum by the 4th section of the intestine which is a straight region running parallel to the 1st section of the intestine. Rectum opens out by anus just in front of the anal fin.

Liver is asymmetrically lobed, the left lobe being smaller than the right and incompletely separated from each other. Gall bladder, a small oval sac, opens into the intestinal bulb just behind the oesophagus and the green coloured bile imparts green colour to it.

Histological studies revealed that the structure of the gut is uniform throughout but for the variations in the number and depth of mucosal folds, shape of the cells and the thickness of musculature. The wall of the intestinal bulb, intestinal proper and rectum consists of mucosa, lamina propria, submucosa, muscularis and serosa. The mucosa is thrown into numerous thin folds called villi. The mucosa of the intestinal bulb (Fig. 5.1a and 1b) is characterized by the presence of deeper mucosal folds than those in the remaining portion of the intestinal tract. The number of folds gradually decreases towards the posterior rectum region. The single layer of epithelium is characterized by the presence of taller columnar cells and more numerous goblet cells.

Lamina propria comprises of loosely arranged network of connective tissue with capillaries and lymph sinuses and extends into the core of the mucosal folds as well. Submucosa, a thin layer of loose connective tissue is traversed by lymph sinuses. The muscularis is made up of inner thicker circular and outer thinner longitudinal layer of smooth muscle fibres. The outermost layer, serosa, is a very thin layer. The villi of intestinal proper are less in number and depth (Fig. 5.2a and 2b). Goblet cells are of fewer occurrences. Between the lamina propria and the small area of submucosa lies a thin layer of muscularis mucosa. Rectum, though not sharply demarcated from the intestinal proper externally, has shorter and broader mucosal folds not forming distinct villi, thicker lamina propria, prominent musculature and large lumen (Fig. 5.3a and 3b). Goblet cells are numerous and the epithelium has a thick basement membrane. Submucosa is provided with lot of lymph sinuses.

Liver is made up of characteristic polyhedral hepatic cells (Fig. 5.4). Each hepatic cell has granular cytoplasm and a prominent round nucleus. They are arranged in irregular cords between which blood sinuses are located. Hepatic ductules are scattered through the liver tissue. Each ductule has a lining of epithelium surrounded by connective tissue sheath. The ductules join together to form hepatic ducts.

The relative gut length (RLG) in different length groups of *O.bakeri*, ranged from 0.74 to 0.89 in indeterminates, 0.86 to 0.95 in males and 0.86 to 1.05 in females (Fig. 5.5).

5.3.1. General diet composition of *O. bakeri*

Analysis of gut contents showed that food items could be assorted into 14 groups (Table 5.1). Insecta was the most predominant dietary item recorded from the gut of the fish round the year represented by five orders: Diptera (*Chironomous* larvae and pupae, *Tanypus* and *Ablabesmiya* larvae), Hemiptera (*Corixa*, *Micronecta*) Ephemeroptera (Mayfly nymphs), Coleoptera (Hydrophilus larvae) and Odonata (Dragonfly nymph). Larvae of *Chironomus* and *Tanypus* were most predominant among them (50–60%). The occurrence of aquatic bugs *viz.* *Corixa* and *Micronecta* were found mainly during the rainy season.

Cladocerans, epitomized by *Daphnia*, *Moina* and *Bosminia*, were the dominant items next to insect larvae. Copepods also formed a major food item. *Cyclops*, *Diaptomus* and harpacticoids were found in varying proportions in the gut content.

Ostracods *(Cypris)* were regularly encountered in the gut of the fish species. Water mites were the arachnids seen in the gut contents but at no-time formed a significant part of their diet. Their larvae, which were only occasionally seen in the gut, are parasitic on other insects and host specificity has not been observed as a general rule. Hence it is probable that they were ingested along with the various insects consumed by the fish.

Among Chlorophyceae, *Oedogonium* (46%) was the most common item. *Cosmarium*, *Ulothrix*, *Spirogyra*, *Closterium*, *Chlorococcum*, *Scendesmus*, *Hydrodictyon* and *Zygnema* were the other algae present. Dinophyceae and Xanthophyceae were found to occur in meagre amounts in the diet. Dinophyceae was represented by *Massartia*, *Gymnodinium* and *Ceratium* while *Ophiocytium*, *Meringosphaera* and *Vaucheria* belonged to Xanthophyceae. *Chrysococcus* was the only representative of Chrysophyceae and was graded as the least preferred food item of this species.

Bacillariophyceae constituted an important food item of *O.bakeri*. *Pinnularia*, *Navicula*, *Gomphonema*, *Melosira*, *Cymbella*, *Fragillaria*, *Anacystis*, *Meridion*, *Nitzchia*, *Biddulphia*, *Pleurosigma*, *Diatoma*, *Rhizosolenia*, *Synedra* and *Bacillaria* were the 15 genera of this group identified from the gut contents. *Pinnularia* was the dominant diatom (48%) followed by *Navicula* (32%).

Among Myxophyceae (Cyanophyceae), *Oscillatoria* was abundant in the diet (41%) followed by *Merismopedia* (34%). *Nostoc*, *Anabaena* and *Lyngbya* were also encountered in the gut.

Semidigested plant matter comprised of fragmentary parts of leaves and stems of aquatic plants and other unidentified vegetable matter. Unidentified animal matter, which was in a semidigested state, formed 4.89 to 6.24% of the gut contents (Fig.5.6b and 6a). All the other items in the gut like protozoans, fish eggs, shell matter, crustacean and insect appendages, spicules of plants and sand particles were treated under miscellaneous matter and made upto 4.65 to 5.74% (Fig. 5.6b and 5.6c).

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

The food of males, females and indeterminates 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 Figs. 5.6. a, b and c respectively. The index of preponderance for different food items in indeterminates is presented in Table 5.6. The study revealed that the food preferences of males and indeterminates were similar with variations in the magnitude of different food items consumed. Insect larvae and adults, cladocerans, copepods and diatoms were preferred in that order. Insecta contributed to 22.13% in males and 24.26% in indeterminates. Cladocerans and copepods, with respective values of 21.65% and 18.37%, were more abundant in indeterminates as against 17 12% cladocerans and 16.37% copepods in males. The preference for diatoms was found to be higher in males (13.95%) than in indeterminates (10.73%). Insecta (19.74%) formed the favourites group of food in females. Cladocerans (15.55%) and diatoms (15.32%) were consumed almost equally, followed by copepods (13.96%). Arachnida, Dinophyceae, Chrysophyceae and Xanthophyceae were not encountered in the gut of indeterminates. In males and females, these groups formed a minor category. Semidigested animal matter was more and plant matter was less in indeterminates when compared to males and females. An overall assessment of the vegetarian and non-vegetarian food components in the diet revealed that 76.6% of the diet in indeterminates was constituted by animal matter, 18.58% plant matter and 4.82% miscellaneous. In contrast, animal matter contributed to 64.99% and 58.91% of male and female diet respectively. 30.39% in males and 35.37% in females were represented by vegetable food items.

5.3.3. 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 values, for the years 2001-'02 and 2002-'03 are given in Tables 5.2, 5.3, 5.4 and 5.5. During 2001-'02, Insecta formed a regular food item throughout the year in males with highest occurrence in April with an index value of 29.96 and minimum in December, the value being 22.28 (Table 5.2). Cladocerans were more in proportion than copepods during the entire period except in the month of July when both were found to occur more or less in the same proportion. The index value for ostracods ranged between 0.93 in October to 2.62 in June. Arachnids, which were never important as a food component, were absent from the diet in March. Chlorophyceae were most abundant in March and least in occurrence in July. Dinophyceae, with index value from 0.19 (November) to 0.97 (August), was lacking in the diet in December. Xanthophyceae was not represented during the months of April, May and December while Chrysophyceae were recorded only in October-November and January-February months. Diatoms were plentiful in May (15.82) and March (15.24) and lowest in October (12.64). Highest amount of Myxophyceae was encountered during May.

Semidigested animal matter was found to exceed the plant matter during all months of the year. The pattern of variation was on a similar line during 2002-'03 also with minor variations (Table 5.3). The quantity of insect intake was more with a corres-ponding decrease in the consumption of cladocerans and copepods. An increase in the consumption of diatoms was evident during most of the months.

Insecta was the most preferred food item of females in all the months during 2001-'02 (Table 5.4). They were found in significant quantities during April to July. Copepods were found to be maximum in July (17.79) and minimum in February (9.28). Cladocerans were fairly abundant during June to January. The index values of ostracods ranged from 0.56 in October to 2.12 in August. Arachnids, with very low index values, were absent in the gut in May. Chlorophyceae varied between 5.67 (November) to 13.25 (March). Diatoms appeared as an important component in the diet during most of the months, 18.56 (April) and 13.68 (December) being the highest and lowest index values recorded. Myxophyceae was moderately high during February, April, May and June. Semidigested plant matter was more in proportion than animal matter in July-August, October-November, January and March and during the rest of the months, vice-versa. During 2002-'03, Insecta were plentiful in the diet in April (31.32) (Table 5.5). Arachnids were absent in October. Diatoms were more abundant during the second year with highest values in February (19.88) and minimum in April (16). Semidigested plant matter was present in higher proportions from June to August and November-December when compared to animal matter.

Dinophyceae formed a small category of food item during both the years. Xanthophyceae was absent from the gut in July, August and December 2001-'02 and June and March in 2002-'03. Chrysophyceae, represented in negligible quantity, were encountered in the diet only very occasionally. Cladocerans and copepods were ingested in lesser amounts from February to May when compared to the rest of the months during both the years. In males, a decrease in the proportion of insects in the food was discernible in the months of October, December, January 2001-'02, September-October and December-January 2002-'03. In females, a similar decrease was seen from October to January during 2001-'02. However, no similar trend was observed in the subsequent year.

5.3.4. Feeding Intensity

5.3.4.1. Guts in different degrees of fullness

The data on the percentage occurrence of guts in different degrees of fullness in males and females of *O.bakeri* during the years 2001-'02 and 2002-'03 are depicted in Figs. 5.7, 5.8, 5.9 and 5.10 respectively.

In males, gorged guts were present only in May during 2001-02. The occurrence of '¾ full' and '½ full' guts was recorded throughout the year. Dominance of '¾ full' guts was seen in May (38.89%) and '½ full' in March (40%) whereas the presence of '¼ full' guts was observed in all months except March. Guts with traces of food were not encountered during October and May while empty guts were encountered from November to March and June with the highest percentage in November (30%). During 2002-'03, 'gorged' guts were not observed while fishes with '¾ full' guts were present throughout the year. Highest percentage of occurrence of '¾ full' guts was observed in April and May (50%) while it was least in November (11.11%). Fishes with '½ full' guts were observed throughout the year except April. Incidence of '¼ full' guts was invariably high during June (48.57%) followed by August (33.33%), February (33.33%) and March (31.25%). However, '¼ full' guts were absent during April and May. Empty guts were observed during June, July, October, November and March with a preponderance in November (33.33%).

'Gorged' guts were encountered in females in May during both the years. During 2001-'02, fishes with 'full' guts were observed during July, August, December, April and May with a highest frequency of 33.33% in May. Fishes with '¾ full', '½ full' and '¼ full' guts were encountered during all the months. The highest percentage of '¾ full' guts was noticed in December (40%) while it was lowest in November and February (11.11%). '½ full' guts were abundant in June, August and December (33.33%) and lowest in March (7.14%). The dominance of '¼ full' guts, compared to the other categories, was evident during most of the months, the maximum and minimum values being 44.44% in February and 8.33% in May respectively. The 'Trace' and 'Empty' guts tended to occur together and were observed from September to November and January to March. The feeding pattern was more or less similar during the succeeding year 2002-'03 with some minor variations.

Contrary to the previous year, fishes with '¾ full', '½ full' and '¼ full' guts were totally absent in January while presence of 'full' gut was recorded during this month. So also empty guts were reported in December, however the same was absent in January. The highest frequency of 'empty' guts was encountered in November during both the years.

5.3.4.2. Gastro-somatic Index (GSI)

Monthly variations in gastro-somatic index of male and female *O.bakeri* during 2001-'02 and 2002-'03 are shown in Figs. 5.11 and 5.12 respectively. The pattern of variation was more or less similar in males during both the years. The GSI values gradually increased from June to September and were moderately high. During 2001-'02, there was a sharp increase in GSI in October, registering the peak value of 1.88, followed by a steep inflexion in November, touching the lowest index value of 0.79. On the other hand, during 2002-'03, a gradual decrease in GSI was observed in October and the lowest value of 0.96 was recorded in November. Thereafter, the GSI showed irregular pattern with ups and downs during both the years. Low index values were recorded in February and March. In females, during 2001-'02, GSI was moderately high during June to August, thereafter it gradually declined to the lowest in November (0.89), and increased again in December. This was followed by a gradual decline upto March and thenceforth increased to attain the peak value of 1.81 in May. The trend was more or less same during 2002-'03, except for the minimum values recorded in March (1.0) and February (1.1).

Lengthwise variation in GSI of males, females and indeterminates is depicted in Fig.5.13. In males, an initial low GSI value (1.64) was found in 100-105 mm TL group, followed by an increase in the next size group (2.17), thenceforth a gradually decreasing trend was discernible upto 125mm TL. A slight increase in GSI was registered in 125-135mmTL size group, thereafter the value declined again to the lowest of 0.73 in 135-140 mm TL group. High GSI values were observed in male fishes above 140mm TL. In females, the highest GSI value of 2.56 was in the smallest size group of 105-110mm TL, thenceforth it declined sharply in 110-115 mm TL group (1.65) and increased slightly in the 115-120 mm length group. Thereafter, a gradual decrease was evident upto 145 mm TL followed by an intermittent increase and decrease in the values. The lowest GSI value (0.8) was recorded in the largest size group of 160-165 mm TL. In indeterminates, the highest value of 3.86 was recorded in the smallest group (85-90 mm TL) while the values were low in larger groups. Generally, higher GSI values were observed in females when compared to their male counterpart while indeterminates showed a definite surpass over males.

It is worth noticing that males and females follow almost similar trends in feeding intensity as indicated by gastro-somatic index during both the two years with minor variations (Fig.5.14 and 5.15). The only striking difference was the intense feeding in males in October 2001-'02, in contrast, the feeding intensity of female was low during this month.

5.4. 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 sub-terminal and protrusible mouth seen in *O.bakeri* are well adapted to suit its column feeding habit. According to Gupta *et al.* (1999), the column feeders are characterised by sub-terminal mouth. Protrusibility of mouth is well described as an adaptation for handling the prey in carnivores and for picking up food from soil or crevices in others (Alexander, 1967). It is generally accepted that dentition and gill rakers show remarkable correlation to the type of feed and feeding. Carnivores possess strong teeth in jaws and other parts of the buccopharynx and also tooth-like gill rakers, in contrast, herbivores are characterized by the absence of teeth on jaws and palate and presence of well developed pharyngeal teeth and numerous elongated gill rakers. On the other hand, omnivores show an intermediate condition (Shafi, 2000). Adults of *O.bakeri* showed feebly developed tongue represented by the raised portion of the buccal floor, absence of teeth in jaws and palate and presence of pharyngeal teeth and moderately developed gill rakers and these would definitely unfold its omnivorous mode of feeding habit. Mucus secreting activity was pronounced in the regions of pharynx and oesophagus. Mucus aids in trapping, lubricating, softening and easy swallowing of food (Dalela, 1969; Gupta *et al.*, 1999). Intestinal bulb of the fish species can be considered as an analogue of food storing stomach (Barrington, 1957; Islam, 1951;

Khanna, 1961; Mohsin, 1962 and Bullock, 1967; Yadav, 1999). According to Caceci (1984), mucosal folds are specifically modified in different areas of the intestine. The mucosa of intestinal bulb of *O.bakeri* possess deeper and slender villi which gradually decrease in depth as well as number posteriorly and finally appearing as short, broad folds in the region of rectum. Hofer (1988) stated that the intestine of cyprinids is characterized by a well developed mucosal surface in the foregut which is getting diminished towards the anus. Mucosal folds increase the surface area for secretion and absorption and/or help in food retention thereby increasing the efficiency of digestion (Junger *et al.*, 1989). Mucus secreting cells, abundant in the intestinal bulb, are fewer in the intestinal proper and again increase numerically in the rectum. Secretion of copious mucus in rectum lubricates the faeces and help in easy defaecation (Martin and Blaber, 1984; Khanna, 1992). Liver of *O.bakeri* is structurally identical to those of other teleosts (Kapoor, 1953; Shafi, 2000). Pancreas is extra-hepatic as described by Weinreb and Bilstad (1955) in rainbow trout, *Salmo gairdneri irideus*.

The coiling of intestine is regarded as a specific feature of herbivores and omnivores. In *O.bakeri*, the intestine is moderately elongated and coiled and represents an intermediate condition between the short straight tube of carnivores and highly coiled condition of herbivores. 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 carnivorous fishes are generally short, on the other hand, that of omnivores are comparatively longer whereas in herbivores, it is still longer. Suyehiro (1942) pointed out the difficulty in forming any definite opinion on the relationship of the gut length with the nature of the food as several fishes are omnivores and the fluctuating features of the intestinal length eliminate the possibility of any precise generalization. Barrington (1957) opined that in addition to diet, several other factors are responsible for the variations in the gut length. Al-Hussaini (1949) suggested that it is the total functional surface area of mucosa that bears a relationship with the feeding habits of fishes. A short gut can achieve a large mucosal surface area with longer and complexly folded mucosal villi. According to Nikolsky (1963), in cyprinids, gut length less than 100% of body length indicates 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 omnivorous whereas RLG value of 2.053 was recorded in a herbivorous species. Among the species with short guts, the authors found that some were exclusively carnivorous while some are predominantly carnivorous and consumed some plant matter also. The same authors also postulated that the latter condition might be true for fishes with intermediate gut length. In the present investigation, RLG values of 0.74 to .89 in indeterminates indicate the tendency towards carnivory. Males with RLG values 0.86 to 0.95 and females with values 0.86–1.05 indicate carnivory/omnivory. In *O.bakeri* , the RLG values in indeterminates as well as both sexes gradually increased with increase in total length of the body. An increase in RLG value with the growth of fish together with the presence of high proportion of vegetable matter in the gut has been reported by many earlier workers (Girgis, 1952; Das and Moitra, 1958; Biswas, 1985; Dasgupta, 1988, 1990, 1991, 1996; Kurup, 1993; Gupta *et al.*, 1999; Basudha and Vishwanath, 1999).

The pH condition of the gut has direct influence on the physiology of digestion and mucus alters slightly the pH (Shafi, 2000). The author stated that the pH of the stomach content is invariably acidic while the intestinal bulb content of stomachless cyprinids is alkaline in nature. The abundance of mucus cells in the intestinal bulb of *O.bakeri* might be related to the maintenance of optimum pH for the proper functioning of the digestive enzymes in the bulb. Saigal (1967) reported an interesting phenomenon of higher mucus secretion in the stomach of *Mystus aor* whenever insects formed the dominant food item,however, it declined when fishes constituted the major food item. He opined that the higher mucus secretion was probably related to the digestion of complex insect matter. Incidentally, insects formed the favourite food item of *O. bakeri*.

The results of the gut analysis in *O.bakeri* revealed that there exists a strong preference towards some food items in indeterminates, males and females. Insecta, especially larvae of *Chironomus* and *Tanypus* formed the most preferred category of food, regularly consumed by all fishes irrespective of sex and size, followed by cladocerans. Copepods and diatoms were the respective of 3^{rd} and 4^{th} preferential prey groups of males and indeterminates. On the other hand, cladocerans and diatoms were consumed in approximately equal percentages by the females while copepods were the next item of food. In indeterminates, ostracods were the next predominant group while in males and females, it was chlorophyceae. 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 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, Insecta, Cladocera and Copepoda could be discerned as the basic food in males and indeterminates while Bacillariophyceae, Chlorophyceae and Ostracoda were the secondary food items. Myxophyceae formed a part of secondary food in males whereas it appeared as an incidental food in indeterminates. In females, basic food included Insecta, Cladocera and Bacillariophyceae while the secondary food comprised of Copepoda, Ostracoda, Chlorophyceae and Myxophyceae. Arachnida, Dinophyceae, Xanthophyceae and Chrysophyceae could be reckoned as the incidental food of males and females.

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 types and 3) monophagic – feeding on only one type of food. The indeterminates of *O.bakeri* were found be more or less selective in their feeding, subsisting mainly on four categories of food items, namely, Insecta, Cladocera, Copepoda and diatoms which represented 75% of their diet whereas males and females fed on a variety of dietary items and therefore, could be categorized as euryphagous in their feeding habits.

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 from Uttar Pradesh 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 variations in their percentages 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 *O.bakeri* in the light of the above categorisation, it appears that this species belonged to omnivorous group. Singh and Subbaraj (2000) reported that when animal matter constitutes over 75% of the diet, the fish can be referred to as carnivore. 76.6% of the diet in indeterminates was of animal matter, indicating their carnivorous nature. As the animal food was found to be more than vegetable food, males can be categorised as carni-omnivores. In contrast, females consumed only 58.91% of animal matter and therefore, can be demarcated as omnivores.

Based on the trophic niches fishes occupy in the water *i.e.* particular water levels where their favourite food items are available, Das and Moitra (1955) divided freshwater fishes into 3 secondary groups: 1) surface feeders 2) mid-feeder or column feeders 3) bottom feeders. Subsequently one more category was incorporated as marginal feeders (Biswas, 1992). The column feeders are peculiar in that they ingest both surface and bottom food organisms like algae, insects, adult crustaceans, fish, aquatic plants, mud, sand, etc., in addition to characteristic column organisms. Surface feeders are mainly omnivorous or carnivorous while mid- and bottom-feeders are herbivores, omnivores or carnivores (Das and Moitra, 1955). On the basis of the results of gut content analysis, the sub-terminal position of mouth and other morpho-anatomical features of the fish species, it can reasonably be asserted that *O.bakeri* is a column feeder. Observations on the feeding habits under aquarium conditions have shown that the fish takes food mainly from the water column and occasionally from the bottom. Further, field observations on the fish species disclosed that *O.bakeri* appeared in shoals along the margins of the river whenever the water became turbid, especially during the rainy season and were found to be feeding on the river margins with their protrusible mouth. Once the water became clear, they were back to the middle deeper regions of the river. According to David *et al.* (1969), the frequent occurrence of ostracods as an item of food in the gut is indicative of marginal feeding habit. Ostracods were eaten regularly by *O.bakeri* even though at no time it formed a significant part of their diet. The regular presence of this food in the guts of this fish species manifests the possibility of browsing habit on the margins of the river for feeding purposes. The fish thus appeared to be a "marginal cum column feeder" as reported by Nautiyal and Lal (1984) in *Tor putitora*. Alikunhi (1957) stated that *Osteobrama cotio* scoops the bottom silt along the margins of ponds with its protrusible lips in search of prey, making small pits during this process.

A comparison of the food habits of *O.bakeri* with that of other related species revealed similarities as well as variations in the diet. *O.cotio* of Jammu province was assessed as an omnivore consuming 58% animal food and 32% plant food (Nath, 1994). This is in conformity with the present findings of 58.91% animal food and 35.37% plant food in the females of *O.bakeri*. Parameswaran *et al.* (1971) asserted the zooplanktophagus nature of *O.cotio* from Assam on the basis of gut content analysis in which 85% of the food was found to be constituted by zooplankton and 9.4% by phytoplankton while the rest was made up by detritus in smaller fishes. In addition to this, mud, small quantities of insects and worms were also seen in the guts of adults. David and Rajagopal (1975) considered *Osteobrama vigorosii* as carnivore. Dominant food item was fish and accounted for 50.8% with a range of 17.2 to 96.8%. Insects, ranged from 0.8 to 53.9% and occupied the 2nd position followed by decayed organic matter (19%). Basudha and Viswanath (1999) observed that *Osteobrama belangeri* of Manipur was an omnivorous fish, feeding mainly on zooplankton, insects and worms (40–60%) in juvenile stage. However in adults a higher preference for plant food (40–60%) was seen followed by insects (20%).Environment plays an important role in governing the food and feeding habits in different fish stock and population (Kishor *et al.*, 1998). Desai (1992), while studying the food and feeding habits of Mahseer from four different localities, found that the diets differed depending on the availability of food. The results of the present study showed that the female of *O.bakeri* is omnivorous in feeding habits and their feeding is similar to that in *O.cotio* of Jammu Province. In contrast, the carni-omnivorous nature of males is in agreement with the smaller *O.belangeri* while the carnivorous mode of feeding seen in indeterminates shows strong agreement with that of *O.vigorosii.*

While analysing 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 the same, there was conspicuous variance in the percentage of occurrences of different food items. Animal matter was found abundant in indeterminates; in contrast, it was least in females whereas plant matter showed a reverse trend. Feeding on some food items at various rates might be an adaptation to minimise intra-specific competition for food (Wijayaratne and Costa, 1988; Kiran and Waghray, 1998).

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 insects, cladocerans, copepods and diatoms during almost all months of the year. It appeared that among the four major groups of food items, a decrease in any of the category was duly compensated by another group. For instance, during 2001-'02, males consumed cladocerans and copepods abundantly and insects and diatoms in relatively small quantities whereas the females showed a reverse situation. Interestingly, during 2002-'03, there was higher percentage of occurrences of insects in males while in females abundance of cladocerans, copepods and diatoms were found. However, there was no variation with regard to the minor components of the diet in males and females during both the years.

The feeding intensity was found to be moderate as higher proportions of ¾ full, ½ full and ¼ full guts were observed. Gastro-somatic index showed an inverse relationship with the occurrence of empty guts. Feeding intensity of fish is 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 *O.bakeri*, 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 preponderance of guts with low degrees of fullness. Higher feeding intensity observed during April-May, which represented one of the spawning seasons of this species, 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. In males, feeding intensity had an upward trend during the pre-spawning period of August and September till it reached maximum in October in 2001-'02 whereas October 2002-'03 showed a downward trend. Feeding activity was very low in November when probably all the fishes completed spawning. Geevarghese (1976, 1984) observed similar phenomena in gobiids, *Glossogobius giuris* and *Oligolepis acutipennis* and ascribed high feeding activity to the extra requirements of energy and low feeding to the exhaustion caused by spawning. 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. The pre-spawning fasting of males during February-March may be due to some other reasons beyond explanation. 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.* (1962) has 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 *O.bakeri*.

Gastro-somatic index indicated higher percentage of feeding among indeterminates than the mature specimens. Females consumed more food than the males. The high feeding rate in indeterminates might be due to higher metabolic activities in young ones (Marshall *et al* 1939; De Silva, 1973a; Dasgupta, 1991). Higher feeding intensity in females compared to males had been reported by Pandian and Rahman (1999) in *Etroplus suratensis*. The highest feeding intensity was observed in the maturing stage of male and female *O.bakeri* as they approached the size at first maturity. Similar finding was reported by Khan *et al.* (1988) in *Mystus nemurus*.

Influence of feeding intensity on condition factor was clearly evident during some of the months in both the sexes of *O.bakeri*. This aspect has been dealt with in detail in Chapter 7 on 'Length-Weight relationship and condition factor'

Studies on the food and feeding habits of *O.bakeri* revealed that the fish is "marginal cum column feeder" Males of *O.bakeri* are carni-omnivorous while females are omnivorous whereas indeterminates are carnivorous in nature. Basic food includes Insecta, Cladocera and Copepoda in males and indeterminates while in females copepods are replaced by diatoms. For domestication of *O.bakeri* as an ornamental fish, it is advisable to provide live feeds comprising of Chironomous larvae, Cladocerans, Copepods and Artemia.

Table 5.1. Index of Preponderance value of different food items in the gut of *O.bakeri*

Sl.No.	Food item	Index value		
		2001-02	2002-03	pooled
1	Insecta	24.57	25.25	24.91
2	Copepoda	15.41	15.55	15.48
3	Cladocera	17.25	17.30	17.27
4	Ostracoda	1.38	1.37	1.38
5	Arachnida	0.75	0.77	0.76
6	Chlorophyceae	7.80	7.45	7.63
7	Dinophyceae	0.43	0.34	0.38
8	Xanthophyceae	0.35	0.38	0.37
9	Chrysophyceae	0.04	0.07	0.06
10	Bacillariophyceae	14.78	16.07	15.43
11	Myxophyceae	4.13	3.68	3.90
12	Semidigested plant matter	3.44	3.03	3.24
13	Semidigested animal matter	4.69	4.32	4.51
14	Miscellaneous	4.98	4.41	4.70

Table 5.2. Monthly Index of Preponderance values of different food items in males of *O.bakeri* during 2001-02

	June	July	August	September	October	November	December	January	February	March	April	May	Average
No.of specimens examined	10	10	10	20	19	10	18	53	18	5	20	18	
Food items						Index of preponderence							
Insecta	28.33	27.22	27.69	23.78	22.56	24.13	22.28	22.92	26.86	27.61	29.96	23.64	25.33
Copepoda	16.28	18.31	17.35	17.64	17.22	17.62	18.54	16.34	14.42	13.24	13.36	14.92	16.44
Cladocera	17.32	18.26	18.92	19.38	19.99	18.98	20.20	20.14	15.47	14.62	16.34	16.55	18.18
Ostracoda	2.62	1.91	1.82	1.65	0.93	1.16	1.04	1.57	1.35	1.50	1.94	1.20	1.52
Arachnida	0.45	0.27	1.20	1.05	0.56	1.64	0.97	0.75	0.27	0.00	0.58	0.49	0.71
Chlorophyceae	5.93	5.65	6.33	6.37	7.33	6.84	8.29	6.87	7 10	10.21	8.12	7.81	7.32
Dinophyceae	0.64	0.54	0.97	0.48	0.27	0.19	0.00	0.31	0.58	0.46	0.37	0.35	0.40
Xanthophyceae	1.22	0.36	0.86	0.26	0.41	0.19	0.00	0.29	0.34	0.33	0.00	0.00	0.33
Chrysophyceae	0.00	0.00	0.00	0.00	0.24	0.19	0.00	0.18	0.15	0.00	0.00	0.00	0.06
Bacillariophyceae	13.87	12.83	13.23	14.90	12.84	14.24	12.67	12.96	13.57	15.24	14.57	15.82	13.79
Myxophyceae	1.96	2.27	2.61	2.64	2.54	2.99	2.26	3.27	3.17	3.93	4.31	6.27	3.11
Semidigested plant matter	2.64	2.06	1.84	3.10	3.86	2.26	2.93	3.91	3.51	2.67	3.53	2.16	2.88
Semidigested animal matter	4.52	5.22	2.31	3.87	4.63	5.12	6.55	5.57	6.32	4.84	4.68	5.85	5.08
Miscellaneous	4.22	5.10	4.87	4.88	6.82	4.45	4.27	4.92	6.89	5.35	2.24	4.94	4.86

Table 5.3. Monthly Index of Preponderance values of different food items in males of *O.bakeri* during 2002-03

	June	July	August	September	October	November	December	January	February	March	April	May	Average
No. of specimens	35	16	12	25	25	9	30	5	6	16	2	6	
Food items						Index of preponderence							
Insecta	29.03	30.62	26.91	24.98	23.89	26.22	23.02	24.99	30.54	28.20	32.32	27.86	27.05
Copepoda	15.88	17.38	17.89	18.47	18.28	16.49	15.63	15.13	12.82	14.86	13.64	14.32	15.88
Cladocera	16.83	16.20	17 12	20.01	18.64	18.26	16.18	23.86	14.86	15.06	15.66	17.95	17.45
Ostracoda	1.82	1.22	2.64	2.28	1.26	1.20	1.18	0.72	1.24	1.53	1.08	1.64	1.46
Arachnida	0.97	0.00	1.90	0.95	0.80	2.10	1.06	0.43	0.21	0.34	0.00	0.87	0.82
Chlorophyceae	8.03	6.24	5.23	5.24	6.22	5.31	9.28	6.23	6.25	8.89	7.35	6.42	6.92
Dinophyceae	0.52	0.38	1.05	0.23	0.39	0.23	0.27	0.22	0.32	0.26	0.00	0.00	0.32
Xanthophyceae	1.32	0.42	1.20	0.48	0.51	0.23	0.27	0.22	0.00	0.00	0.00	0.00	0.38
Chrysophyceae	0.33	0.00	0.00	0.00	0.18	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.07
Bacillariophyceae	12.96	13.90	12.97	15.35	14.32	14.39	13.96	12.34	14.23	16.66	15.64	16.92	14.43
Myxophyceae	3.42	2.35	3.28	2.11	1.92	1.88	3.67	2.84	2.29	4.32	2.89	2.33	2.84
Plant matter	2.02	3.74	3.04	2.46	1.65	3.62	4.66	1.62	2.67	1.16	1.22	2.34	2.68
Animal matter	2.89	3.62	3.13	3.53	5.31	3.84	7.34	6.32	7.69	5 26	5.87	4.89	5 16
Miscellaneous	3.98	3.93	3.64	3.91	6.63	6.23	3.29	5.08	6.88	3.46	4.33	4.46	4.55

Table 5.4. Monthly Index of Preponderance values of different food items in females of *O.bakeri* during 2001-02

	June	July	August	September	October	November	December	January	February	March	April	May	Average
No.of specimens examined	3	6	6	9	12	18	15	10	9	14	20	12	
Food items						Index of preponderence							
Insecta	26.05	26.21	25.11	25.23	21.66	21.84	19.76	22.57	25.14	24.06	26.04	26.03	23.80
Copepoda	13.81	17.79	17.69	15.76	14.39	14.96	14.31	15.46	9.28	13.96	12.60	12.60	14.38
Cladocera	15.88	17.00	16.24	19.50	17.90	16.75	17.08	20.16	11.60	14.19	13.98	14.78	16.32
Ostracoda	1.46	1.83	2.12	1.06	0.56	0.96	1.30	0.91	1.26	0.87	1.29	1.29	1.25
Arachnida	1.27	0.54	1.67	0.53	0.57	2.25	1.12	0.17	0.44	0.23	0.44	0.00	0.80
Chlorophyceae	9.77	6.81	6.36	6.31	7.42	5.67	10.09	6.95	8.52	13.25	8.04	8.48	8.29
Dinophyceae	0.50	0.40	1.51	0.39	0.40	0.16	0.47	0.22	0.61	0.25	0.30	0.30	0.46
Xanthophyceae	1.24	0.00	0.00	0.63	0.50	0.16	0.00	0.48	0.69	0.33	0.42	0.42	0.37
Chrysophyceae	0.20	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.11	0.00	0.03
Bacillariophyceae	14.58	15.32	14.67	17.32	13.93	14.84	13.68	16.64	15.44	18.50	18.56	17.87	15.77
Myxophyceae	6.87	4.55	4.09	2.98	4.69	3.61	4.49	4.11	7.29	4.93	7.37	7.37	5.14
Plant matter	1.97	3.00	4.31	2.67	4.97	6.26	5.52	3.91	5.22	2.82	2.88	2.88	4.00
Animal matter	2.51	2.62	2.46	2.80	4.91	5.79	7.27	3.41	6.71	2.62	3.72	3.72	4.29
Miscellaneous	3.90	3.93	3.79	4.82	8.10	6.71	4.92	5.02	7.80	3.91	4.25	4.25	5.10

Table 5.5. Monthly Index of Preponderance values of different food items in females of *O.bakeri* during 2002-03

	June	July	August	September	October	November	December	January	February	March	April	May	average
No.of specimens examined	**12**	**40**	**6**	**7**	**5**	**8**	**16**	**1**	**10**	**15**	**15**	**18**	
Food items						**Index of preponderence**							
Insecta	22.68	21.98	23.28	22.64	24.45	22.55	22.31	20.67	23.24	21.68	31.32	25.80	23.45
Copepoda	14.92	16.54	18.42	14.33	15.89	15.68	17.63	15.33	11.02	13.54	14.40	12.55	15.22
Cladocera	16.23	16.37	16.88	18.67	21.27	17.55	18.59	19.83	12.34	15.31	15.53	15.82	17 15
Ostracoda	1.28	1.65	2.46	2.26	0.49	0.57	1.28	0.97	1.35	0.94	0.92	1.16	1.28
Arachnida	1.35	0.84	1.24	0.83	0.00	1.68	0.99	0.26	0.37	0.22	0.39	0.26	0.72
Chlorophyceae	9.26	7.12	6.98	7.25	6.23	5.88	9.68	6.57	7.45	11.67	8.35	7.56	7.98
Dinophyceae	0.37	0.32	0.42	0.22	0.46	0.22	0.37	0.34	0.59	0.46	0.24	0.30	0.36
Xanthophyceae	0.00	0.41	0.36	0.27	0.53	0.22	0.63	0.55	0.62	0.00	0.36	0.38	0.38
Chrysophyceae	0.00	0.28	0.00	0.00	0.00	0.26	0.00	0.32	0.00	0.00	0.00	0.00	0.07
Bacillariophyceae	16.64	17.94	16.45	18.27	16.02	19.28	16.10	18.23	19.88	19.83	16.00	19.60	17.72
Myxophyceae	7.86	5.65	3.61	4.54	3.67	3.84	2.22	4.28	6.93	4.33	3.32	6.21	4.51
Plant matter	2.97	3.24	3.92	2.38	3.94	4.91	2.93	3.64	5.06	3.28	2.45	2.38	3.39
Animal matter	2.70	2.98	2.12	3.64	4.52	2.66	2.66	3.96	7.23	3.94	3.12	3.22	3.49
Miscellaneous	3.74	4.68	3.86	4.70	2.53	4.70	4.61	5.05	3.92	4.80	3.60	4.76	4.27

Table 5.6. **Index of preponderance values for different food items in indeterminates of *O. bakeri***

Food items	% Volume (Vi)	% Occurrence (Oi)	ViOi	ViOi/∑ViOi
Insecta	18.70	24.26	453.66	32.08
Copepoda	16.65	18.37	305.86	21.63
Cladocera	17.14	21.65	371.08	26.24
Ostracoda	4.86	6.08	29.55	2.09
Chlorophyceae	5.83	5.24	30.55	2.16
Bacillariophyceae	11.67	10.73	125.22	8.85
Myxophyceae	3.62	1.20	4.34	0.31
Semidigested plant matter	5.93	1.41	8.36	0.59
Semidigested animal matter	7.28	6.24	45.43	3.21
Miscellaneous	8.32	4.82	40.10	2.84
Total	100.00	100.00	1414.16	100.00

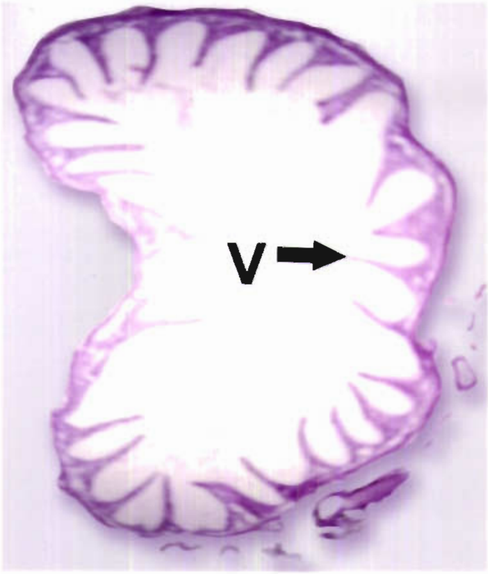


Fig. 5.1a. T.S. of foregut

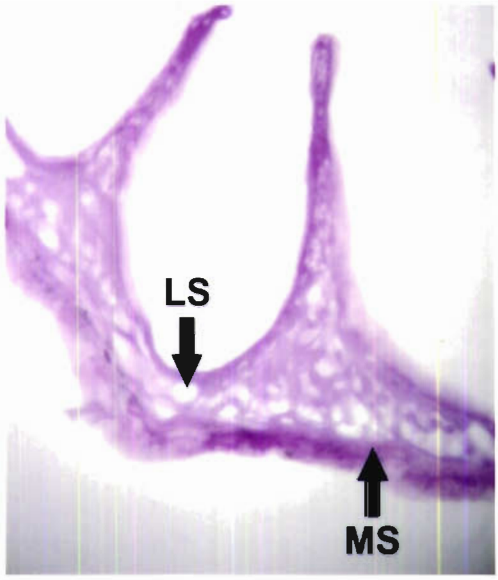


Fig. 5.1b. A portion enlarged

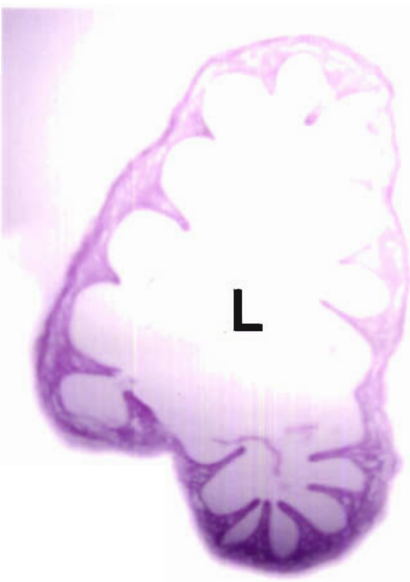


Fig. 5.2a. T.S. of mid gut

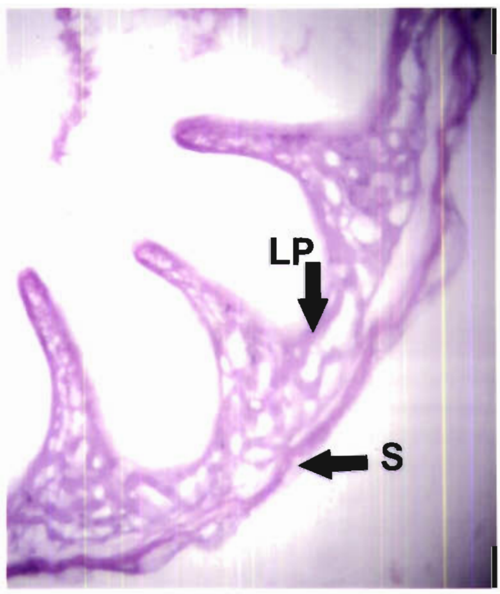


Fig. 5.2b. A portion enlarged

L - Lumen
LP - Lamina propria
LS - Lymph sinus

MS - Muscularis
S - Serosa
V - Villus

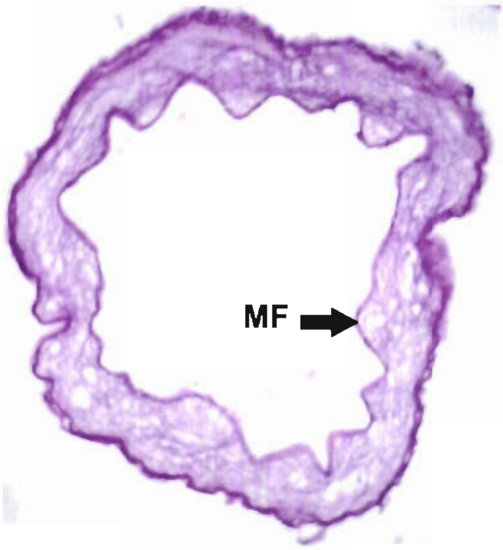


Fig. 5.3a. T.S. of Hindgut

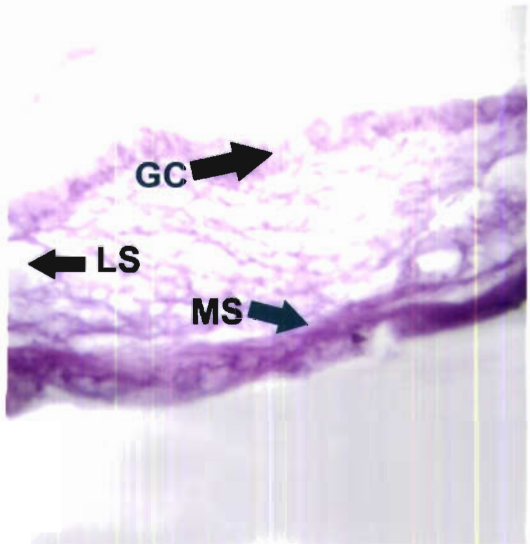


Fig. 5.3b. A portion enlarged

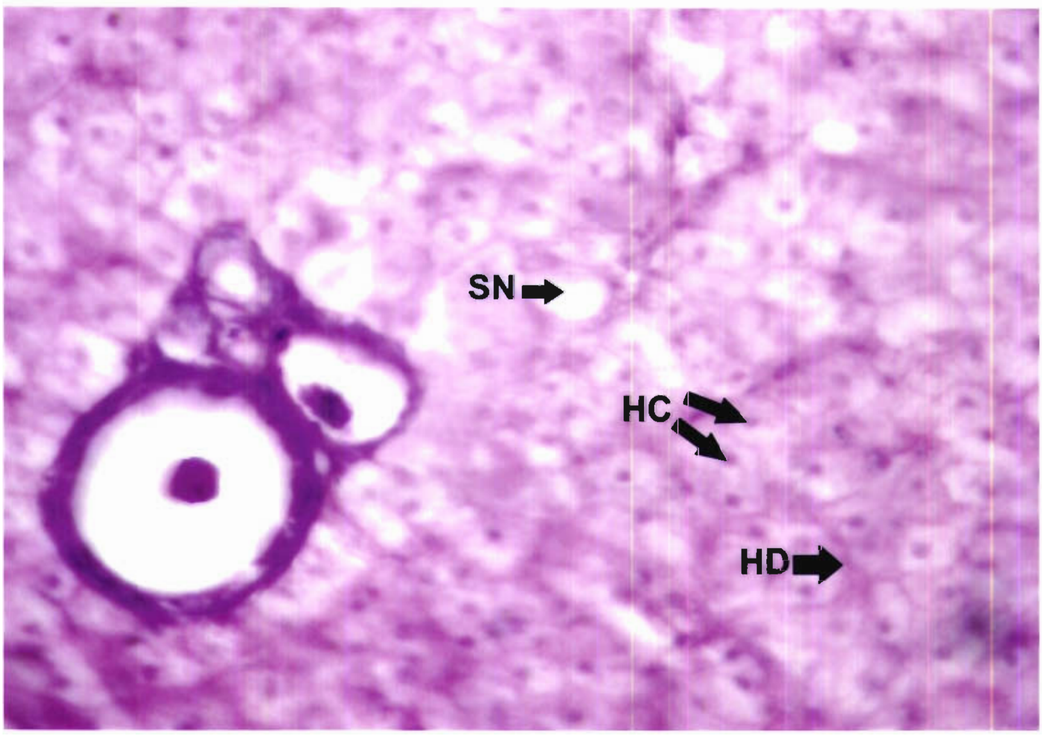


Fig. 5.4. T.S. of liver

GC - Goblet cell
HC - Hepatic cells
HD - Hepatic ductule

LS - Lymph sinus
MF - Mucosal fold
MS - Muscularis

Fig.5.5. Variation in relative gut length in different length groups of *O.bakeri*

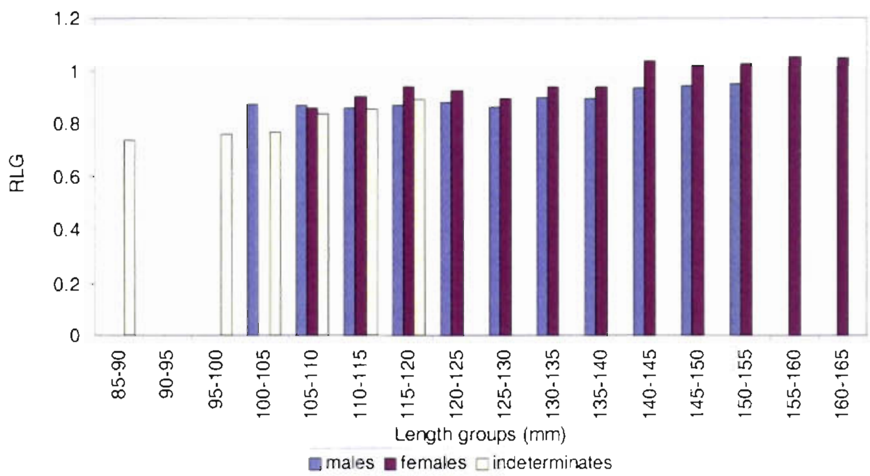
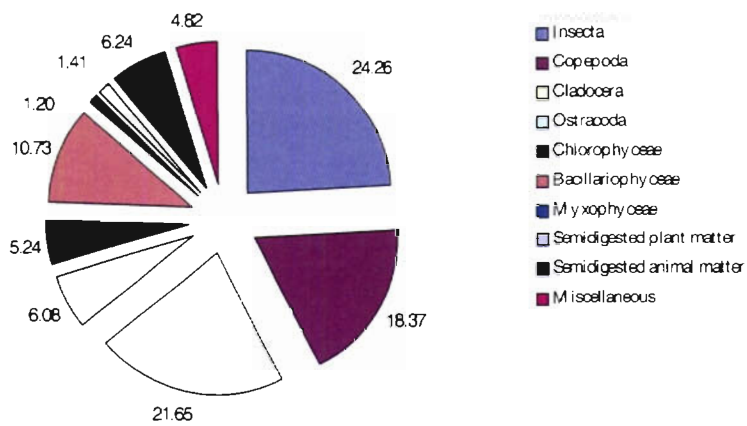
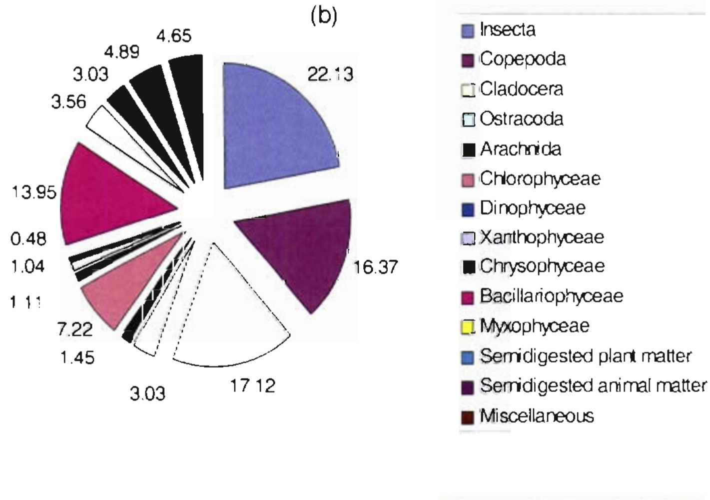


Fig.5.6. Diet composition of (a) indeterminate (b) male and (c) female of *O. bakeri* (Pooled for 2001-02 and 2002-03)

(a)



(b)



(c)

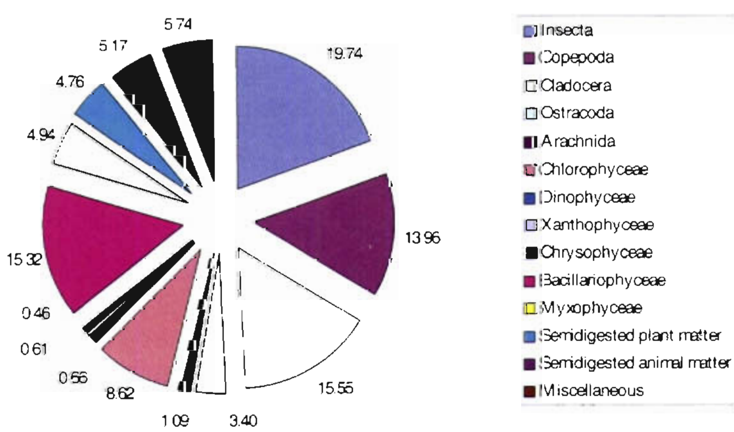


Fig.5.7. Percentage occurrence of guts in different degrees of fullness in males of *O. bakeri* during June2001-May 2002

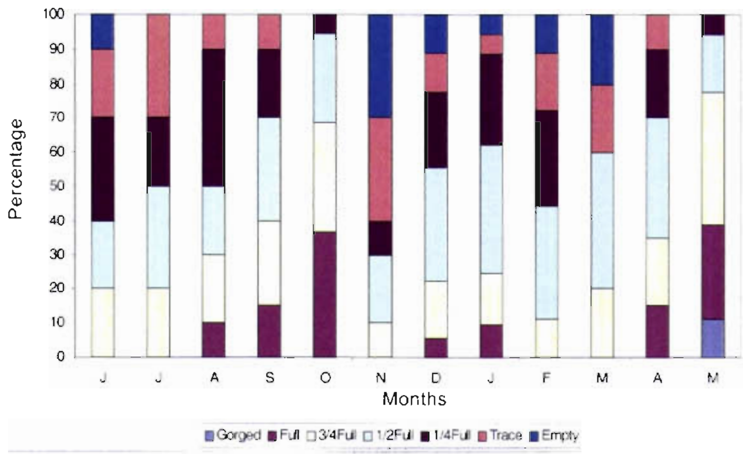


Fig.5.8. Percentage occurrence of guts in different degrees of fullness in males of *O. bakeri* during June 2002- May2003

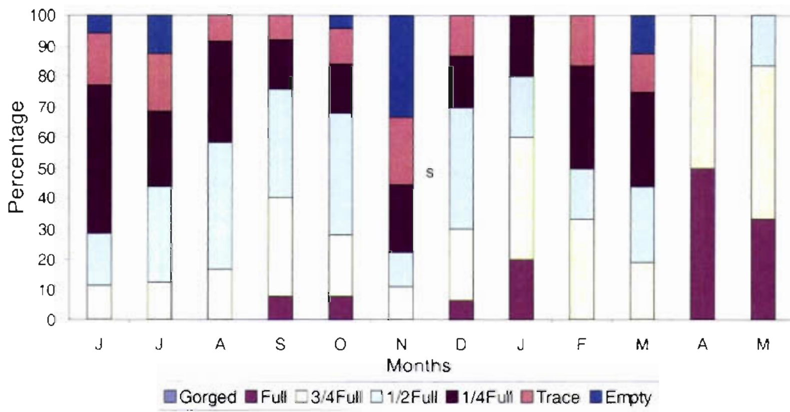


Fig.5.9. Percentage occurrence of guts in different degrees of fullness in females of *O. bakeri* during June 2001- May 2002

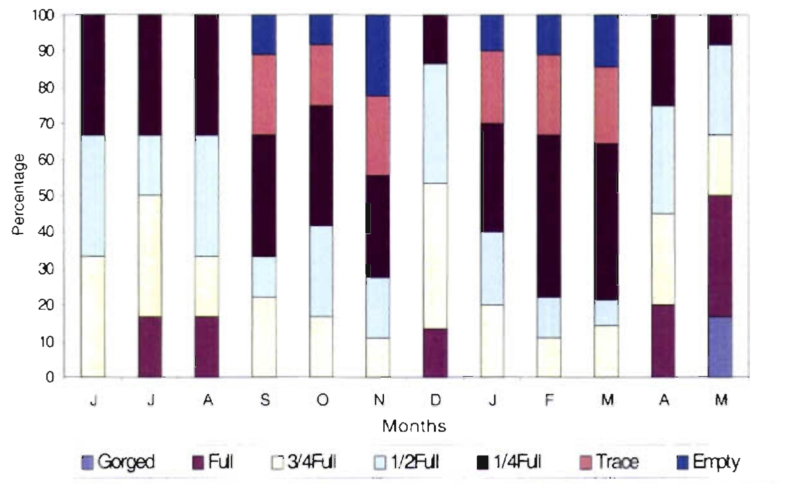


Fig.5.10. Percentage occurrence of guts in different degrees of fullness in females of *O. bakeri* during June 2002- May 2003

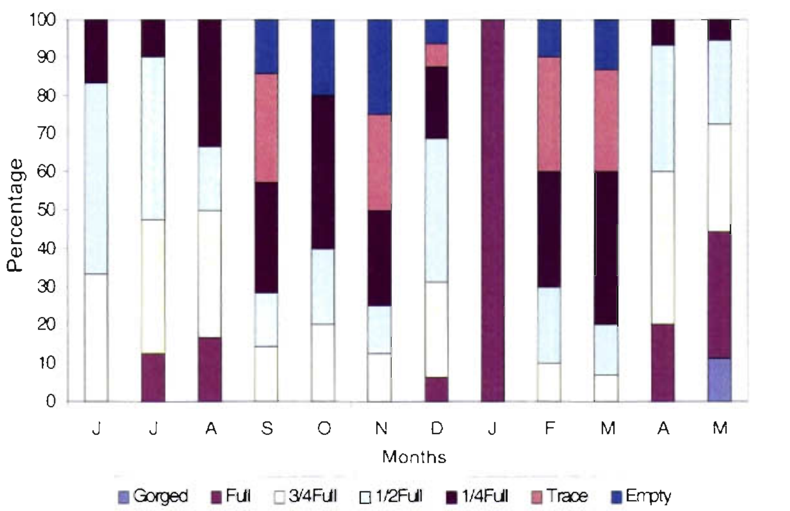


Fig.5.11 Monthly variation in gastro-somatic index of males of *O. bakeri*

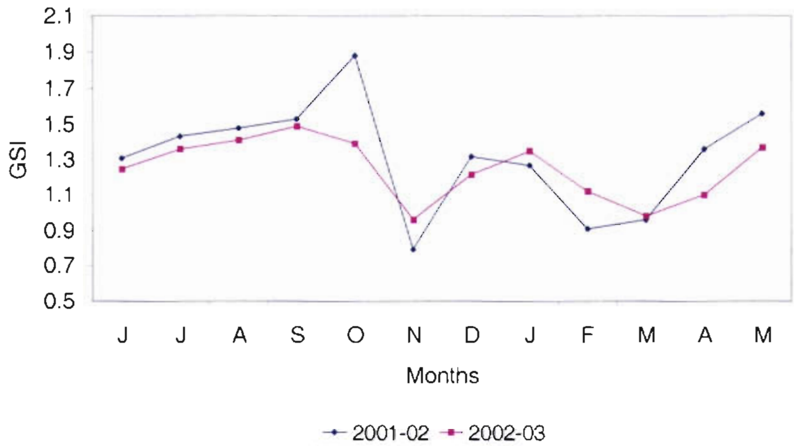


Fig.5.12. Monthly variaion in gastro-somatic index of females of *O. bakeri*

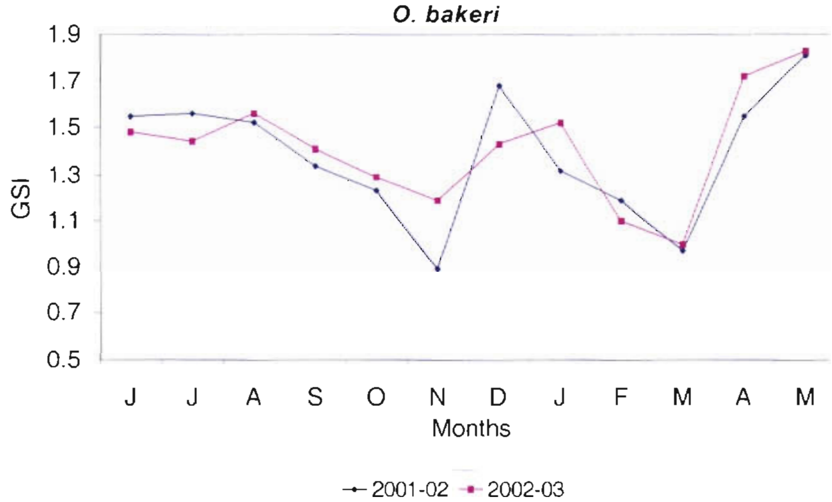


Fig.5.13. Lengthwise variation in gastro-somatic index of *O. bakeri*

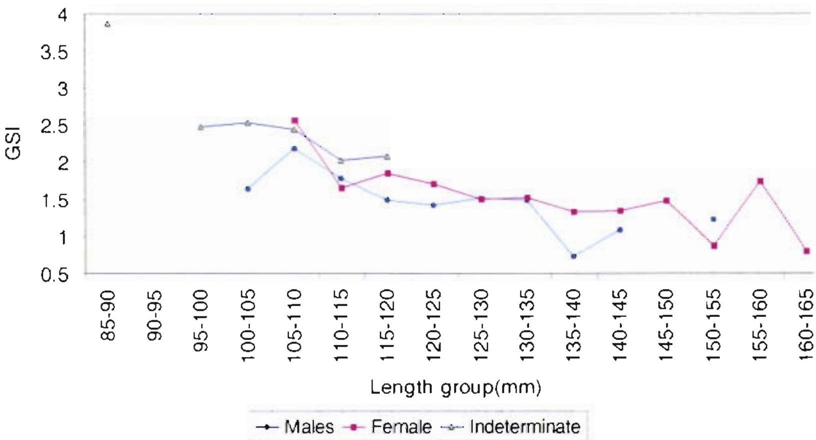


Fig.5.14. Monthly variation in gastrosomatic index of *O. bakeri* during June 2001- May 2002

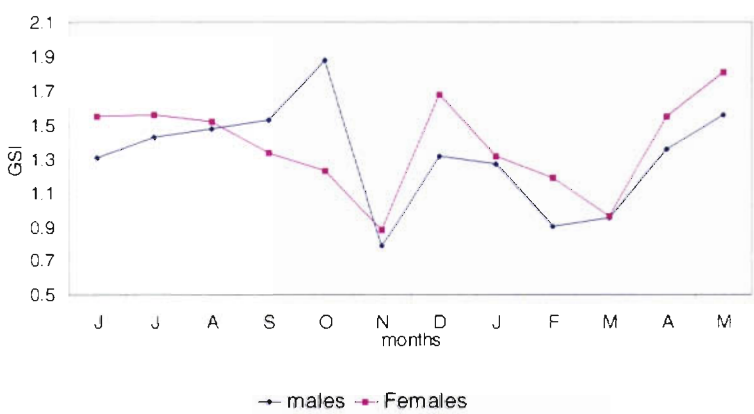
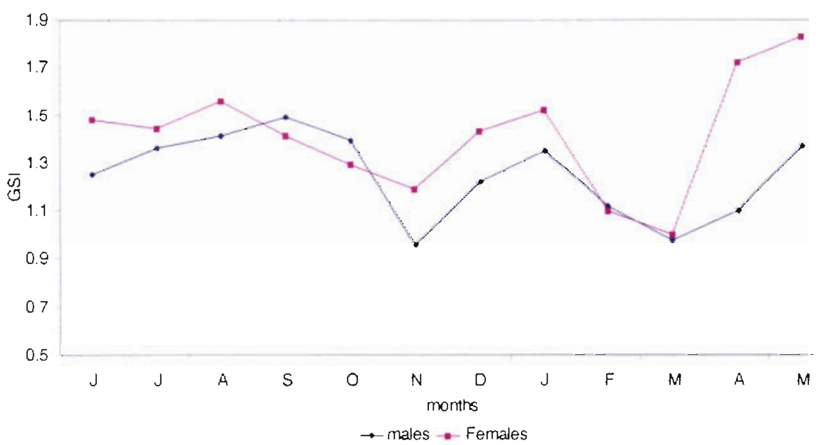


Fig.5.15. Monthly variation in gastrosomatic index of *O. bakeri* during June 2002- May 2003



CHAPTER VI

REPRODUCTION

6.1. Introduction

Every living organism has immense power of reproduction and recruitment. Under favourable 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 a majority of the off-springs perishes before reaching maturity. During recent past, the natural and anthropogenic 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 overexploitation 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 brood stock 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 breeding 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 (NATP, 2001).

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 (Khan, 1945; Mookherjee, 1945; Ahmad, 1948; Ganapathi and Alikunhi, 1950; Alikunhi, 1956; Prabhu, 1956; Khanna, 1958; David, 1959;

Sathyanesan, 1959, 1962; Qasim and Qayyum, 1961; Belsare, 1962; Das, 1964; Saigal, 1967; Malhotra, 1966, 1967; Desai and Karamchandani, 1967; Bhatnagar, 1967, 1972; Parameswaran *et al.*, 1972; Selvaraj *et al.*, 1972; Saxena, 1972; Desai, 1973; Varghese, 1973; Sobhana and Nair, 1974; Sinha, 1975; Murty, 1975; Chaturvedi, 1976; Siddiqui *et al.*, 1976; Chondar, 1977; Raina, 1977; Ritakumari and Nair, 1978, 1979; Joshi and Khanna, 1980; Pathani, 1980, 1981; Somavanshi 1980; 1985; Nagendran *et al.*, 1981; Thakre and Bapat, 1981, Singh *et al.*, 1982; Geevarghese and John, 1983; Sheila and Nair, 1983; Badola and Singh, 1984; Nautiyal, 1984, 1985; Nautiyal and Lal, 1985; Rao and Karamchandani, 1986; Shrestha, 1986; Sunder, 1986; Joshi, 1987; Pisca and Waghray, 1989; Kaushal and Rao, 1990; Guha and Mukherjee, 1991; Reddy and Rao, 1991; Jyoti and Abrol, 1992; Kaul, 1994; Kurup 1994; Kurup and Kuriakose, 1994; Nath, 1994; Gaur and Pathani, 1996; Mathew *et al.*, 1999). A review of literature showed that hitherto no information is available on the reproductive biology of *O.bakeri.* However, some preliminary observations were reported by Parameswaran *et al.* (1971) on the breeding biology of its closely related species *O. cotio, from Assam waters.*

6.2. Materials and Methods

The study was based on 895 specimens of *O.bakeri*, 567 males and 328 females ranging in total length from 95 mm to 150 mm and 104 mm to 163 mm respectively and weight between 6.48 – 24.52g and between 8.14 – 40.12g in males and females respectively. Monthly samplings of the fishes were done from Periyar River at uniform intervals during the period from June 2001 to May 2003. After removing the excess water by blotting, length (to the nearest mm) and weight (to the nearest .01g) were recorded for each fish. Fishes were dissected out to identity the sex and the condition of the gonad. Gonads were taken out and their length and weight were noted down. After assessing the stage of maturation, the ovary was preserved in 4% formalin for ova-diameter and fecundity studies. For histological studies, gonads were taken out from freshly killed specimens and washed, adhering fat was removed and immediately fixed in Bouin's fixative. Conventional histological techniques were followed for processing testes and immature and spent ovaries (Weesner,1960). Since routine wax-embedding method leads to crumbling and collapse of yolk-laden oocytes, yolky oocytes were processed following the double embedding method of Khoo (1979) as modified by Gopala-krishnan (1991). The spawning season was delineated based on: (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 (1964a, b, c) and Qasim (1973), the testes and ovary were grouped into 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 histological observations such as the size of the ova and their yolk content. To trace the development of ova, ova diameter was measured from ovaries belonging to the five stages of maturity, following the method of Clark (1934). A total of 210 ovaries in different stages of maturation were examined. Since the ova taken from the anterior, middle and posterior regions of the ovary did not vary much, ova were selected at random from each ovary, at an average of 325 ova per ovary. 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 50µm intervals and the monthly percentage frequency of each size group was calculated and the prominent mode recorded. Immature oocytes (28-150µm) 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 analysed 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

$$\chi^2 = \sum \left[\frac{(O-E)^2}{E} \right]$$

where O = observed number of males and females in each month / length group
E = expected number of males and females in each month / length group

Fecundity estimation was done on the basis of 33 ripe females of *O.bakeri* in the length range of 122 to 163 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 sub-sample

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 gonosomatic 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.

6.3. Results

As in most teleosts, the gonads in the males and females of *O.bakeri* are paired, elongated structures lying on the sides 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 mesorchium. 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.

6.3.1. Gametogenesis

Gametogenesis involves the differentiation of primordial germ cells into mature gametes passing through a series of cellular stages. Spermatogenesis is the development of spermatozoa from sperm mother cells while oogenesis is the process of transformation of oogonia into ripe egg, both processes involving complicated changes occurring in cytoplasm as well as nucleus.

6.3.1.1. Spermatogenesis

The different stages of spermatogenesis in *O.bakeri* are as follows:

1. **Primary Spermatogonia:** They are large, relatively inconspicuous cells with lightly staining nucleus and distinct nucleolus. Cytoplasm shows less affinity to basic dyes like haematoxylin (Fig. 6.1).

2. **Secondary Spermatogonia:** Similar to primary spermatogonia except in size these are smaller round cells with less cytoplasm (Fig. 6.1).
3. **Primary Spermatocytes:** They are much smaller than secondary spermatogonia with reduced cytoplasm. Cytoplasm stains faintly and nucleus purple with haematoxylin-eosin. Nucleolus is not visible in all cells (Fig. 6.2).
4. **Secondary Spermatocytes:** They are formed by the meiotic division of primary spermatocytes. The cytoplasmic connections between the dividing primary spermatocytes persist in most cells. Cytoplasm is less. Nucleolus is no longer visible (Fig. 6.2).
5. **Spermatids:** The spermatids are much smaller compact dot like structures, which are formed by the second meiotic division of secondary spermatocytes. They appear deeply stained with haematoxylin-eosin. Nucleolus is absent (Fig. 6.3).
6. **Spermatozoa:** The transformation of spermalids into spermatozoa is spermiogenesis. Spermatozoa are small cells with distinct tail and darkly stained nucleus. The lumen of the seminiferous lobules in ripe males are richly packed with mature sperms (Fig.6.3). In mature individuals, the spermatozoa are arranged in a characteristic 'parachute-like' arrangement with the tails facing the centre and the heads directed towards the periphery of the cyst (Fig. 6.4) and are also liberated into the lumen of the seminiferous tubules.

6.3.1.2. Oogenesis

Each ovary is covered by a thin peritoneum beneath which lies the thick tunica albuginea containing blood vessels, connective tissue and smooth muscles. The innermost layer is a layer of germinal epithelium which projects into the ovocoel forming ovigerous lamellae. The oogonia appear on these lamellae. Each oogonium in *O.bakeri* passes through the following stages to form a mature ovum.

1. **Chromatin nucleolus stage:** The oocytes have a centrally placed nucleus with a distinct nucleolus lying in the meshwork of chromatin thread. A thin layer of basophilic cytoplasm surrounds the nucleus (Fig. 6.5).
2. **Perinucleolus stage:** This stage is characterised by the peripheral arrangement of a large number of nucleoli of different sizes at the inner side of the nuclear membrane. They are strongly basophilic in nature. In the early perinucleolus stage (Fig.6.6a), the nucleoli are found mainly scattered in the chromatin meshwork and the oocyte is surrounded by layer of small follicle cells which are interrupted at some places. More nucleoli move to the periphery of the nucleus in the late perinucleolar stage, some are still in the centre of the nucleus (Fig.6.6b). There is conspicuous increase in the size of the oocyte. The cell shows reduced affinity to haematoxylin. Just outside the nuclear membrane, a spherical deeply-stained body, the yolk nucleus or nucleus of Balbiani, appears in the

cytoplasm. Later it migrates to cortical ooplasm and gradually disappears.

3. **Yolk vesicle stage:** Minute vacuoles called cortical alveoli or yolk vesicles make their first appearance in the peripheral region of the cytoplasm. The nuclear membrane is wavy in appearance. Nucleoli still occupy their peripheral position. The oocyte with these characteristics is said to be in the early yolk vesicle stage (Fig.6.7a). Later the yolk vesicles increase in size and number until they occupy the entire cytoplasm. The cytoplasm appears as a vacuolated structure as it remains unstained with basic dyes. The nuclear membrane becomes more wavy in nature and the nucleoli become reduced in size. The follicular layer around the oocyte is complete and the oocyte is in the late yolk vesicle stage (Fig. 6.7b).
4. **Yolk globule stage:** Very minute particles of yolk globules appear in the extra vesicular cytoplasm which later unite to form large yolk globules in the early yolk globule stage (Fig.6.8a). Nuclear membrane exhibits the tendency for dissolution. The outer layer of follicle cells thickens. The late yolk globule stage (Fig.6.8b) is characterised by the extensive deposition of the yolk globules in the whole of cytoplasm. Then they invade yolk vesicles which appear to be displaced towards periphery of the cytoplasm. At the final stage of vitellogenesis, some globules fuse to form larger ones. The oocyte is surrounded by well developed innermost zona radiata, middle follicular epithelium and the outermost thecal layer.

5. **Migratory nucleus stage:** More accumulation of the yolk globules in the inner portion of the cytoplasm leads to an overall increase in the size of the oocyte. This is accompanied by reduction in the size of the nucleus and gradual dissolution of the nuclear membrane. The nucleus gets shifted to one pole of the egg (Fig. 6.9).
6. **Ripe egg stage:** The mature ova increase considerably with the accumulation of more and more yolk. The entire cytoplasm is so much packed up with yolk globules that the nucleus becomes invisible (Fig. 6.10). These ripe eggs, on ovulation, pass out of the follicles into the lumen of the ovary from where they are extruded via the oviduct.

Atretic cells: The examination of various sections of the ovary of *O.bakeri* revealed the presence of some atretic oocytes in the mature and spent ovaries (Fig. 6.11).

6.3.2. Stages of maturation

The following stages of maturation were recognised in the males and females of *O.bakeri*.

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 appear oval/irregular under microscope, transparent with a distinct central nucleus,

	devoid of yolk, not more than 196μm in diameter. (Fig. 6.12a)
	Testes: Extremely thin, thread-like, translucent, occupy nearly ½ of the body cavity.
Maturing virgins/ Recovered spents	**Ovaries:** Somewhat flattened pale yellow, occupy ½ of the body cavity (Fig. 6.14a). Ova more or less spherical and translucent, yolk deposition commences, Ova diameter between 196-350μm.
	Testes: Opaque, firm, white, occupy more than ½ of the body cavity (Fig.6.16c). Well defined seminiferous lobules with spermatogonia and spermatocytes. Seminiferous cysts of dividing cells appear.
Ripening	**Ovaries:** Slightly cylindrical, yellow, opaque, occupy ¾ of the body cavity, the inner side slightly depressed to accommodate the gut, asymmetry in the lobes, the right lobe slightly longer than the left (Fig. 6.14b); yolk deposition increases, spherical ova with diameter between 350-868μm; ova are of two types (i) small opaque ova (350-700μm) (ii) larger opaque / semi-transparent ova (700-868μm) (Fig. 6.12b).
	Testes: Creamy white, lobulated with irregular outer margin, occupy ¾ of the body cavity (Fig. 6.16d). Seminiferous lobules with spermatogonia as well as seminiferous cysts of actively dividing spermatocytes, spermatids and spermatozoa. Spermatozoa either liberated into the lumen of seminiferous tubules or arranged in parachute-like manner (Fig. 6.4).

Ripe **Ovaries:** Considerably enlarged, occupy nearly the entire length of the body cavity, golden yellow/orange yellow in colour, distended outer membrane, loosely arranged and clearly visible mature and ripe ova, rich blood supply (Fig. 6.15a), almost transparent ova ranging between 868-966µm diameter (Fig. 6.13a).

Testes: Very soft, ivory coloured, more than ¾ of the body cavity (Fig. 6.16e). Seminiferous cysts very much reduced. The entire lumen filled with motile spermatozoa (Fig. 6.16a).

Spent **Ovaries:** Shrunken, flaccid, blood shot, translucent, occupy a little more than ½ of the body cavity (Fig. 6.15b); ova small and invisible expect a few large whitish ones. Immature stock of oocytes along with a few residual eggs and empty follicles (Fig. 6.13b).

Testes: Shrunken, flabby, partly opaque and partly semitransparent occupy less than ¾ of the body cavity. The lumen of seminiferous lobules contains residual spermatozoa and empty spaces (Fig. 6.16b).

6.3.3. 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 Figs. 6.17a and 6.17b respectively. In males, immature and maturing individuals occurred almost round the year. The immature individuals (Stage I) were predominant during August with 63.64% in 2001-'02 and

58.33% in 2002-'03. The percentage occurrence of maturing virgins/recovered spent (Stage II) was almost similar during June to August and December to February in 2001-'02 while during 2002-'03, they were predominant in April, August and July. Ripening males (Stage III) made their appearance in September and continued upto May with highest contribution of 57 14% and 60% in April 2001-'02 and January 2002-'03 respectively. Ripe males (Stage IV) were observed from September to November and February to June. Their maximum occurrence was recorded in March 2001-'02 (40%) and October 2002-'03 (38.24%). The appearance of spent individuals (Stage V) was first noticed during May and continued upto July and reappeared again in October–November during 2001-'02 whereas during 2002-'03, they were found to occur from April to July and were further encountered in November-December. The preponderance of spent fishes was quite discernible during June, July and November.

Immature and maturing females of *O.bakeri* were present almost round the year, similar to their male counterpart. Immature fishes were dominant during August. The presence of maturing individuals was quite discernible when compared to immature ones throughout the year. Specimens with IIIrd stage of maturity appeared abruptly in September and were recorded from the catches till May with a peak in February during 2001-'02 (77.78%) and in January (100%) followed by March (66.67%) in the succeeding year. Gravid females (Stage IV) were observed from September to November in 2001-'02, showing preponderance in October with 33.33% while in the succeeding year, they were noticed only in October and November with highest occurrence in October (40%). They were further encountered during March to June with peak values in May during 2001-'02. However, during 2002-'03, a single gravid female was collected in February while they were totally absent in May. The spent individuals of stage V started appearing in April and their number increased during the subsequent months and reached the peak in July (40%) during 2001-'02 while in 2002-'03, percentage occurrence was highest in June (50%).They reappeared again in October–November during 2001-'02 while during 2002-'03, their presence was noticed in November-December.

6.3.4. Pattern of progression of ova during different months

The pattern of progression of ova during September to June is depicted in Fig. 6.18. All the ova less than 196 µm diameter were immature. In the next group of ova above 196µm, yolk deposition had just commenced and was thus found to be maturing ones. The ova ranging between 350-868 µm were yolked and represented the ripening eggs. Ova measuring 868 µm and above were in fully ripe condition. The development of ova during different months showed the preponderance of immature and maturing ova (28-350 µm) during July and August. Oocytes upto 800µm appeared in September with two major modes at 301-350 µm and 401-450 µm and a minor mode at 601-650 µm. Thereafter, the progression of ova was very rapid with the result that ripening oocytes were very prominent with the mode shifting to 651-700 µm in October and November and also with a few ripe eggs in the ovary. However, the major mode reversed back to 451-500μm while the two minor modes encountered were having ova diameters of 301-350 and 601-650 μm in December. A gradual increase in the frequency of ova with 801-850 μm diameter was discernible during January and February. Thereafter, the ova size increased until it reached highest in April, thenceforth, it again diminished in May and June.

During October to June, wide range of ripening and ripe oocytes having 350-966 μm diameter were observed in the ovaries in varying proportions. Largest oocytes having 966μm diameter were encountered only during October and April. It is interesting to note that ripening eggs at mode 651-700 μm were dominant in almost all months except during July, August, September and December.

6.3.5. Gonadosomatic Index

The mean monthly variation of gonadosomatic index (GSI) values of males and females during June 2001 to May 2003 are depicted in Fig. 6.19 and 6.20. During 2001-'02, the testicular weight started increasing from August (0.3) and attained the peak in October (1.08). A sharp decline was discernible in November (0.53) which was followed by a slight increase in December (0.73). Thereafter, the GSI values remained more or less the same till March. The highest value of 1.17 was registered in April and thereafter, declined again in the succeeding months. The trend was more or less the same during 2002-'03 except for the variations in the values. Females showed distinct seasonality in GSI values similar to those of males. Index values, which were lowest in July (1.98) steadily increased and attained peak in October (5.45) during 2001-'02. The values declined during December followed by a slight increase in January and decrease in February. A second peak in GSI values was again attained in April (5.15) and inflexed in the subsequent months. During 2002-'03 also, the females exhibited similar trend except for the low GSI value in January.

6.3.6. Length at first maturity

Occurrence of males and females at different stages of maturity in various size groups are shown in Tables 6.1 and 6.2 respectively. Fig. 6.21 represents the relation between maturity and length of the male and female *O.bakeri*. It appeared that specimens upto 105mm total length were immature and maturing fishes. The percentage of ripening fishes increased rapidly upto 135mm TL beyond which all the fish attained ripe gonads. The smallest ripe male belonged to the 110-115 mm TL size group while the smallest ripe female belonged to 115-120 mm 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 115mm and 118mm for males and females respectively. Thus, males were found to mature at a lower size than their female counterpart.

6.3.7. Sex-ratio

Altogether 1108 fishes were examined in the laboratory to determine the sex-ratio. Due to the absence of sexual dimorphism in

O.bakeri, the fishes were sexed by internal examination. Out of the 1108 fishes examined, 567 were males, 328 females and the remaining 213 indeterminates. The month-wise distribution of the two sexes (Table 6.3) revealed that the sexes were disproportionate in the sample populations. Males outnumbered females in almost all the months except in November and March during 2001-'02 and July, February, April and May during 2002-'03. Chi-square test confirmed that the males were significantly dominant in June, September and January 2001-'02 while females in November and March. The ratio did not skew significantly from the expected 1:1 proportion during the remaining months of the year. During 2002-'03, the preponderance of males was glaringly evident from the chi-square values in June, September, October and December and that of females in July, April and May. 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 ($P<0.01$). The mean ratio of males to females was 1 0.55 for the year 2001-'02 and 1:0.60 for 2002-'03 and the respective Chi-square values of 34.47 and 28.38 lend support to the above observation that the sex ratio significantly skewed from the expected 1 1 ratio ($P<0.01$). During spawning season, the ratio skewed significantly in November and June during 2001-'02 whereas in 2002-'03, the ratio significantly skewed in almost all the months except November ($P<0.01$).

Table 6.4 shows the variation in sex ratio among the various size groups. Males were dominant upto 125mm TL and thereafter females became dominant. Beyond 155mm TL, only females were encountered.

Chi-square values indicated that there was significant variation from 1 :1 ratio in the size groups between 105 and 135mm TL whereas those between 100-105mm TL and 135-155mm TL did not skew significantly from the expected values. The Chi-square value of 61.11 for the overall sex ratio showed that the variation was highly significant (P<0.01).

6.3.8. Fecundity

The average values of fecundity indices of *O.bakeri* are given in Table 6.5. 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 Figs. 6.22 – 6.25. Figs. 6.26 and 6.27 represent the regression of ovary weight on total body length and body weight.

6.3.8.1. Fecundity indices

The absolute fecundity ranged from 2834 ova in a fish of 123 mm TL to 8213 ova in fish with 131 mm TL and the average was worked out to be 6290 ova. The relative fecundity was estimated to be between 195 (123 mm TL) and 385 (131mm TL) with an average of 254 while the number of ova per gram ovarian weight varied between 3115 (143 mm TL) and 4735 (125 mm TL), with the average 3631. The coefficient of maturity increased in fishes upto 134 mm TL and thereafter, it stabilised around 8 and beyond 144 mm TL, it showed a declining trend. Similar results were observed in respect of gonosomatic index as well. The coefficient of maturity and gonosomatic values were between 5.73 (160-164mm size group) and 8.07 (130-134mm TL) and between 6.08 (160-164mm TL) and 8.83 (130-134mm TL) respectively.

6.3.8.2. Relationship between Fecundity and body parameters

Fecundity and total length (TL) showed a straight line relationship when expressed logarithmically (Fig. 6.22). The regression equation thus arrived at is:

$$\log F = -2.0126+2.7017 \log TL$$

The logarithmic relationship between fecundity and body weight (W) (Fig. 6.23) can be expressed as:

$$\log F = 2.6918 +0.8026 \log W$$

Fecundity was related to the measurements of ovary, the ovary length (OL) (Fig. 6.24) and ovary weight (OW) (Fig. 6.25) which can be expressed as follows:

$$\log F = 0.0954 + 2.3773 \log OL$$

$$\log F = 3.606 +0.7765 \log OW$$

The regression equation of ovarian weight (OW) on body length (TL) (Fig. 6.26) and body weight (W) (Fig. 6.27) are given below.

$$\log OW = -6.932 + 3.3366 \log TL$$

$$\log OW = -1.1026 + 0.9762 \log W$$

With the help of t-test, the exponential or 'b' values were tested against '3' in the case of length and against unit or 1 in respect of weight and the results are presented in Table 6.6. The exponents of all parameters, except that of ovary weight, did not deviate significantly from '3' and '1'

Table 6.7 represents the results of the statistical analysis carried out to test the significance of correlation coefficient. Among the various body parameters, highest correlation existed between fecundity and ovarian weight (OW) (0.9817), on the other hand, the lowest correlation was observed between fecundity and total body length (0.7041). All body parameters were found significantly correlated to fecundity.

6.4. Discussion

The male and female reproductive organs of *O.bakeri* are built on the general teleostean 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 *O.bakeri*, the testes are united at the posterior region to form the spermatic duct as reported in *Barbus tor* (Rai, 1965), *Channa gachua* (Sanwal and Khanna, 1972a), *Schizothorax richardsonii* (Bisht, 1974) and *Schizothorax plagiostomus* (Agarwal, 1996). Histologically, the testes of *O.bakeri* are composed of numerous seminiferous lobules separated from each other by stromal tissue which is in agreement with earlier observations (Joshi and Joshi, 1989; Agarwal, 1996; Shafi, 2000).

It is well known that the differentiation of primordial germ cells into gametes (Spermatogenesis and Oogenesis) is an orderly process and follows a distinct pattern. The various stages involved in the development of spermatozoa, *viz.* the primary and secondary spermatogonia, primary and secondary spermatocytes, spermatids and spermatozoa, as observed in *O.bakeri*, have been identified and described in other freshwater teleosts such as *Mystus seenghala* (Sathyanesan, 1959), *Clarias macrocephalus* (Mollah, 1988), *Puntius dukai* (Joshi and Joshi, 1989) and *Schizothorax plagiostomus* (Agarwal, 1996).

Teleostean ovaries have been studied in detail by many authors (Yamamoto, 1956; Hoar 1969; Gupta, 1975; Jones, 1978; Nagahama, 1983; Saat and Veersalu, 1990; Elorduy-Garay and Ramirez-Luna, 1994; Colombo and Grandi, 1996; Maddock and Burton, 1999; Rideout *et al.,* 1999, 2000; Merson *et al.*, 2000; Arocha, 2002). Reports on Indian fish species include those of Sathyanesan (1962), Belsare (1962), Lal (1963b), Rajalakshmi (1966), Khanna and Sanwal (1971), Aravindan and Padmanabhan (1972); Guraya *et al.* (1977); Sobhana and Nair (1977); Mercy *et al.* (1982) Mollah (1986), Mukherjee *et al.* (1989); Jayasankar and Alagarswami (1994), Agarwal (1996); Shafi (2000) and Ram *et al.* (2001). The results of the present study on oogenesis in *O.bakeri* lend support to the findings of the above authors.

The nucleus of an oocyte undergoes several changes during its development into mature ova. The nucleus, which occupies a major part of the cell space during the early growth phase, becomes proportionately smaller as the cell grows. In perinucleolus stage, several nucleoli appear which lie beneath the nuclear membrane. There are several views regarding the formation of nucleoli. According to Khanna and Pant (1967), Sobhana and Nair (1977), Shrestha (1980) and Agarwal (1996), the nucleoli are formed by the division or fragmentation of the original nucleoli. Guraya *et al.* (1975) and Ritakumari and Nair (1979) opined that nucleoli arise from certain heterochromatic regions of chromosomes known as nucleolar organiser. Cunningham (1898) stated that the dark specks of chromatin found scattered within the nucleus also contribute to the formation of nucleoli. Mercy *et al.* (1982) observed that in the blind catfish, *Horaglanis krishnai*, the nucleoli arise partly by the division of the original nucleolus and partly by the transformation of dark staining chromatin particles. In *O.bakeri*, nucleoli decrease in size as they increase in number, thus suggesting the possible division or fragmentation of the original nucleolus in the formation of nucleoli.

Controversy regarding the extrusion of nucleoli during oogenesis still exists. According to Lal (1963b), nucleolar extrusion does not occur in fish oocytes whereas the phenomenon has been reported in a number of teleosts by some authors (Khanna and Sanwal, 1971; Guraya *et al.*, 1975, 1977; Shrestha, 1980; Guraya, 1986). Kapoor (1977) suggested the passage of nucleoli into the surrounding cytoplasm of oocytes in *Puntius ticto,* which finally disappeared near the periphery of the oocyte. After extrusion, the nucleoli were found to break up into pieces and disappear in *S.plagiostomus* (Agarwal, 1996). Nucleoli lying partly inside and partly outside the nuclear membrane were observed in *O.bakeri*, indicating the movement of nucleoli into the cytoplasm of the oocyte.

Opinions differ about the origin and functions of yolk nucleus. Wheeler (1924) and Sathyanesan (1962) were of the view that yolk vesicle had nuclear origin and passed through the nuclear membrane to reach cytoplasm while Narain (1951) and Nayyar (1964) believed it to be of cytoplasmic origin. In *O.bakeri* yolk nucleus makes its first appearance in the cytoplasm close to the nuclear membrane and migrates to the periphery of the oocyte. Yolk nucleus appears before the formation of yolk vesicles as well as onset of vitellogenesis. Hence it is probable that yolk nucleus is partly responsible for the process of yolk formation as reported by Khanna and Sanwal (1971), Bisht and Joshi (1975), Shrestha (1980), Mercy *et al.* (1982) and Agarwal (1996). The cortical alveoli which appear in the peripheral cytoplasm of oocytes, gradually spread to the inner regions and in the later stages of maturity again occupy the peripheral ooplasm forming a conspicuous zone (Agarwal, 1996 Shafi, 2000). The pattern of distribution of cortical alveoli observed in the oocytes of *O.bakeri* is in agreement with the above observations. Generally, the oocyte envelope of teleosts consists of theca, follicular epithelium and zona radiata and the oocyte of *O.bakeri* is also covered by these 3 layers.

Some of the developing oocytes fail either to reach the ripe egg stage or to get spawned. Instead they get degenerated and resorbed. The formation of such atretic oocytes or corpora atretica is a widely occurring phenomenon in teleost ovary. It may occur at any stage of follicular development (Saidapur, 1978). The factors involved in atresia may be hormonal (Saidapur, 1978), unfavourable environmental conditions such as overcrowding, temperature and inadequate food supply (Lam, 1983) and pollution (Mani and Saxena, 1985). Atretic oocytes were encountered in *O.bakeri* during pre-spawning, spawning and post-spawning periods, a situation similar to that of *S.plagiostomus* (Agarwal, 1996).

The development of oocytes is basically the same in all teleosts with minor variations in yolk composition, its deposition, rapidity of oocyte growth and surrounding membranes (Lal, 1963b). The maturation process, which agrees with the conditions of other related teleost species, indicates that the morphological changes undergone by the oocytes during maturation are normal.

Breeding season 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 gonado-somatic index. Results of the two years data have shown that as far as occurrence of gonads in different stages of maturity is concerned, both the males and females followed almost similar trend. During August, all fishes collected belonged to immature and maturing stages. Thenceforth, majority of the fishes underwent ripening rapidly and interestingly, by the end of September, most of them were in the advanced degree of maturing and ripening and a small number had even reached the ripe condition. During October, a major part of the population had spawned as manifested by the appearance of spent fishes in the population in

November. Majority of the fish belonged to the maturing and ripening stages from December to February. A single gravid female was caught in February and their number showed a rapid increase in the subsequent months to attain peak in May. Males showed strong oscillations in their occurrence from March to June. Though ripe individuals appeared in insignificant numbers during March, the presence of spent fishes was observed only by the end of April in males and females, which would suggest that actual spawning might have commenced in April. The single gravid female, which appeared during February 2002-'03, might be a precocious one. The fish might have completed its spawning by the end of July, as manifested by the total absence of spent fishes during August and September. During July and August, there was total absence of ripening (Stage III) and ripe (Stage IV) ovaries and therefore, these months can be considered as months of recrudescence. During the remaining period of the year, two distinct spawning seasons could be delineated, which were found preceding and succeeding the months of recrudescence. Based on the results of the present study, it can well be concluded that *O.bakeri* inhabiting Periyar river spawns twice in an year, the first spawning takes place during April-June with intense spawning during May while the second spawning occurs during October-November with intense spawning activity during November.

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; Murty, 1975; James and Baragi, 1980; Jayaprakas and Nair, 1981; Thakre and Bapat, 1981; Geevarghese and John, 1983; Kurup, 1994).

In *O.bakeri*, all the ova measuring 868µm and above were fully ripe while the group having diameter between 350-868µm were ripening ones. Those falling below 350µm were adjudged as maturing and immature categories. From the appearance of largest oocytes of 966µm in fully ripe conditions in April and October, it can be reasonably concluded that this species starts spawning during the above months and this is in close agreement with the spawning season delineated for *O.bakeri* in the present study. From the pattern of ova diameter frequencies arrived at during different months, a peak observed at 651-700µm during all months except July and August was worth mentioning. According to Jalbert (1976), after completion of vitellogenesis, oocytes are maintained within the ovary for a variable period until a series of endocrine events stimulates their final maturation and ovulation. The presence of a peak at 651-700µm group of ova in almost all months can be justified in the light of the above findings. Perhaps these groups may serve as the stock of ripening ova which will undergo sudden ripening and are shed in batches during the spawning season. This peculiarity may be very much advantageous to *O.bakeri* which is endowed with a very narrow abdominal cavity due to the lean nature of the body.

Multiple spawning is helpful in increasing the fecundity of fishes (Nikolskii, 1961, 1963; Wootton, 1984). The spent individuals of *O.bakeri* showed only a few ova greater than 350µm in diameter.

According to Prabhu (1956), all ova that are opaque, full of yolk and with yolk spherules are mature ones. Accordingly, in *O.bakeri*, large opaque/semitransparent ova above 700µm were found to be mature. The upper limits of the monthly ranges reflected the presence of individuals with mature ova in all months except July and August. Endogenous rhythm involved in sexual cycling in tropical fishes (Scott, 1979; Lam, 1983) takes gonadal development to final maturity which is then maintained until spawning is triggered by sudden environmental fluctuation (Schwassmann, 1971, 1978). 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. In carps, even though gametogenic cycle is almost completed as early as October, further development is suspended until the environment is warm enough for final maturation and ovulation after winter (Bye, 1984).

Ova diameter of *O.bakeri* 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 mainly characteristic of tropical and subtropical species of fishes and may not only be just an adaptation to increased food supplies, they also ensure the survival of the species under unfavourable spawning conditions. The succession of maturing group of ova implied that each individual fish spawned more than once at intervals of several days or weeks. In such forms, the breeding cycle of each individual takes an independent course (Qasim and Qayyum, 1961). Fulton (1899) stated that the occurrence of large numbers 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, in some, majority of the eggs become ripe more or less at the same time while in others the process is comparatively slow and only a part of the ova ripen and are 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 indefinite 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 *Clarias 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 *O.bakeri*, different batches of oocytes continuously passing from one stage to other were observed and hence the fish exhibited asynchronism in oocyte maturation. It should be mentioned that the duration of spawning in *O.bakeri* is found to be intermediate between group synchronous and asynchronous forms. 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, relatively longer when it lasts for 4-5 months and non-seasonal occurring over a greater part of the year.In *O.bakeri*, the breeding season lasts for 2-3 months and therefore, this species can be categorised under ‘moderately long’ following Kramer (1978).

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). Stacey (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), Alikunhi and Rao (1951), Khanna (1958), David (1959), Karamchandani (1961), Belsare (1962), Bhatnagar (1967), Parameswaran *et al.* (1972), Rao and Rao (1972), Khan and Jhingran (1975), Murty (1975), Siddiqui *et al.* (1976), Pathak and Jhingran (1977), Somavanshi (1980), Vinci and Sugunan (1981), Badola and Singh (1984), Shreshtha (1986), and Kurup (1994) lend support to 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 (Alikunhi 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 *O.bakeri* 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). There is an initial growth of spermatogonia and increase in weight in the testes until spermiogenesis. Thereafter a part of the germ cell cytoplasm, the so called residual body is eliminated from the cell and the Sertoli's cells remove them by phagocytosis (Grier, 1976; Nagahama, 1983; Billard, 1984). As a result, the weight of testes is reduced. 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 June, July, and August is concomitant with a period of early development of gonads and occurrence of spent fishes. The slightly high values observed from December to March reflected a diversity of gonad stages including a large number of maturing (II stage) and ripening (III stage) gonads. The peak GSI values encountered in October and April coincided with the highest incidence of ripe males and gravid females. 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 *O.bakeri*, the sudden drop in the values in November and May is indicative of the onset of spawning season. The conclusion drawn earlier that *O.bakeri* spawns twice a year can be further substantiated by the two peaks of GSI, the former in April and the latter in October.

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 valves, it can reasonably be inferred that this species is reproductively active for 2-3 months (April- June) with the onset of pre-monsoon showers and during the early part of south west monsoon. After a short period of quiescence, breeding activity is resumed for about 2 months (October-November) synchronous with north-east monsoon. Parameswaran *et al.* (1971) reported the presence of ripe specimens of *Osteobrama cotio* from late March which continued till the end of July. It breeds in the ponds of Assam from late April/early May with the onset of pre-monsoon rains and upto the end of July. According to him, majority of the fish spawned during the third week of May when there was continuous rains. The same author also suggested that the species matures within a year and breeds only once a year. Nath (1994) studied the spawning ecology of fishes of Jammu Province and observed that the cyprinids, *Labeo rohita*, *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 *O.bakeri* fits into Type 'C' of Prabhu (1956) and category II of Qasim and Qayyum (1961). *O.bakeri* was found to breed twice in an year in the Periyar 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 intra-specifically (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 *O.bakeri*, the males and females were found to be mature at 115 and 118mm 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* (Murty, 1975), *Tor tor* (Chaturvedi, 1976), *Labeo gonius* (Siddiqui *et al.*, 1976), *Labeo bata* (Siddiqui *et al.*, 1976), *Noemacheilus triangularis* (Ritakumari and Nair, 1979), *Schizothorax longipinnis* (Sunder, 1986), *Labeo dussumieri* (Kurup, 1994) and *Schizothorax plagiostomus* (Agarwal, 1996). Jayaprakas and Nair (1981) reported almost similar situation in the *Etroplus suratensis* wherein males (140mm) attained maturity slightly ahead of females (144mm) which is comparable to that of *O.bakeri*. The first appearance of ripe and spent individuals in 110-120 mm group in males and in 115-120mm size group in females of *O.bakeri* suggests 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 *O.bakeri* also, the females are larger in size. The maximum size of the males and females encountered during the present investigation is 150mm and 163mm 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 (Murty, 1975).

Age and growth studies revealed that the males attained a length of 107mm and 148mm during the first and second years respectively while females grew upto 129mm in the first year itself (Integrated method of Pauly,1983) (See Chapter 8 for details). Hence, it may be inferred that the males first spawned during the early or middle part of the second year of life while females spawned during the first year itself. The size at first maturity may be related to the relative condition factor (Kn) of the fish. According to Hart (1946), the point of inflection in Kn curve may be indicative of the commencement of maturity. In *O.bakeri*, the Kn curve showed the inflection at 105-110mm which was ensued by the attainment of size at first maturity (Refer Chapter 7).

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 in some of the months of the two years. Murty (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*, *Ophicephalus punctatus* and *Schizothorax plagiostomus* respectively.

The ideal sex-ratio in natural adult 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 fertilisation 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 *O.bakeri.* Spawning migration of fishes can lead to alterations in sex-ratio drastically (Nautiyal, 1994; Singh, 1997). According to Laroche and Richardson (1980), the adults may often be segregated by sex. 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. As cited by Bhatnagar (1972) in *Labeo fimbriatus*, the females of *O.bakeri* were stouter than the males and during the breeding season, the females with well developed ovary became more rounded, sluggish and less agile when compared to males and therefore, will be more vulnerable to easy exploitation. 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 *O.bakeri* are corroborating with the findings in a number of fish species (Bennet, 1962; Bailey, 1963; Bhatnagar, 1972; Chaturvedi, 1976; Siddiqui *et al.*, 1976; 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. However, in *O.bakeri*, size-wise, males were found to mature earlier than females while age-wise it was the females which matured first during the first year of life itself. Siddiqui *et al.* (1976) stated that the predominance 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 *O.bakeri* 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 fecundity as the number of eggs produced by an individual fish in its life time. 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) have been proposed to explain such variations. Fecundity in teleosts ranges 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.bata* (Alikunhi, 1956; Bhatnagar, 1967; Siddiqui *et al.*, 1976), *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* (Somavanshi, 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 *O.bakeri*, the fecundity ranged from 2834-8213, which is comparable to P.ticto. Parameswaran *et al.* (1971) estimated the fecundity of an allied species *O.cotio* to be 3006-10970. The slight increase in the number of ova in *O.cotio* might be attributed to the variation in ova size of both the species. The diameter of mature ova in *O.cotio* ranged between 629-731µm while in *O.bakeri*, it is comparatively larger (700-966µm). Bulkley (1967) 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 *O.bakeri* was 254. This value is comparable to the fecundity estimate of 252 ova in *L.calbasu* by Pathak and Jhingran (1977) and of 256 ova in *L.rohita* by Varghese (1973).

Reports on the relative fecundity of other cyprinids include that of *Labeo bata* with 285 ova (Alikunhi, 1956),*Barilius bendelisis* with 275 ova (Dobriyal and Singh, 1987), *L. gonius* with 271 ova (Joshi and Khanna, 1980), *P.vittatus* with 228 ova (Ibrahim, 1957), *P.sarana subnasutus* with 227 eggs (Sobhana and Nair, 1974), *L.calbasu* with 201 eggs (Vinci and Sugunan, 1981) and *L.dussumieri* with180 eggs(Kurup,1994) *O.cotio* (Parameswaran *et al.*, 1971) was found to possess 514-599 ova per gram body weight. It would thus appear that *O.bakeri* produced only less than half the number of ova per gram weight of the body when compared to *O.cotio*. However, the number of ova per gram ovarian weight of both species of *Osteobrama* was almost comparable in the former it ranged from 3115 to 4735 while in the latter, it ranged from 3796 to 4664. Ibrahim (1957) reported slightly higher ranges of ova in *P.stigma* and *P.ticto* when compared to *O.bakeri*. Sivakami (1982) estimated the average number of ova per gram ovarian weight in *P.dorsalis* as 3319 which is slightly lower than that of *O.bakeri* (3631 ova).

The coefficient of maturity increased upto 134 mm TL, stabilised in the next groups and thereafter declined. 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. Gonosomatic 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 *O.bakeri* is marked by changes not only associated with maturity index but also with gonosomatic 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 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). Bagenal (1978) stated that the exponent often ranged from 2.3 to 5.3 and frequently exceeded 3. 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 *O.bakeri* was observed to be 2.7017 which did not deviate significantly from the value of '3' and this finding is in total agreement with the above reports. The value of the exponent in the length-weight relationship of female was found to be 3.1967 (Chapter 7). Since the exponential value in the length-fecundity relation (2.7017) was observed to be lower than that in length-weight relationship (3.1967), it appears that the fecundity in the species increased at a rate lesser 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' value of 0.8026 did not significantly deviate from unity. In other words, the number of ova increased in proportion to body weight. The coefficient of determination (r^2) indicated that approximately 50% of the variation in fecundity was associated with body length. The correlation of fecundity on body weight was slightly closer than that for length as nearly 60% of the variation in egg production was explained by the changes in weight. Smith (1947) stated that the number of ova was related to the weight or volume of fish than the length. 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.*, 1976), *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 Chaturvedi (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, but body weight was more closely related to ovary weight than length, as observed in *L.dussumieri* by Kurup (1994).

From the multivariate analysis, ovary weight was identified as the most appropriate predictor of ovarian egg count, 96% of the variation in fecundity being explained by the changes in weight. But it is undesirable to sacrifice the fish to determine the gonad weight. Bagenal (1957) has stated that fish length, being easier to measure in the field, is more suitable to make prediction of fecundity when large samples are to be dealt with within limited time. Fecundity in *O.bakeri* was found to be almost close to the cube of length and directly proportional to the fish weight and these results would be invaluable in enumerating the fecundity without sacrificing the specimens.

Table 6.1. Maturity stages (in %) in different length groups of male *O. bakeri*

MATURITY STAGES

Length group(mm)	1	11	111	1V	V
95-100	75	25			
100-105	62.5	37.5			
105-110	42.22	46.67	11.11		
110-115	27.85	29.11	37.97	5.06	
115-120	18.63	27.10	38.15	7.48	9.35
120-125	2.56	27.21	45.87	7.69	16.67
125-130		18	50	16	16
130-135		6.25	34.38	40.63	18.75
135-140			11.76	35.29	52.94
140-145			15.38	38.46	46.15
145-150				50	50
150-155					100

Table 6.2. Maturity stages (in %) in different length groups of female *O. bakeri*

	MATURITY	STAGES			
Length group(mm)	1	11	111	1V	V
100-105	66.67	33.33			
105-110	70.59	29.41			
110-115	47.37	42.11	10.53		
115-120	17.24	34.48	37.93	3.45	6.90
120-125	6.45	32.26	46.77	8.06	6.45
125-130	1.49	25.37	47.76	10.45	14.93
130-135		19.57	52.17	10.87	17.39
135-140			33.33	25	41.67
140-145			28.57	28.57	42.86
145-150			16.67	25	58.33
150-155				50	50
155-160				50	50
160-165				100	

Table 6.3. Sex ratio of *O.bakeri* during different months of 2001-02 and 2002-03

2001-2002 Months	Total	Male	Female	M:F	Chi square	Probability
June	14	11	3	0.27	4.57	P<.05
July	16	10	6	0.60	1	P>.05
August	17	11	6	0.55	1.47	P>.05
September	30	21	9	0.43	4.8	P<.05
October	31	19	12	0.63	1.58	P>.05
November	32	10	22	2.20	4.5	P<.05
December	33	18	15	0.83	0.27	P>.05
January	97	87	10	0.11	61.12	P<.01
February	27	18	9	0.50	3	P>.05
March	19	5	14	2.80	4.26	P<.05
April	52	28	24	0.86	0.31	P>.05
May	36	23	13	0.57	2.78	P>.05
Total	**404**	**261**	**143**	**0.55**	**34.47**	**P<.01**
2002-2003						
June	51	39	12	0.31	14.29	P<.01
July	107	42	65	1.55	4.94	P<.05
August	17	12	6	0.50	2.00	P>.05
September	65	58	7	0.12	40.02	P<.01
October	62	57	5	0.09	43.61	P<.01
November	17	9	8	0.89	0.06	P>.05
December	75	54	20	0.37	15.62	P<.01
January	6	5	1	0.20	2.67	P>.05
February	16	6	10	1.67	1	P>.05
March	31	16	15	0.94	0.03	P>.05
April	19	2	17	8.50	11.84	P<.01
May	25	6	19	3.17	6.76	P<.01
Total	**491**	**306**	**185**	**0.60**	**28.38**	**P<.01**

Table 6.4. Sex ratio in *O.bakeri* in each 5 mm length group

Length group(mm)	Total	Males	Females	M:F	Chi square	Probability
95-100	4	4	0			
100-105	11	8	3	0.38	2.27	P>.05
105-110	62	45	17	0.38	12.65	P<.01
110-115	141	122	19	0.16	74.22	P<.01
115-120	182	153	29	0.19	29.19	P<.01
120-125	183	114	69	0.61	11.07	P<.01
125-130	124	50	74	1.48	4.65	P<.05
130-135	84	32	52	1.63	4.76	P<.05
135-140	44	17	27	1.59	2.27	P>.05
140-145	34	13	21	1.62	1.88	P>.05
145-150	20	8	12	1.50	0.80	P>.05
150-155	3	1	2	2.00	0.33	P>.05
155-160	2	0	2			
160-165	1	0	1			
Total	**895**	**567**	**328**	**11.51**	**61.11**	**P<.01**

Table 6.5 Average values of fecundity indices in the spawners of *O.bakeri*

Length group (mm)	Averge fish length(mm)	Average fish weight (g)	Average ovarian weight(g)	No of fishes examined	No of ova		Maturity index	Gonosomatic index	Absolute fecundity
					per g fish weight	per g ovarian weight			
120-124	123	15.97	1.07	3	251	3922	6.53	7.03	4090
125-129	127	16.86	1.21	7	277	3893	7.19	7.76	4662
130-134	131	17.89	1.45	9	300	3791	8.07	8.83	5388
135-139	137	20.47	1.64	6	290	3641	7.98	8.68	5936
140-144	141	24.56	1.99	4	268	3405	8	8.73	6640
145-149	146	25.56	1.88	1	253	3435	7.36	7.94	6457
150-154	151	31.2	2.1	1	240	3566	6.73	7.22	7488
155-159	155	37.56	2.24	1	210	3525	5.96	6.34	7896
160-164	163	40.12	2.3	1	201	3500	5.73	6.08	8049
Average	141.56	25.58	1.76		254	3631	7.06	7.62	6290

Table 6.6. Statistical analysis to test deviation from Cube law

	b	df	Sb	t=b-3/Sb	t=b-1/Sb	Probability
F vs TL	2.7017	32	0.4894	-0.6096		NS
F vs W	0.8026	32	0.1190		-1.6585	NS
F vsOL	2.3773	32	0.4073	-1.5288		NS
F vs OW	0.7765	32	0.0271		-8.2577	P<0.01
OW vsTL	3.3366	32	0.6324	0.5323		NS
OW vs W	0.9762	32	0.1584		-0.1502	NS

NS =not significant

Table 6.7. Statistical analysis to test the significance of correlation coefficient

	r	T	Probability
F vs TL	0.7041	5.52	P<0.01
F vs W	0.7712	6.75	P<0.01
F vsOL	0.7236	5.84	P<0.01
F vs OW	0.9817	28.69	P<0.01
OW vsTL	0.6878	5.28	P<0.01

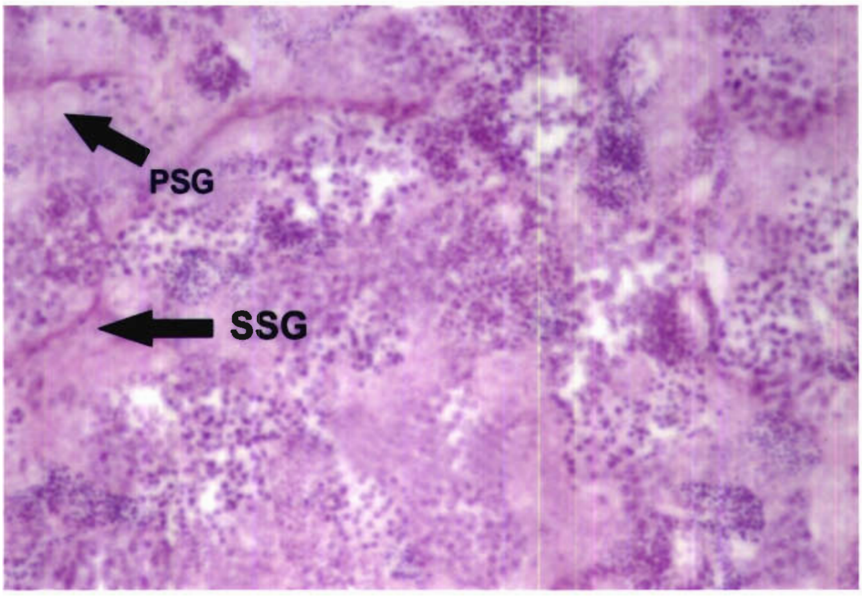


Fig. 6.1. T.S. of testis showing primary and secondary spermatogonia

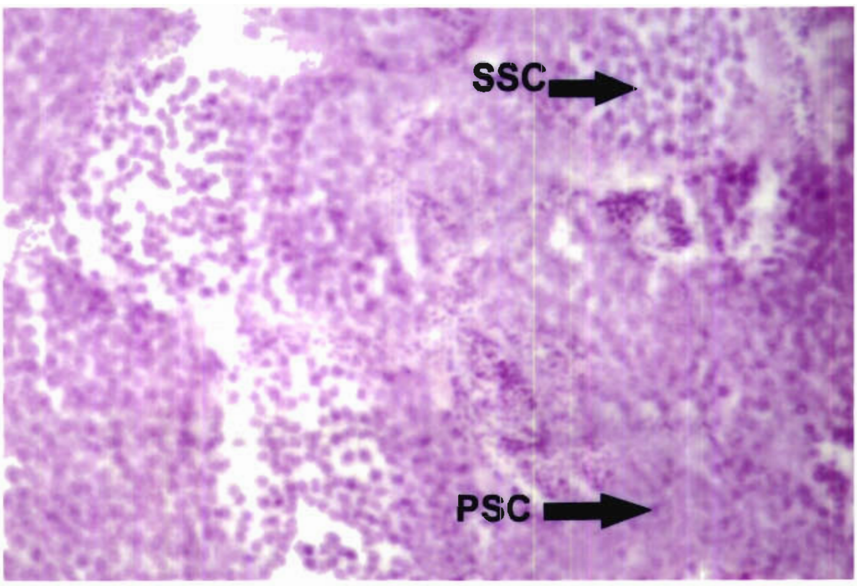


Fig. 6.2. T.S. of testis showing primary and secondary spermatocytes

PSG - Primary spermatogonia
SSG - Secondary spermatogonia
PSC - Primary spermatocytes
SSC - Secondary spermatocytes

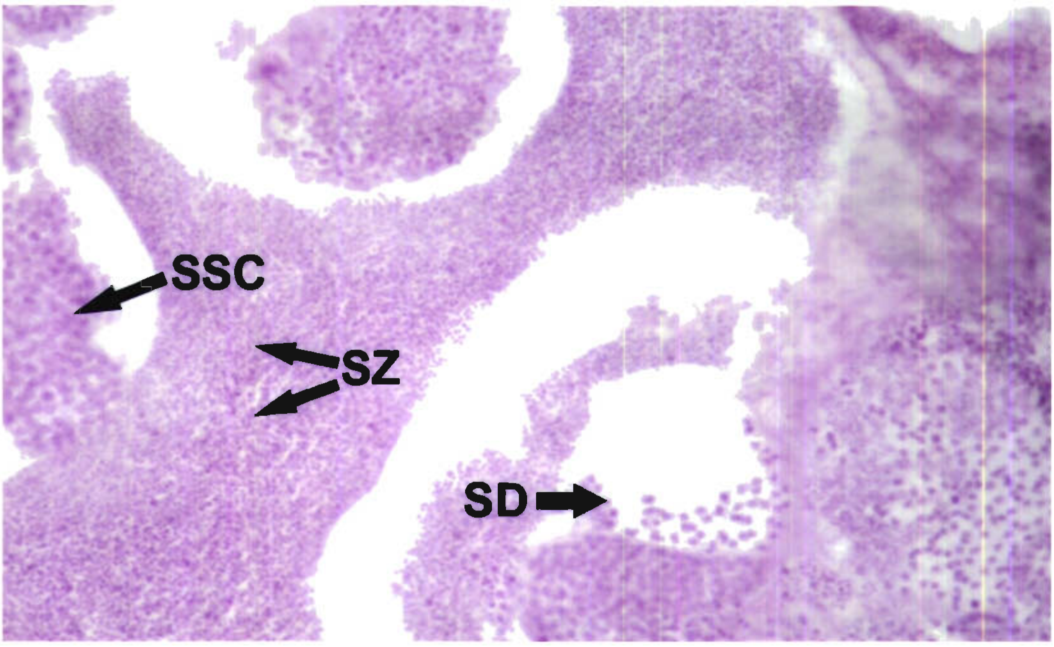


Fig. 6.3. T.S. of testis showing secondary spermatocytes, spermatids and spermatozoa

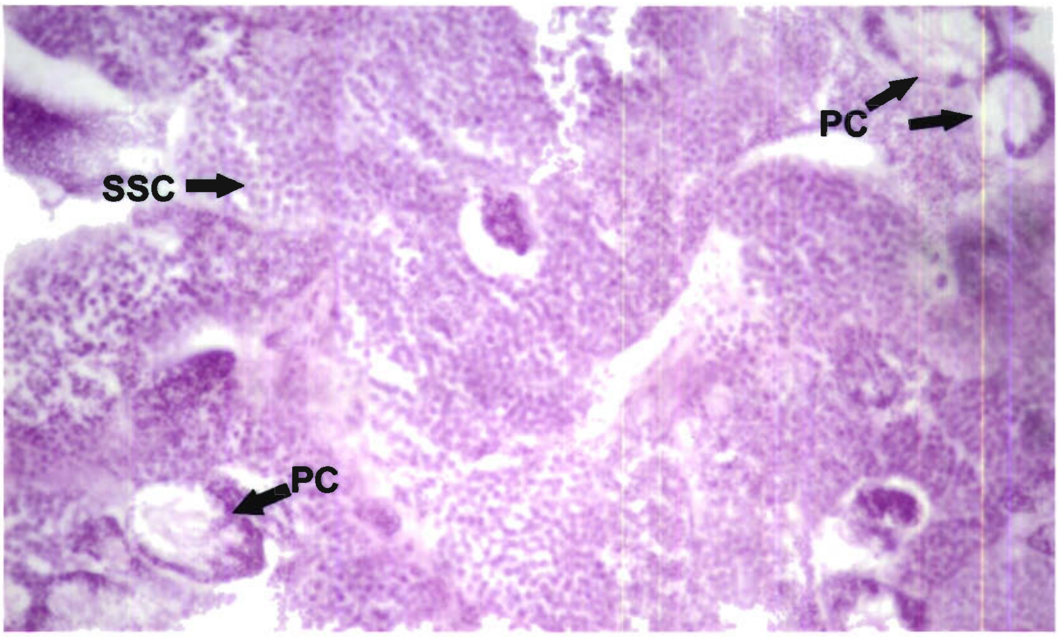


Fig. 6.4. T.S. of testis showing secondary spermatocytes and parachute arrangement of spermatozoa

SZ - Spermatozoa, SD - Spermatid,
SSC - Secondary spermatocytes,
PC - Parachute arrangement.

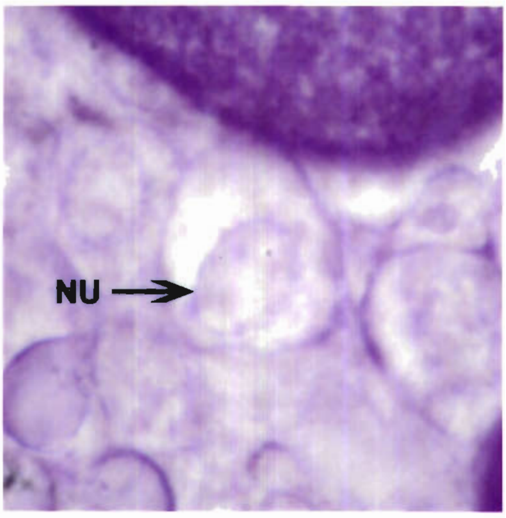


Fig. 6.5. Chromatin nucleolus stage

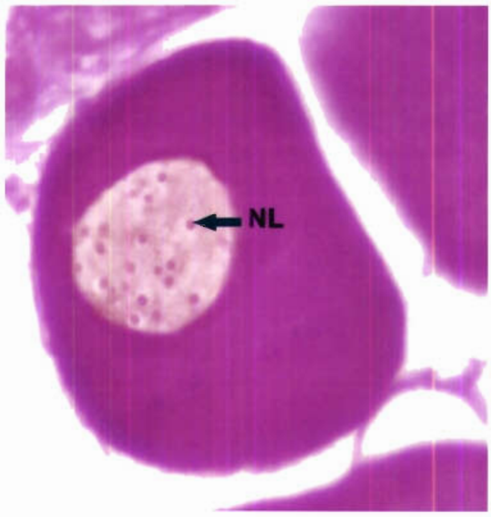


Fig.6.6a. Early perinucleolus stage

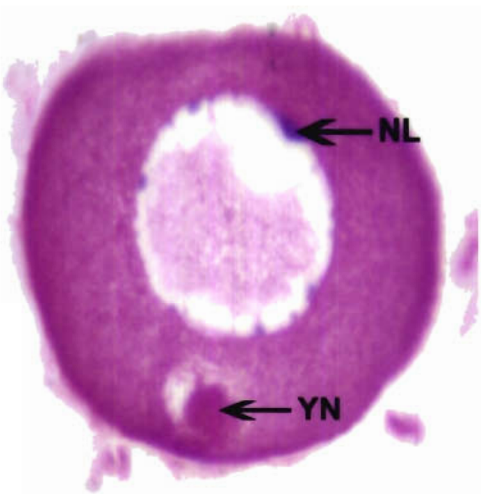


Fig. 6.6 b. Late perinucleolus stage

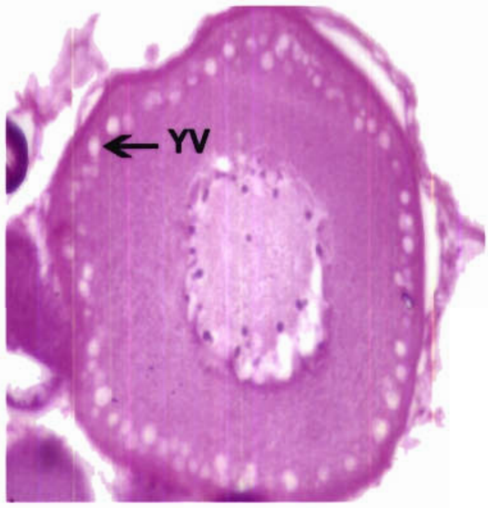


Fig. 6.7a. Early yolk vesicle stage

Fig. 6.7b. Late yolk vesicle stage

Fig. 6.8 a. Early yolk globule stage

NL - Nucleolus, NU - Nucleus, YN - Yolk nucleus, YV - Yolk vesicle, YG - Yolk globule

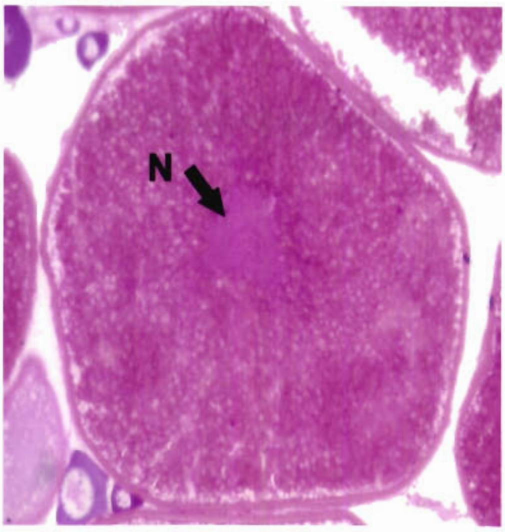


Fig. 6.8b. Late yolk globule stage

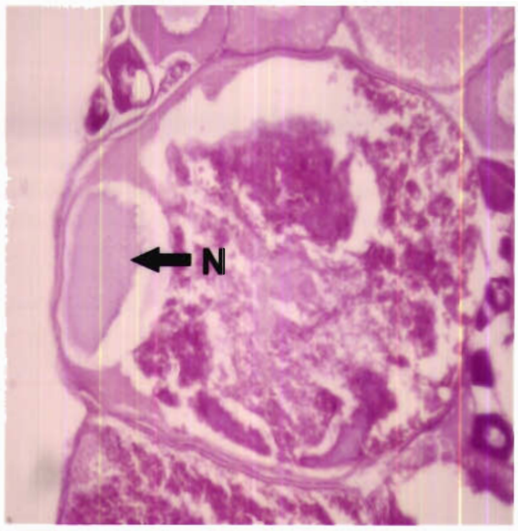


Fig. 6.9. Migratory nucleus stage

Fig. 6.10. Ripe egg

Fig. 6.11. Atretic oocytes

N - Nucleus, YG - Yolk globules,

HZG - Hypertrophied zona granulosa

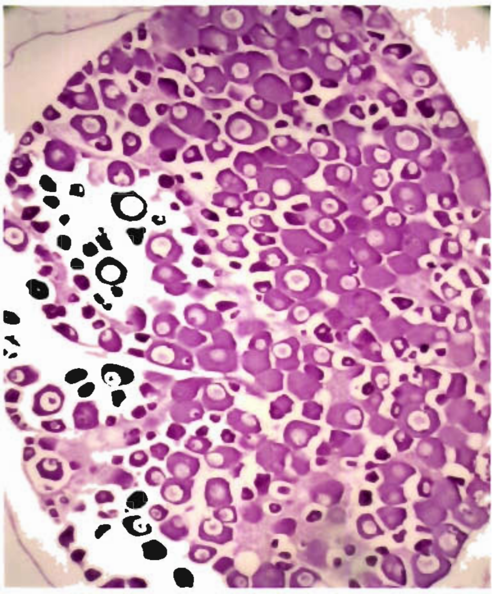


Fig. 6.12a. Immature ovary

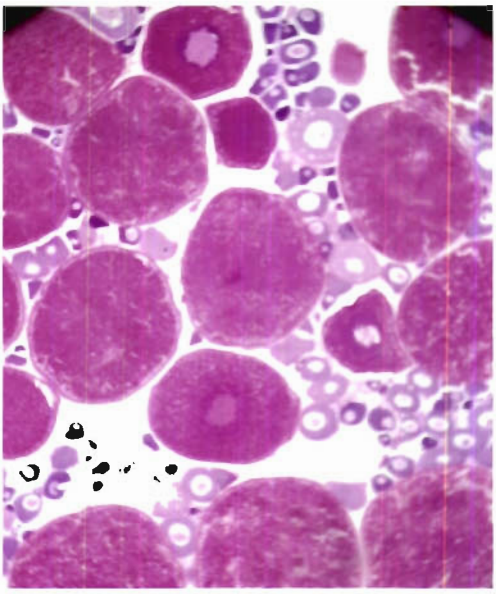


Fig. 6.12b. Ripening ovary

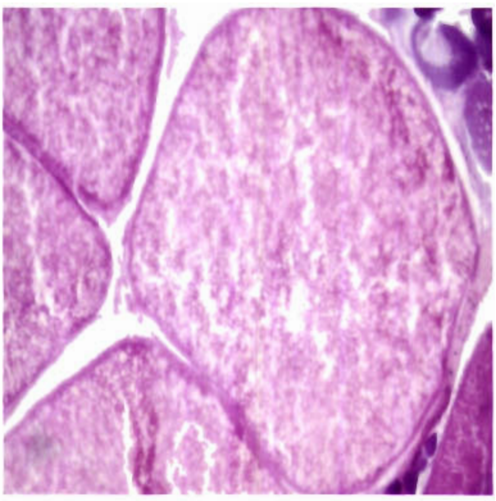


Fig. 6.13a. Ripe ovary

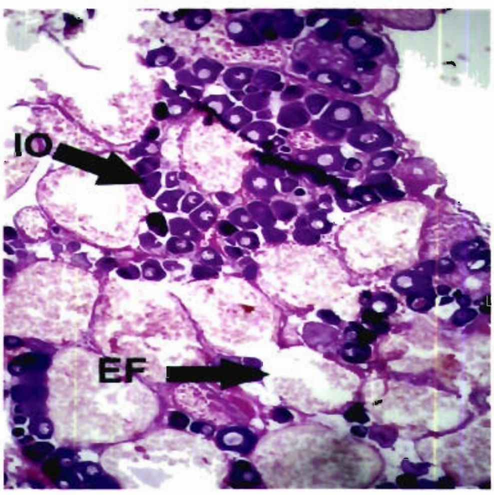


Fig. 6.13b. Spent ovary

IO - Immature ova

EF - empty follicle

Fig. 6.14a. Maturing ovary (Stage 2)

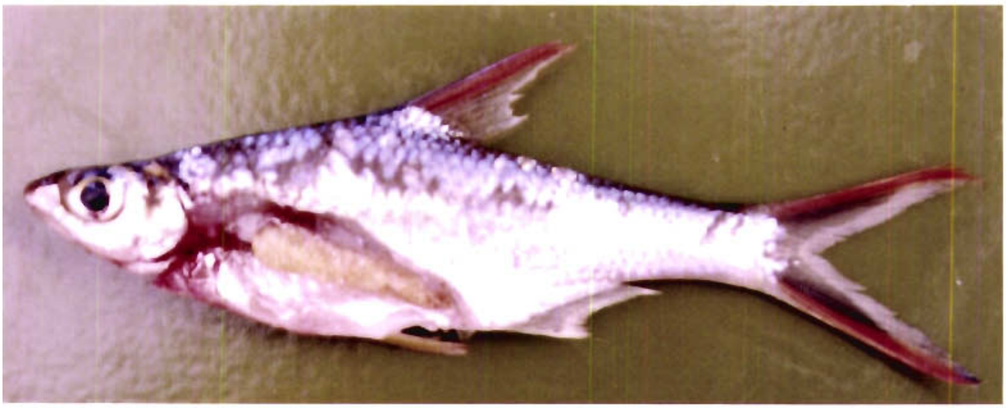


Fig. 6.14b. Ripening ovary (Stage 3)

Fig. 6.15a. Ripe ovary (Stage 4)

Fig. 6.15b. Spent ovary (Stage 5)

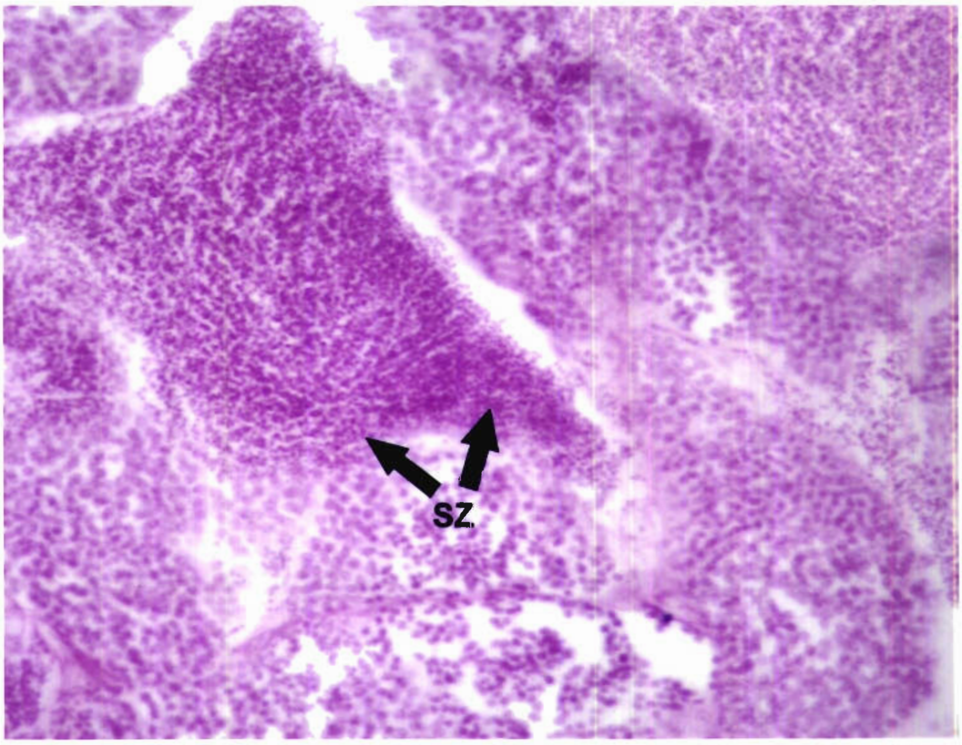


Fig. 6.16a. Ripe testes (Stage 4)

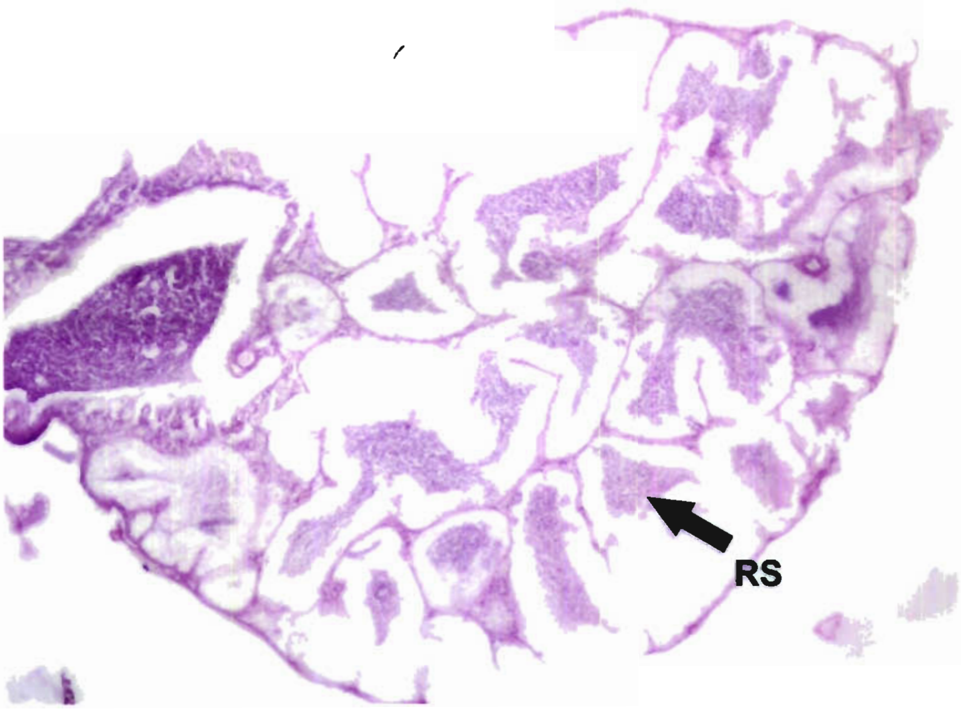


Fig. 6.16b. Spent testes (Stage 5)

RS - Residual spermatozoa, SZ - Spermatozoa

Fig. 6.16c. Maturing testis (stage 2)

Fig. 6.16d. Ripening testis (stage 3)

Fig. 6.16e. Ripe testis (stage 4)

Fig. 6.17a. Monthly percentage occurrence of gonads in different stages of maturity *O.bakeri* during 2001-02

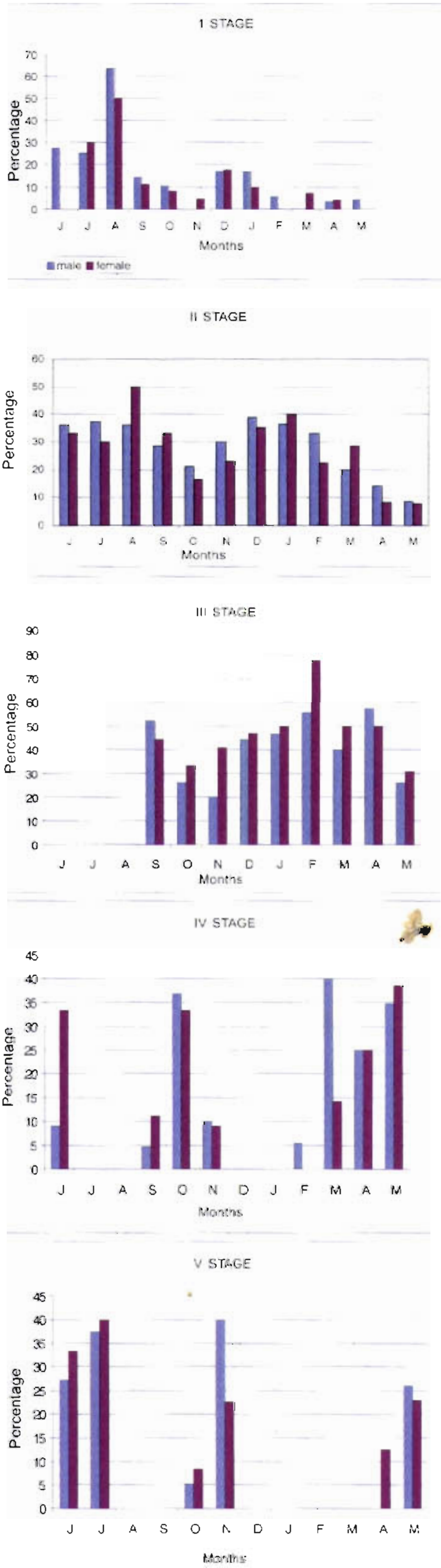


Fig: 6.17b. Monthly percentage occurrence of gonads of *O. bakeri* in different stages of maturity during 2002-03

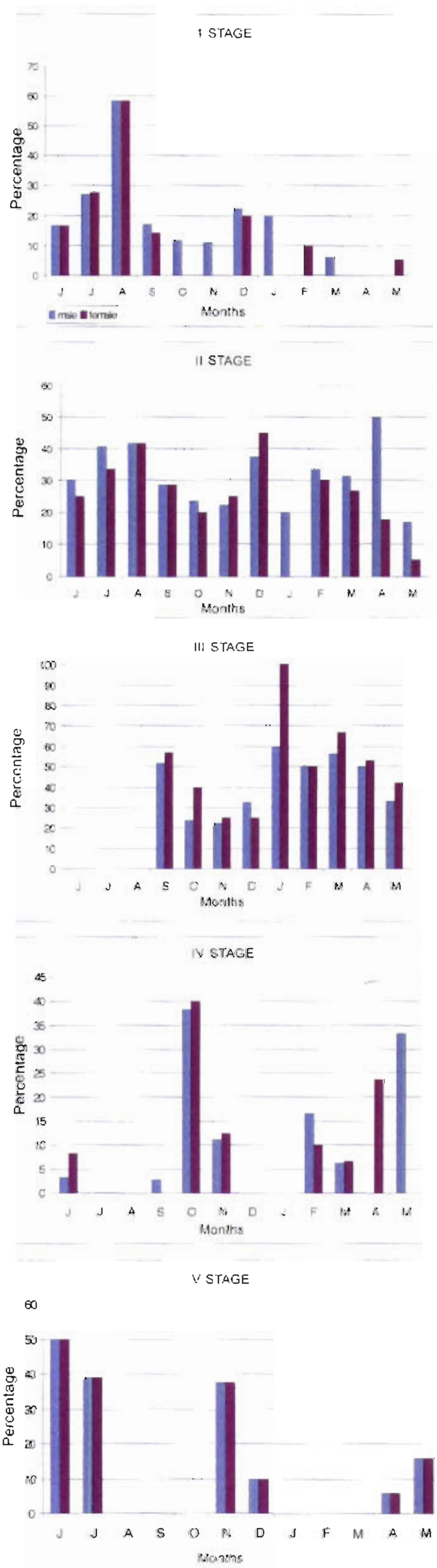


Fig: 6.18. Monthly variation in ova diameter percentage frequency of *O. bakeri*

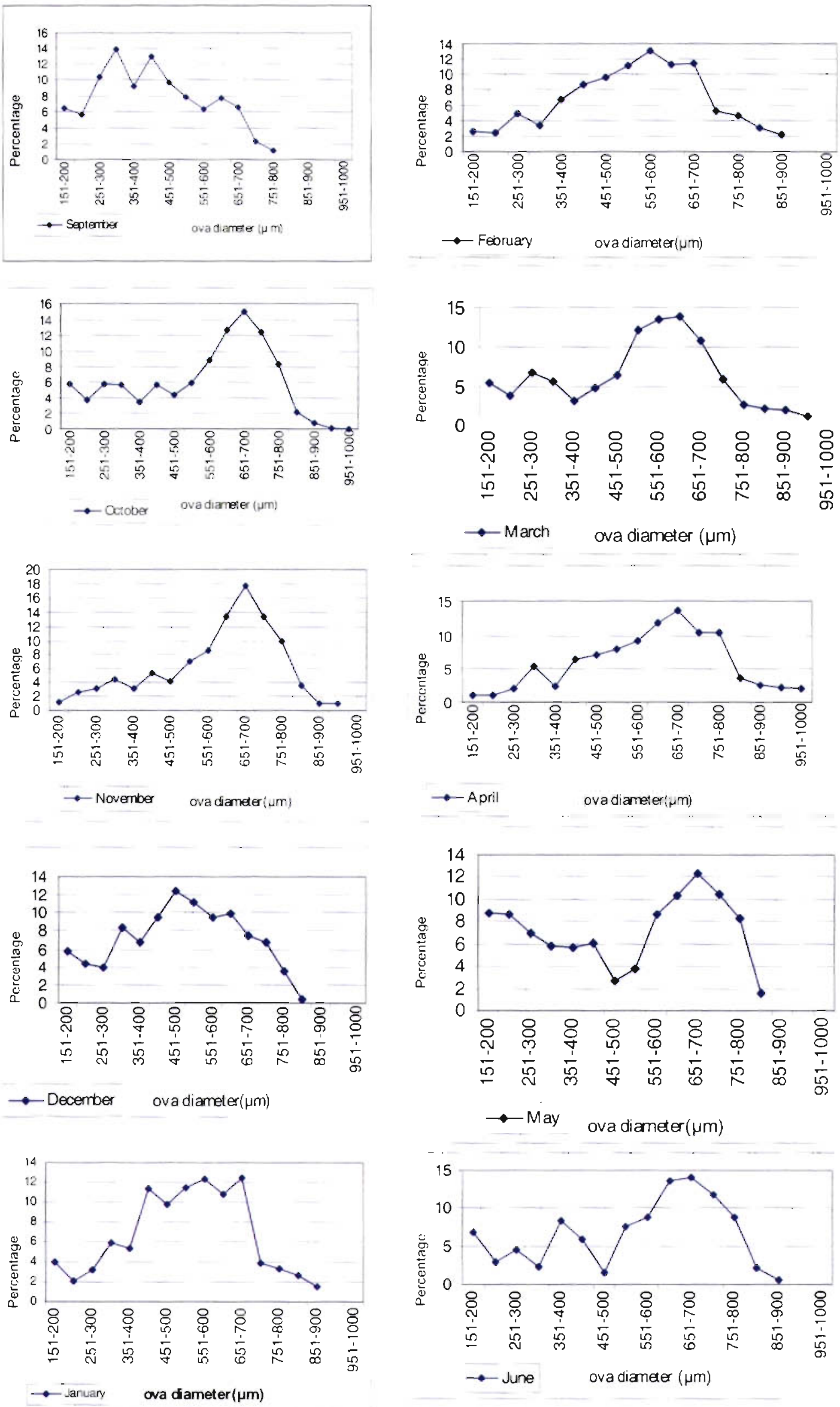


Fig. 6.19. Monthly variation of gonadosomatic index in *O. bakeri* during 2001-02

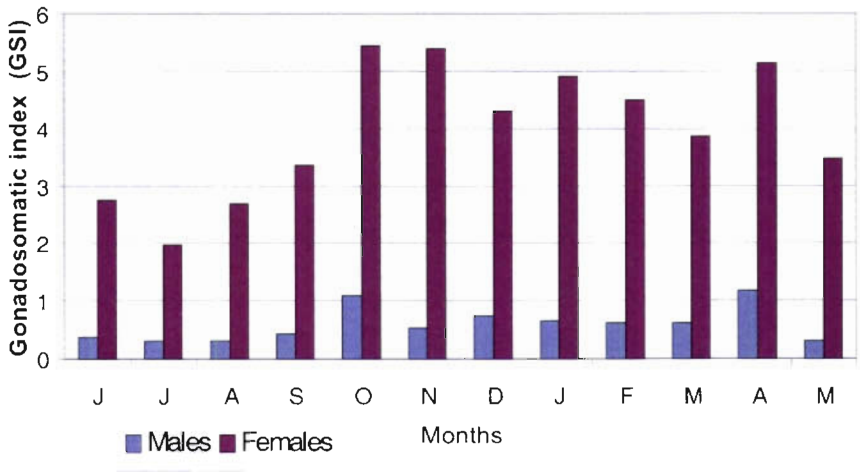


Fig. 6.20. Monthly variation of gonadosomatic index in *O. bakeri* during 2002-03

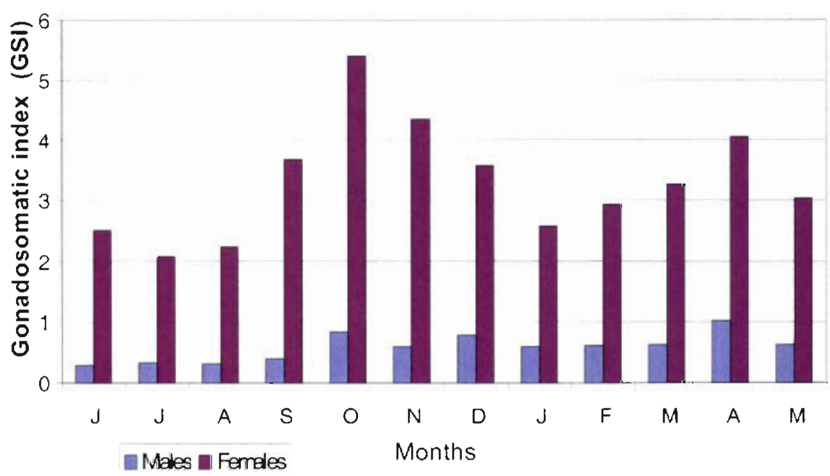


Fig. 6.21. Percentage occurrence of mature males and females in *O.bakeri*

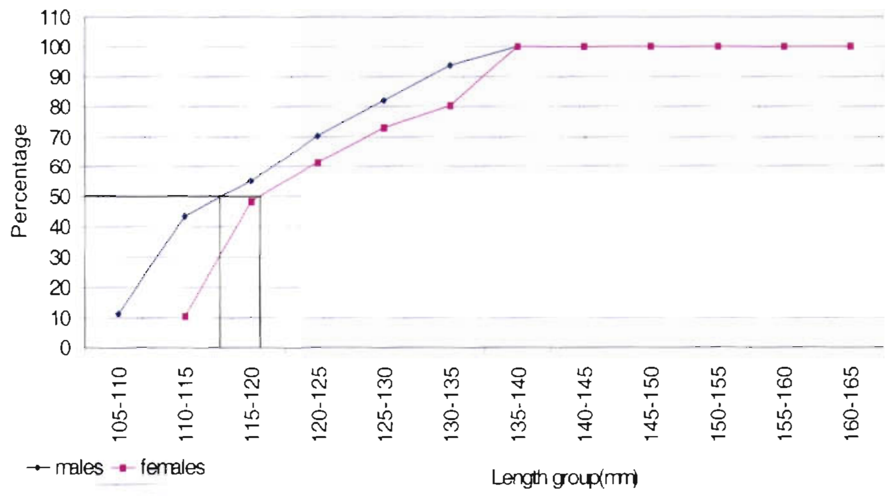
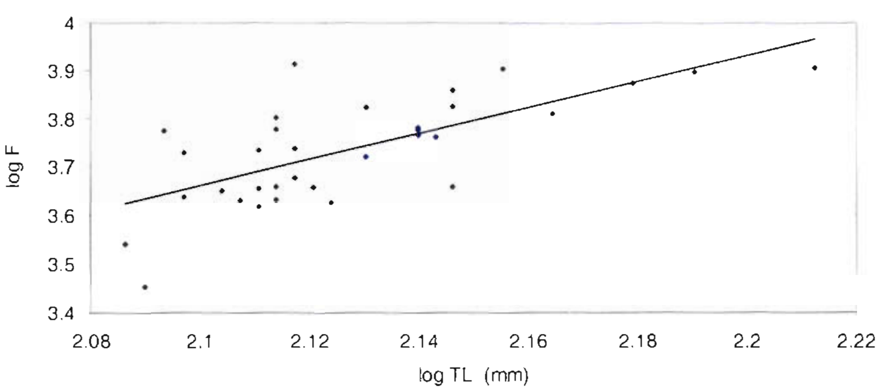
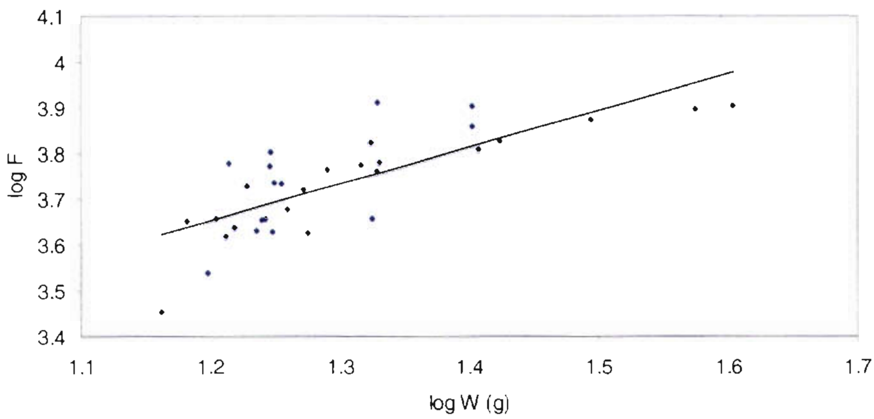


Fig.6.22. Relationship between fecundity and total length



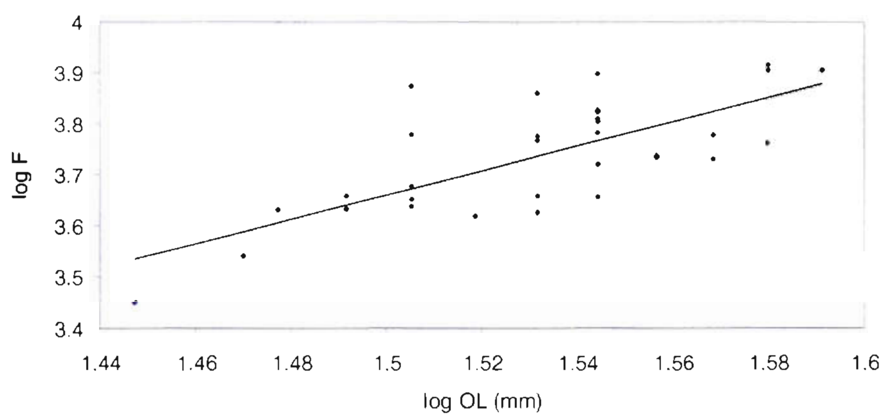
$\log F = -2.0126 + 2.7017 \log TL$ $r = .7041$

Fig. 6.23. Relationship between fecundity and body weight



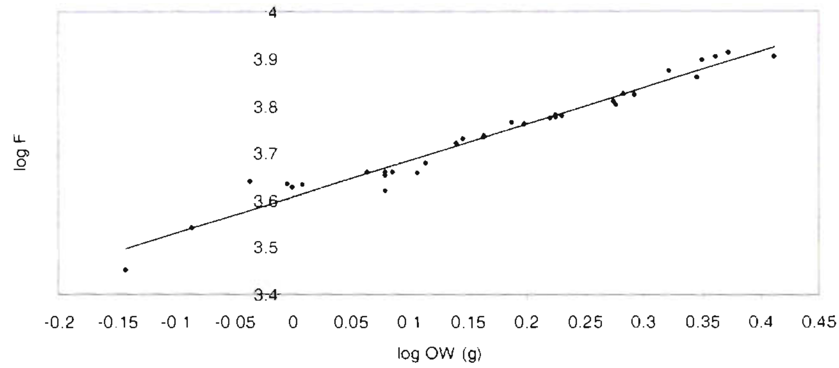
$\log F = 2.6918 + .8026 \log W \qquad r = 0.7712$

Fig.6.24. Relationship between fecundity and ovary length



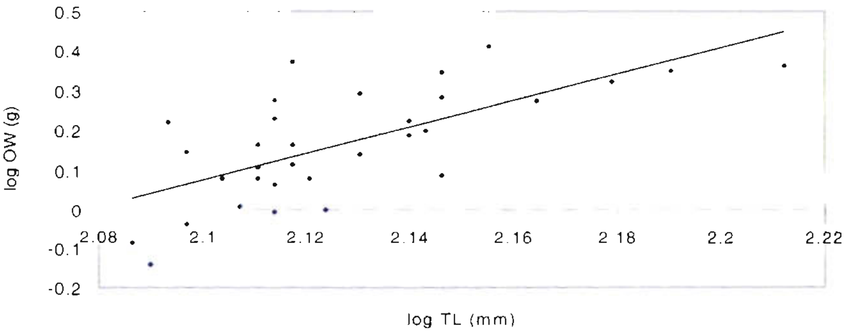
$\log F = .0954 + 2.3773 \log OL \qquad r = 0.7236$

Fig.6.25. Relationship between fecundity and ovary weight



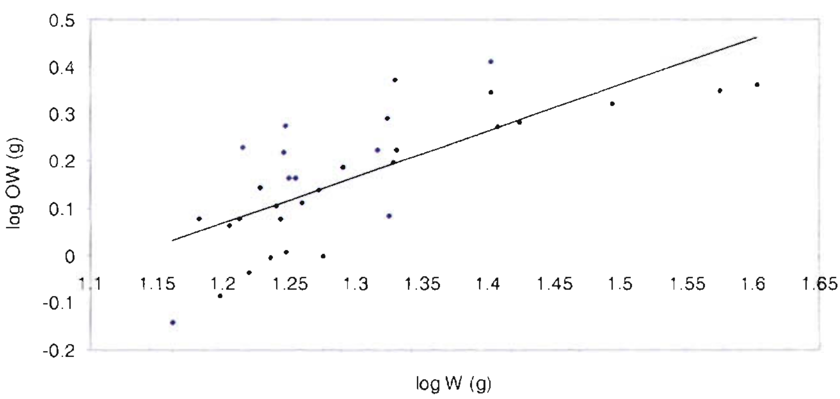
log F = 3.606 + 0.7765 log OW $\qquad$ r = 0.9817

Fig.6.26. Relationship between total length of fish and ovary weight



log OW = -6.932 + 3.3366 log TL $\qquad$ r = 0.6878

Fig. 6.27. Relationship between body weight of fish and ovary weight



log OW = -1.1026 + 0.9762 log W $\qquad$ r = 0.7419

CHAPTER VII

LENGTH–WEIGHT RELATIONSHIP AND CONDITION FACTOR

7.1. 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-weight 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 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 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 (K_n) 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 exponent value is equal to 3. Thus 'K' factor measures the variations from an ideal fish which holds the cube law while K_n 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), Natarajan and Jhingran (1963), Sinha (1972), Pathak (1975), Chatterji (1980), Chatterji *et al.* (1980), Vinci and Sugunan (1981), Sivakami (1982), Choudhury *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), Mercy *et al.* (2002), Kurup *et al.* (2002) and Mohan and Singh (2003). However, no information is available on the length-weight relationship and condition factor of *O.bakeri* and therefore, the present study was undertaken to elucidate the pattern of growth and general well-being of this fish species.

7.2. Materials and Methods

1108 specimens of *O.bakeri* comprising of 567 males, 328 females and 213 indeterminates were collected from Periyar river (Kerala) using gill net (22mm mesh size) during June 2001 to May 2003. After blotting the specimens to remove excess water, the total length to the nearest millimeter and weight to the nearest 0.0l 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 95 to 150 mm, 104 to 163 mm and 89 to 117 mm respectively and the weight from 6.48 to 24.52g in males, 8.14 to 40.12g in females and 4.74 to 12.42g 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 logarithmic transformation of which gives the well known 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 slope 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 logarithmic values and fitting a straight line by the method of least squares. The data was processed in EXCEL software. The significance of regression was assessed by ANOVA. The regression coefficients of the sexes and indeterminates were compared by analysis of covariance (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 ($t = (b-3)/Sb$ where b = regression coefficient, 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 (K_n) as per Le Cren (1951) and Ponderal index (Condition factor, K) as per Hile (1936) are expressed as follows:

$$K_n = \frac{W}{\hat{W}}$$

where W = observed weight

$\hat{W}$ = calculated weight derived from length-weight relation

$$K = \frac{W \times 10^5}{L^3}$$

where W = observed weight

L = body length

The number 10^5 is a factor to bring the ponderal index to near unity (Carlander, 1970).

Fluctuations in condition were examined both seasonally and size wise.

7.3. Results

Length-weight relationship of males, females and indeterminates of *O.bakeri* can be expressed as follows:

	Logarithmic equation	**Parabolic equation**
Males	log w = -3.4252 + 2.1738 log l	$0.0003757\ L^{2.1738}$
Females	log w = -5.5205 + 3.1967 log l	$0.000003016\ L^{3.1967}$
Indeterminates	log w = -5.0059 + 2.939 log l	$0.000009865\ L^{2.939}$

The 95% confidence limit of 'b' values were:

Male	=	2.0394 - 2.3082
Female	=	3.0675 - 3.3259
Indeterminates	=	2.7499 - 3.1280

The logarithmic relationship between length and weight of males, females and indeterminates of *O.bakeri* together with correlation co-efficient is depicted in Figs.7.1, 7.2, and 7.3 respectively. The correlation coefficient 'r' between log length and log weight was found to be 0.8007in males, 0.9376 in females and 0.9036 in indeterminates. The't' test on 'r' values (Table 7.1) 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 7.2,7.3 and 7.4 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 (r^2) (Croxton, 1953), 64.11% of the variation in weight in males, 87.9% in females and 81.66% in indeterminates were found to be associated with the change in the length of the fish. The errors in the regression coefficients (Table.7.1) were highest in indeterminates indicating that more than one weight is obtained for a given length more frequently than in females and males while the errors were minimum in the case of females.

The results of the analysis of covariance (ANACOVA) (Table 7.5) revealed significant differences in the regression coefficient of males, females and indeterminates (F value = 61.07, df: 2, 1102) thereby indicating heterogeneity of the samples. Hence pair wise comparison between males and females, males and indeterminates, females and indeterminates was carried out using students 't' test (Zar, 1974). The results (Table 7.6) show that 'b' values are significantly different ($P<0.01$) in all expect females and indeterminates.

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 *O.bakeri* 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 2.1738 while in females it was 3.1967 whereas in indeterminates, the same was 2.939. The 't' values arrived at, 12.07(df: 565) in males and 2.9955 (df: 326) in females, manifested significant departure of 'b' value from 3 in both the sexes ($P<0.01$) while in indeterminates 't' value (0.6366, df: 211) was found as non-significant.

The fluctuations noticed in K_n values of males and females during 2001-'02 and 2002-'03 are represented in Figs.7.4 and 7.5 respectively. In 2001-'02, the K_n values of males showed 2 peaks (October and April-May) and 2 troughs(July and January) whereas 3 peaks (November, February and April) and 3 troughs (August, December and March) were discerned during 2002-'03. Incidentally, the values of ponderal index (K) (Fig. 7.8) were found in conformity to the K_n values during 2002-'03. On the other hand, a conspicuous difference was noticed in the above two values in October 2001-'02, during when K_n value was higher and 'K' value was low. During 2001-'02, females showed low K_n values in June. An increase in K_n value in July and a decrease in August was followed by a gradual increase in the values upto October. There was not much fluctuation in condition during

November and December but a sharp inflexion occurred in January, thus recording the lowest value of 0.8722. It again shot up in February and declined in March-April and thenceforth showed an increase in May. The trend was more or less same during both the years from May to October; in contrast, an inverse relationship was discernible from November to April. During 2001-02, the peak of relative condition (K_n) was observed in October, registering a value of 1.0546 while during 2002-03, the highest K_n value (1.0548) was found in November. The seasonal variations in the values of condition factor (K) (Fig. 7.9) were more or less similar to that of relative condition factor (K_n).

The average values of relative condition factor in respect of indeterminates and sexes belonging to different size groups are plotted in Figs. 7.6 and 7.7 respectively. In males, higher K_n value of 1.02 was found in 95-100 mm length group, followed by a decreasing trend in 100-110mm size groups and thenceforth, the values gradually increased to culminate in a peak value of 1.1469 in 130-135 mm group. Beyond 135 mm TL, there was a downward trend in K_n values, the lowest value of 0.7294 being recorded for 150-155 mm size group. The pattern of K values was similar to K_n values in the smaller fishes upto 110 mm TL and larger fishes beyond 135 mm TL but in contrast to the K_n values, in the intervening length range from 110 to 135 mm TL, the K values were almost stabilised around 0.75 (Fig. 7.10). In females, high K_n values were recorded in smaller and larger fishes. The value estimated in the smallest size group(100-105 mm TL) was 1.1821, followed by a decline in the next size group of 105-110 mm TL. Thereafter the values remained almost static around 1 in 105 to 150 mm length group. Highest value of 1.1963 was recorded in 155 to 160 mm group and lowest value of 0.8924 in 150-155 mm length group. An almost similar pattern of variation was noticed in K values too (Fig.7.10). Indeterminates exhibited lowest K_n value of 0.9493 in smaller fishes(85-90mm TL) whereas the highest value(1.0241) was recorded in 95-100 mm size group. The K_n value declined in the 100-105mm length group, followed by a slight increase in the 105-110 mm size class and thereafter, a gradually declining trend was discernible. The condition factor (K) showed exactly the same trend as that of relative condition factor (Fig. 7.11).

The seasonal variations in K_n values of males and females were more or less similar during 2001-'02, attaining the peak values in October followed by May and lowest values in January. A fall in the value was noticed in July in males during both the years of study, contrary to those of females which showed a minor peak. During 2002-'03, lowest value was observed in August in both males and females. On the other hand, highest K_n value was registered in April in males and November in females. In males, relative condition was low in October when compared to females whereas in February the condition was reverse. A scrutiny of the lengthwise variation in relative condition factor showed low K_n values in smaller and larger males as against the high values in females. In males, higher K_n values were observed in the length group from 115-135 mm TL, showing a slight dominance in condition over the females. The slightly higher K_n values observed in 115-125 mm length group of males further advanced to attain the peak in 130-135 mm group, followed by a sharp decline in the higher groups. A comparison of K values of males and females (Fig. 7.10) revealed that Ponderal index (K) values of females were higher than those of males round the year.

7.4. 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 isometric 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 to the inadequacy of the cubic law in explaining the length-weight relationships in fishes, many researchers adopted the general formula in the form $W=aL^b$ Le Cren (1951) suggested that the deviations from the cube law might be attributed 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 life 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 *O.bakeri* followed by indeterminates and males. The exponential value of 3.1967 in females implies that the females gain weight at a faster rate in relation to its length whereas the low exponential value of 2.1738 observed in males reveals the reverse condition. On the other hand, the 'b' value of 2.939 in indeterminates did not deviate significantly from the isometric value of '3', suggesting that the juvenile fishes are neither heavier nor lighter in relation to its length. It may be concluded that during the early stages of life, the fish grows isometrically, more or less obeying cube law and thereafter diverge from the law diametrically exhibiting allometric growth. The low 'b' values of males indicate negative allometry, which means the fish gets relatively thinner as they grow (Wootton, 1992). The females manifest positive allometric pattern of growth.

Reports on the length-weight relationship of cyprinid fishes divulge 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), *Schizothorax plagiostomus* (Bhagat and Sunder, 1983) and *Puntius denisonii* (Mercy *et al.*, 2002).

Deviation 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), L*abeo dero* (Malhotra and Chauhan, 1984), L*abeo dyocheilus* (Malhotra, 1985), *Puntius ticto* and *Barilius bendelesis* (Gairola *et al.*, 1990) and *Cyprinus Carpio Communis* and C*tenopharyngodon idella* (Dhanze and Dhanze, 1997). The value of the slope was found to be higher than 3 in *Puntius sarana* (Sinha, 1972), *Labeo bata* (Chatterji *et al.*, 1977; Azadi and Nazer, 1996), *Labeo dussumieri* (Kurup, 1990) and *Puntius sophore* (Reddy and Rao, 1992). *Labeo calbasu* of river Kali (Chatterji *et al.*, 1980) and Nagarjuna Sagar (Vinci and Sugunan, 1981) showed higher regression coefficients contrary to those from Brahmaputra river (Choudhary *et al.*, 1982) and Rana Pratap Sagar reservoir (Choudhary *et al.*, 1991) which registered exponential values below '3'. Thakre and Bapat (1984) estimated an exponential value of 3.1524 for *Rasbora daniconius* from Maharashtra whereas Sunil (2000) recorded the value to be less than 3 (2.641) for the same species collected from Kerala waters. All these earlier reports corroborate the present findings on the length-weight relationship in *O.bakeri* in which significant departure of 'b' value from the isometric value of 3 was noticed in respect of both males and females.

Females of *O.bakeri* 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* (Bhatnagar, 1963) *Labeo fimbriatus* (Bhatnagar, !972) *L. dero* (Malhotra and Chauhan, 1984) *R.daniconius*(Thakre and Bapat, 1984) and

L.dussumieri (Kurup, 1990). Biswas (1993), while studying *Labeo pangusia* from Meghalaya, found that the females have higher slope values (3.197) when compared to males (2.7858) and juveniles (2.9721). According to Thakur and Das (1974), the males of *Heteropneustes fossilis* became lighter for their length as they grew larger. In *Ompok bimaculatus* (Rao, 1990), the regression coefficients of males (2.3148) was found to be lower than that of females (2.7223). Similar sequels were also recorded in *Salmo trutta fario* (Kumar *et al.*, 1979), *Tilapia mossambicus* (Nair, 1988), *Horabagrus brachysoma* (Kumar *et al.*, 1999), and *Monopterus cuchia* (Narejo *et al.*, 2002). Krishnamoorthi (1971) found highly significant difference between males (2.0769) and females (2.9423) of *Nemipterus japonicus* of Andhra-Orissa coast. The results of the present study are in conformity to the above findings.

The difference in growth performance between the two sexes may be due to intrinsic changes in their physiological systems. Analysis of the proximate composition of *O.bakeri* registered higher protein content ranging between 17.23 and 19.72% and fat content between 1.4 -1.83% in females compared to the low proportions of protein (17.12-18.89%) and fat (0.81-1.16%) in males (See Chapter 1V). Feeding intensity was found to be higher in females, season wise as well as size wise (Chapter V). Females are heavier that the males of the same length probably because of the difference in fatness and gonadial development (Le Cren, 1951). 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 *O.bakeri* may be attributed to their more robust appearance and deeper body as against the more slender males.

The values of regression coefficients of *O.bakeri* are in the range between 2 to 4 as reported by Tesch (1968). Hile (1936) and Martin (1949) stated that the values of 'b' usually fluctuate between 2.5 and 4. The exponential value in females and indeterminates comply with the range proposed by the above authors.

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 that 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 female *O.bakeri* indicates that the general parabolic equation $W=aL^b$ expresses the length-weight relationship in adults better than the cubic law while the cube law $W=aL^3$ holds good for the indeterminates 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 *O.bakeri*, the higher K_n values recorded in October and November and April-May almost coincided with the occurrence of high gonadosomatic index (GSI) in both males and females. The values in males inclined to decrease from June to August and December to January which may be due to the increased spawning strain in them, as opined by Menon (1950). Females also disclosed more or less similar tendency except for July which showed a minor peak in the K_n values. Thus, it appears that reproductive cycle in *O.bakeri* is related to the variations in the condition factor.

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 males, though the gonad was in its far advanced condition in October, low K_n values as well as low feeding rate were observed during 2002-'03 while higher K_n values and high feeding rate were noticed in 2001-'02. It indicates that the K_n values in males might be more closely related to feeding rate or other environmental and physiological factors than their gonad weight which did not undergo much seasonal changes. Similarly, low condition factor was found to be associated with low gastro-somatic index in March 2002-03. In females, high K_n values observed in December 2001-02 and January 2002-03 could be attributed to the high feeding intensity.

The decline in K_n value in March 2001-02 and February 2002-03 might be due to the fall in feeding intensity. The peak K_n values in May coincided with the occurrence of mature fishes as well as high feeding intensity. Male and female fishes with gorged stomach were encountered only in May. In July, the feeding was done at a moderately high level in females and the K_n values showed minor peak, although the ovaries were in spent condition. An inverse relationship between K_n and feeding intensity was established in November and August in both the sexes during both the years of the study. In females, a similar relationship was observed between K_n and feeding intensity from August to October during both the years.

Variations in condition during certain months could not be related to either reproduction or feeding. In females, comparatively poor condition was observed in April 2001-'02 when gastrosomatic and gonadosomatic indices were high. Similarly in males, the lowest condition was recorded in January 2002-'03 at a time of moderate feeding intensity and moderate gonadal weight. In February 2002-'03, in spite of low feeding tendency and moderate gonadosomatic index, the value of K_n in males was high. Likewise in November 2002-'03, gastrosomatic index was low, still K_n values revealed better condition. It may,therefore, be inferred that the variations of K_n may also be due to some unknown environmental and physiological factors.

The point of inflection in the K_n curve of different length groups indicates the length at which sexual maturity of fish starts (Hart, 1946). In males and females of *O.bakeri*, this point, which may be indicative of the commencement of maturation, lies at 105-110 mm. The minimum size at maturity arrived at was 115 mm and 118 mm in males and females respectively (See Chapter V1). Similar relationship between condition and size at first maturity has been established in many cyprinids (Bhatnagar, 1963; Chakrabarty and Singh, 1967; Choudhary *et al.*, 1982; Kurup, 1990; Gairola *et al.*, 1990; Choudhary *et al.*, 1991). The high K_n values observed in 120-135 mm size group of males might be due to the occurrence of large number of maturing and mature individuals which constituted about 65% of the total male population within that particular range. Spent individuals began to appear in length groups beyond 135 mm. However, such correlation could not be made in females. High K_n values in 100-105 mm size group of females might be due to the high feeding intensity for rapid growth as reported in *Cirrhinus mrigla* (Shafi and Quddus, 1974; Raizada and Raizada, 1982), *Puntius ticto* (Gairola *et al.*, 1990), *L. calbasu* (Choudhary *et al.*, 1991) and *Monopterus cuchia* (Narejo *et al.*, 2002). K_n values of mature males in the size group 115-135 mm were higher than their female counterparts. This reversal in K_n values might manifest the size at first maturity (Bhatnagar, 1963). The reversal in K_n values in this species occurred at 115-120 mm which agreed with the size at first maturity arrived at for this species. Oslen and Merriman (1946) reasoned that due to the conversion of proportionately more food into ovarian tissue and yolky material as against the small sized testes of the males and the extrusion of the sexual products during spawning, the average weight of females was less than that of males. Supporting this view, Natarajan and Jhingran (1963) stated that this reasoning applied in every respect to *Catla catla*. The above explanation seems to be appropriate in the case of *O.bakeri* too.

Sinha (1972) reported that the monthly condition values in *Puntius sarana* were influenced by gonadial maturity, feeding intensity and changes in the amount of fat stored in the body tissues. Seasonal fluctuations in the condition of *Labeo gonius* were mainly due to maturation and depletion of gonads and partly by feeding rhythm of fish (Chatterji, 1980). In *Cirrhinus reba*, Gupta (1975) reported the existence of a close relationship between K_n and gonad weight. Desai (1970, 1973) attributed the variations in condition factor in *Tor tor* to maturation of gonads and feeding intensity while in *Tor putitora*, Dasgupta (1991) found that in addition to the above two factors, the effect of seasons on the body was also involved. Biswas (1993) attributed fluctuations in K_n values to food availability, gonadial maturity and abiotic factors.The present study on the condition of *O.bakeri* suggests that K_n values were influenced by sexual cycle, feeding intensity as well as some other unknown factors.

Sex-wise analysis of K_n values revealed that the mean K_n values in females (1.033) was higher that that of males (0.9554). In indeterminates, the mean value was 0.9939. According to Le Cren (1951), K_n 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 K_n values in females of *L. calbasu* and *L. pangusia* respectively. Pandey and Sharma (1997) studied the condition of 4 exotic carps and only the scale carp, *Cyprinus carpio communis* was found to have values above 1 (1.0109). High K_n 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). High K_n values observed in females of *O.bakeri* in the present study suggest that the females are in better condition when compared to males and indeterminates.

A comparison of the ponderal index (K) and K_n values revealed that in the case of females and indeterminates, both the values were closely synchronised whereas males showed different trends. The result of the present findings strongly corroborated with the earlier findings that the ponderal index is applicable only if the fish obeys the cube law in its length-weight relationship (Le Cren, 1951). Indeterminates, which follow cube law, depicted exactly the same trend in K and K_n values while females, having b value slightly higher than 3 showed almost the same nature of variation in the values. On the other hand, males with very low regression coefficient rendered different patterns for the K and K_n values.

Based on the results of the length-weight relationship and condition factor of *O. bakeri*, it may be concluded that that the growth of females is quite satisfactory and the overall growth performance of females and indeterminates of *O.bakeri* is significantly higher than that of males.

Table 7.1. 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	567	-3.4252	2.1738	0.0684	12.07	P<0.01	0.8007	31.77	P<0.01
Females	328	-5.5205	3.1967	0.0657	2.9955	P<0.01	0.9376	48.69	P<0.01
Indeterminate	213	-5.0059	2.939	0.0959	0.64	P>0.05	0.9036	30.64	P<0.01

Table 7.2. Analysis of variance on the regression of the length weight relationship in males of *O. bakeri*						
	df	*SS*	*MS*	*F*	*Significance F*	P
Regression	1	2.756497	2.756497	1009.09465	8.2095E-128	P<0.001*
Residual	565	1.543384	0.002732			
Total	**566**	**4.299882**				

* significant at 1% level

Table 7. 3. Analysis of variance on the regression of the length weight relationship in females of *O. bakeri*						
	df	*SS*	*MS*	*F*	*Significance F*	P
Regression	1	4.172356	4.172356	2369.733367	1.3395E-151	P<0.001*
Residual	326	0.573984	0.001761			
Total	**327**	**4.74634**				

* significant at 1% level

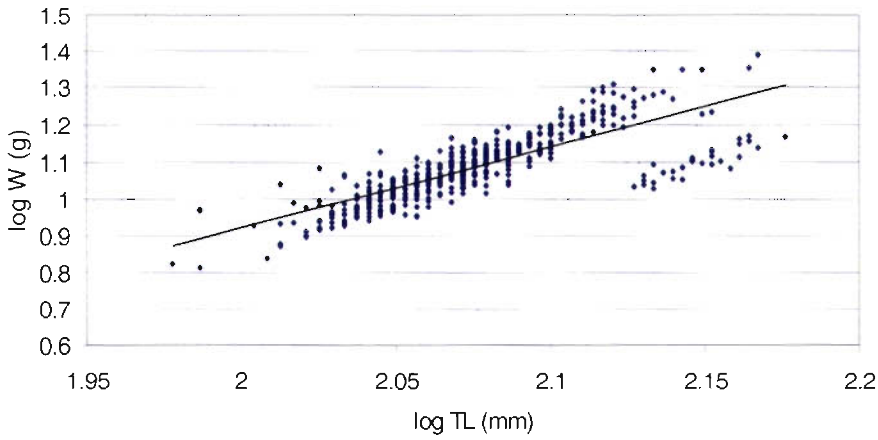
Table 7. 4. Analysis of variance on the regression of the length weight relationship in Indeterminates of *O. bakeri*						
	df	SS	MS	F	Significance F	P
Regression	1	0.807941	0.807941	888.6824237	1.39047E-77	P<0.001*
Residual	211	0.19183	0.000909			
Total	**212**	**0.999771**				

* significant at 1% level

Table 7. 5. Comparison of slopes of male, female and indeterminate *O.bakeri* using ANACOVA					
	df	**RC**	**Deviation from regression**		
			df	**SS**	**MSS**
Males	565	2.1797	564	1.5363	0.0027
Females	326	3.1956	325	0.5756	0.0018
Indeterminate	211	2.9431	210	0.1549	0.0007
Total			1099	2.2668	0.0021
Pooled	1102		1101	2.5233	0.0023
Difference			2	0.2565	0.1283
Total	1108		1103	2.8584	0.0026
Between Adjusted means			2	0.3351	0.16755
Comparison of Slope , (df : 2,1102) **F = 61.07** (Significant at 1%)					
Comparison of Elevation (df : 2,1108) **F = 73.11** (Significant at 1%)					

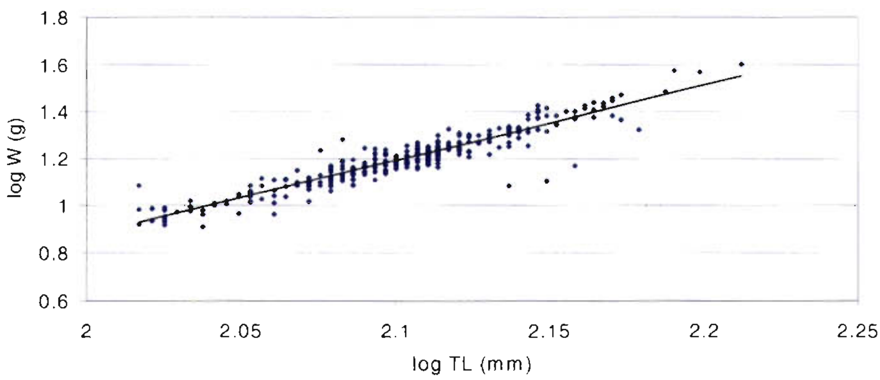
Table 7.6. Result of pair wise comparison of regression coefficients of male, female and indeterminates of *O.bakeri* using t-test				
Between		**df**	**t**	
Males	Females	889	10.2	Significant
Males	Indeterminate	774	4.34	Significant
Females	Indeterminate	535	1.77	Not Significant

Fig.7.1. Length weight relationship in males of *osteobrama bakeri*



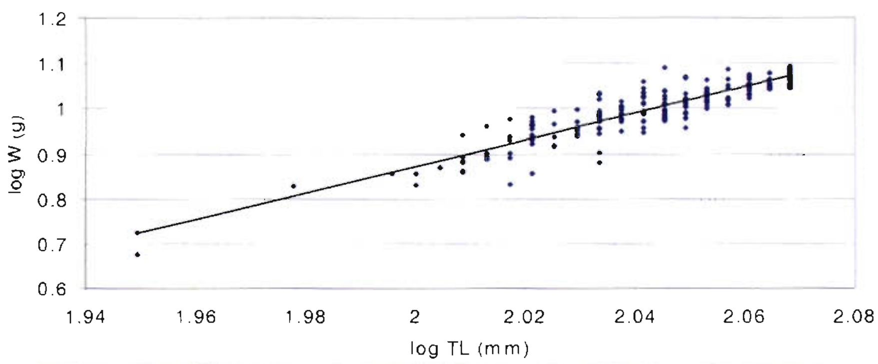
log w = -3.4252 + 2.1738 log l   r = 0.8007

Fig. 7. 2. Length-weight relationship in females of *Osteobrama bakeri*



log w = -5.5205 + 3.1967 log l   r = 0.9376

Fig.7.3. Length - weight relationship in indeterminates of *Osteobrama bakeri*



log w = -5.0059 + 2.939 log l   r = 0.9036

Fig.7.4. Seasonal variation in relative condition factor (Kn) of *Osteobrama bakeri*

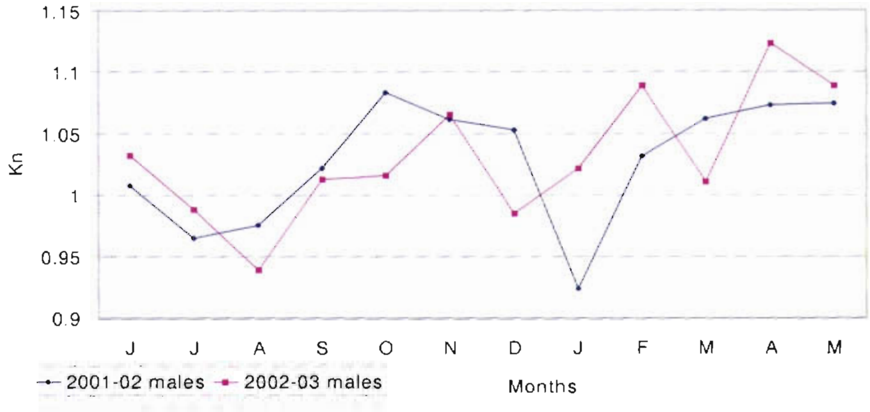


Fig.7.5. Seasonal variation in relative condition factor (Kn) of *Osteobrama bakeri*

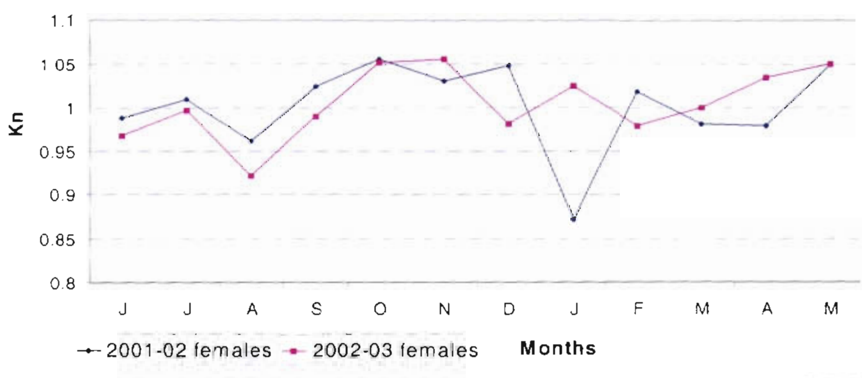


Fig.7.6. Lengthwise variation in relative condition factor (Kn) of *Osteobrama bakeri*

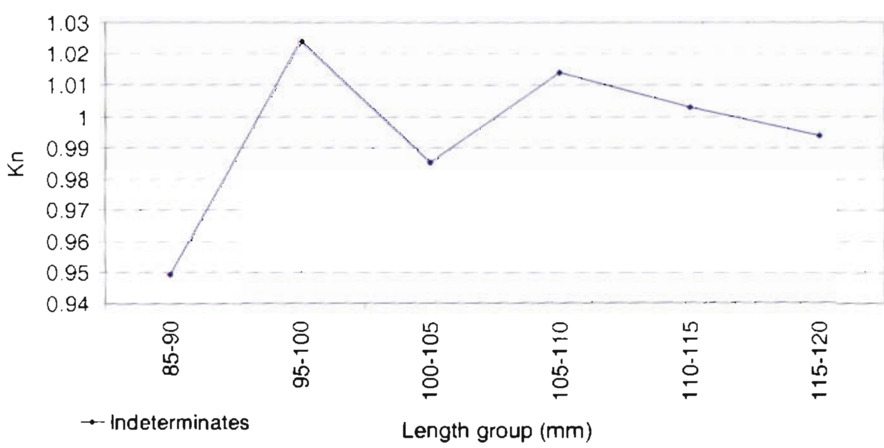


Fig.7.7. Lengthwise variation in relative condition factor (Kn) of *Osteobrama bakeri*

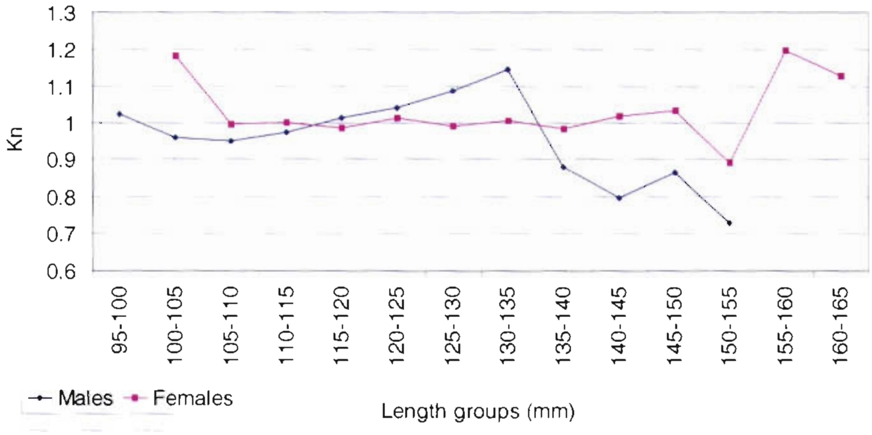


Fig. 7.8. Seasonal variation in ponderal index (K) of] *Osteobrama bakeri*

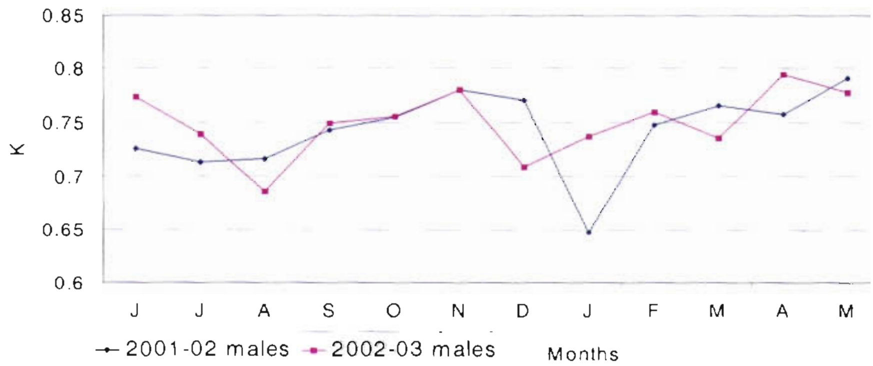


Fig.7.9. Seasonal variation in ponderal index (K) of *Osteobrama bakeri*

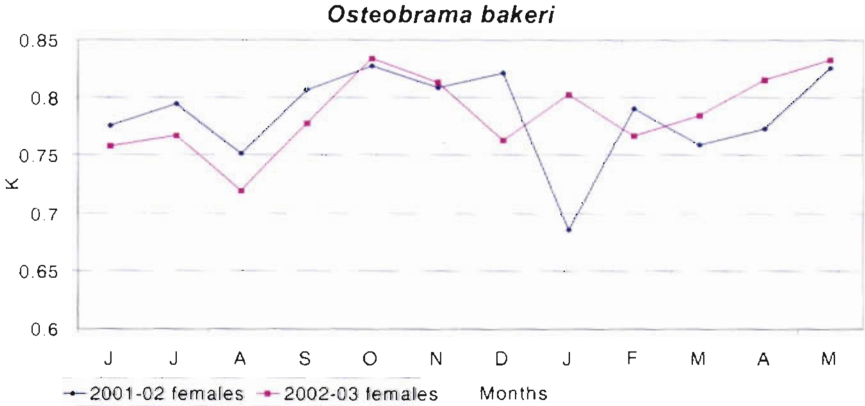


Fig.7.10. Lengthwise variation in ponderal index (K) of *Osteobrama bakeri*

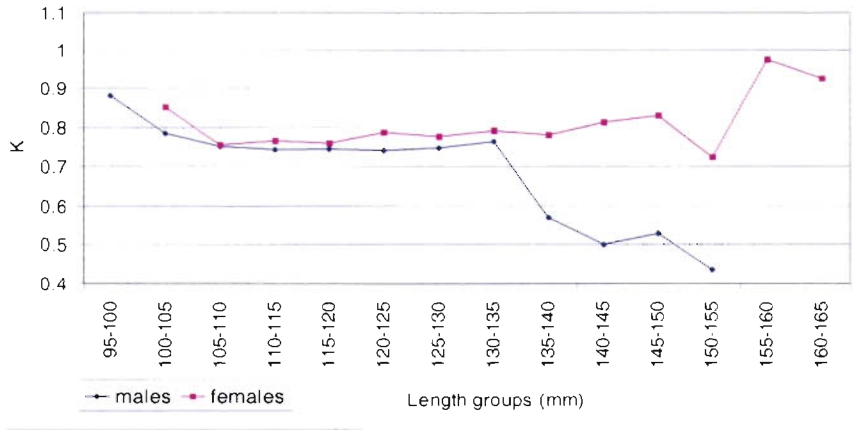
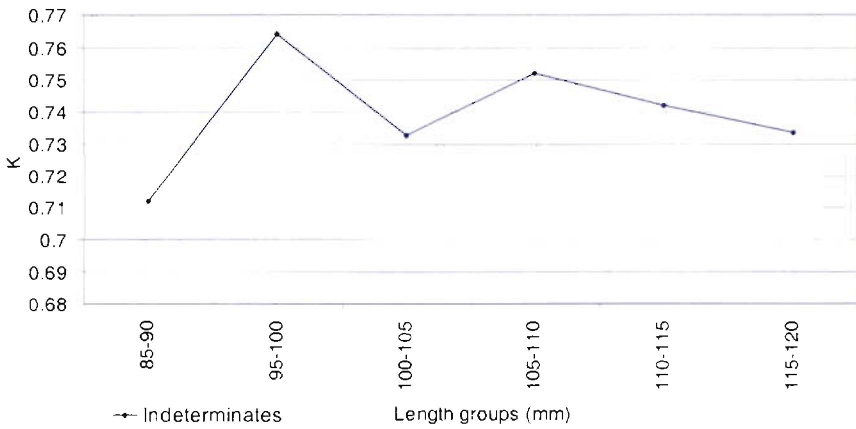


Fig.7.11. Lengthwise variation in ponderal index (K) of *Osteobrama bakeri*



CHAPTER VIII

AGE AND GROWTH

8.1. Introduction

Age and growth of fish are 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, 1975 a). Information on growth rate, natural and fishing mortality, age at maturity and spawning, age composition of the exploited population, etc., can be evolved from the age data of fish populations. Such information are essential tools for the scientific interpretation of the fluctuations in the fish populations over space and time and to formulate scientific and economic management policies for the fisheries in question (Seshappa, 1999).

The growth process is specific for each species of fish. 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 the 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 a series of direct and indirect methods. The direct methods include rearing the fishes in captivity under controlled conditions and observing their growth and also using mark recapture method (tagging programmes). Dissection of annual rings laid down on scales, otoliths or 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 method 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 reading of check marks is difficult because the growth rings do not necessarily represent year marks. Qasim (1973 b),while critically reviewing the age and growth studies by Indian authors, has drawn attention to the fact that though tropical fishes do show clear zonations on hard parts, it is difficult to conclude that they are formed annually only.

The length frequency analysis method of Peterson (1895, 1903) is well known. In this method, the peaks of the length distribution are assumed to represent the different age groups. The method is very good for younger fish (2-4 years of life) but in older fishes, as the growth rate slows down, there are possibilities of overlapping of length frequencies in individuals of different age groups. Length-frequency distribution does not apply well also to the fishes with prolonged breeding season. 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), is 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. This 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, 1976; Chatterji *et al.*, 1979; Pathani, 1981; Reddy, 1981; Mathew and Zacharia, 1982; Tandon and Johal, 1983; Shree Prakash and Gupta, 1986; Desai and Shrivastava, 1990; Devi *et al.*, 1990; Johal and Tandon, 1992). Das (1961) discussed in detail about the importance of scales in age determination. Qasim (1973 b) critically evaluated 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 Naryani and Tamot (2002) in *Tor tor*. Seshappa (1999) has briefly reviewed the recent studies on age determination of Indian fishes using scales and other hard parts. Information on the age and growth of *O.bakeri*, an endemic vulnerable carp of Kerala, is totally unknown and hence a pioneer study is attempted in this direction.

8.2. Materials and Methods

850 individuals of *O.bakeri* comprising of 557 males and 293 females were collected from Periyar river during August 2001 to May 2003. All specimens were measured to the nearest mm in total length (TL). Length frequency data were grouped into 10 mm class interval. Growth was estimated separately for males and females. The von Bertalanffy growth formula (VBGF) (Bertalanffy, 1938) was used to describe the growth. The equation in growth in length is given by :

$$L_t = L_\alpha \,[\,1\text{-exp}^{-K\,(t-t_0)}\,]$$

where L_t = length at age t.

L_α = 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 in the FiSAT software(Gayanilo and pauly, 1997). Age length key at 3 months interval was prepared from ELEFAN 1. Estimate of t_0 was made using von Bertalanffy(1934) plot in which the results of the regression of – ln $(1-L_t/L_\alpha)$ against t was used to calculate t_0.

$$t_0 = -a / b$$

The growth-parameters arrived at were further revalidated following Integrated method of Pauly (1983a). Estimate of L_α and K were done using Ford-Walford Plot (Ford, 1933; Walford, 1946) which in linear form is given by:

$$L_t+1 = L_\alpha (1-e^{-K}) + e^K L_t$$

OR

$$L_t+1 = a + b\, L_t$$

The lengths at age derived were subjected to linear regression and the results obtained were employed to calculate L_α and K following:

$$L_\alpha = a/(1-b)$$

$$K = -\log e^b$$

The time interval used was 3 months and hence, annual growth coefficient was arrived at by multiplying the K value obtained by 4.

Since ELEFAN curves showed the existence of two broods in *O.bakeri*, the growth parameters were estimated separately for the two cohorts. Growth performance of the two cohorts in terms of length 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_α 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 male and female *O. bakeri* were obtained from FiSAT.

An attempt was also made to determine the age from the study of scales. For this purpose, scales were collected from the region just below the dorsal fin above the lateral line (Jhingran, 1959). They were cleaned, dried and mounted between 2 glass slides and were examined with a slide projector at a magnification of 15 times of its actual size.

8.3. Results

8.3.1. Distribution of length

The length composition of males ranged from 95 to 150 mm TL and the modal length was 110-120 mm TL. The length of females ranged from 104 to 163 mm TL with a mode at 120-130 mm. The smallest fish observed was 89 mm TL and belonged to immature undifferentiated sex.

8.3.2. Estimation of growth parameters

ELEFAN 1 growth curves (Figs. 8.1 and 8.2) showed that the male and female populations of *O.bakeri* were composed of 2 cohorts annually generated by two annual recruits. The first cohort represented individuals recruited during May-June in males and March-June in females while the second cohort was composed of individuals originated during November-December in both the sexes. The growth parameters estimated separately for the two cohorts by ELEFAN 1 and Integrated method of Pauly along with the growth performance index, ϕ', are given in Tables 8.1 and 8.2 respectively. The growth performance index values obtained by ELEFAN 1 were identical for the males (2.4) and females (2.3) for the two cohorts. The response surface (Rn) values used for the estimates of growth parameters through ELEFAN 1 are given in Table 8.1. The ϕ' values derived using Integrated method of Pauly for male were the same for both the cohorts (2.5) while in females, the values were slightly different (2.3 and 2.5).

Based on the values obtained through ELEFAN 1, the von Bertalanffy growth equation (VBGE) of *O.bakeri* can be express as:

Males: $L_t = 168\ [1\text{-exp}^{-0.805\ (t\ -\ .0865)}]$

Females: $L_t = 177[1\text{-exp}^{-0.\ 645\ (t\ +\ 1.0604)}]$

The von Bertalanffy growth equation, when expressed by taking the growth parameters estimated by the Integrated method of Pauly, is as follows.

Males: $L_t = 169.09\ [1\text{-exp}^{-1.0904\ (t\ -\ .0865)}]$

Females: $L_t = 171.75\ [1\text{-exp}^{-0.9962\ (t\ +\ 1.0604)}]$

On applying the average growth coefficients estimated by ELEFAN 1, the males were found to attain average length of 87,132 and 152 mm at the end of I, II and III years respectively. On the contrary, females attained a higher length of 130 mm at the end of first year, 152 mm at the end of second year and 164 mm at the end of third year of life. From the growth equation arrived at from Pauly (1983a), it was found that the males were 107, 148 and 162 mm TL and females 129, 154 and 166 mm TL at the end of first, second and third years respectively (Table. 8.3).

The recruitment pattern obtained for the two cohorts of males and females through FiSAT is given in Figs. 8.3, 8.4 and 8.5, 8.6 respectively. It manifested the occurrence of two recruitment pulses every year. In male *O.bakeri,* for the stock originated in May-June, the major recruit was identified from March to September with a peak in June (17.24%) whereas the minor mode of recruit appeared in April and showed its peak in October (13.5%). Thereafter it gradually declined and continued till March. For the stock originated in November – December, the major recruit could be traced from April to December with highest occurrence in August (16.71%) while the minor one was registered from December to August with peak in April (9.24%). In females, for March-June cohort, the major recruit first showed its entry in September and continued till August with a peak in March (18.08%). On the other hand, the minor mode of recruit was found during March-September with peak in June (14.83%). For the stock generated in November – December, the major recruit was identified from October to September, attaining a peak in February (15.67%) while the minor one corresponded to September - February with a peak in December (11.8%).

The study of the scales of *O.bakeri* revealed the absence of any definite pattern of the growth rings. Hence a meaningful conclusion on the age of the species based on the rings which appeared on the scale could not be made.

8.4. Discussion

Age and growth determination in fishes is possible only by indirect methods such as length frequency analysis and rings appearing on the scales. In the present study, L_α estimated by ELEFAN 1 and Integrated method of Pauly are comparable in males; in contrast, in females, L_α obtained by ELEFAN 1 was slightly higher than that obtained by Integrated method of Pauly. Higher values of K were also derived by Integrated method of Pauly in both the sexes compared to ELEFAN 1. The higher values of K in males indicated that males attained asymptotic length at a faster rate than the females. The values of growth performance index ϕ' were identical for both the cohorts of males and females except for a slight variation found in the values of females obtained by integrated method of Pauly. Therefore, the average values of L_α and K for the two cohorts were used to describe the growth.

In the present study, the maximum size of male *O.bakeri* was found as 150 mm and that of female 163 mm. The length of males at the end of first, second and third years of life were estimated to be 87,132 and 152 mm and that of females 130,152 and 164 mm (ELEFAN 1) respectively while the corresponding values from integrated method of Pauly were

107, 148 and 162 mm for males and 129,154 and 166 mm for females. The length at age values obtained by the above two methods were almost similar in females, on the contrary, variation was observed in the values of males. Based on the results of the present study, it can reasonably be inferred that the longevity of *O.bakeri* is around three years. Since majority of the male fishes fall in the length class 110-120 mm and females in 120-130 mm, it can be postulated that the exploited population of males belonged to two year age group and conversely, the same with respect to female is less than one year age group. Both in males and females, individuals belonging to age group three and above were very sparsely represented in the catches.

O.bakeri is 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 stock is by allowing a fish to breed at least once in its lifetime for ensuring the natural recruitment. In *O.bakeri*, the length at first maturity has been estimated to be 115 mm in males and 118 mm in females (Chapter VI). This implies that the female fishes can mature and spawn before they complete one year of their life cycle and conversely, males spawn only during its second year of life cycle. Johal and Tandon (1987 a) recommended to harvest carps in the second and third years of life when the fish definitely attained size above 30 cm in TL fulfilling their size at maturity. Harvestable size of *L.rohita* has been calculated as 46 cm, which is attained after third year (Sing *et al.*, 1998). Based on the results of the present study, it can be recommended that females of

O.bakeri can be exploited during the second year of their life while males shall be allowed to grow up to two years before they are exploited ensuring their recruitment and regeneration in the open waters.

O.bakeri was found to exhibit fastest increment in length during the first year of its life history and it was relatively higher in females compared to its male counterpart. A drastic reduction in the growth rate was observed in the second and third years of life during when males performed better than females. Similar results of faster growth rate during the first year and subsequent decline in the following 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), major carps (Mathew and Zacharia, 1982), *Labeo dussumieri* (Kurup, 1997), *Labeo rohita* (Singh *et al.*, 1998) and *Tor putitora* (Nautiyal, 2002).

The K values reported for other cyprinids like *L.rohita* (0.41), *Catla catla* (0.53), *C.mrigala* (0.55) and *L. calbasu* (0.63) in Sylhet basin by Haroon *et al.* (2002) and Indian major carps (*C. catla*-0.1044, *C.mrigala*-0.2750, *L.rohita*-0.2551) by Mathew and Zacharia (1982) are less than that of *O. bakeri*. However, 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 beels. The growth coefficient of *L. dussumieri* was estimated to be 0.64 for males and 0.81 for females by Kurup (1997) revealing better growth rate in females. Pauly (1984 a) reported that species having shorter life have higher 'K' value and reach their L_α within one or two years. On the other hand, those having flat growth rates have lower 'K' values and take many years to reach their L_α. *O.bakeri* has moderately high 'K' values and moderate life span, which is in general agreement with the relationship between 'K' values and L_α as reported by Pauly (1984 a).

Recruitment to the fishery was found to occur throughout the year and two recruitment pulses were identified for both the sexes. This is very much in agreement with the results of maturation and spawning studies (Chapter VI) which could identify two spawning seasons in *O.bakeri viz.,* April-June and October-November. The growth curves obtained using ELEFAN 1 also strongly corroborate the possible existence of two broods in one year. The products of spawning of a particular season appeared to grow to commercial size and enter the fishery of the next year.

Difficulties were encountered in the age determination using scales. It appeared that the rings found in the scales did not show any definite pattern and hence it was reasonably assumed that age determination based on the rings present in the scales may not be dependable method in *O.bakeri* for the age determination. However, a more detailed and systematic study of the regular and annual nature of the true rings can be taken up for further validation on the use of scales for the age determination in the species.

O.bakeri, an endemic species to Kerala, is having the status of a vulnerable fish. Non-availability of enough specimens belonging to all size groups at regular intervals had been one of the major limiting factors in pursuing the studies on length frequency using more refined methods. Since there is total lack of knowledge on the age and growth of *O.bakeri*, the results of this pioneer work on these parameters would definitely advance our knowledge on the biology of fish species and immensely help in formulating relevant conservation and management programmes for the protection and preservation of the germplasm of the endemic fishes of Kerala.

Table 8.1 Growth parameters estimated by ELEFAN 1 for male and female *O.bakeri*

Sex	Cohort	L_α(mm)	K	Rn	ϕ'
Males	May-June	161	0.98	.215	2.4
	November-December	175	0.63	.228	2.4
Average		168	0.805		2.4
Females	March-June	172	0.63	.406	2.3
	November-December	182	0.66	.454	2.3
Average		**177**	**0.645**		**2.3**

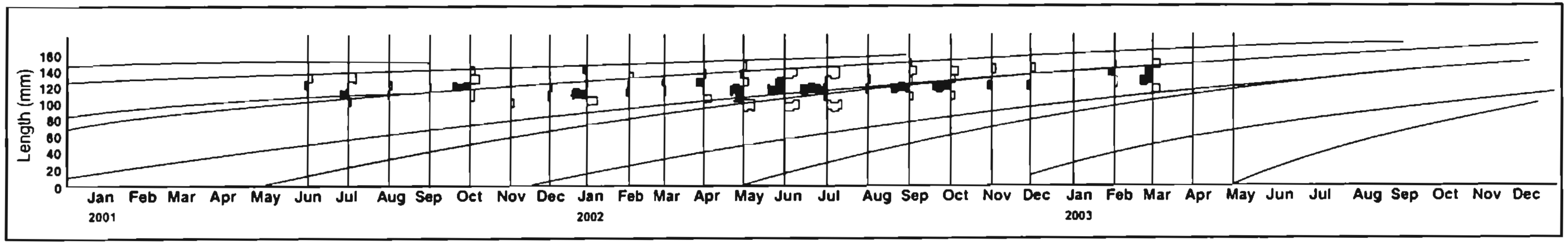
Table 8.2 Growth parameters of male and female *O.bakeri* estimated by Integrated method of Pauly (1983)

Sex	Cohort	L_α (mm)	K	t_0	ϕ'
Males	May-June	165.71	1.0919	-0.0836	2.5
	November -December	172.48	1.0889	0.2566	2.5
Average		169.0972	1.0904	0.0865	2.5
Females	March-June	178.5124	0.6985	-0.8549	2.3
	November -December	164.9775	1.2939	-1.2658	2.5
Average		**171.7450**	**0.9962**	**-1.0604**	**2.4**

Table 8.3 Length arrived at various ages in males and females of *O.bakeri*

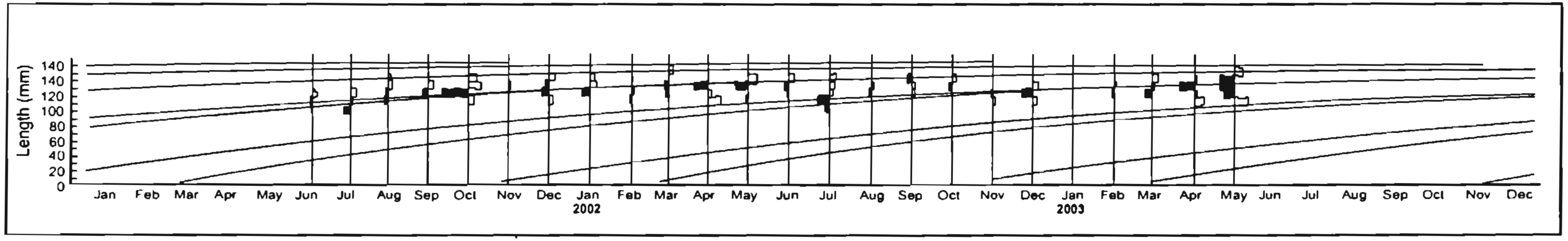
	Age (years)	Length (mm) Male	Female
ELEFAN 1	1	87	130
	11	132	152
	111	152	164
Integrated method of Pauly	1	107	129
	11	148	154
	111	162	166

Fig. 8.1 Growth Curve of male *O. bakeri* as estimated using the ELEFAN 1 programme



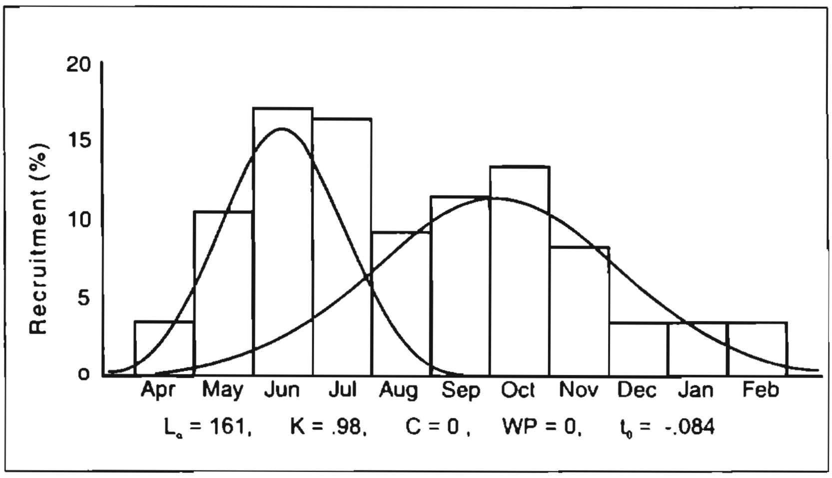
Cohort 1			Cohort 1		
L_∞	=	161.000	L_∞	=	175.000
K	=	0.980	K	=	0.630
C	=	0.000	C	=	0.000
WP	=	0.000	WP	=	0.000
SS	=	2.000	SS	=	13.000
SL	=	110.000	SL	=	110.000
Rn	=	0.212	Rn	=	0.224

Fig. 8.2 Growth Curve of female *O. bakeri* as estimated using the ELEFAN 1 programme



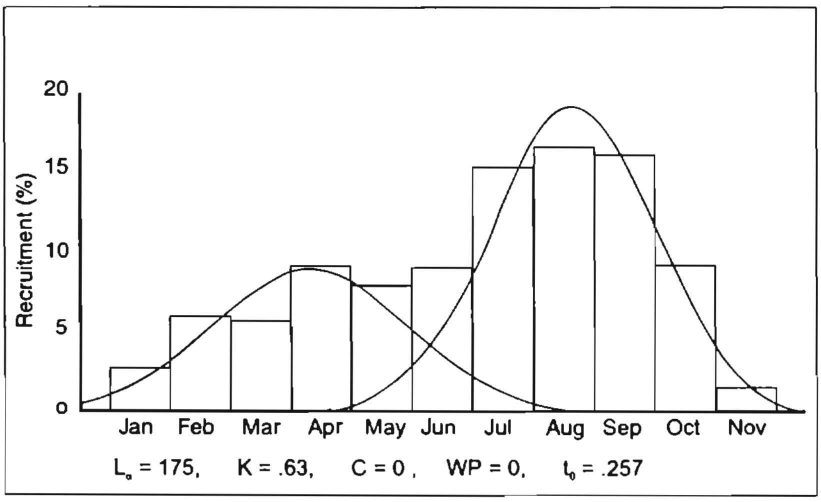
Cohort 1			**Cohort 1**		
L_α	**=**	**172.000**	**L_α**	**=**	**182.000**
K	**=**	**0.630**	**K**	**=**	**0.660**
C	**=**	**0.000**	**C**	**=**	**0.000**
WP	**=**	**0.000**	**WP**	**=**	**0.000**
SS	**=**	**2.000**	**SS**	**=**	**8.000**
SL	**=**	**120.000**	**SL**	**=**	**135.000**
Rn	**=**	**0.406**	**Rn**	**=**	**0.454**

Fig. 8.3. Recruitment Pattern of males (May - June Cohort) of *O.bakeri*



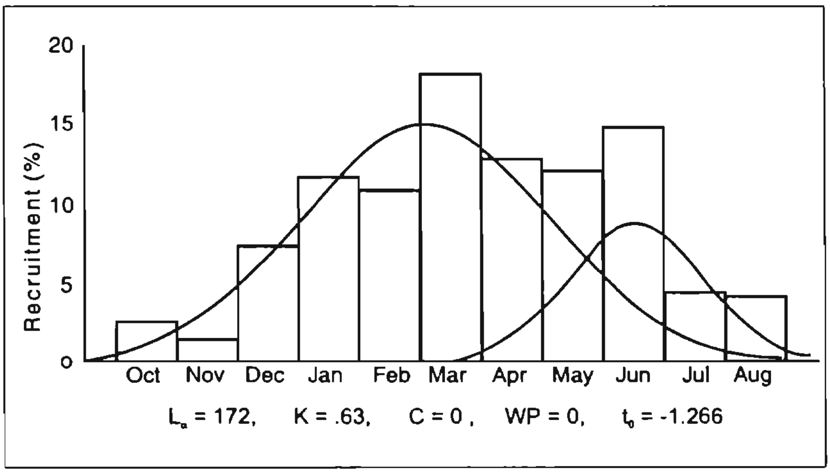
Absolute Time		Percent Recruitment
1	Apr	3.38
2	May	10.56
3	Jun	17.24
4	Jul	16.54
5	Aug	9.25
6	Sep	11.49
7	Oct	13.50
8	Nov	8.18
9	Dec	3.40
10	Jan	3.22
11	Feb	3.24
12	Mar	0.00

Fig. 8.4. Recruitment Pattern of males (November - December Cohort) of *O.bakeri*



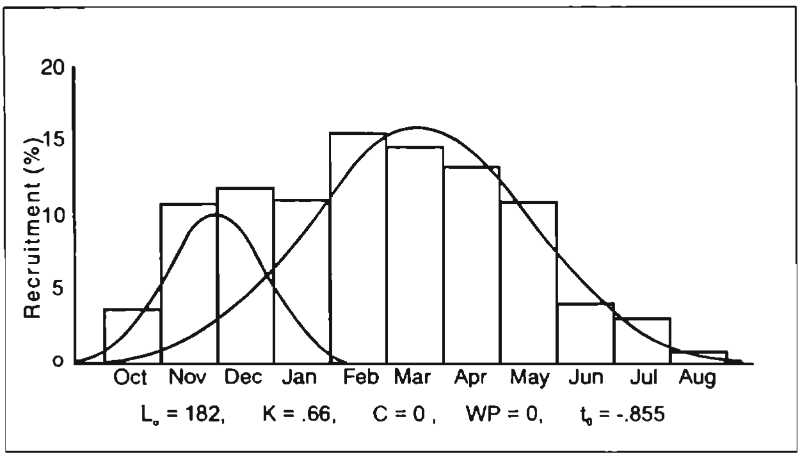
Absolute Time		Percent Recruitment
1	Jan	2.71
2	Feb	6.02
3	Mar	5.71
4	Apr	9.24
5	May	7.94
6	Jun	9.02
7	Jul	15.52
8	Aug	16.71
9	Sep	16.36
10	Oct	9.22
11	Nov	1.55
12	Dec	0.00

Fig. 8.5. Recruitment Pattern of females (March - June Cohort) of *O.bakeri*



Absolute Time		Percent Recruitment
1	Oct	2.51
2	Nov	1.46
3	Dec	7.27
4	Jan	11.62
5	Feb	10.74
6	Mar	18.08
7	Apr	12.78
8	May	12.07
9	Jun	14.83
10	Jul	4.43
11	Aug	4.20
12	Sep	0.00

Fig. 8.6. Recruitment Pattern of females (November - December Cohort) of *O.bakeri*



Absolute Time		Percent Recruitment
1	Oct	3.59
2	Nov	10.77
3	Dec	11.80
4	Jan	11.10
5	Feb	15.67
6	Mar	14.68
7	Apr	13.44
8	May	11.03
9	Jun	4.01
10	Jul	3.01
11	Aug	0.89
12	Sep	0.00

CHAPTER IX

POPULATION DYNAMICS

9.1. 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 very 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; 1983a, b; 1984a, b; 1987), Banerji and Chakraborty (1973), Pauly and David (1981), Devaraj (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.rohita*, *L.calbasu* and *L.gonius* and Nurulamin *et al.* (2001) on *L.rohita.*

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 works of Sekharan (1974) on oil sardine and mackerel, Krishnamoorthi (1976) on *Nemipterus japonicus*, Yohannan (1983) on mackerel, Annigeri (1989) on *Sardinella gibbosa*, Karthikeyan *et al.* (1989) on *Leiognathus* sp., Khan (1989) on *Harpodon nehereus*, Khan and Nandakumaran (1993) on *Cynoglossus sp.*, Reuben *et al.* (1994) on *Upeneus sp.*, Philip and Mathew (1996) on *Priacanthus hamur*, Reuben *et al.* (1996) on *Ariomma* sp. and Jaiswar *et al.* (2001) on *Decapterus russelli* are worth mentioning. Goswami and Devaraj (1993) estimated the potential yield of *L.rohita* from a flood plain lake in Assam. Optimum yield assessment of *L.rohita* and *Wallago attu* was carried out by Goswami and Devraj (1994). The total mortality estimates of *W.attu* was made by the above authors (1996) from Brahmaputra 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 Pampa of Kerala (S.India).

O.bakeri is an endemic vulnerable species of Kerala which requires protection and judicious exploitation of stock. Hitherto, no information is available on any aspect of population dynamics of this endemic species. The present study is aimed at providing information on the mortality parameters and exploitation rate of *O.bakeri* inhabiting river Periyar.

9.2. Materials and Methods

A total of 850 individuals, comprising 557 males and 293 females, collected from Periyar river during June 2001 to May 2003 were used for the stock assessment study. Assuming that the growth of this species follows von Bertalanffy growth formula (VBGF), the VBGF parameters, L_{α},K and t_0 were estimated using the FiSAT (FAO – ICLARM stock Assessment Tools) computer software package (Gayanilo and Pauly, 1997) as per the procedure mentioned in Chapter 8 and the values were used for the estimation of various parameters given below.

9.2.1. 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 (1966), 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).

9.2.1.1. Beverton and Holt method (1966)

Z was calculated from the mean length $\overline{L}$, L_α and K of the von Bertalanffy growth parameters.

$$Z = K \left[\frac{L_\alpha - \overline{L}}{\overline{L} - L^1} \right]$$

where $\overline{L}$ = Mean length of fish

L^l = Lower limit of the size group from which length upwards all lengths are under full exploitation.

9.2.1.2. Ssentongo and Larkin method (1973)

$$Z = K \left[\frac{n}{n+1} \right] \left[\frac{1}{\overline{y} - y_c} \right]$$

where $y = -\ln (1 - l/1_\alpha)$

$y_c = -\ln (1 - l_c/1_\alpha)$

$\overline{y} = \Sigma fy / \Sigma f$

where $n = \Sigma f$, $n+1 = \Sigma f + 1$

y_c = Corresponding to 1_c value

n = Number of fish caught from y_c onwards.

l = Mid length

9.2.1.3. Pauly's pile up method (1983)

$\log_e (Nt/t) = a - b\, t^*$

$Z = -(-b)$, $t^* = t_1 + ½\, t$

t = Time taken to grow from lower limit of the length class to upper limit.

$t = 1/K \log_e (L_\alpha - L_1) / (L_\alpha - L_2)$

$t_1 = 1/K \log_e (1-1/L_\alpha)$

l = Lower limit of length class.

t_1 = 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'.

9.2.1.4. Jones and van Zalinge method (1981)

Jones and van Zalinge found a linear relationship between catch and survivors. This method employs the following formula.

$$\ln (C_{i,\alpha}) = a + \left[\frac{Z}{K}\right] \times \ln (L_\alpha - L_1)$$

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.

9.2.1.5. Length converted catch curve method (Gayanilo *et al.*,1996)

The length converted catch curve was obtained using the following formula:

$\ln (N_i / t_i) = a + b\, t_i$

where N_i = number of specimens in length class i

t_i = relative age corresponding to length class i

9.2.2. Natural mortality coefficient (M)

The methods of Sekharan (1974), Rikhter and Efanov (1976) and Pauly's empirical formula (Pauly, 1980 b) were used for calculating natural mortality coefficient.

9.2.2.1. Sekharan's method (1974)

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 VBGE equation.

9.2.2.2. Rikhter and Efanov method (1976)

This method uses the following formula

$$M = (1.521/t_m^{-0.72}) - 0.155$$

where t_m = Age at which 50% of the population is mature.

In *O.bakeri*, length at which 50% of the individuals mature were 115 mm and 118 mm in males and females respectively (See Chapter V1). The corresponding t_m values were calculated as 1.53 and 0.91 years for males and females respectively.

9.2.2.3. Pauly's empirical formula (1980)

Natural mortality is given by the following empirical formula:

$$\log_{10} M = 0.0066 - 0.279 \log_{10} L_{\alpha} + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

Where M = Natural mortality

$L\alpha$ and K = Growth parameters of VBGF

T = Annual mean temperature (^{0}C) of the water in which the fish lives. In the present study, T was taken as 27^{0}C.

9.2.3. Fishing Mortality Coefficient (F)

Instantaneous rate of fishing mortality (F) was computed by subtracting natural mortality (M) from total mortality (Z).

$$F = Z - M$$

9.2.4. 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

$$N(L_1) = [N(L_2)\, S(L_1, L_2) + C(L_1, L_2)]\, S(L_1, L_2)$$

$$\text{Where } S(L_1, L_2) = [(L_\alpha - L_1) / (L_\alpha - L_2)]^{M/2K}$$

The exploitation rate is determined from the relationship

$$F/Z = C(L_1, L_2) / [N(L_1) - N(L_2)]$$

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 VBGE. 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.

9.2.5. 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:

$$U = \frac{F}{Z}(1 - e^{-z})$$

9.2.6. 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:

$$E = F/Z = F/(M+F)$$

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).

9.2.7. 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 L_c/L_α and M/K (Pauly and Soriano, 1986). The estimates were made using the FiSAT software.

9.3. Results

The growth parameters used for the stock assessment studies were estimated using ELEFAN 1 programme of FiSAT software(See Chapter 8). L_α and K computed in respect of males and females of *O.bakeri* were 168 mm, 0.805 yr^{-1} and 177 mm, 0.645 yr^{-1} respectively. The t_0 was estimated as 0.0865 in males and–1.0604 in females.

9.3.1. Total mortality coefficient (Z)

Total mortality (Z) of males and females of *O.bakeri*, estimated following different methods, are presented in Table 9.1. 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 4.15 (Pauly's pile up method, 1983) to 6.53 (Beverton and Holt method, 1966). The average of the estimates by various methods was 5.59. In female population, the values of Z varied between 2.745 (Pauly's pile up method,1983) and 5.49 (Jones and van Zalinge method,1981), the average being 4.09.The results of the catch curve analysis for male and female *O.bakeri* are depicted in Figs.9.1 and 9.2 respectively.

9.3.2. Natural mortality coefficient (M)

Natural mortality coefficient values obtained by different methods along with M/K values are given in Table 9.2. Sekharan's method (1974) gave the lowest value of 1.24 while Pauly's empirical formula (1980) gave the highest of 1.82 in males, the average being 1.41. In females, the same ranged from 0.99 by Sekharan's method (1974) to 1.55 by Pauly's empirical formula (1980)and the average was found to be 1.2.

9.3.3. Fishing mortality coefficient, Exploitation ratio and Exploitation rate

Fishing mortality coefficient worked out for males and females were 4.18 and 2.89 respectively. The exploitation ratio (E) in male and female *O.bakeri* were 0.72 and 0.68 respectively. Similarly, the exploitation rate (U) was found to be 0.72 in males and 0.67 in females.

9.3.4. Length based cohort analysis

The results of the length based cohort analysis of male population (Fig. 9.3) revealed that the exploitation started at 90 mm and increased upto 140 mm and thereafter decreased. In females (Fig. 9.4) also, the exploitation began from 90 mm and gradually increased upto 150 mm size, followed by a decline.

9.3.5. Relative yield per recruit (Y/R)

The relative yield per recruit (Y/R) and biomass per recruit (B/R) of male and female populations of *O. bakeri* are given in Figs. 9.5 and 9.6 respectively. The L_c/L_α and M/K used for Y/R analysis were 0.6 and 1.83 in males and 0.56 and 2.02 in females. The yield/ recruit reached a maximum at an exploitation rate of 0.94 in males and 0.92 in females and as the exploitation rate increased, the Y/R decreased. The present exploitation rates of 0.72 and 0.67 in males and females respectively did not exceed the optimum exploitation rates (E_{max}) of 0.94 in males and 0.92 in females.

9.4. Discussion

Studies on population dynamics of fishes from tropical waters became popular after the formulation of length based methods and models and the introduction of suitable computer softwares like FiSAT. In India, most of these studies 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. *O.bakeri* is a vulnerable endemic species of Kerala. 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 changes, senility, etc. in an unexploited stock while in exploited stocks, in addition to natural causes, fishing is the major contributing factor to mortality. Total mortality includes both natural and fishing mortalities. For estimating total mortality, five methods *viz.,* Beverton and Holt method (1966), 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 *O.bakeri*, Z value was lowest in Pauly's pile up method (1983) and highest in Beverton and Holt method (1966). The estimate of 'Z' was comparable in Jones and van Zalinge method (1981)and length converted catch curve method and was close to the average value of 5.59. The values obtained by Beverton and Holt method (1966) and Ssentongo and Larkin method (1973) were similar and were found to be higher when compared to other methods. In females, the values arrived at by Beverton and Holt method (1966) and Ssentongo and Larkin method (1973) were comparable. Pauly's pile up method (1983) gave the lowest value while it was highest in Jones and van Zalinge method (1981).

Natural mortality is influenced by several biological and environmental factors and hence an accurate estimation of it is often difficult. (Pauly, 1980 b; Cushing, 1981; Liu and Cheng, 1999). Among the M values arrived at by three methods, the values estimated by Sekharan's method (1974) and Rikhter and Efanov method (1976) were comparable in male *O.bakeri*. Interestingly, Pauly's empirical formula (1980) gave the highest while the value from Sekharan's method was the lowest in both males and females. The natural mortality of fish is closely related to age and size as the larger fishes are less prone to predation. Therefore, M can be correlated to longevity of the fish and the latter to growth coefficient K. M/K ratio can be used as an index for checking the validity of M and K values arrived at following different methods and the ratio usually ranged between 1 and 2.5 (Beverton and Holt, 1959). The estimated K values for males and females of *O.bakeri* were 0.805 and 0.645 respectively. The M values in males were 1.24 (Sekharan's method,1974), 1.18 (Rikhter and Efanov method, 1976) and1.82 (Pauly's empirical formula,1980) while in females, the values were 0.99, 1.06 and 1.55 respectively. Thus M/K ratios in males were computed as 1.54, 1.47 and 2.26 whereas in females, the values were 1.54, 1.64 and 2.4. Interestingly, the M/K values arrived at using Sekharan's method was exactly the same in both males and females. Thus, in the present study, the M/K values computed by using M values estimated by the three different methods were within the limits proposed by Beverton and Holt (1959) in both the males and females. It may be inferred that all the three methods presently employed for the estimation of natural mortality can be appropriately used for the computation of M values in both the sexes of *O.bakeri*. M/K ratio is found to be constant among closely related species and sometimes within the similar taxonomic groups (Beverton and Holt, 1959; Banerji, 1973). M/K ratios in male *O.bakeri* were 1.54,1.47 and 2.26 and in females 1.54, 1.64 and 2.4 by applying Sekharan's method (1974), Rikhter and Efanov method (1976) and Pauly's empirical formula (1980) respectively. Similar values were reported in *Labeo dussumieri* by Kurup (1998), *L.calbasu* by Alam *et al.*(2000) and *L.rohita* by Nurulamin *et al.*(2001).

Fishing mortality was found to be higher in males compared to females. The length converted Cohort analysis showed that in males as well as females, fishes below 90 mm were not exploited. Fishing mortality increased from 90 mm up to 140 mm in males and 150 mm in females and thereafter declined. The present exploitation rate of 0.72 and 0.67 in males and females respectively is less than the respective E_{max} values of 0.94 and 0.92. This implies that the stocks of *O.bakeri* are not under excess fishing pressure and are well within the optimal level of exploitation. The results of the present study indicate that the harvest of *O.bakeri* can be kept at sustainable level by maintaining the present rate of exploitation.

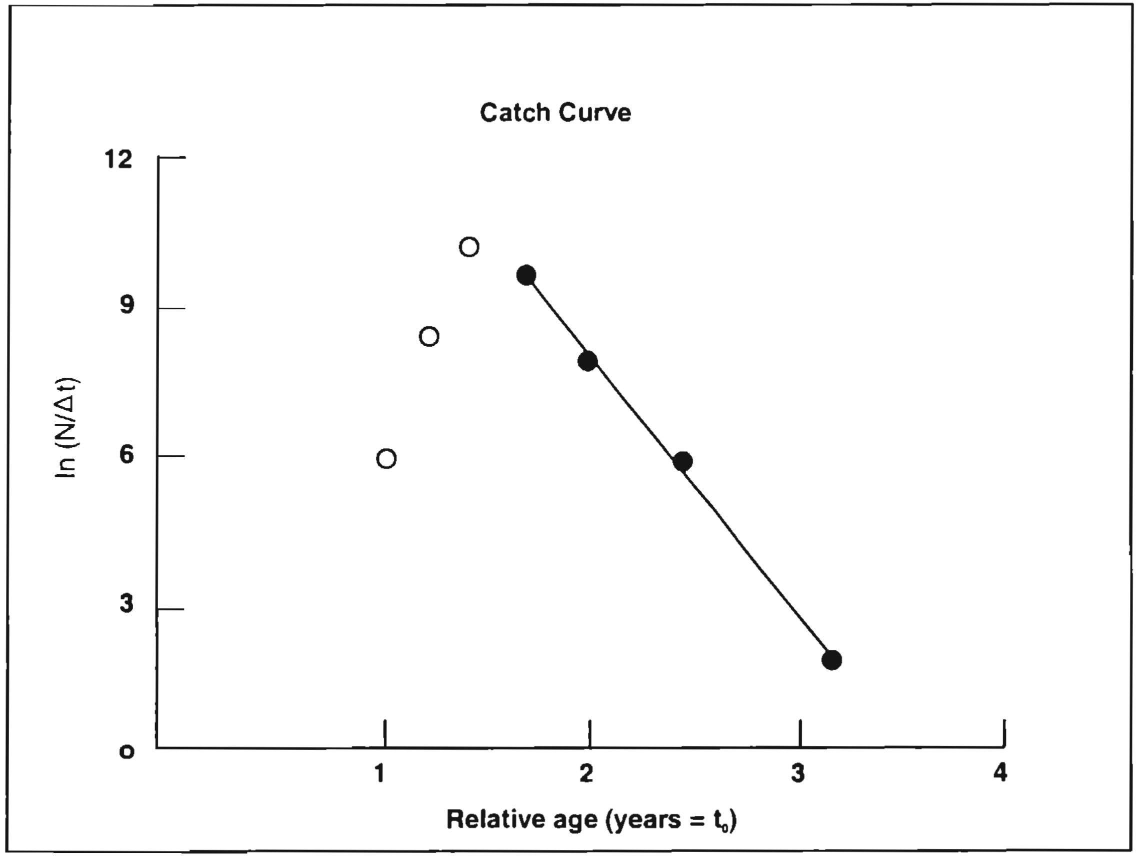
Table 9.1. Estimates of total mortality coefficient (Z) by different methods for male and female *O.bakeri*

Sl. No.	Method	Estimates	
		Male	Female
1	Beverton and Holt method	6.53	4.528
2	Sscentongo and Larkan method	6.2	4.224
3	Pauly's pile up method	4.15	2.745
4	Jones and van Zalinge method	5.77	5.493
5	Length converted catch curve method	5.31	3.46
	Average	**5.59**	**4.09**

Table 9.2. Estimates of natural mortality coefficient (M) by different methods and M/K ratios for male and female *O.bakeri*.

Sl. No.	Method	Male		Female	
		M	M/K	M	M/K
1	Sekharan's method	1.24	1.54	0.99	1.54
2	Rikhter and Efanov method	1.18	1.47	1.06	1.64
3	Pauly's empirical formula	1.82	2.26	1.55	2.4
	Average	**1.41**		**1.2**	

Fig. 9.1. Estimation of total mortality (Z) for male *O.bakeri* based on Catch Curve method



Growth Parameters

L_∞ = 168.00mm		K	0.81
C = 0.00		WP	0.00

Regression Statistics

n	=	4
y-intercept (a)	=	18.69
slope (b)	=	-5.31
Corr. Coef. (r)	=	-.999
Z from catch curve	=	5.31

(C1 of Z 6.13 to 4.49)

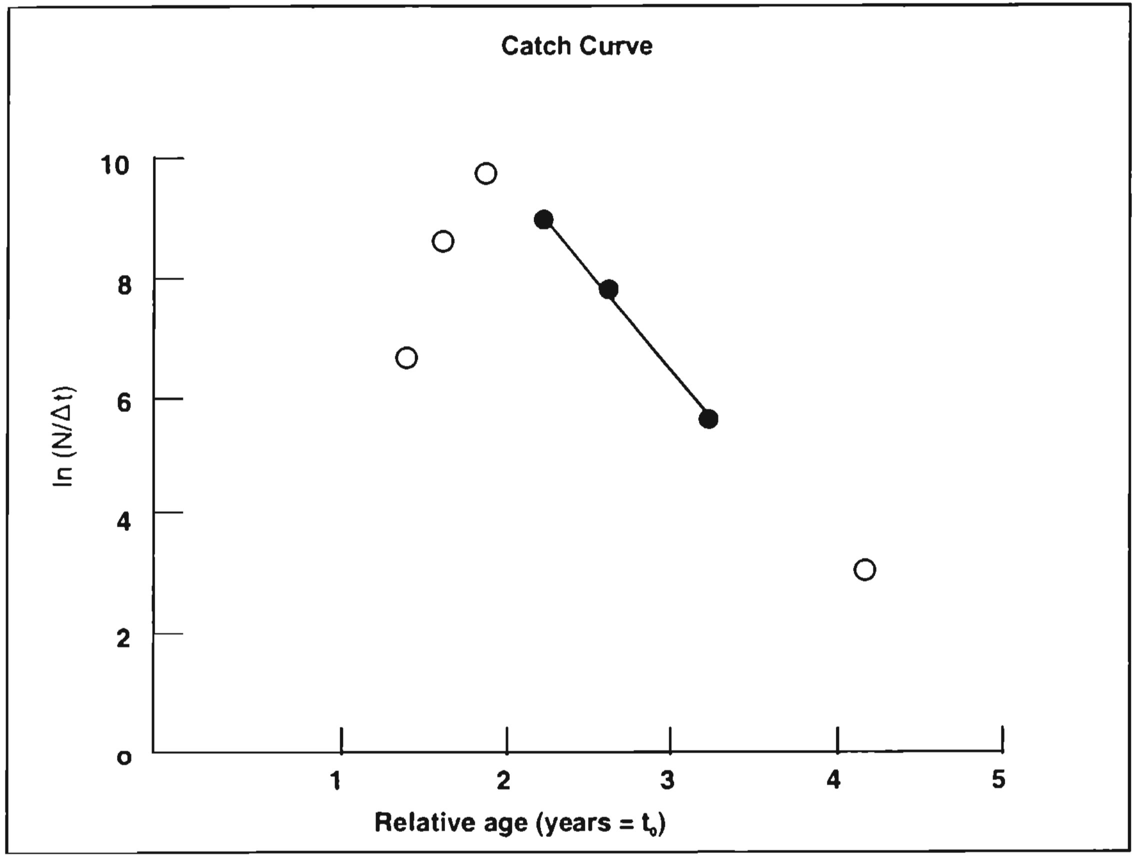
Range of length observations :

▶ 90 - 160 mm

Class Size

▶ 10 mm

Fig. 9.2. Estimation of total mortality (Z) for female *O.bakeri* based on Catch Curve method



Growth Parameters

L_∞ = 177.00mm		K	0.65
C = 0.00		WP	0.00

Regression Statistics

n	=	3
y-intercept (a)	=	16.89
slope (b)	=	-3.46
Corr. Coef. (r)	=	-.996
Z from catch curve	=	3.46

(C1 of Z 7.20 to -0.27)

Range of length observations :

▶ 100 - 170 mm

Class Size

▶ 10 mm

Fig. 9.3. Length based cohort analysis of males of *O.bakeri*

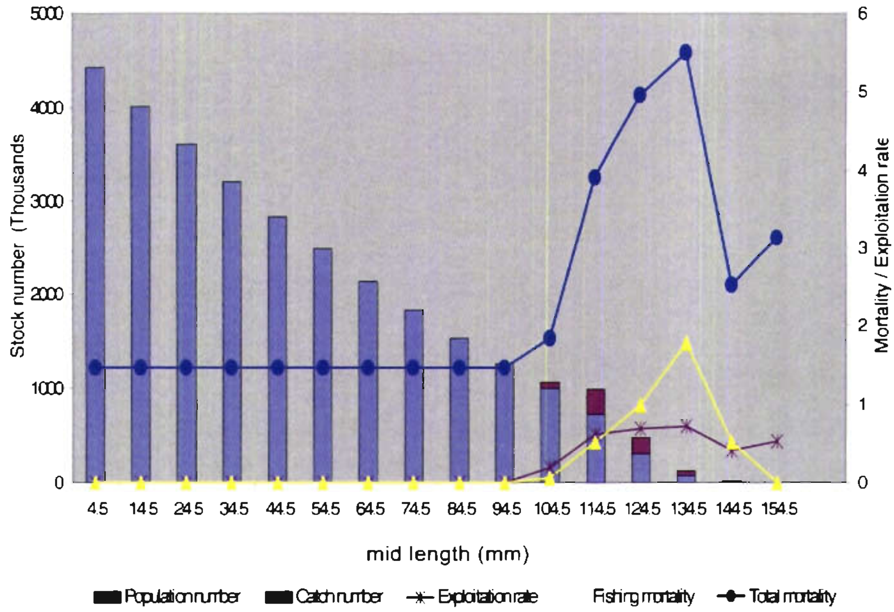


Fig. 9.4. Length based cohort analysis in females of *O.bakeri*

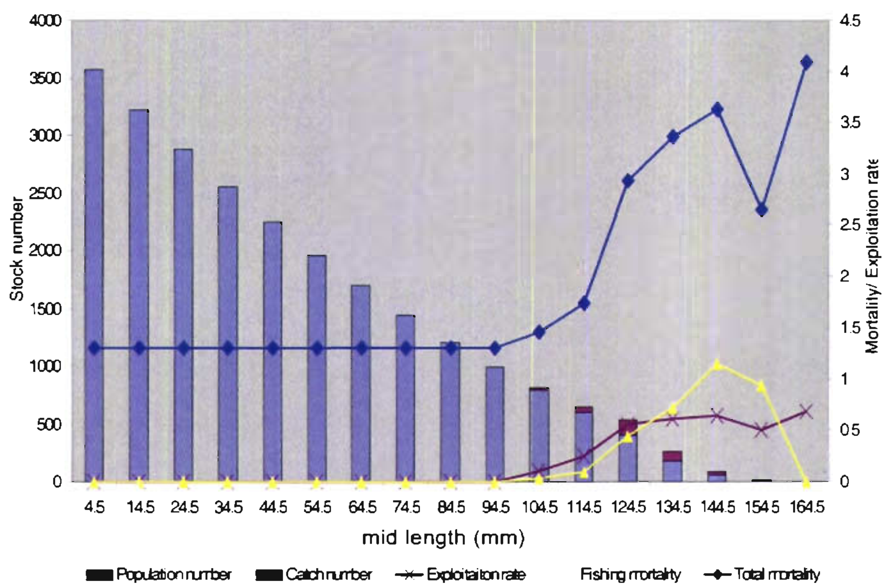
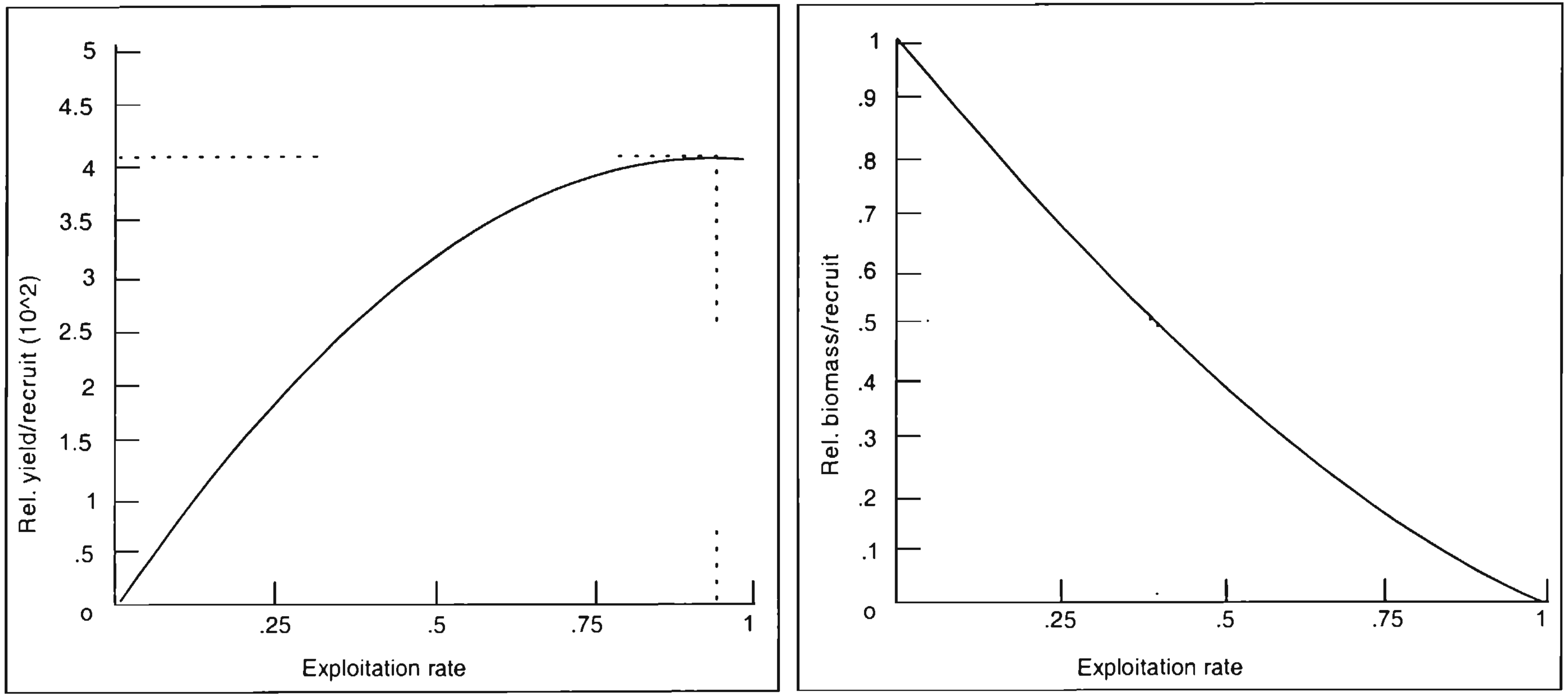


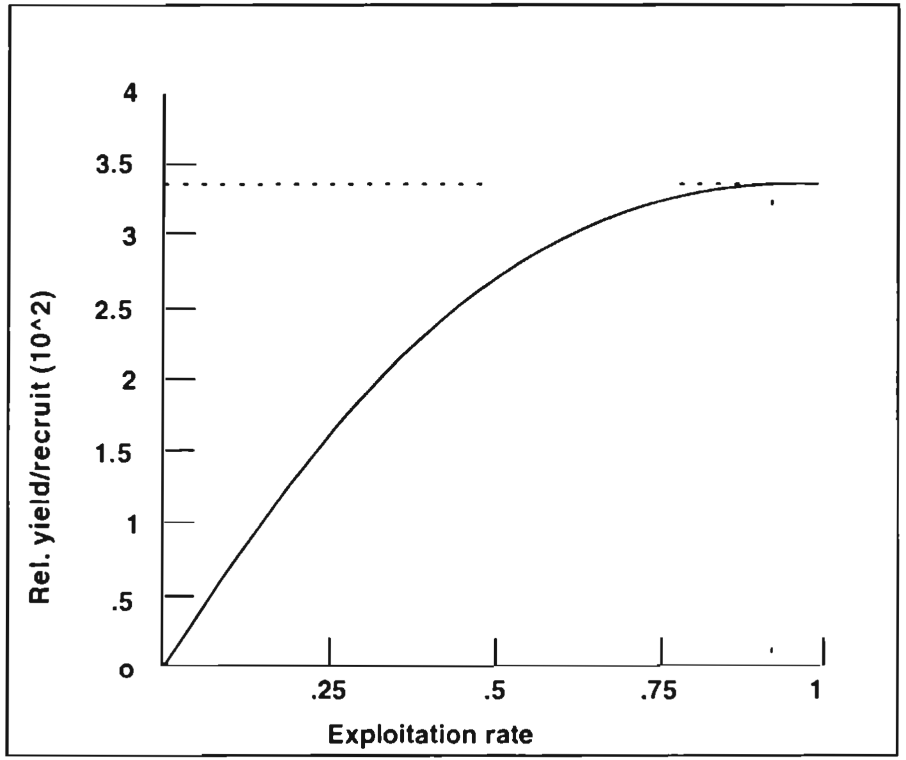
Fig. 9.5. Relative yield per recruit and biomas per recruit analysis for males of *O.bakeri*

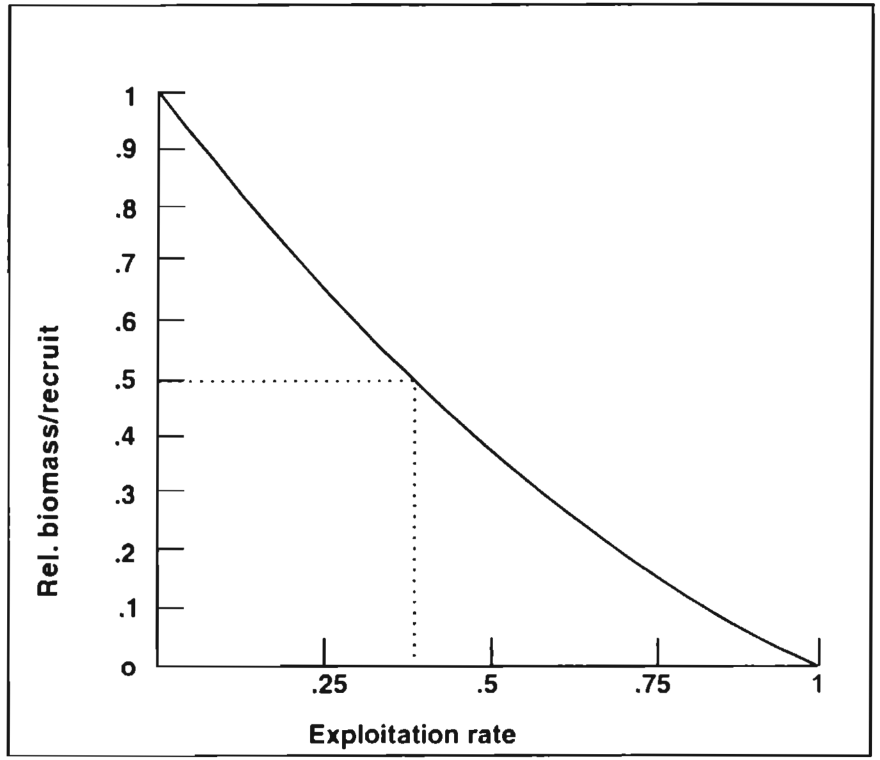


Optima:

E_{max}	0.9410	Lc/L_∞	=	0.60
E-.1	0.8709	M/k	=	1.83
E-.5	0.3940			

Fig. 9.6 Relative yield per recruit and biomas per recruit analysis for females of *O.bakeri*





Optima:

E_{max}	0.9230	Lc/L_{∞}	=	0.56
E-.1	0.8538	M/k	=	2.02
E-.5	0.3867			

CHAPTER X

SUMMARY AND RECOMMENDATIONS

10.1. Summary

Aquatic organisms exhibit great genetic diversity and species richness, maintenance of the organic diversity is an essential pre-requisite for the sustenance of any ecosystem. An international meeting on the 'General state of knowledge on Biodiversity' held in Bayreuth (Germany) in October 1991 stressed the importance of undertaking studies on biodiversity of fauna and flora of this Universe. The Convention on Biological Diversity (CBD) was adopted in Nairobi in May 1992 and signed by more than 150 countries during the 'Earth Summit' in June 1992 at Rio de Janeiro. By signing the Rio Convention, India has agreed to prioritize its species and sites and develop strategies for conservation of biodiversity. The convention highlighted the importance of conserving the areas of megadiversity and giving priority to endemic species in culture practices. India with a rich diversity of biotic resources, is one among the 12 mega-diversity countries in the tropics (Mc Neely *et al.*, 1990). Apart from this, India harbours 2 global hotspots, Western Ghats and Eastern Himalayas (Meyers, 1988, 1990). With respect to endemic fish taxa, Western Ghats is known as the richest region in India encompassing around 192 endemic species of the total 287 species of fishes reported (Shaji *et al.*, 2000). It forms a natural wall on the eastern side of the state of Kerala and is the watershed of the 44 rivers flowing through Kerala. Most of these rivers abound very rich, diversified, rare and endemic fish fauna. In the World Bank Technical paper on 'Freshwater biodiversity in Asia with special reference to Fish' (Kottelat and Whitten, 1996), the streams in

Kerala have been identified as freshwater sites of exceptional biodiversities with high degree of endemism. It is widely accepted that a majority of the freshwater fishes of Kerala are facing endangerment due to many reasons, among them the impact of human interventions are well documented. Habitat destruction due to mining of lakes and rivers, construction of dams across rivers and lakes, abstraction of water from rivers for agricultural purposes, pollution from industries and agriculture, application of destructive and indiscriminate fish catching methods, introduction of exotic species, waterway modification for navigation and other purposes, forest clearance, etc. are the common threats the fish population are prone to. However, among the 734 species of threatened fishes listed in the IUCN Red Data book from all over the world, only two species namely *Horaglanis krishnai* (Family: Claridae) and *Schistura sijuensis* (Family: Balitoridae) are included from India (IUCN, 1990). None of the fish taxa from India is treated as being threatened in the Indian Red Data book of 1994 prepared by the Zoological Survey of India. This situation points towards the serious dearth of information on the conservation status of Indian freshwater fishes. A perusal of the literature revealed that most of the previous works on freshwater fishes of Kerala were faunistic studies concentrating mostly on the taxonomical and zoogeographical aspects. Inadequacy of the data base is felt on aspects such as regional distribution and abundance pattern, resource characteristics, stock size, spawning season and time, fecundity and size at first maturity which are inevitable for the conservation and management of freshwater fishes. A meaningful assessment of the biodiversity status of the freshwater fishes cannot be done justifiably due to want of most of the above information and therefore no suitable conservation plans and management programmes are forthcoming for the protection and preservation of the unique fish germplasm resources of Kerala. Against this background, the present study was undertaken to revalidate the list of threatened freshwater fishes of Kerala following IUCN categorization, identify the threats these fishes are prone to and propose management plans for the conservation of endemic endangered fish germplasm resources of the state. The study also aims at generating an authentic data base on the distribution pattern, stock size, catch per unit effort, length-weight relationship, food and feeding habits, maturation and spawning, etc. of the threatened fishes in the rivers of Kerala.

The study was carried out during the period from March 2000 to August 2003 as part of NAT-ICAR project on 'Germplasm inventory, evaluation and gene banking of freshwater fishes' being implemented at the School of Industrial Fisheries, Cochin University of Science and Technology. Extensive surveys and sampling were carried out using diverse types of fishing gears and methods such as cast nets, gill nets, drag nets, scoop nets and other local contrivances like ottal, mada vala *etc.* in the 19 major river systems of Kerala to bring out the fish fauna with special reference to the threatened fishes. Ichthyo-biodiversity was also assessed in protected areas and wildlife sanctuaries of Kerala such as Silent Valley National Park, Aralam Wildlife Sanctuary, Chinnar Wildlife Sanctuary, Muthanga Wildlife Sanctuary, Periyar Tiger Reserve and Angamoozhi Elephant Sanctuary. Sampling was done giving representation to pre-monsoon, monsoon and post-monsoon seasons of each year. The biodiversity status of each species was assessed based on IUCN criteria (1994). In addition to the scientific data, informal or traditional knowledge was also applied to evaluate the conservation status of fishes. A total of 122 species of fishes were collected and identified during the present study. Among them, 33 species were threatened while 35 belonged to Lower risk- near threatened and 35 to Lower risk-least concern category. 16 species were listed as Data Deficient due to want of adequate data and 3 were not evaluated as they were introduced species. Among the threatened fishes, 8 species were considered critically endangered (CR) while 14 as endangered (EN). The remaining 11 species were grouped under vulnerable (Vu) category. The fishes belonging to critically endangered category were *Lepidopygopsis typus, Gonoproktopterus micropogon periyarensis, Crossocheilus periyarensis, Travancoria elongata, Balitora mysorensis, Channa micropeltes, Dayella malabarica and Silurus wynaadensis*. All the above fish species except *Silurus wynaadensis* were found restricted to a single location within a single river system while *Silurus wynaadensis* was restricted to three locations of a single river system. Out of the 14 endangered species, 8 were found to inhabit a single river system each while 6 of them inhabit in two river systems each. 12 of the threatened fishes were strictly endemic to Kerala waters whereas 9 were found endemic to Western Ghats region, thus showing their distribution outside Kerala also. A groupwise analysis showed that as high as 21 species belonged to order Cypriniformes, 6 to Siluriformes, 3 to Perciformes and one species each to Anguilliformes, Clupeiformes and Osteoglossiformes. A brief description of these rare fishes together with information regarding stock size and availability, distribution, habitat, threats, river-wise catch per unit effort, length- weight relationship, food and feeding habits, sex and stage of maturity etc., are furnished under each species.

Osteobrama bakeri (Day), commonly known as Malabar Osteobrama and locally known as Mullanpaval, belongs to the family Cyprinidae and subfamily Cyprininae.It is an endemic fish, belonging to the category of vulnerable fishes. Besides being valued as food fish, due to its vibrant and attractive colouration and easiness for domestication, it has great potential for being propagated as an ornamental fish. 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 is also made to investigate the life history traits, resource characteristics, proximate composition, etc., of *O.bakeri.*

The nutritive value of the fish was evaluated by analyzing the proximate composition, minerals and amino acids. The muscle tissue of *Osteobrama bakeri* was found to be rich in protein and poor in fat content. The protein content was 17.97, 18.32 and 17.55% in males, females and indeterminates respectively. Indeterminates recorded 0.6% fat while in males it was 1% and in females higher fat content of 1.6% was observed. Among minerals, sodium and potassium were found in higher concentrations. Glutamic acid contributed to the major share among the amino acids with 17.10% followed by Aspartic acid (11.64%). All the essential amino acids were present in the muscle tissue of *Osteobrama bakeri.* Among them, leucine showed the highest concentration (8.16%) while tryptophan was the lowest (1.39%).

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 asess the food preferences of males, females and indeterminates. The study indicated that the basic food of *Osteobrama bakeri* was insect larva. The other major food items were cladocerans, copepods and diatoms. Males were found to be carni-omnivorous while females were omnivorous and indeterminates were carnivorous in their feeding habit. The morphological and histological structures of the alimentary canal of *O.bakeri* corroborated with the above finding. Feeding intensity was moderate 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. Gastro-somatic index (GSI) indicated higher rate of feeding among indeterminates than the mature individuals. Females consumed more food when compared to males.

The various aspects of reproduction such as gametogenesis, 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 results of histological studies of the ovary revealed that each oogonium passed through a series of stages to form ripe egg. They were chromatin nucleolus stage, perinucleolus stage, yolk vesicle or cortical alveolar stage, yolk globule stage, migratory nucleus stage and ripe egg. Atretic oocytes were also encountered. Similar studies conducted in testes showed that the different stages in spermatogenesis were primary and secondary spermatogonia, primary and secondary spermatocytes, spermatids and spermatozoa. The spawning seasons were 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. Two spawning seasons were delineated, the first spawning during April-June, succeeded by the second one during October-November, the former coincident with the onset of pre-monsoon showers and the latter synchronous with north-east monsoon. The wide size range of mature ova with minor modes within the group of mature ova manifested the tendency for fractional spawning within the season. Males matured at a lower length (115 mm) than the females (118 mm).The overall sex-ratio showed the preponderance of males during almost all months. Males were dominant in the population up to 125 mm TL and thereafter the preponderance of females was quite discernible. Beyond 155 mm TL only females were encountered. Fecundity of *Osteobrama bakeri* ranged from 2834 (123 TL) to 8213 (131 TL). Fecundity showed very good correlation to the weight of ovary than the other body parameters. It was correlated to the fish length by a factor close to the cube.

The length-weight relationship in males, females and indeterminates was established by the general linear equation. The values of regression coefficient for males and females were 2.1738 and 3.1967 respectively which showed significant departure from '3' indicating that the growth followed allometric pattern. On the contrary, the exponent value of 2.939 revealed isometric pattern of growth in indeterminates. The general well-being of the fish was ascertained from the relative condition factor (Kn) and ponderal index (K) values. 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. Ponderal index (K) closely followed Kn values in females and indeterminates whereas males showed different trends.

Length frequency data was used to determine the age and growth of fish. The growth parameters were estimated separately for the two cohorts of male and female populations following ELEFAN I programme and integrated method of Pauly. Munro's ϕ prime index revealed that the results of the two cohorts were comparable. The growth parameters estimated by (a) ELEFAN 1 and (b) the Integrated method of Pauly were as follows:

a)	Males	$L_\alpha = 168$, $K = 0.805\ yr^{-1}$
	Females	$L_\alpha = 177$, $K = 0.645\ yr^{-1}$
b)	Males	$L_\alpha = 169.0972$, $K = 1.0904\ yr^{-1}$
	Females	$L_\alpha = 171.745$, $K = 0.9962\ yr^{-1}$

The values of t_0 was estimated as 0.0865 and 1.0604in males and females respectively. von Bertalanffy growth equation was used to describe the growth. On applying the average growth coefficients estimated by ELEFAN 1, males attained a length of 87,132 and 152 mm and females 130, 152 and 164 mm at the end of I, II and III years respectively. Recruitment to the fishery was found to occur throughout the year. The recruitment pattern manifested the occurrence of two recruitment pulses every year.

An attempt was also made to determine the age from the study of scales. However, it appeared that the rings found in the scales did not show any definite pattern and therefore a meaningful conclusion on the age of the species based on the rings which appeared on the scales could not be made in *O.bakeri*

The total mortality values (Z) calculated for males ranged from 4.15 (Pauly's pile up method, 1983) to 6.53 (Beverton and Holt method,1966). The average of the estimates by various methods was 5.59. In female population, the values of Z varied between 2.745 (Pauly's pile up method,1983) and 5.49 (Jones and van Zalinge method,1981), the average being 4.09. The natural mortality coefficient (M) estimated by Sekharan's method (1974) gave the lowest value of 1.24 while Pauly's empirical formula (1980)gave the highest of 1.82 in males, the average being 1.41. In females, the same ranged from 0.99 by Sekharan's method (1974) to 1.55 by Pauly's empirical formula (1980) and the average was computed at 1.2. Fishing mortality (F) was calculated as 4.18 (males) and 2.89 (females).The exploitation ratio (E) were 0.72 and 0.68 in males and females respectively. The exploitation rate in males and females were found to be 0.72 and 0.67.The results of the length converted cohort analysis of male and female populations revealed that the exploitation started from 90 mm in both sexes and increased up to 140 mm in males and 150 mm in females and thereafter decreased. The relative yield/recruit analysis showed E_{max} as 0.94 in males and 0.92 in females against the present exploitation rates of 0.72 and 0.67 in male and female populations. The study indicated that the harvest of Osteobrama *bakeri* can be maintained at sustainable level at the present rate of exploitation.

10.2. Recommendations

Based on the results of the present investigation, the following measures are suggested for the conservation of fish species in the rivers of Kerala.

1. Data on the freshwater fish fauna of Kerala is deficient at present. It is felt that there is an urgency to intensify the systematic and extensive fish surveys and samplings in 44 rivers of Kerala to strengthen the available database of freshwater fishes of Kerala.
2. Regular monitoring of existing threatened populations must be done along with their stock assessment. Location specific conservation strategy of these fishes shall be worked out and implemented.
3. Endangered fishes should be included under the Wildlife (Protection) Act (1972, amended 1991), thereby ensuring greater protection to them. The threatened fishes identified in the present study shall be banned in trade.
4. The critically endangered and endemic freshwater fishes shall be brought under the purview of the list of similar fishes prepared by the Ministry of Environment and Forest, Government of India.
5. In view of the paucity of information on endangered fish on aspects related to population structure, distribution range, habitat, life history traits and the factors responsible for their

endangerment, it is recommended that research in these lines shall be initiated and strengthened.

6. The natural breeding grounds and nurseries of the threatened fishes shall be identified and regions so demarcated shall be declared as aquatic sanctuaries.

7. In view of the indiscriminate exploitation of brood-stocks of freshwater fishes observed during the spawning season, especially during the south west monsoon, imposition of a seasonal closure for fishing during this period is found necessary to maintain the stock recruitment relationship of freshwater fishes in general and threatened fishes in particular.

8. Regulate the human interventions in the habitats of critically endangered species such as sand mining, conduct of unethical fishing practices, discharge of polluted water, diesel spillage from boats, etc.

9. Any fish species whose distribution is well restricted to a single location is always prone to extinction in near future due to natural or anthropogenic reasons. In such cases, translocation of such species would be a rewarding conservation activity. Identification of ideal habitats and translocation of critically endangered species which are restricted to a single location to new locations would also be worthwhile. To begin with, any one of the following endemic species can be taken up: *Silurus wynaadensis*,

Crossocheilus periyarensis, *Garra periyarensis*, *Gonoprokto-pterus micropogon periyarensis* and *Lepidopygopsis typus*.

10. Development and standardization of captive breeding technology of the following fish species such as *Neolissocheilus wynaadensis*, *Travancoria elongata*, *Horabagris nigricollaris*, *Osteochilichthys longidorsalis*, *Puntius ophicephalus*, *Travancoria jonesi*, *Macrognathus guentheri* are inevitable for their rehabilitation as a tool for the sustenance of stock. Ex-situ conservation of threatened fishes are also recommended on a war footing.

11. Government of Kerala shall set up a fish hatchery exclusively for the breeding and propagation of critically endangered and endemic freshwater fishes of Kerala.

12. *Osteobrama bakeri* is recommended as a potential ornamental fish. Captive breeding of this species is advocated for commercial purposes. For domestication purposes, live feeds such as insect larvae, copepods, cladocerans and artemia can be fed. High protein and low fat content make it a good food fish too.

13. It is felt that there is inadequacy of appropriate legislation to curb the unethical and unscientific fishing methods and practices which are very rampant in the rivers and rivulets of Kerla. By totally conceiving this, immediate enactment of Kerala Inland Fisheries Regulation Act (KIFRA) is found indispensable for the conservation of threatened fishes of Kerala.

14. Sanctuaries, reserves and national parks need to be set up for fishes also as done for the protection and preservation of other wild animals. Display boards depicting the details of the sanctuary and legal measures taken against offenders should be exhibited at eye-catching places.

15. Introduction of exotic species should be allowed only after studying its biology, habitat and potential threats to native fish species and environment.

16. Prepare a 'Freshwater Icthyofauna Biodiversity register' on similar line of 'People's Biodiversity Register' prepared by the Ernakulam district panchayats under the Ninth Five Year Plan. Traditional knowledge on ecology, behaviour and abundance of a species may prove invaluable in many cases. Documentation of knowledge and perception of the local people on biodiversity and conservation can be done using a questionnaire. Educated youth can be deployed for the purpose after giving proper training, instructions and guidelines.

17. The 'Biodiversity Conservation Order' passed by the Government of Kerala in 2000 should be given wide publicity through mass media.

18. Successful fish conservation on long-term basis is mainly dependant on habitat protection which in turn can be achieved only through public awareness. Educate the fishermen community, local people, governmental and non-governmental

agencies, students and the general public regarding the importance of conservation of fish fauna through group discussions, seminars, training camps and publicity through mass media. Awareness campaign need to be initiated by bringing out posters, stickers, stamps, showing clippings in electronic media, etc. Implementation of location specific conservation programmes giving due representation to inland fishermen at local body level is found very necessary for the protection of fast depleting ichthyofauna of the state.

19. Students may be encouraged to observe 'Ichthyofauna week' on the line of 'Wild Life Week'. Postage stamps may be issued in this connection.

20. Aquarium keeping using indigenous fishes shall be promoted as a hobby. Collection of fishes from wild for domestication and export as ornamental fishes shall be regulated and fishes bred under captivity shall only be used for trade purposes.

21. A state-level apex body including representatives from governmental and non-governmental organizations and research centres shall be constituted for the conservation of fish biodiversity which can control, co-ordinate and evaluate the performance of various committees formed for regular monitoring of water bodies and implementation of mass awareness programme.

22. The State Fisheries Department and the research community of the state should start working together in a meaningful manner for the formulation and implementation of research projects and other appropriate measures for the conservation of fishes. The expertise of Cochin University of Science and Technology in germplasm inventory and Kerala Agricultural University in captive breeding may be made use of for the same.

23. Installation of future hydroelectric projects like the one proposed by Kerala Government at Pathrakkadavu across Kunthi river less than 500 metres downstream of Silent Valley National Park must be realized only after assuring that fish movements are not hampered and their breeding grounds and nurseries are least disturbed. Fish passes, fish-ladders etc. should be provided for fish movements.

24. Conservation management programmes can be implemented by generating financial assistance from various international and national funding agencies.

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