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 prerequisite 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 assess 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 carnio-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
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 $\phi$ 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 $L_0 = 168$, $K = 0.805 \text{ yr}^{-1}$
Females $L_0 = 177$, $K = 0.645 \text{ yr}^{-1}$
b) Males $L_0 = 169.0972$, $K = 1.0904 \text{ yr}^{-1}$
Females $L_0 = 171.745$, $K = 0.9962 \text{ yr}^{-1}$

The values of $t_0$ was estimated as 0.0865 and 1.0604 in 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 $E_{\text{max}}$ 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*,

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Crossocheilus periyarensis, Garra periyarensis, Gonoproktopterus 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, Macroganathus 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 Ichthyofauna 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.