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PATTERNS AND PROCESSES OF FISH ASSEMBLAGES IN PERIYAR LAKE VALLEY SYSTEM OF SOUTHERN WESTERN GHATS

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ABSTRACT

The ecological structure and functional processes of fish assemblages in the 26 Km^2 man-made Periyar lake in Periyar Tiger Reserve (PTR) and 75 Km long streams (Periyar and Mullayar) were studied during 1994 - 96. A total of 27 fish species were encountered in the system. Of these, 14 (52%) are endemic to Western Ghats. 52% are threatened and 33% are endemic and/or threatened. A comparison in the list of fishes recorded in 1948 with that of the present study indicates loss of many species (16?) and addition of a few species (8). Most of the threatened fishes are found in the streams than in the lake. The exclusive (stenotopic) endemics of Periyar lake-stream system like *epidopygopsis typus, Puntius micropogon periyarensis and Crossocheilus periyarensis* are relatively abundant in the streams. The population densities of the threatened and endemic fishes are generally low in the system.

The diet and morphological analysis reveal that the fishes largely depend on food bases like aquatic and terrestrial insects and other benthic macroinvertebrates with distinct trophic segregation patterns. Based on diet. the fishes are classified into groups by hierarchical clustering technique namely, terrestrial insectivore, benthic insectivore. insectivore-omnivore, insectivore-detritivore, omnivore and algivore. Similarly, on morphological characteristics, the fishes are grouped into water-column rovers, bottom clingers, deep-bodied rovers. bottom eel-likes and surface-orienters. These are again readily separated into various niche types based on dietary and morphological features such as surface, pelagic, benthic. substrate and individualistic. Resource requirements based on habitat associations like depth flow, substrates and food are assessed for endemic and threatened fishes.

Biological invasion by exotic fishes like *Oreochromis mossambicus* and *Cyprimus carpio communis,* analysed with ecological tools like diet, morphologic as well as habitat overlaps indicate the existence of a high degree of interspecific interaction between these exotic fishes and a few native. endemic and/or threatened fishes. A comparison with the fish communities in the adjacent zones or biotopes (downstream systems and the streams in nearby leeward slope) .indicate a high degree of icthyofaunal diversity in Periyar lake and streams in relation to downstream reaches and streams in the leeward slope

The local inhabitants living around the PTR selectively fish on the exotic as well as the endemidthreatened fishes of the lake. The average daily fish catch per fisherman is estimated to be 4.2 Kg. which realised an amount of Rs. 168.00 per fisherman per day. The annual catch for the four selected fish species (2 exotics and 2 natives) is estimated as 12 tonnes against a possible projected annual fish production of around 22 tonnes

INTRODUCTION

The Western Ghats, one of the 18 biodiversity 'hotspots' of the world is unique for high rate of endemism (Gadgil, 1996; Pascal, 19%). The Kerala part with an area of 20,000 Km^2 gives rise to 41 west flowing rivers, many of which drain mainly the forested catchments and empty into Arabian Sea. The Southern Western Ghats section, south of Palghat Gap, forms catchments of many coastal river systems (Nair, 1991) like Chalakkudy, Periyar, Pamba, Manimala, Achenkovil and Kallada. The rivers in the Western Ghats of Kerala support rich and diverse icthyofauna of about 200 species (Nair and Easa, 1997). This includes many endemic as well as threatened species. Inventory on the fishes of these river systems are mostly partial and the listing still continues (Pethiyagoda and Kottelat, 1994; Easa and Basha, 1995; Menon and Jacob, 1996; Shaji et al.. 1996)

Investigations on the fishes of the fluvial systems in Kerala or India are mostly limited to mere descriptions on taxonomy or distribution and in few cases, their biology, if the species are commercially important. Studies on fluvial icthyofauna have long been neglected on an ecological scale that the habitat requirements or structure of fish communities are mostly unknown, while fisheries research investigations are completely restricted to species or its biology (Lowe-McConnoll, 1975; 1987). The next level of understanding the fishes, i.e, from species to community/assemblage level, sheds ample insight into the structure and functioning of fish communities in natural systems. The habitat associations, usage and requirements of fish species could reveal delicate relations with their environment. Studies on community level is rather very common in temperate systems (Ross, 1986), while in tropics especially of South Asia, are thoroughly under investigated (Moyle and Senanayake, 1984; Wikramanayake and Moyle, 1989; Arun, 1992). The fish communities in tropical streams are structured through temporal and spatial dimensions (Zaret and Rand, 1971; Angermier and Karr, 1983) and by biological interactions (Welcomme, 1969; Power, 1983; Watson and Balon, 1983; Moyle and Senanayake, 1984). Among the

available resource, food seems to be one of the most important variables in community structuring (Schoener, 1970; ROSS, 1986). The importance of food in species segregation pattern and community structuring of fishes in relation to morphological make-up have already been tested both in temperate and tropical systems (Power, 1983; Moyle and Senanayake, 1984; Gregor and Deacon, 1988; Wikramanayake and Moyle, 1989; Winemiller, 1990; Flecker, 1992).

The tropical fish communities in their native ecosystems have always been under various threats and disturbances of both natural and human origin. These disturbances are mainly through habitat alterations or modification by construction of dams, intensive agricultual practices in catchment and irrational fishing practices. The introduction of non-resident or alien fish species into local aquatic systems and the consequent invasion and establishment by the introduced species can also cause threats to native fish fauna. Consequences of similar disturbances to native fish populations have already been witnessed world wide (Langford, 1983; Goldsmith and Hildyard, 1984; Baret *et al.*, 1985; Witte *et al.*, 1992; Balon, 1992; De Jalon *et al.*, 1994; Zhong and Power, 1996). Another social dimension of disturbances to fish communities is the involvement of indigenous groups, the earlier hunter-gatherers, who depend heavily upon the unique and diverse fish resources for their livelihood especially in the high altitude areas. Understanding the rate of exploitation and the level of dependence by these groups on the fish resources could help design appropriate management strategies for sustainable natural resource exploitation in the protected areas of Kerala

The present study on the fish assemblages of the Periyar lake and adjacent streams is designed to comprehend broadly on:

1. The pattern of distribution and abundance of fishes in the lake and streams
2. The functional processes in the structuring of fish communities in the system.

The twin objectives are attained through studying (i) the current status and distribution of fishes in the lake and streams, (ii) the relative abundance of fish

species, (iii) the basic water quality and production parameter, (iv) the ecological structure of fish communities on diet, morphology and macro habitat attributes, (v) alien-native fish species interactions, (vi) habitat associations of endemic and threatened fishes, (vii) downstream variations in fish communities, (viii) habitat and fish diversity in adjacent micro-watersheds and (ix) current fishery practice in the lake by indigenous group.

STUDY AREA

The study area is located (9° 6'-9° 37' N and 77° 8'-77° 24' E) in southern Western Ghats. The area lies inside the Periyar Tiger Reserve (PTR), one of the world famous Wildlife Sanctuaries, which is known for the unique possession of larger mammals. The Periyar lake-stream system consists of a man-made lake and two major streams (Fig. 1). The lake, with an area of 26 Km^2, is formed by the construction of a dam across the streams, Mullayar and Periyar in 1895. These two streams have mainly drained the lake. The Mullayar originating at an altitude of 1780 m MSL has a length of about 31 Km and joins the southern tip of the lake. The Periyar stream joining the eastern tip of the lake from southern direction originates at an altitude of 1593 m MSL and has a length of 43 Km. This aquatic ecosystem is more or less a completely closed one. Water from the reservoir is not directly opened downstream but overflows the dam when the water level reaches 41 m. This level is very seldom attained (once or twice for a couple of days in a decade). The only continuous outlet of the reservoir is the drainage pipes laid from the lake to the plains of Tamil Nadu (the pipe are laid from 900 m MSL to 540 m MSL with a drop of 90 m/Km). The lake and streams are surrounded mostly by evergreen and semi-evergreen forest types.

The Mullapperiyar dam, one of the oldest dams of India has recently become a subject of controversy regarding the amount of water shared between the beneficiaries and the State. The history of the dam as well as of the wildlife sanctuary is described elsewhere (Asari, 1986; Ramachandran *et al*., 1987).

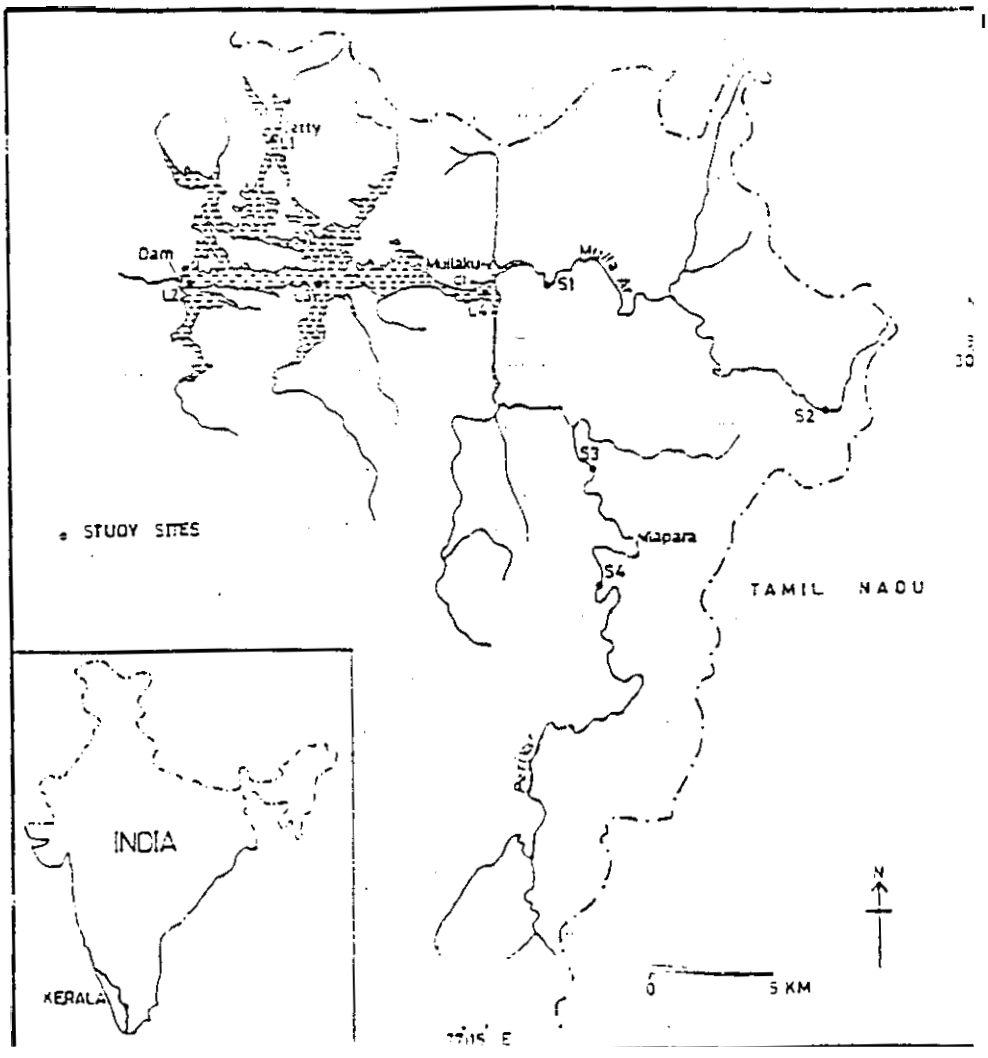

Fig.1 Location of study sites in Periyar lake-stream system

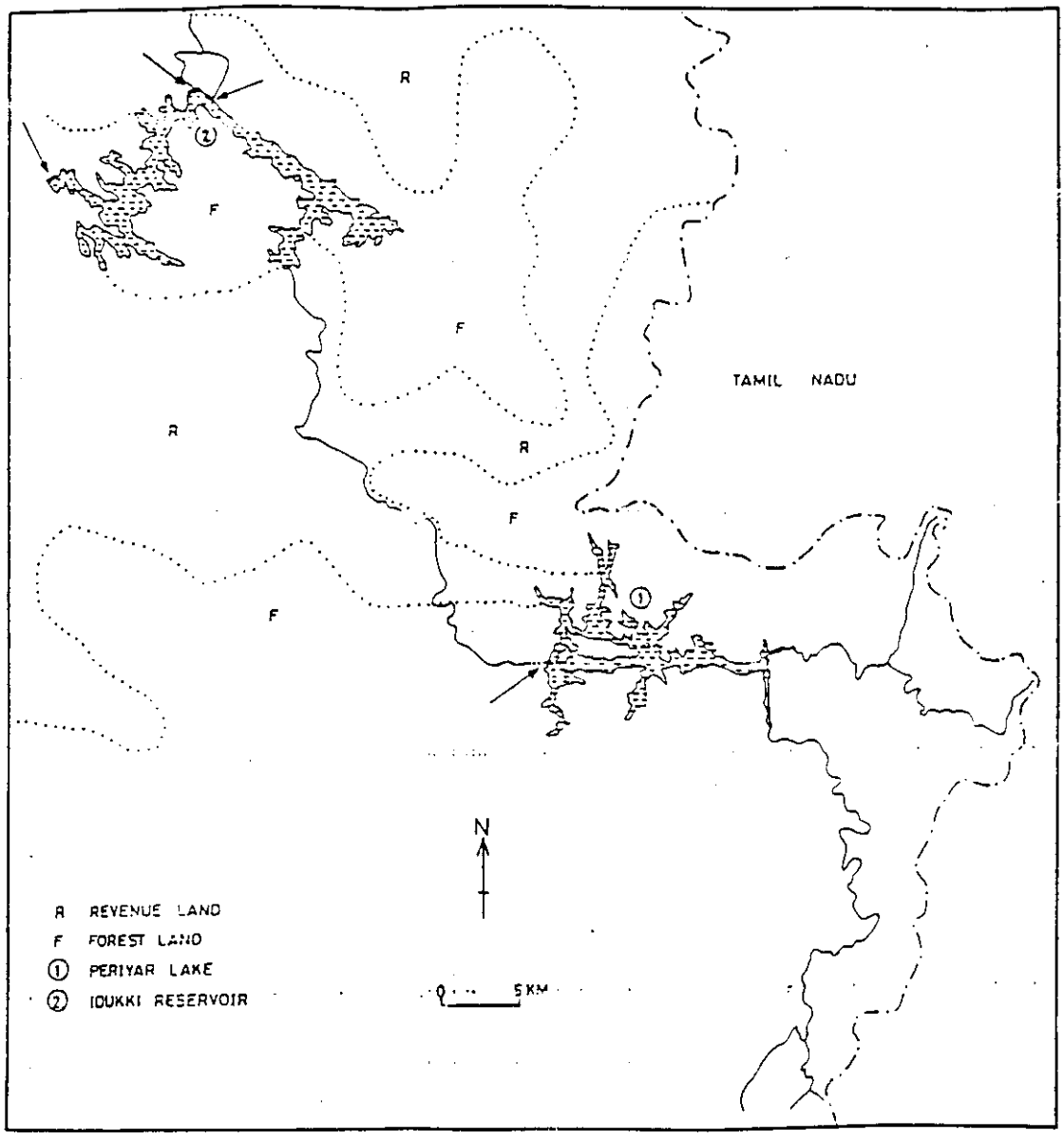

Fig2 Study area showing the location of dams (indicated by bold headed arrows) and use pattern in differennt zones of Periyarriver basin

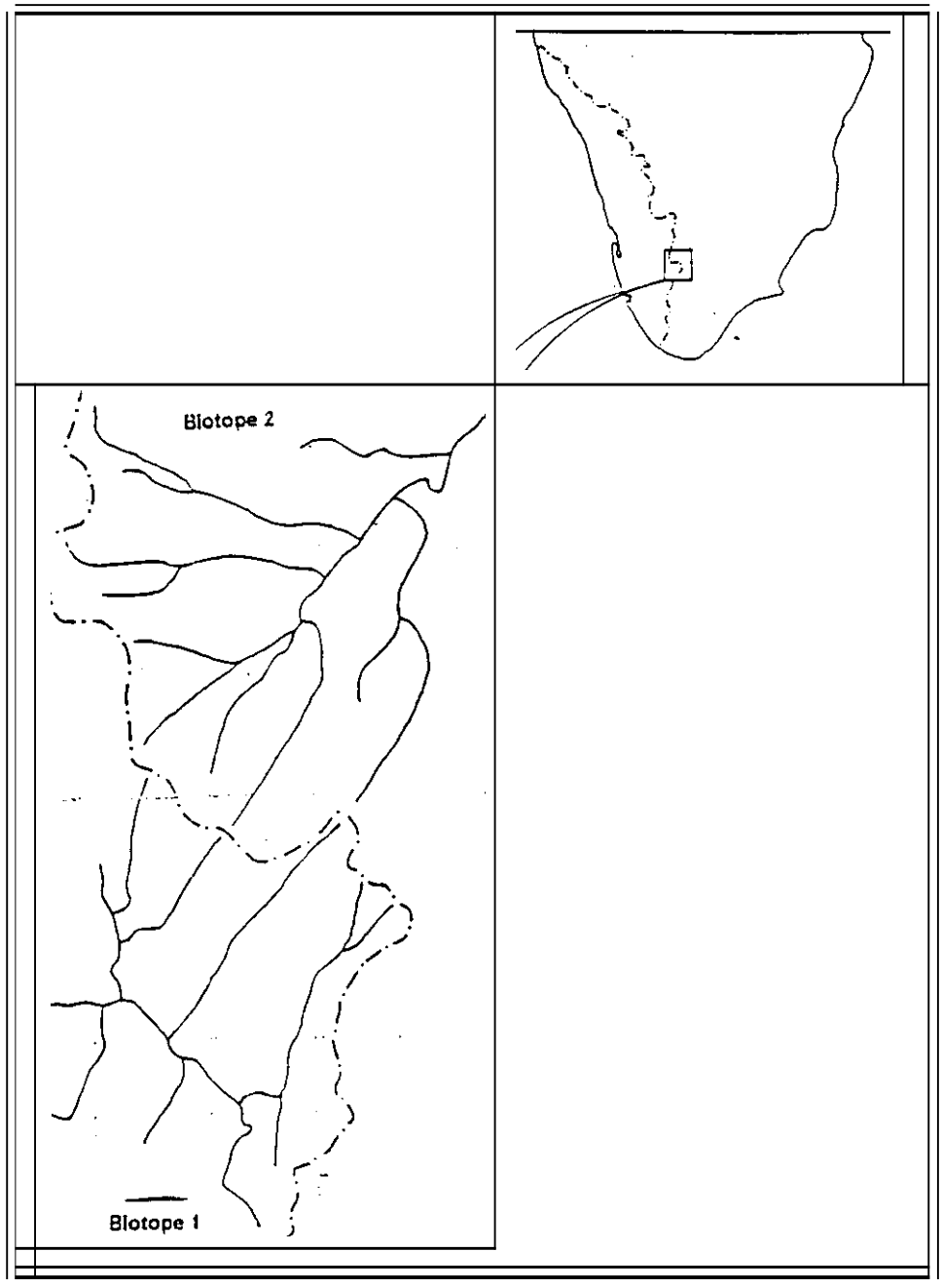

Fig.3 Location of streams in adjacent biotopes inwindward and leeward slopes of souther Wester Ghats

The study was extended downstream to understand the variations in fish communities in adjacent zones and biotopes. To study the downstream sections, 4 stations were identified in the river flowing after the Mullapperiyar dam (Fig 2) until the confluence of Idukki reservoir at a length of 38 Km. After traversing 38 Km, the Periyar river drains into Idukki reservoir, a multipurpose river valley project commissioned in 1976. Idukki reservoir (60 Km^2) is formed by the construction of 3 dams viz, Idukki, Cheruthony and Kulamavu. Thus first 120 Km of Periyar river from its origin is studied here (9^o 16'- 9^o 51' Nand 76^o 53'-77^o 24' E).

An adjacent biotope was selected on the eastern slope of Western Ghats for comparison with Periyar streams on habitat and faunal diversity. These were Biotope 1, the windward slope in Kerala and biotope 2, the leeward direction in Tamil Nadu. So both the biotopes were of equal areas of about 50 Km^2. Biotope 1 lies in PTR and the streams in it form the headwaters of Periyar river, while biotope 2 is in the Varashnadu highway mountains of Meghamalai Forest Range in Tamil Nadu and the streams are the headwaters of Vaigai river system (Fig. 3).

METHODS

Estimation of water quality and production parameters: Studies on water quality and production parameters were conducted during June 1994 - May 1995. Seasonal samplings based on pre-monsoon, monsoon and post monsoon were carried out at 4 stations in the lake and 2 stations in the stream for water quality estimation and 4 stations in the lake for production appraisal (see Figure 1 for study locations). The subsurface water was collected for laboratory analysis. The dissolved oxygen content was estimated at study sites using AQUAMERCK DO Test Kit. The DO test Kit was calibrated and standardized at the laboratory using Winkler's full bottle technique (APHA, 1985). pH was measured using electronic conductivity meter (LF-91), Alkalinity, free carbon dioxide, total hardness and chloride were estimated in the laboratory by standard titrimetric methods (EPA, 1979; APHA, 1975). Air and water temperatures were recorded using a glass mercury thermometer and water

transparency was measured by Seechi disk Morpho-edaphic index (MEI) at lake stations was estimated using the formula (Ryder, 1965): MEI = Electrical conductivity (μ S/cm)/ mean depth (m). Primary productivity was estimated by the light – and – dark – bottle technique (Benton and Werner, 1965) incubated for 24 hours.

The results obtained from light and dark oxygen bottles by Winkler titration method were extrapolated using an oxycalorific coefficient of 3.51 to calculate energy production. The plankton, organic matter and carbon production were calculated on the basis of gross oxygen production (gO_2) using the following formulae: Carbon = gO_2 x 0.375 (g); organic matter = gO_2 x 0.690 (g) and plankton biomass = gO_2 x 3.300 (g).

Assessment on the status and distribution of fishes: Fish sampling was conducted at 4 pre-selected locations in the lake(Ll, L2, L3 and L4) and 4 in the streams (S1, S2, S3 and S4). Seasonal collections (pre-monsoon, monsoon and post-monsoon) were made at locations between June 1994 and May 1996 during 0800-1600 Hrs and occasionally during overnight (2000-0600) hours to sample nocturnal fishes or to understand fish composition variations, if any. The fishes were caught using mono-filamentous gill nets of different mesh sizes viz, 4,6,8,10,13,15,18.5,22,25, 30, 40, 50, 67,75,85 and 100 mm and hand/scoop nets of mesh size 1 mm, 2 mm as well as cast nets. Special care was taken to maintain uniformity in fish catch per unit effort (CPUE) so as to enable comparisons of populations at each location of the lake and the stream. The fishes were identified using the keys and descriptions of Jayaram (1981) and Talwar and Jhingran (1991). Shortly after the capture, the fishes required for laboratory examination were preserved in 10% formaldehyde and the rest live fishes were released back into the system.

The normally used percentage composition estimation was not considered here as a measure of the population density of fishes because of the limitations in employing comparable fishing techniques in both stream and lake habitats. But the fishing unit (FU) is defined as the unit time (20 minutes) a gill net (30m x lm) of a

particular mesh size is set in water, excluding the time spent for spreading and hauling. Later, the density of the fish population at each location was estimated as abundance index (AI). Thus the abundance index of fish species k is calculated as

$$AI(k)=(n(k)/N \times \text{Total FU}) \times 100$$

Where n(k) is the number of individuals of the species k caught at the study sites and N is the total number of individuals of all species caught at that site. Further, the values of abundance index were grouped into four classes viz., <0.37 (scarce), 0.38-0.74 (moderate), 0.75-1.11 (plenty) and > 1.12 (abundant). Thus AI reveals the relative abundance of each species in each location of the lake and stream. The status of each species, whether, threatened and or endemic was assigned by referring to Swengel (1990; 1993), Ponnaiah (1994) and by the observation of the present study. The present status of ichthyofauna of Periyar was compared with the earlier listing of Chacko (1948) to assess the changes in fish communities over the past fifty years.

Dietary analyses: At the laboratory, the identified fishes were measured for total length to the nearest millimeter. A total of 40 specimens for common and abundant fishes, 20 for less abundant fishes and less than 10 for rare and threatened fishes were selected from the whole pool of fish collection for dietry analyses, which represented a cross section of all size classes present and all habitat types sampled. Each fish was treated individually for dietary analyses and was cut open and gut removed Gut fullness was visually estimated and relatively less filled guts were excluded from analyses. For each fish gut the contents of the stomach, or intestine up to the first bent, if no stomach was present, was removed to gridded glass slide and was examined in a stereo/dissection microscope. The entire food items were then carefully identified and visually quantified to percentage volumes (Biovolume method; Hynes 1950; Hyslop, 1980) in the following categories: (I) Littoral vegetation and macrophytes (LTV); (ii) Higher terrestrial plant matter, their remains such as seeds, flowers etc (TEP); (iii) small algae including diatoms (SAL); (iv) filamentous algae (FAL); (v) Water mites (WAT) (vi) chironomids (CHR); (vii) Ephemeropterans (EPH); (viii)

Trichopterans (TRI) (ix) insects of terrestrial origin such as ants (TEI) (x) adult aquatic insects (AQI) (xi) benthic micro-invertebrates (BEI) (xii) detritus including debris , mud/ clay particles (DET) (xiii) Fish or parts of fishes like scales, fins etc (FIS) (xiv) Crustaceans and its parts (CRU) (xv) molluscs and its parts (MOL) (xvi) all phytoplanktons (PHP) and (xvii) all zoo planktons (ZOP).

The diet overlap (S) between each pair of species was determined using Schoener's (1970) formulae.

$$S=100\ (0.5\ \Sigma\ /P_{xi} - P_{yi}/)$$

Where P_{xi}, is the proportion of the resource category i used by species x and P_{yi} is the proportion of the same category used by species y. The overlap determined by this formula ranges from 0.00 to 1.00 with 1.00 indicating a complete overlap and 0.00 indicating no overlap. In this study, a value of 0.33 or less was considered to indicate a low overlap, while a value of 0.67 or above was considered to indicate high overlap (Moyle and Senanayake, 1984; Wikramanayake and Moyle, 1989). The trophic grouping among the fishes were done using a single linkage agglomerative heirarchical (tree) clustering with a statistical program CSS: STATISTICA (3.1) of statsoft, USA. Before performing the cluster analyses, the data was tested with the analyses of variance (ANOVA) to see whether the diet of fish showed any significant difference among the food categories consumed.

Morphological analyses: Morphological features of each species were quantified using selected measurements from Gatz (1979a). A total 15 individuals of each species (or all the fishes, if the number is <15 as in the case of rare or threatened fishes) prior to dietry analyses, was measured for the following characteristics.

(i) Relative length (REL) = ratio of standard length to total length; (ii) Relative head length (RHL) = ratio of head length to standard length; (iii) Flatness index (FLT) = the ratio of maximum body depth to maximum body width (iv) Relative caudal span (RCS) = the ratio of span of caudal fin to maximum body depth; (v) relative pectoral

fin (RPF) = the ratio of the length of the longest pectoral fin ray to standard length; (vi) relative pelvic fin (RVF) = ratio of the length of pelvic fin ray to standard length; (vii) relative eye (RED) = ratio of eye diameter to standard length; (vii) relative mouth width (RMW) = ratio of maximum mouth width to standard length; (ix) relative mouth depth (RMD) = ratio of maximum mouth depth to standard length; (x) total number of barbels (NBL); (xi) shape of pectoral fins (PES) rated as rounded (A) or intermediate (B) and pointed (C); (xii) eye position (EPS) rated as lateral (A)/ slightly dorso lateral (B)/ bulging on the top of the head (C) and (xii) mouth position (MPS) rated as supra terminal (A)/ terminal (B)/ sub terminal (C)/ inferior and ventral (E). These morphological features were chosen for analyses because they generally reflect habitat and trophic specialisations of fishes (Gatz, 1979a, Moyle and Cech, 1982)

Assessment on habitat and faunal variations in adjacent aquatic systems: Four zones were identified in the study section (Fig. 2), including the upstream sections, lake and stream down sections. This zonation is based morphodynamically on flow pattern, substrate distribution, depth and slope. Zone 1 (unregulated upstream, section from the origin of Periyar streams to the confluence with the Periyar lake); Zone 2 (regulated upstream section from confluence until the Mullapperiyar dam ie. Periyar lake); Zone 3 (unregulated down stream section after the down up to confluence of the Idukki reservoir); and Zone 4 (regulated down stream section comprising the whole Idukki reservoir water spread) were demarcated. Fish sampling was carried out at pre selected locations in the area during June 1994 and May 1996 except at zone 4. An earlier study (Gopinath and Jayakrishnan 1984) conducted at Idukki reservoir on fish community composition was used for comparison. Physiographic details and land use pattern in the study areas were recorded from topo sheets (1 :50,000 and 1 :2,50,000) of Survey of India. The fishes were identified and status assigned by methods described in the previous section. The index of similarity between zones for ichthyofaunal elements were estimated using Sorensen's index (ISs);

ISs = (2C/A+B)x100, where C= no of species common to two zones ; A= total number of species in zones A and B = total number of species in zone B.

Two micro-watersheds of equal area on either (windward and leeward) slopes of Western Ghats for the propose of comparison were selected The habitat characterstics of the study sites (four sits from each watershed); namely K1, K2, K3 and K4 from windward side and T1, T2, T3 and T4 from the leeward side) were measured at a fifty meter length of the streams. Six transects were selected at the 50m stretch at an interval of 10m. Substrates, habitat types, canopy cover, debris distribution along with depth and width were measured at these transects. Substrate distribution at each point at an interval of 0.5m along the transects was recorded. Similarly, habitat type was also noted in the areas between the transects (Platts *et.al.*, 1983). Canopy cover (overstorey) of the stream was noted at the transect and later was estimated for percentages. Similar technique was adopted for debris distribution. Flow pattern was visually estimated as stagnant, slow, moderate, fast, turbulent, and projected to m/second from pre - prepared flow Tables (Arun, 1992). Land use was noted as the type of the riparian forest type. Disturbance, mainly anthropogenic, was recorded in relative visual scales as nil, low, moderate, high and very high. Altitude, stream order, distance from the source and drainage area were estimated or recorded from 1:25,000 totpgraphic sheets of Survey of India and also by using digital planimeter (Tamya Planex 5000). Climate and rainfall were recorded from 1:50,000 maps of French Institute of Pondicherry (Pascal, 1982). The fishes were collected, identified and status assigned as per the methods described in the previous section

Assessment of the commercial fisheries of the lake: The fishery activities of indigenous groups residing around the sanctuary was estimated from primary as well as secondary sources. A comparison between the catches of the tribals with that of the experimental catches during the study period was done to understand whether any selection is done by the tribals in their catches. The fishing licences, number of fishermen engaged etc. were obtained from the management plans of the sanctuary

and also from administrative records, while the details regarding the quantities of fish collected, number of fishermen engaged, types fishes collected etc. were obtained from the records of Kumily Girijan Matsya Vyvasaya Co-operative Society Ltd F(I) 74, Mannankudy, Kumily. Key inforamtions from the colony were identified and focus group was organised to review the details about the activity pattern of tribals engaged in fishing, extent of dependency on fish resources and the pertinent problem in fishery sector.

RESULTS

Water quality and production parameters of the lake and streams: The variation in water quality and production parametrs at four (stations 1-4) study sites in the lake and two in the streams (station 5 & 6) of the Periyar lake stream system during different seasons of 1994-95 are shown in Table 1.

The dissolved oxygen content (DO) at two stations of the stream was relatively high varying between 7.9 and 8.2 mg/l without marked variation during seasons, while the DO content was relatively less in sites of the lake varying from 6.8-7.8 mg/l. There were not any marked variation in dissolved oxygen concentration between seasons. Total hardness ranged from 5.94 to 8.97 mg/l. The variation between seasons was relatively higher than the variation among study sites, while, the total hardness values were markedly higher in stream sites than in lake sites. The seasonal variation in alkalinity ranged from 36.44 to 53.78mg/l. High and low values were recorded during pre monsoon season in both the stream and lake sites.

Free carbon dioxide concentration was generally low during monsoon season and high during pre monsoon season. The maximum concentration was observed at station 1 in the lake during pre monsoon (6.71mg/l.) while the lowest value was recorded at station 6 in the stream during post monsoon (3.63mg/l). The mean pH value of the system was in the acidic range close to neutral (6.92) and varied between 6.35 and

Table 1. Seasonal variation in water quality characteristics and production parameters in the lake and streams of Periyar during 1994-95.

Season	Parameters	Station 1	2	3	4	5	6
	01.Dissolved oxygen (mg\l)	7.20	6.80	7.40	7.80	8.00	8.20
	02.Totalhardness (mg\l)	7.96	8.17	6.63	8.74	8.20	8.71
	03.Alkalinity (mg\l)	48.33	51.76	42.57	39.60	53.78	36.44
	04.Free carbon dioxide (mg\l)	6.71	4.37	5.82	6.10	4.76	3.87
	05.pH	6.76	6.84	7.40	6.67	7.12	6.94
	06.Chloride (mg\l)	5.95	5.14	5.60	5.90	4.76	5.10
	07.Gross oxygen production ($g/m^2/d$)	0.57	0.48	0.65	0.61		
	08.Carbon production ($g/m^2/d$)	0.26	0.19	0.29	0.20		
	09. Organic matter production ($g/m^2/d$)	0.39	0.33	0.46	0.42		
Pre monsoon	10. Plankton biomass ($g/m^2/d$)	1.33	1.84	2.37	2.16		
	11.Air temperature (^oC)	26.10	27.20	25.60	25.70	25.20	24.80
	12. Water temperature (^oC)	25.20	26.40	24.20	23.90	24.15	24.00
	13. Transparency (M)	1.17	1.20	1.36	0.76		
	14. Conductivity	376.86	521.43	430.00	397.23	471.76	521.63
	15. Morphoedaphic index (MEI)	10.77	18.62	17.20	39.72		
	01.Dissolved oxygen (mg\l)	7.20	7.60	7.10	7.30	8.10	8.10
	02.Totalhardness (mg\1)	6.98	7.10	5.94	6.76	7.87	8.12
	03.Alkalinity (mg\l)	38.27	40.10	37.64	39.64	38.12	40.17
	04.Free carbon dioxide (mg\1)	4.96	4.87	4.81	3.90	4.10	3.86
Monsoon	05.pH	6.35	7.00	7.15	6.89	6.95	7.15
	06.Chloride (mg\l)	5.17	5.24	4.85	4.50	4.20	3.90

	07.Gross oxygen production (g/m^2/d)	0.69	0.74	0.72	0.68		
	08.Carbon production (g/m^2/d)	0.22	0.28	0.24	0.17		
	09. Organic matter production (g/m^2/d)	0.38	0.50	0.48	0.47		
	10. Plankton biomass (g/m^2/d)	1.85	2.80	2.60	2.45		
	1 .Air temperature (^{o}C)	21.80	20.30	21.60	20.90	20.00	21.40
	12. Water temperature (^{o}C)	20.40	19.80	20.30	20.10	19.80	20.30
	13. Transparency (M)	1.20	1.10	1.00	0.53		
	14. Conductivity	480.65	587.38	538.46	520.64	590.60	576.28
	15. Morphoedaphic index (MEI)	13.73	15.58	17.94	43.39		
	01.Dissolved oxygen (mg\l)	7.10	7.20	7.40	7.40	7.90	8.00
	02.Totalhardness (mg\l)	7.87	8.12	6.10	7.17	8.97	8.24
	03.Alkalinity (mg\l)	42.18	39.16	42.79	41.12	48.17	36.64
	04.Free carbon dioxide (mg\l)	5.10	4.66	4.94	4.45	4.25	3.63
	05.pH	6.60	6.50	7.15	6.75	7.21	7.10
	06.Chloride (mg\l)	6.00	5.85	6.21	5.74	4.80	4.25
Post monsoon	07.Gross oxygen production (g/m2/d)	0.69	0.74	0.72	0.74		
	08.Carbon production (g/m2/d)	0.26	0.30	0.27	0.32		
	09. Organic matter production (g/m2/d)	0.35	0.40	0.38	0.42		
	10. Plankton biomass (g/m2/d)	1.85	2.74	2.24	2.95		
	11.Airtemperature (^{o}C)	21.30	22.40	22.10	21.90	20.10	18.90
	12. Water temperature (^{o}C)	20.60	20.80	21.20	20.70	19.40	17.60
	13. Transparency (M)	1.30	1.24	1.32	0.84		
	14. Conductivity	540.17	566.28	471.83	521.12	480.30	494.14
	15. Morphoedaphic index (MEI)	15.43	19.53	18.15	47.37		

7.40. Most of the neutral or near neutral values for pH was noted in the stream sites. The mean seasonal chloride concentration varied between 4.64 and 5.48 mg/l with the lowest during monsoon and highest during post monsoon. The maximum chloride concentration was recorded at station 3 in the lake during post monsoon (6.21 mg/l) and lowest value was noted at station 6 in the stream during monsoon.

The production parameters like carbon production, organic matter production and plankton biomass, which are derivatives of gross oxygen production was estimated only in the lake site. The highest gross oxygen production values were recorded during post monsoon seasons. Carbon production, organic matter production and plankton biomass was relatively high during post monsoon compared to different seasons in other stations.

Water temperature was generally low in the lake and streams (mean annual water temperature = 21.6^{o}C) than the air temperature which varied between 20.0 and 27.2^{o}C during different seasons. The water column was completely transparent in the stream sites with high visibility to the bottom, while the transparency measured using Seechi disc varied between 0.53 and 1.63 m in the lake sites. Relatively low transparency of the water column was recorded during the monsoon, while the water column was found to be more transparent during pre and post monsoons. High conductivity values were generally recorded in all study sites in the lake and streams. The conductivity was generally high during monsoon. The highest value was noted at station 5 in the stream during monsoon (590 ms/cm) while the lowest value was recorded at station 1 in the lake during pre monsoon (376.86ms/cm). The mean morpho edaphic index (MEI) for the lake was 16.99 (excluding the shallow station 4) and it changed to 23.62 when the relatively shallow section of the lake (station 4) was included. The index was relatively low in stations 1, 2 and 3 during all seasons varying between 10.77 and 19.58. Relatively higher indices were observed at station 3 with an average of about 43.49.

Status and distribution of fishes in the lake and streams: A total of twenty seven species of fishes were encountered in Periyar lake river system (Table 2). Among these, 14 were endemic to Western Ghats and or Periyar, fourteen were threatened and 9 were threatened and endemic. All loaches, except Malabar loach *(Lepidocephulus thermalis)*found in the system were endemic to Western Ghats and one among them was threatened *(Travancoria jonesi).* Tilapia *(Oreochromis mossambicus)* and European carp *(Cyprinus curpio communis)*were the exotic (alien) fishes found in the system. The two snakeheads present in the system were threatened and were very seldom found in the catches. Among the 13 cypnnids, 8 were endemic to Western Ghats, of which three were exclusively endemic to Periyar Lake and streams *(Lepidopygopsis typus, Crossocheilus periyarensis* and *Puntius micropogon periyarensis).* All the endemic cyprinids, except *Garra mullya* were threatened. Other threatened fishes found in the system were cat fishes *(Heteropneustes fossilis* and *Glyptothorax madraspatanum)*and spiny eel *(Mastacembelus armatus).*

The overall abundance index (Al) estimated for the species of the system showed that the most abundant fish was *Garra mullya* followed by *G. mcClellandi, Barilius bakeri, Travancoria jonesi, Channa gachua, C. striatus* and *Glyptothorax madraspatanum.* The exotic species were present only in the lake. The total number of fish species present in the lake (18) was less than that in the stream habitats (21). All the loaches except, *Travancoria jonesi* were found only in the streams, while the snakeheads were found only in the lake habitat. The exclusive (narrowly) endemics of Periyar *(L. typus, C. periyarensis, P. micropogon periyurensis)* were mostly distributed and relatively abundant in the streams. The two stone suckers *(Garra mulya* and *G. mcClellandi)* were present in all locations of both the streams and the lake. Another highly endemic fish *Puntius ophiocephalus* was found scarcely distributed in some locations of the streams. One of the most endangered fishes of

Table 2. Status of the fish species encountered in Periyar lake-stream system

Scientific name	Common name	Local name	status
Aplocheilidae			
01. ***Aplocheilus lineatus*** (Bloch)	Top minnow	Manathukanii	
Balitoridae			
02. Bhavania australis (Jerdon)	Western Ghat loach	Kalnakki	EW
03. Noemucheilus denisonii Day	Denison's loach	Koitha	EW
04. ***N.guentheri*** Day	Guenther's loach	Koitha	EW
05. *N.* ***keralensis*** (Rita and nalbant)	Kerala loach	Koitha	EW
06. Travancoria jonesi Hora	Travancore loach	Kalsravu	EW, *TT* (rare & endemic-Kurup, 1994)
Channidae			
07. Chunna gachua (Ham-Buch)	Brown snake head	Vatton	TT (endangered, Kurup, 1994)
08. C. ***striatus*** (Bloch)	Striped snake head	Varal	TT (endangered, Kurup, 1994)
Cichlidae			
09. ***Oreochromis mossambicus*** (Peters)	Tilapia	Tilapia	XO
Cobitidae			
10. ***Lepidocephalus thermalis*** (Val.)	Mlalabar loach	Manalaron	
Cyprinidae			
11. ***Barilius bakeri*** Day	Malabar baril	Pavukan	EW, TT (rare and endemic, Kurup, 1994)
12. ***Crossochilusperiyarensis*** Menon & Jacob	Periyar latia	Karimbachi	EP, TT, (limited distribution?)
13. ***Cyprinus carpio communis*** (Linnaeus)	European carp	Gold fish	XO

14. *Danio aequipinnatus* (McClelland)	Giant danio	Pavukan	EW, TT, rare and endemic Kurup 1994
15. *Garra mcClellandi* (Jerdon)	Cauvary garra	Kallotti	EW
16. *Garra mullya* (Sykes)	Common stucker	Kallotti	
17. *Lepidopygopsis typus* Raj	Periyar trout	Brahmanakanda	EP,TT (indeterminate-*Mohanta et. al., 1994)
18. *Puntius curmuca* (Day)	Curmuca barb	Kooral	EW TT(endangered, Kurup, 1994)
19. *P. ophiocephalus* (Raj)	Channa barb	Eettilakanda	EW, TT (Limited distribution?)
20. P. ***micropogon periyarensis*** (Raj)	Periyar barb	Kariyan	EP, TT, limited distribution?
21. *P.melanampyx* Day	Tiger barb	Vazhakkavarayan	EW, TT (endangered, Kurup, 1994)
22. *Rasbora daniconius* (Ham-Buch)	Common rasbora	Kanajon	
23. *Tor khudree* (Sykes)	Mahseer	Kuyil	TT (endangered, Kurup, 1994)
Mastacembelidae			
24. *Mastacembelus armatus* (Lacepaede)	Spiny eel	Aron	TT (indeterminate-*Mohanta et.al., 1994)
Hekropnuestidae			
25. *Heterpnuestes fossilis* (Bloch)	Stinging cat fish	Kari	
Siluridae			
26. *Ompok bimaculatus* (Bloch)	Indian butter cat fish	Chottavala	TT (vulnerable-*Mohanta et.al.. 1994)
Sisoridae			
27. *Glyptothorax madraspatnum* (Day)	Travancore sucker cat fish	Kalsravu	EW, TT (Rare and endemic, Kurup, 1994)

Table 3. Abundance index (A) of fish species I different locations of Periyar lake-stream system

		Lake				Stream						
	Fish species	L1	L2	L3	L4	S1	S2	S3	S4	Lake	Stream	Overall
01.	***Aplocheilus lineatus***	0.25			0 07					0.08 **(s)**		0.04 (s)
02.	***Bhavania australis***							0.34	0.22		0.14 **(s)**	0.07 (s)
03.	***Noemacheilus denisonii***					0.62	0.54	0.85	0.49		0.63(m)	0.31(s)
04.	***N.guentheri***					1.56	1.46	1.04	1.75		1.45 **(a)**	0.73(m)
05.	***N keralensis***					0.13	0.08	0.04			0.06 (s)	0.03 **(s)**
06.	***Travancoriajonesi***				0.04			0.04		0.01 (s)	0.0l(s)	0.01 (s)
07.	***Channagachua***			0.03	0.03					0.02 (s)		0.01 (s)
08.	C. ***striatus***		0.05							0.01 (s)		0.01 (s)
09.	***Oreochromismossambicus***	0.94	0.19	0.27	0.09					0.37 (s)		0.09 (s)
10.	***Lepidocephalus thermalis***					0.23	0.37		0.05		0.10(s)	0.05 (s)
11	***Barilius bakeri***	0.61				1.80	1.08	1.48	1.25	0.15 (s)	1.40 (s)	0.78 (p)
12.	***Crossochilus periyarensis***					0.31	0.25	0.34	0.21		0.28 (s)	0.14 (s)
13.	***Cyprinus carpio communis***	1.17	0.62	0.07						0.46 (m)		0.23 **(s)**
14.	***Danio aequipinnatus***					1.66	1.83	0.85	1.10		1.36 (a)	0.68 (m)
15.	***Garra mcClellandi***	0.62	1.60	0.66	0.64	0.53	0.80	0.79	0.85	0.88 (P)	0.74(m)	0.81 (p)
16.	***Garra mullya***	1.43	2.20	1.15	1.07	**0.55**	1.42	0.96	1.70	1.46(a)	1.16(a)	1.31 (a)
17.	***Lepidopygopsis typus***				0.26	0.33	0.15	0.57	0.57	0.06 (s)	0.40(m)	0.23 (s)
18.	***Puntius curmuca***	0.37		**1.13**	1.24	0.90	0.72	0.79	0.95	0.68 (m)	0.84 (p)	0.76 (p)
19.	***P. ophiocephalus***					0.10	0.32		0.17		0.25 (s)	0.13 (s)
20.	***P. micropogon periyarensis***				0.34		0.41	0.38	0.56	0.10 (s)	0.34 (s)	0.22 (s)
21.	*P.melanampyx*			0.95	1.03	0 16	030	0.30	0.09	0.49 (m)	0.21 (s)	0.35 **(s)**
22.	***Rasbora daniconius***	0.70	1.37	1.35	0.86	0.20				1.07 **(P)**	0.11 (s)	0.59 (m)
23.	***Tor khudree***	0.04		0.84	1.20	0.86	1.08	0.68	1.08	0.52 (m)	0.93 (p)	0.72 (m)
24.	***Mastacembelus armatus***	0.18		0.07						0.06 (s)	0.01 (s)	0.04 **(s)**
25.	***Heterpnuestes fossilis***	0.60	0.85	0.62						0.52 (m)		0.26 **(s)**
26.	***Ompok bimaculatus***	0.09	0.05					0.07	0.04	0.03 **(s)**	0.03 **(s)**	0.03 (s)
27.	***Glyptothorax madraspatnum***							0.04	0.04		0.02 **(s)**	0.01 **(s)**
	Number of species	12	**8**	**11**	**12**	15	15	17	17	18	21	21

Table 4. The "disappeared" fish species of Periyar lake-stream system"

	Scientific name	Common name
Anguillidae		
01	*Anguilla bengalensis* (Gray)	Indian long fin eel
02	*A. bicolor* McClelland	Short fin eel
Bagridae		
03	*Macrones* ***cavasius*** (Hamilton-Buchanan)	Gangetic mystus
04	*M. vittatus* Day	Striped dwarf cat fish
Cyprinidae		
05	*Brilius bendelisis* (Hamilton-Buchanan)	Hamilton's baril
06	*B. gatensis* (Valenciennes)	River carp haril
07	*Chela boopis* (Day)	Razor belly minnow
08	*Garra lamta* ((Hamilton-Buchanan)	Lmata garra
09	*Puntius amphibius* (Valenciennes)	Scarlet bended barb
10	*P. arulius* (Jerdon)	Long fin barb
11	*P. melanostigma* (Day)	Wynaad barb
12	*P. pinnuratus* (Day)	Olive barb
Gobiidae		
13	*Glossogobius giuris* (Hamilton-Buchanan)	Tank goby
Mastacembelidae		
14	*Rhyncobdella aculuta* (Bloch)	One stripe eel
Notopteridae		
15	*Notopterus notopterus* (Pallas)	Grey feather back
Schillbeidae		
16	*Silundia sykesi* Day	white cat fish

*These fishes were listed by Chacko (1948) were not encountered in the present study

India, *Tor khudree,* was relatively abundant (moderate to abundant) in the lake as well as in the streams. All cat fishes were generally scarce in the system, hut the stinging cat fish *(Heteropneustesfossilis)* was moderately abundant in most of the locations of the lake. Eight of the fourteen threatened fishes (mostly cyprinids) were more abundant in the stream habitats than in the lake. Other threatened fishes like snake heads and cat fishes were abundant in the lake than in the streams.

A comparison with the list of the fishes observed in the survey by Chacko (1948) in 1948 with the present study indicated the disappearance of 16 species of fishes from the system (Table 4). Even though this study made extensive fish surveys in the lake and streams, there exists very remote chance for the presence of these "disappeared" fishes. But surprisingly, even a single individual of these probably disappeared fishes was never encountered. The disappeared species include eels, cat fishes, goby and cyprinids. Fifteen percent (8) of the disappeared species were cyprinids which includes Barils *(Burilius bendelisis).* Stone suckers *(Gurru lamta)* barbs *(Puntius amphibius, P. arulius, P. melanostigma* and *P. pinnurutus)* and silver bellies *(Chela boopis).* Some fish species (8), other than the ones listed by Chacko (1948) were recorded later. These include seven species in the present study viz.; *Bhavania australis, Cyprinus carpio communis, Garra mcClellandi, Noemucheilus denisonii, N. guentheri. Oreochromis mossambicus* and *Travancoria jonesi* (Arun *et.al.,* 1996) and one new species, *Crossochilus periyarensis* (Menon and Jacob, 1996).

Ecological structure of fish assemblages:

Diet: Dietry analyses of the fishes of Periyar system revealed (Table 5) that six categories of food items were the major food bases on which the fishes fed heavily. Theses were (1) algae including diatoms (2) terrestrial insects (3) aquatic insects both macro and micro invertebrates (4) crustaceans and molluscs (5) plankton and (6) detritus, Among these food categories, the fishes fed aquatic insects most heavily. Fishes of the family Balitoridae *(Noemacheilus* spp, *Travancoria jonesi* and *Bhavania australis)* fed mostly on aquatic macro invertebrates and ephemeropterans, while the members of the family Cyprinidae (to which family most of the fish species of the system belong) consumed terrestrial insects, aquatic insects, algae and plankton. The fishes which fed mostly on terrestrial insects belonged to the families Cyrprinidae, Aplocheilidae and Siluridae. Detritus, plankton, molluscs and crustaceans were very

Table 5. Dietary composition of (mean %volume) fish species in Periyar lake-stream system. (see appendix for abbreviations of food categories)

Fishes	LTV	TEP	SAL	FAL	WAT	CHR	EPH	TRI	TEI	AQI	BEI	DET	FIS	CRU	MOL	PHP	ZC
A. lineatus	4.0	8.7							87.3								
B. australis	4.1		3.9		5.7	9.8	6.5	17.4	2.3		48.8	2.3					
N. denisonii				1.7		16.9	21.3				53.0	7.1					
N. guentheri			1.0			8.7	17.4	2.8			62.1	8.5					
N. keralensis							11.1		4.6		84.3						
Travancoria jonesi						12.8	5.3			14.2	67.7						
Channa gachua				1.00			28.3		11.7	20.3	10.6		4.2	23.9			
C. striatus								4.0		85.3	8.0						
O. mossambicus				6.2		13.9			8.6	12.7	24.7	22.1		7.0		1.4	2.8
L. thermalis			12.7	30.8		36.1	5.00		2.1	4.7		8.6					
Barilius bakeri		9.3							90.7								
C. periyarensis	2.0			12.6		16.9	7.8		5.0	38.2	3.2	14.3					
C. carpio communis	3.6					34.3	10.8			7.2	25.0	1.0		10.7	4.8	1.0	1.6
D. aequipinnatus		7.7							91.3								
G. mcClellandi			72.6	20.0								7.4					
G. mullya	1.8		83.4	14.8													
L. typus				13.1		14.5		8.8	3.5	17.9	36.3	5.9					
Puntius curmuca	2.8		5.0			41.4				1.3	32.5			12.1	6.5	1.0	2.4
P. ophiocephalus				2.3		15.3	11.7	2.0	1.7	21.2	39.6	3.7		2.5			
P. periyarensis		2.3	13.7	27.6		8.7			3.0	11.4	23.2	7.6	2.5				
P.melanampyx	3.6				5.0	68.6				22.8							
R. daniconius	1.0				1.6				97.4								
Tor khudree					10.2	47.3		4.00			19.6	1.3		12.4	5.2		
M. armatus							33.7	33.1		13.4	9.8			10.0			
H. fossilis						13.7				17.2	39.3	10.8		12.3	6.7		
O. bimaculatus		11.3							86.7			2.0					

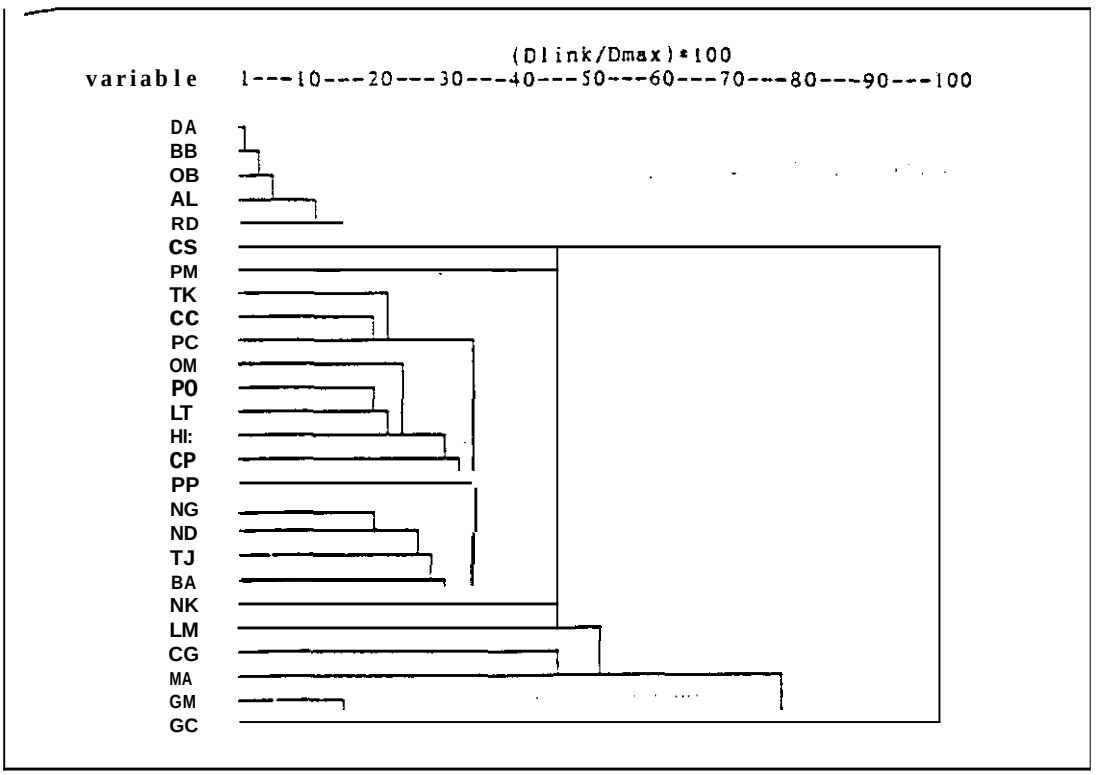

Fig 4 Dendrogram used for assigning tropic guilds among me fishes of Periyar. See Table 6 for species abbrevaiations

scarcely consumed by fishes. Piscivorous fishes were absent in the system except for traces of fish or fish part that found in the guts of a few fishes.

Of the 325 possible species combinations (Table 6) only eight percent (28) showed meaningful overlaps (>0.67). These high overlaps were observed mainly among fishes feeding on terrestrial insects and fishes belonging to the family Balitoridae. The highest diet overlap values were observed between *Danio aequipinnatus, Barilus bakeri* and *Rasbura danicunius.* These species heavily (>90%) depended on terrestrial insects. Most of the overlaps (297 forming about *92%)* were either low (218) or medium (79) and have values less than 0.67. This indicates high trophic segregation. Some of the endemic and/ or threatened fishes showed high or medium overlaps. In general the high overlap values were either among loaches or between exotics and resident species or-between terrestrial insect feeding fishes.

Hierarchical tree clustering (Figure 4) resulted in the identification of seven feeding guilds *viz* (1) terrestrial insectivore (2) benthic (aquatic) insectivore (3) aquatic insectivore - omnivore (4) benthic macro insectivore *(5)* aquatic insectivore – detritivore *(6)* omnivore and (7) algivore.

Terrestrial insectivore guild includes *Danio aequipinnatus Barilius bakeri Aplocheilus lineatus, Ompok bimaculatus* and *Rasbura daniconius,* which fed predominantly on terrestrial insects especially red and black ants of terrestrial foliage origin. Aquatic insectivore detritivore guild includes *Oreochromis mossambicus, Puntius ophiocephalus, Lepidopygopsis typus* and *Heteropneustes fossilis.* They consumed fairly large volumes of aquatic insects as well as detritus. Benthic insectivore guild fed mainly on aquatic micro invertebrates. This guild includes *Noemacheilus guentheri, N. denisonii, Travancoria jonesi, Bhavania australis* and *N. kerlafensis.* All these fishes belong to the family Balitoridae. Some of the cyprinids like *Tor khudree, Cyprinus carpio communis* and *Puntius curmuca* belong to the guild. Benthic macro insectivore fed largely on chironomids and relatively smaller quantities of aquatic micro invertebrates. Aquatic insectivore – omnivore guild includes *Channa*

guchua, Mastacembelus armatus and *Lepidocephalus thermalis* which consumed benthic invertebrates as well as smaller crustaceans. Another guild *viz.* omnivore, includes *Crossocheilus perjarensis* and *Puntius micropogon periyarensis* fed aquatic invertebrates, both micro and macro invertebrates as well as little volumes of algae. *Garra mullya* and *G. mcClellandi* belonged to the guild called algivore and they consumed exclusively on algae, both filamentous and unicellular including diatoms. Two fishes *viz., Puntius melanampyx* and *Channa striatus* were classified apart from the groups as they consumed largely on chironomids and benthic insects respectively.

Morphology: The thirteen eco-morphological attributes measured for the fishes of Periyar lake stream system (Table 7) show high variations in morphological characteristics. The relative length of the fish species showed less variations, while flatness index varied from 0.58 to.2.10. Most of the cyprinids showed high relative head length compared to the fishes of other families. The relative caudal span length was low for the fishes of families Mastacembelidae, Siluridae and Heteropneustidae, while it was high for Silurid fishes. The relative length of pelvic and pectoral fins showed less variations in all fishes. The relative eye diameter was low in fishes of the families Balitoridae, Heteropneustidae and Siluridae. These fishes are commonly called loaches and cat fishes. The relative mouth width and depth was low in *Mastacembelus armatus, Heteropneusestes fossilis*, all loaches of the family Balitoridae and all cat fishes of siluridae compared to Cyprinids. Three pairs of barbels were present in fishes of family Balitoridae which have small eyes while most of the other fishes which have relatively bigger eyes had two pairs of barbels. Some fishes like *Rasbora daniconius, Danio aequipinnatus and Barilius bakeri*, which are surface oriented lacked barbels. They possessed relatively larger eyes. The shape of the pectoral fin in majority of the fishes was either rounded or intermediates. The eye position of the fishes in Periyar lake stream system was either lateral or slightly dorso lateral. Most of the fishes in Periyar have supra terminal, terminal sub terminal or inferior mouth positions.

Table 6. Diet overlap of fish species in Periysr lake-stream system (under lined figures indicate high overlap)

Fishes	BA	ND	NG	NK	TJ	CG	CS	OM	LM	BB	CP	CC	DA	GC	GM	LT	PC	PO	PP	PM	RD	TK	MA	HF	OB
A. lineatus	005	0.00	0.00	0.05	0.00	0.12	0.00	0.09	002	0.96	0.07	0.04	0.95	0.00	0.02	004	0.03	0.02	0.05	0.04	0.88	000	0.00	0.00	0.95
B. australis	BA	0.65	0.70	058	0.64	0.19	0.12	0.48	023	0.00	0.26	0.49	0.02	0.04	0.06	0.60	0.49	0.62	0.40	0.18	0.05	040	0.34	0.51	004
V. denisonii		**ND**	086	064	0.71	0.33	0.08	0.52	0.31	0.00	0.37	0.56	0.00	0.09	0.02	0.58	0.33	L.72	0.41	0.17	0.00	0.38	0.31	0.60	0.02
N. guentheri			**NG**	0.73	n.76	n.28	0.11	0.46	023	000	028	0.48	0m	0.01	0.01	0.54	042	0.66	0.41	0.09	000	032	030	057	002
N. keralaensis				**NK**	0.73	0.26	0.08	0.29	0.07	0.05	0.10	0.33	0.05	0.00	0.00	0.40	0.33	0.52	0.26	0.00	0.04	0.20	0.20	0.40	0.05
T. jonesi					**TJ**	0.31	0.22	0.51	0.23	0.00	0.36	0.50	0.00	0.00	0.00	0.63	0.47	0.74	0.44	027	0.00	0.33	0.28	0.57	0.00
C. gachua						**CG**	0.29	0.40	043	0.12	0.37	0.39	0.12	0.01	0.01	0.33	0.24	0.46	0.30	0.20	0.12	0.23	0.62	0.40	0.11
C. striatus							**CS**	0.21	0.05	0.00	0.42	016	0.00	0.00	0.00	0.30	On9	0.31	0.19	023	0.00	0.12	0.26	026	000
O. mossambicus								**OM**	0 37	0.09	0.56	0 51	0.09	0 14	0.07	0.68	0.46	0.59	0.30	0.23	0.09	0.41	0.23	0.68	0 11
L. thenrmalis									**LM**	0.02	0.51	0.45	0.02	0.41	0.28	0.41	0.42	0.28	063	041	0.02	0.38	0 10	0.28	004
B. bakeri										**BB**	0.05	0 00	0 98	0.00	0 On	0.04	0 n0	002	0.05	0 00	0 91	0.00	0.00	0 n0	0.87
C. periyarensis											**CP**	037	0.05	021	0.15	059	024	0.57	048	0.41	006	022	024	045	007
C. c. caommunis												**CC**	0.00	0.01	0.02	0.49	0 72	0.62	0.30	0.46	0.01	0 71	0.38	0.62	0.01
D. acquipinnatus													**DA**	0 00	0 On	0.04	0 00	0.02	0 06	0 00	0 91	0.00	0 n0	0 00	0 94
G. mcClellandi														***GC***	0.87	0.13	0.05	0.02	0.34	0.00	0.00	0.01	0.00	0.07	0.00
G. mullya															**GM**	0.13	0.07	0.02	0.29	0.02	0.01	0.00	(1.00	0.00	0.00
L. typus																**LT**	0.49	0.79	0.66	0.33	0.04	0.40	0.32	0.73	0.06
P. curmuca																	**PC**	0.52	0.38	0.44	0.00	0.89	0.21	0.67	0.00
P. ophiocephalus																		***Yo***	0.52	0.36	0.02	0.42	0.40	0.77	0.04
P. m. periyarnesis																			**PP**	0.20	003	0.29	0.22	0.51	0.08
P. melanampyx																				**PM**	0.03	052	0.13	0.31	0.00
R. daniconius																					**RD**	002	0.00	0.00	0.87
T. khudree																						**TK**	0.24	036	001
M. armatus																							**MA**	0 33	000
H. fossilis																								**HF**	0.02
O. bimaculatus																									

Table 7. Means of morphological characteristics of fish species on Periyar We-stream system.(see appendix for abbreviations)

Fish species	REL	RHL (X_{10})	FLP	RCS (X_{10})	RPF (X_{10})	RVF (X_{10})	RED (X_{10})	RMW (X_{10})	RMD (X_{10})	NBL	PES	EPS	MPS
Aplochilus lineatus	1.23	2.66	1.05	170	1.70	1.28	0.53	0.63	0.21	0	B	A	B
Bhavania australis	1.91	1.36	0.58	1.11	1.98	1.73	0.31	0.25	0.12	0	A	B	E
Noemacheilus denisonii	1.24	2.17	1.31	1.52	1.52	1.52	0.32	0.65	0.54	6	A	B	D
N. guentheri	1.21	1.88	1.17	1.25	1.41	1.41	0.31	0.55	0.16	6	A	B	D
N. keralaensis	1.14	1.97	1.21	1.38	1.46	1.48	0.32	0.61	0.28	6	A	B	D
Travancoria jonesi	1.20	1.75	0.66	0.46	1.84	1.40	0.44	0.35	0.17	6	A	B	E
Channa gachua	1.19	2.74	1.07	1.21	1.76	0.54	0.44	0.98	0.38	0	A	B	B
C. striatus	1.23	1.81	1.12	1.68	1.43	1.32	0.42	0.65	0.13	4	A	B	B
Oreochromis mossambicus	1.24	2.53	2.55	1.92	2.88	1.99	0.55	0.62	0.27	0	B	A	B
Lepidocephalus thenrmalis	1.21	1.72	1.59	1.41	1.33	1.09	0.39	0.31	0.16	6	B	B	D
Barilius bakeri	1.20	2.18	0.89	2.26	1.33	1.05	0.56	0.56	0.36	0	B	A	A
Crossochilus periyarensis	1.28	1.70	1.89	1.52	2.00	1.56	0.40	0.60	0.12	4	B	A	E
Cyprinus carpio caommunis	1.19	2.84	1.80	2.19	1.69	1.64	0.52	0.65	0.15	4	B	A	C
Danio aequipinnatus	1.25	1.95	2.10	1.45	1.58	1.58	0.48	0.48	0.36	0	C	A	A
Garra mcClellandi	1.20	1.82	1.11	1.17	1.41	1.31	0.43	0.66	0.12	4	A	B	E
Garra mullya	1.24	1.98	1.16	2.15	1.57	1.16	0.38	0.83	0.25	4	A	B	E
Lepidopygopsis typus	1.28	1.70	1.99	1.80	2.20	1.50	0.53	0.53	0.27	4	B	A	D
Puntius curmuca	1.24	2.05	1.54	2.45	1.83	1.34	0.44	0.46	0.13	4	B	B	D
P. ophiocephalus	1.23	2.31	1.26	1.66	1.48	1.48	0.55	0.74	0.14	4	B	B	C
P. micropogon periyarnesis	1.30	1.82	1.99	2.12	2.12	1.59	0.50	0.47	0.08	4	B	B	D
P. melanampyx	1.20	2.38	1.90	2.26	1.66	1.31	0.59	0.77	0.48	4	C	A	B
Rasbora daniconius	1.23	2.04	1.66	1.26	1.26	1.02	0.44	0.58	0.34	0	C	A	B
Tor khudree	1.30	2.11	1.60	1.69	2.11	1.63	0.54	0.48	0.09	4	B	B	D
Mastacembelus armatus	1.04	1.39	1.43	0.47	0.29		0.09	0.19	0.09	0	A	B	C
Heteropnuestes fossilis	1.13	1.26	1.36	0.78	0.87	0.75	0.21	0.51	0.15	6	B	A	C
Ompok bimaculatus	1.46	1.72	1.44	0.93	1.26	0.59	0.23	0.76	0.13	4	A	A	A

Hierarchical tree clustering (Fig.5) identified 5 categories of fishes based on their morphological characteristics *viz.,* (I) water column-rovers (ii) bottom clingers (iii) deep bodied rovers (iv) bottom eel likers and (v) surface orienters. *Lepidopygopsis typus, Crossochilus periyurensis, Puntius melanampyx* and *Cyprinus carpio communis* belonged to water column rovers. These fishes have already high flatness index (>l.8). The bottom-clingers include *Garra mcClellandi* and *Garra mullya*, both of which have ventral mouths developed with suckers that helped to cling to substratum on which the fish feeds for most of the time. The other group, deep-bodied rovers, includes cyprinids like *Puntius micropogon periyarensis, P. vphiocephalus, Tor khudree* and *Puntius curmuca.* These fishes have high body width and the body is highly stream lined for fast flowing waters or torrential habitats. Eel-like bodied fishes include most of -balitorids (Loaches) like *Travancoria jonesi, Noemacheilus guentheri, N. denisonii , N keralensis Heterpneustes fossilis,* all of which have elongated bodies, small mouths and smaller eyes. The surface-oriented group consisted of *Danio aequipinnatus, Barilius bakeri, Aplocheilus lineatus,* and all these have supra-terminal mouths for terrestrial insect feeding habits and highly stream lined body for swimming swiftly in fast flowing waters. The remaining fishes which were grouped other than these were either rovers or eel-likes.

Based on the body shapes and other ecomorphological features, these groups were categorised into various niche types. Five niche types *viz.* surface, pelagic, benthic, substratum and individualistic were identified. The surface niche types, which included the surface orienters were characterised by dorsal mouth orientation and high mouth gap. A large amount of their body depth occurred below the body mid line by dorsal mouth orientation and high mouth gap. A large amount of their body depth occurred below the body midline to give a high index of ventral flattening. Eye position of these fishes was lateral and they possessed relative high pectoral fin aspect ratios for high maneuverability and longer peduncle for high swimming ability. This second niche type identified was pelagic type which is characterised by high caudal fin

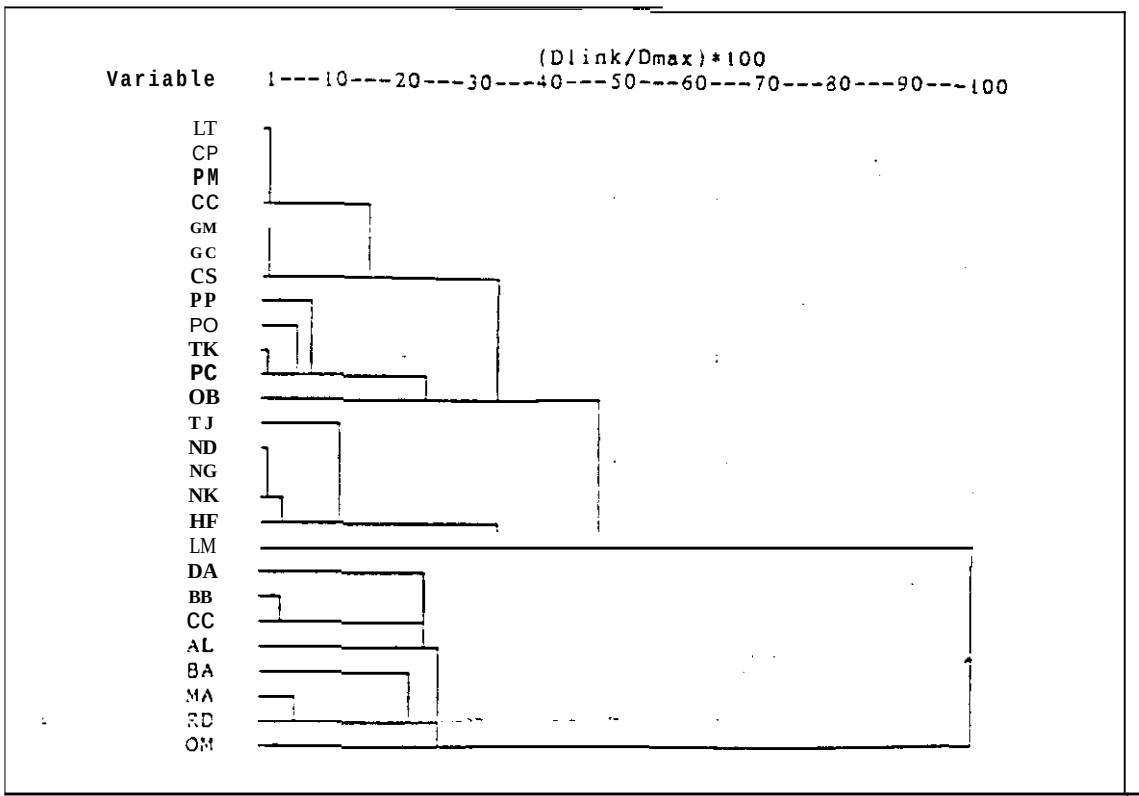

Fig.5 Dendrogram used for assigning morphological guilds among the fishes of Periyar. See Table 6 for species abbreviations

aspect ratio. These features indicate high maneuverability in cruising swift waters. Third niche type identified was benthic, which includes bottom eel-like fishes having elongated bodies and relatively long heads. The substratum niche type includes fishes of the bottom clinger group. Rests of the fishes were classified into individualistic niche type.

Habitat associations: Most of the endemic and threatened fishes of Periyar lake stream system preferred stream habitat than the lake habitats. Majority of fishes which are narrowly (exclusively) endemic to Periyar lake like *Crossochilus periyarensis*, *Lepidopygopsis typus*, *Puntius ophiocephalus* and *P. micropogon periyarensis* were dominant (>88%) in the stream than in the lake, while another endemic and threatened cyprinid *Puntius curmuca* preferred lake habitats (Table 8). Among the microhabitat variables (depth and flow), fishes like C. *periyarensis*, *L. typus* and *P. mciropogon periarensis* preferred moderately fast and deep waters, *P. ophiocephalus* selected moderately fast and shallow waters. *Puntius melanampyx* mostly remained in shallow; slow flowing waters. *Puntius curmuca* was mostly associated with deep, stagnant or moderately deep, slow flowing waters. The fast flowing moderate to very deep waters was preferred by *Barilius bakeri.* The most preferred substrate for fishes in the stream habitat was boulders followed by pebbles/or cobbles and sand Mud and detritus or debris were also preferred by the fishes of the habitat.

Inter specific (nativealien) competitive interactions: The two exotic fishes, which are deliberately or accidentally introduced into the system are *Oreochromis mossambicus,* and *Cyrinus carpio communis.* They are commonly known as Tilapia and common European carp respectively. These fishes are well known for fast growth, high fecundity and easy establishment in alien waters. Of the possible twenty four combinations with native fishes (Table 9), *Ureochromis mossambicus* showed thirteen high and medium diet overlap (>0.33). Among the thirteen overlaps, one combination was with an endemic and threatened fish, *Lepidopygopsis typus* Raj and

Table 8. Habitat associations (mean %) of endemic and threatened fishes in Periyar lake stream system

	Macro habitat		Microhabitat														
			Depth			Flow						Substrata					
	Lake	Stream	Shallow	Moderate	Deep	Stagnant	Slow	moderate	Fast	Bed	Boulder	Pebble/ cobbles	Gravel	Sand	Mud	Detritus/ debris
B abkeri	20	80	12	46	42	12	-	26	62	2	29	41	16	7	-	5
C. periyarensis	3	97	36	55	9	5	17	40	38	8	32	SO	14	11	7	8
L.typus	12	88	20	44	36	9	11	64	16	3	32	19	6	21	10	9
P. curmuca	62	38	11	31	58	42	17	31	10	-	33	12	-	7	20	28
P. ophiocephalus	-	100	61	37	2	-	8	63	*29*	-	54	37	-6		3	
P.m. periyarensis	7	93	24	41	35	5	21	62	12	-	44	38		-	10	8
P melanampyx	34	66	68	29	3	29	66	5	.	-	18	17	19	18	16	12

Table 9. Possible species combinations with high and medium diet overlap between exotic and native fishes (high overlap values are under lined)

Species combinations	Overlap value
Oreochromis mossambicus	
Vs *Bhavania australis*	0.48
Vs *Noemacheilus denisonii*	10.52
Vs *N. guentheri*	0.46
Vs *Travancoriajonesi*	0.51
Vs *Channa gachua*	0.40
Vs *Lepidocephalus thenrmalis*	0.37
Vs *Crossochilus periyarensis*	0.56
Vs *Cyprinus carpio caommunis*	0.51
Vs *Lepidopygopsis typus*	0.68
VS *Puntius curmuca*	0.46
VS *P. ophiocephalus*	0.59
Vs *Tor khudree*	0.41
Vs *Heteropnuestes fossilis*	**0.68**
Cyprinus carpio communis	
Vs *Bhavania australis*	0.49
Vs *Noemacheilus denisonii*	0.56
Vs *N. guentheri*	0.48
Vs *N. keralensis*	0.35
Vs *Travancoriajonesi*	0.50
Vs *Channa gachua*	0.39
Vs *Lepidocephalus thenrmalis*	0.45
Vs *Crossochilus periyarensis*	0.37
Vs *Oreochromis mossambicus*	0.51
Vs *Lepidopygopsis typus*	0.49
Vs *Puntius curmuca*	0.72
Vs *P. ophiocephalus*	0.62
Vs *P. melanampyx*	0.46
Vs *Tor khudree*	0.71
Vs *Mastacembelus armatus*	0.38
Vs *Heteropnuestesfossilis*	10.62

Table 10. List of fish species encountered at different zones of Periyar river (+ denotes presence and - indicates absence

Scientific name	Status	Zone 1	2	3	4
01. Aplocheilus lineatus	-		+	+	+
02. Bhavania australis	EW	+		-	-
03. Noemacheilus denisonii	EW	+		-	-
04. N.guentheri	EW	+		+	+
05. N. keralensis	EW	+		-	-
06. N. rupecola	-	-		-	+
07. N. scaturigina	-	-		-	+
08 N. traingularis	-	-		+	-
09 Travancoriajonesi	EW, TT	+	+	+	-
10. Channa gachua	TT	-	+	-	+
11. C. striatus	TT	-	+	-	-
12. Oreochromis mossambicus	XO	-	+	-	+
13. Lepidocephalus thermalis	-	+		-	-
14. Barilius bakeri	EW, TT	+	+	+	-
15. Barilius bendelisis	-	-		-	+
16. Crossochilus periyarensis	EP, TT	+		-	-
17. Cyprinus carpio communis	XO	-	t	-	+
18. Danio aequipinnatus		+	-	-	-
19. Garra mcClellandi	EW	+	+	-	-
20. Garra Iamta	-	-		-	+
21. G. mullya		+	+	+	+
22. G. surendranathinii	EW	-		+	-
23. Lepidopygopsis typus	E W . TT	+	+	-	-
24. Puntius curmuca	EW, TT	+	+	+	-
25. P. ophiocephalus	E W , TT	+		-	-
26. P. bovanicus	-	-		-	+
27. P. micropogon periyarencis	EP, TT	+	+	-	+
28. P.melanampyx	EW, TT	+	+	+	+
29. Rasbora daniconius		+	+	+	+
30. Tor khudree		+	+	+	+
31. Cirrhinus cirrhosa	-	-	-	-	+
32. Mastacembelus armatus	TT	+	+	+	-
33. M. guentheri	-	-	-	-	+
34. Heterpnuestesfossilis	-	+	-	-	-
35. Ompok bimaculatus	TT	+	+	-	+
36. Glyptothorax madraspatnum	EW,TT	+	-	-	-
37. G. annandaelei	EW, TT	+	-	-	-
Total number		21	18	13	17

EW= Endemic to Western Ghats; EP= Narrowly endemic to Periyar; TT= Threatened; XO= Exotic

another with *H. fossilis* were high (>0.67). The Common European carp, showed 16 high and medium overlaps with native fishes in twenty four possible combinations. Among these combinations, one combination with an endemic and threatened cyprinid *P. curmuca* and another with threatened *Tor khudree* were high (>0.67). This indicates high possibilities of competition for food among *0. mossambicus* , *L. typus* and *H. fossilis* and between *C. curpio communis*, *P. curmuca* and *Tor khudree.* Further, there might be a high overlap in space ie, habitat, since *0. mossambicus* and *C. curpio communis* are abundant in the lake, where the native endemic and threatened fishes like *P. curmuca* and *Tor khudree also* exist abundantly.

Structural variation of fish communities in adjacent zone/biotpes

Down stream variation in fish communities: A total of 37 fish species were encountered in the 4 study zones (Table 10). The most diverse fish community with 21 species was represented by the zone 1, which composed most of the endemic and threatened fishes of the Western Ghats. A variation in community composition was observed in zone 2, where some of the rheophilic fishes were replaced by lacustrine ones. At zone 3, the unregulated running water sections, the number of species increased to 17, comprising a few lacustrine and exotic fishes. The estimates of the index of similarity between the zones (Table 11) show that the ichthyofaunal composition in zone 1 and 2 was most similar and zone 1 and 4 was most dissimilar.

Table 11. Sorensen's similarity index between zones

Zone	index
Zone 1 x zone 2	61.5
Zone l x zone 3	53.0
Zone l xzone 4	31.6
Zone 2 x zone 3	58.1
Zone 2 x zone 4	51.4
Zone 3x zone 4	40.0

The high similarity between zone 1 and zone 2 (with an index of similarity of 61.5) is mainly because of the physical continuance and absence of disruptions like dams, while zone 1 and zone 3 was most dissimilar (with a similarity index of 31.6) because of the presence of dams and consequent changes in flow regime. The distinctive fish species found in zone 4 were *Nemcaheilus rupicola, N. scaturiginu, Burilius bendelisis, Puntius bovanicus, Cirrhinus cirrhosu, Mustacembelus guentheri* and *Glyptothorax annandalei* **.** The zone 3 was found with *N. triangularis* and new species of *Garra* namely *Garra surendranathinii.*

Variation in fish and habitat diversity in the adjacent river basin: The study sites at biotope 1 (Periyar basin) were at relatively higher altitudes (Table 12) with low temperatures and high rainfall compared to sites at biotope 2 (Vaigai basin). The distance of study sites from the source of the stream at two biotopes were below 10 kms. The total drainage area of the two streams were around 40 and 51 Km2 respectively. The most dominant substrate at two biotopes was boulders, followed by bed rock in biotope 1 and gravel in biotope 2. A high proportion of gravel was noted at biotope 2 and bed rock at biotope 1. Riffle was the dominant habitat type at biotope 1 and pool was dominant in biotope 2. Accumulation of debris/ detritus in biotope 1 was far more higher than that of the biotope 2. The canopy cover in biotope 1 was fairly high compared to biotope 2. Water was relatively fast flowing in biotope 1 and moderate in biotope 2. The streams in biotope 1 were relatively wider than the streams of biotope 2. The depths were mostly comparable. The land use pattern/ vegetation type in the riparian land was completely of evergreen forests in biotope 1, where as the moist deciduous forests constituted the riparian vegetation in biotope 2. Among the habitat characteristics; altitude, substrate composition, habitat type, canopy cover and debris were significantly different in the two biotopes ($P<0.05$). Further the climate, riparian vegetation type and flow regime were obviously different in the two biotopes. Anthropogenic disturbances were completely absent at biotope 1 and were relatively low at biotope 2.

Table. 12. Variation in the fish and habitat diversity in adjacent river basin.

Characteristics	Biotope 1 K1	K2	K3	K 4	General/total	Bioptope 2 T1	T2	T3	T4	General/total	ANOVA F-value
Location					77 28-77 31E& 921-9 25N					77 31-77 34E & 9 21-9 25N	
Drainage area (Km2)					40.39					51.92	
Climate (Pascal, 1982)											
Temperature					13.5-23.0					16.0->23.0	
Rainfall (mm/year)					2,000-5,000			1500-2000			
Altitude (m MSL)	1120	I060	980	940		826	755	711	730		32.16**
Distance from source (Km)	2.51	4 06	5.62	6.10		4.97	7.24	10.21	8.36		5.23
Substrates (%)											
Bed rock	20	15	25	15		10	0	5	0		19.64**
Boulder	50	45	45	50		35	50	25	25		5.11
Pebbles/cobble	15	20	10	10		20	10	20	15		0.55
Gravel	0	0	5	0		15	20	30	30		32.40***
Sand	15	20	15	25		20	20	20	20		0.27
Silt	0	0	0	0		0	0	0	10		1.00
Habitat type (%)											
Pool	10	15	20	40		30	50	45	60		7.59*
Riffle	60	65	55	35		45	40	45	30		2.73
Run	30	20	25	25		25	10	10	10		1.60
Debris %	15	10	20	10		10	5	<5	<5		7.71*
Canopy cover (%)	70	60	55	45		30	20	25	15		32.67***
Flow pattern (visual scale	F	F	F	F		F	M	M	M		
Width (meanm ± SD	11.5 ± 3 6	22.5 ± 4 7	28.0 ± 8.4	26.1 ± 7.9		7.6 ± 1.3	12.8 ± 3.1	9.7 + 4.2	21.3 ± 2.6		1.88
Depth (mean ± SD)	0.40 ± 0.18	0 36 ± 0 24	0.29 ± 0.15	0.80 ± 0.26		0.30 ± 0.17	0.37 ± 0.12	0.48 ± 0.17	0.79 ± 0.40		0.02
Land use (vegetation type)	EVG	EVG	EVG	EVG		MDF	MDF	MDF	MDF		
Disturbance (visual scale)	Nil	Nil	Nil	Nil		Nil	Nil	Low	Low		

F= fast; M= moderate; EVG= Evergreen Forest; MDF= Moist deciduous Forest; ***p<0.001;**p<0.01; *p

Table 13. Status and distribution of fish species in two biotopes

Fish species	Status	Distribution at study sites (biotope.1)	Abundsnce ranking (biotope1)	distribution at study sites (biotope21)	abundance ranking (biotope 2)
01. *Noemacheilus denisonii*	EW	K3, K4	5	T1, T2, T3,T4	3
02. *N.guentheri*	EW	K1, K3	3		
03. N. *keralensis*	EW	K3. K4	9		
04. *N. species*	EW			T2, T3	5
05. *N. semiarmatus*	EW	K3, K4	13		
06. *Travancoria jonesi*	EW, TT	K3	14		
07. *Lepidocephalus ihermalis*		K2, K3	10	T3,T4	7
08. *Barilius bakeri*	EW, TI	K3: K4	4		
09. *Barilus galensis*	EW			T3,T4	1
10. *Crossochilus periyarensis*	EP, TT	K3	11		
11. *Danio aequipinnaius*		K2,K3 K4	2	T3,T4	2
12. *Garra mcClellandi*	EW	K2,K3	6		
13. *Garru mullya*		K1, K2. K3, K4	1	T1, T2, T3,T4	4
14. *P. ophiocephalus*	EW, TT	K1, K2	12		
15. *Rusbora daniconius*		K3, K4	7	T2, T3,T4	6
16. *Tor khudree*	TT	K3, K4	8		
Total number of species		**14**		**7**	

A total of 16 fish species were recorded from 8 study sites representing 10 genera and 3 families (Table 13). The fishes belonged to loaches, barbs and minnows.The diversity was high in west flowing streams (biotope 1) while a low fish diversity was noted in east flowing streams (biotope 2). The cyprinids were relatively abundant in the west flowing streams whereas both cyprinids and loaches were almost equally abundant in the east flowing streams. Among the 16 species encountered at the study sites, 9 were endemic to Western Ghats and /or in the river basins and 4 were threatened. The most endangered cyprinid of India, Mahseer *(Tor khudree* (Sykes) *was* recorded at two sites of the west flowing streams. Among the endemics, *Crossocheilus periyarensis* and *Puntius ophiocephalus,* which are narrowly endemic (stenotopic) with very limited distribution, were abundant in the upstream sections of Periyar. The density of fishes in the west flowing streams was higher compared to the density in the east flowing streams. Among the 16 species, *5* species ***viz,*** 2 loaches and 3 cyprinids were common *to* both basins. A loach namely *Noemacheilus semiarmatus* and a cyprinid *(Barilius gatensis)* were present only in the east flowing streams, while 4 loaches and 5 cyprinids were exclusive to the west flowing streams. (A loach belonging to the genera *Noemacheilus* could not be confirmed for its species status; it seemed to be a new species or might be a rediscovery of *N. pulchellus* (Kottelat, M. personal communication).

Commercial fisheries by indigenous groups: The indigenous people (Mannans and Paliyans) from Mannankudy and Paliyankudy in Labbakandatn near Kumily / Thekkady were involved in the lake fishery The percentage composition of fishes collected during experimental catches compared with that of the catches of tribals (Table 14) indicate that the tribals selectively fished largely on two endemic and threatened fishes as well as on two exotic fishes viz, *Cyprinus carpio communis, Tor khudree, Puntius curmuca* and *Oreochromis mossambicus.* The most commonly and largely caught fishes *C. carpio communis* and *Tor khudree,* constituted about 75% of the total catch.

Table 14. Percentage of fishes in the experimental catches during study and in the commercial catches of tribal groups

	Cyprinus carpio communis	Tor khudree	Puntius curmuca	Oreochromis mossambicus	Rest
Experimental catches	4.0	7.0	12.0	7.0	70.0
Commercial catches	50.00	24.0	18.0	8.0	<1.0

Table 15. Mean monthly variation in fish catch (nearest to Kg) at Periyar lake by indigenous groups

Montb	Category **I (Kgms)**	Category **II(Kgms)**	Total **(Kgms)**	No. fishermen **involved**
January'95	980	196	1176	266
February	760	218	979	249
March	731	112	843	211
April	501	129	630	197
May	485	102	587	186
June	1091	195	1286	274
July	1150	245	1395	281
August	998	185	1183	269
September	774	174	948	237
October	765	122	887	210
November	811	166	977	203
December'95	706	159	865	235
Mean monthly values	812.8	166.9	979.67	234.8
Mean daily values	26.6	5.5	32.1	7.7

Category l- Mahseer + Gold dish

Category II- Tilapia + curmuca barb (kooral)

The records of the fisheries society indicated (Table 15) that mean monthly catch was highest in July with highest number of fishermen involved, while lowest mean monthly catch was recorded in May with lowest number of fishermen engaged. Two categories of fishes could **only** be identified from the society records, because the

society pooled total of the catches of *C. carpio communis* and *Tor khudree* into category 1 and *O. mossambicus* and *P. curmuca* into category II The monthly estimates for the year 1995 reveal that the annual monthly catch is around 980 Kgs with an average of 235 fishermen involved in fishing. Hence the daily catch per fisherman can be estimated as 4.2 Kgs which realised an amount of Rs. 168.00 per fisherman per day at a rate of Rs. 40.00 per Kg of fish sold. The tribes usually go for fishing in the afternoon in groups or very seldom with families and fishes overnight. The catch will be sold in the market through the society in the next morning. The gears commonly used are gill nets and hook and line. Traps are very seldom used. Of the 240 families of Mannans, 144 (60%) families depended primarily or secondarily on fish resources for their livelihood, while the rest of the families depended on agriculture or NTFP (Non Timber Forest Produce) collection. Among 101 families of Paliyans, very few (6 families) depended on fisheries, while they mainly depended on NTFP and agriculture for livelihood.

Discussion

The fish communities in Periyar lake and streams are highly unique, diverse and threatened. The communities are ecologically highly structured on the basis of macrohabitat, diet and morphological attributes. Furthermore, the communities greately vaned on structural patterns with the fish communities in the adjacent zones or biotopes based on the differences in habitat diversity and variations due to habitat modification or alterations. The endemic fishes heavily faced threats by the invasion of exotic (alien) fishes in the lake and by the habitat modifications as well as by fishery activities of indigenous (tribal) groups.

The stenotopic nature of distribution of fishes like *Puntius micropogon periyarensis,Crossocheilus periyarensis, Puntius ophioceophalus* and *Lepidvpygopsis typus* in the streams has enhanced the importance and uniqueness of the fish communities to a greater extent that the entire aquatic ecosystem needs high priority in conservation. Moreover, all the loaches of the family Balitoridae and more than half

of the cyprinids found in the system are either endemic to Western Ghats or highly threatened. This further adds the importance of the necessity for a high degree of protection to these communities. The sub family Schizothoracinae to which *Lepidopygopsis typus* belong is of typical cold water species of Himalayan origin. This is the only species found outside the Himalayan ranges and its existence in Periyar remains inexplicable. In general, Of the 27 species encountered in the system, 14 (52%) are endemic to Western Ghats, 14 (52%) are threatened and 9 (33%) are threatened and endemic. About 56% (18) of the total endemic fishes of Kerala is represented in Periyar lake and stream communities (Arun. 1996). The population densities of threatened and endemic fishes ,in the system are generally low in comparison to other native fishes. This situation indicates at the measures to be taken legally for the protection of the hitherto underprotected group of lower vertebrates. The Wildlife (Protection) Act, 1972 has included most of the endangered, rare and threatened animals like small & large mammals, birds, amphibians, reptiles and even some butterflies and certain plants in the list. But so far no attempt was done to include fishes in the schedule and hence to impart protection to fishes. This could be applied to both freshwater and marine fishes. A list of threatened fishes of India furnished by Mahanta *et al.* (1994) can be provisionally considered for the schedule. Once the fishes are scheduled under the Wildlife (Protection) Act, the Forest Department personnel can impart protection measures to the freshwater fishes, since most of the habitats in which these threatened fishes live come under the Protected Area Network in India.

The fish communities in Periyar lake and streams are well structured on various resources axes *viz,* microhabitat, diet and morphology. Primarily along the macrohabitat axis, the fishes are readily separated into rheophilic fishes and still-water fishes. Still-water fishes *Aplocheilus lineatus, Channa gachua, C. striatus, Oreochromis mossambicus, Cyprinus carpio communis* and *Heteropneustes fossils,* preferred stagnant, lake waters while 9 species are rheophilic and remained in

torrential habitats. The rest of the fishes are found both in the streams and lake. Another resources axis on which the fishes segregated was diet. The trophic segregation among the fishes in Periyar was so pertinent that only 8% of the total possible combinations of species have high (meaningful) overlap values. This could easily segregate the fishes into different trophic groups. Similarly depending on morphological characteristics, the fishes were grouped into various niche types (Watson and Balson, 1984). So the fishes with a primary separation on macrohabitat and then on diet and/or morphology, totally segregated the fishes with separate niches. This compartmentalisation indicates less competition for space and food. Similar categorisation depending on the structure of fish communities in other tropical aquatic ecosystems has proved the existence of niches and low levels of competitions among fishes (Moyie and Senanayake, 1984; Wikramanayake and Moyle, 1989; Arun, 1992). Investigations on other tropical fish communities, similar to this, showed that the members of the community segregated largely on two niche dimensions *viz,* diet and relative position in water column (Moyle and Senanayake, 1994). Body shape and morphological characteristics associated with feeding in fishes have showed the same pattern (Lowe-McConnell, 1975). Such morphological diversity is generally considered to reflect reduced competition for limited resources (Gatz, 1979b). Similar specialised trophic structure with diet habits are found among the Amazonian fishes (Knoppel, 1970). In contrast, morphological specialisation in Periyar fishes was associated with dietary/microhabitat specialisations. This is especially noticeable among *Noemacheilus Spp.*and *Garra spp.*, which fed on benthic (aquatic) insects and algae respectively.

The fish assemblages of Periyar lake stream-system are segregated in both ecological and morphological spaces. If some species are morphologically similar, they are separated ecologically through habitat variable and such species rarely co-existed. The morphological factors associated with (micro) habitat segregated the fishes according to body shape and size. The general assumption that small fishes and

fishes with deep, laterally compressed bodies concept holds true with the Periyar fish assemblages. The species with deep and laterally compressed body like *Puntius melanampyx, Aplocheilus lineatus* and other smaller fishes occupy relatively slower waters. The larger, active species with fusiform body such as *Danio aeuinpinnatus* and *Tor khudree* occupy habitats with faster waters. The benthic fishes such as *Garra mullya, G. mcClellandi, Noemacheilus spp.* that occupy fast flowing waters in streams had rather broad, dorsally flattened heads and axial fins held out towards the body. Such morphological adaptations serve to hold the fish against the substrate in fast flowing waters (Aleev, 1963). Some morphological features commonly associated with trophic specialisations indicate the relative position of the fish in water column of the habitat. The dorsally oriented mouths in non-benthic species *ie,* surface-orienters, indicate that they feed from upper water column and sub–terminal or ventral mouths are normally associated with benthic feeding.

The exotic fishes like tilapia *(Oreochromis mossambicuss)* and common European carp *(Cyprinus carpio communis)* have substantially augmented the fish production in inland waters of India (Sreenivasan, 1991) and other parts of Asia (De Silve, 1985; 1987; Fernando and Holick, 1991). But scientists have different opinions about these introductions. Some believe that these introductions have ruined the native fish fauna, while others think it has never affected the native fish diversity (Sreenivasan, 1991). However, the trend in Periyar lake stream system generally shows that when the exotic fishes are abundant, the erst-while abundant (Chacko, 1948) and the presently highly endangered fish like mahseers are scarce. The tilapia and European carp, which are prevalent in the lake habitat may probably compete with the native and endemic/ threatened fishes for resources, especially food. Similarly the destruction of endemic haplochromine fishery has taken place in Lake Victoria due to the introduction of Nile perch *(Lates nilotica)*. This introduction done with the intention of augmenting fish production to provide fish ('protein') cheapily for local people has infact not only destroyed the whole indigenous fishery of the *lake* but made the available indigenous

fishes, an expensive commodity (Barel *et al.*, 1985; Witte *et al.*, 1992; Owuor, 1996). The populations of the once-plentiful and the major food fish of Himalayan region, *Schizothorax richardsonii* (commonly called snow trout or Himalayan trout), declined sharply eversince the introduction of common carp *(Cyprinus carpio)* in the late 1950's (Qadri *et al.*, 1983). High fecundity rates, omnivorous feeding habits, fast growth rates and easy establishment in alien waters by these exotic fishes may seriously affect the existence of the highly sensitive endemic/threatened fishes of Periyar, which are highly specific on breeding and feeding habits. A high/medium interspecific competitive interaction exists between tilapia and other 12 native fishes, and between European carp and 15 native fishes (Table 9). Among these interspecific interactions, the competition among tilapia, *L. typus* and *H. fossils* and among *C. carpio communis, P. curmuca* and *T. Khudree* seem high, because of high overlap values which indicates high amount of sharing of food resources between these fish species.

The official records of the forest department lack the details about the date of introduction of the two exotics into the lake. Hence these fishes might have been introduced deliberately by the fisheries department without prior permission from forest department or might have (un)intentionally done by fishery enthusiasts from downstream sections. The possible year of introduction seems to be in late 70's or early 80's and it is possible that by now these exotic species have well established in the system. There are records available (Gopinathan and Jayakrishnan, 1984) indicating the introduction of these exotic fishes in Idukki reservoir by the Kerala fisheries department during mid 70's as a part of the fisheries development programme in reservoirs. But physically it seems to be impossible for the fishes to migrate upstream to reach Periyar lake due to the existence of Mullapperiyar dam. But illicit introductions from down streams by local fishery enthusiasts might have caused the proliferation of these non-native fish species in the lake.

A variation in community composition between the 4 zones of the Periyar lake, upstream and downstream sections at a rate of 21 in zone 1 to 18 in zone 2 and further 13 in zone 3 and finally 17 in zone 4, is against the theoretical expectation of a downstream increase in species richness (Vannote *et al.,* 1980; Cross, 1985). A general species reduction along the length of the river and an impoverished icthyofauna at the inter-reservoir section (zone 3) can be ascribed to the presence of dams at two location of the river and changes in land use pattern in the watersheds. Unlike the (micro) watersheds of zone 1, 2 and 4, which are protected by rain forests (evergreen, semi-evergreen and moist deciduous forest types), watershed of zone 3 (Fig 2) is thoroughly disturbed by plantation activities and habitations resulting in high disturbance levels to the ecosystem and irrational practices by local people using explosives and poisons, high rate of soil erosion and point and non point sources of pollution might also add problems to the existing ones. A complete change in species mix, as revealed by the Sorensen's similarity index, from zone 1 to zone 4 might be attributed to the absence of physical connection between the zones by the existence of Mullapperiyar dam, irrespective of the availability of similar habitats and other resources at both zones. The possibility of interconnection between the two zones (zone 1 & 2) in the upstream section made these zones most similar among the zones. These physical barriers (dams) prevented free movements and intermixing of fishes between zones 1 and 2 to zones 3 and 4 and vice-versa The prevention or hindrance by dams to the migratory routes of diadromous fishes is a well established fact even in the presence of fish passages (Langford, 1983). The knowledge on the migratory patterns of fishes is generally insuficient in tropics and particularly absent in Peninsular India. The presence of eels *(Anguilla bengalensis* and *A. bicolor)* were reported by Chacko (1984) from Periyar lake. But during the present study no eels were caught and there are no reports from local fishermen about their recent availability. The absence of eels and some other species (Table 4) supports the fact about the negative impact of high-headed dams on fish life. A new species, *Garra Surendranathaniii* (Shaji *et al.*. 1996) having intermediary taxonomic features to G.

mullya, G. *gotyla stenortynchus* and *G. mcCleilandi* has been encountered in Zones 3 during the study. The presence of this species G. *Surendranathanii* in zone 3 indicate the fact that a possible reproductive isolation of fish species resulting in genetic variations or possibilities of hybridization. Chances of hybbridization and genetic variance due to dams in River Danube have been perceived earlier by Balon (1992). Lack of information on the status of fishes in the last century in the headwaters of Periyar river thwarts to arrive at conclusions about the impact of dams on fish life.

The variations in habitat characteristics and fish species composition at the two biotopes in the windward and leeward sides of Western Ghats can be generally attributed to the variation in bioclimatic regimes existing in the respective zones. Altitude, temperature, rainfall and other associated abiotic factors like edaphic, determine the forest types in the respective zones. These factors might determine the perennial water discharge from soils to the streams. The year round vailability of water in streams determine the persistence of fish communities (Moyle and Voudreek, 1985). High rainfall and stable vegetation structure help maintain perennial supply of water to streams in west-flowing streams. These reasons might be attributed to the high diversity of fishes in west flowing streams. Eventhough, studies are scanty on the comparison of vegetation on both the slopes of Western Ghats, it is generally observed that there exists a (high) variation in vegetation type, species and diversity in the above said slopes (Pascal, 1988, Ganesh *et al.,* 1996). Due to high mobility and long ranging habits, 'small-scale' bioclimatic or biogeographic variations do not normally restrict distribution of large vertebrates including birds. But studies to understand such a pattern in lower vertebrates like amphibian, reptiles and fishes or invertebrates like insects were mostly unattempted. However, the restricted distribution of grizzled-giant squirrel *(Raufa macroura)* in the leeward slopes of Western Ghats could probably explain this pattern to certain extent but it needs further investigation (Ramachandran, 1993). Temperature, rainfall and canopy cover can be some of the limiting factors in the distribution of fishes (as far as the physical factors

are concerned); water temperature could be a limiting factor in the distribution of fishes like *Tor khudree, C. periyarensis* and *P. ophiocephalus* while food resources and habitat characteristics can limit the distribution of fishes like loaches. The loaches are generally benthic insects, the distribution and abundance of which are greatly influenced by the presence of organic matter in the form of leaf litter, debris, dead twigs etc. Since the subtrates and habitat types available to the fishes in both biotopes are mostly similar, the fish composition does not seem to be affected by these variables.

The general trend in exploiting large quantities of exotic fishes (tilapia and European carp) in Periyar lake by the tribals is rather commendable that further proliferation of these species can be checked to a certain extent. But the imminent threat hidden in this, is the exploitation of the endemic and threatened fishes along with the exotics. It has become clear that about 12 tonnes of fishes worth about Rs. 5 lakhs is caught annually from the lake by the tribal fishermen. An annual catch of 12 tonnes seems to be meagre in a lake of an area of 26 sq. km like Periyar. But it is important to consider that the calculated average of 12 tonnes of fishes caught is constituted only by 4 species. This projection of 12 tonnes might never happen to be the real figure. It could be sometimes 2 or 3 times greater that this quantity, when considering the chances of illegal fishing by local communities, other than the tribals, or the chances of selling fish by tribes directly to the markets, thus by-passing the society, Average fish yield in lakes with comparable morphoedaphic index (MEI) to that of Periyar lake varies between 4.2 to 23.5 Kg/ha. (Sreenivasan, 1992). When the fish yield of Periyar lake is projected according to this standard, it could be between 11 and 62 tonnes. This figure includes the total fish production in the lake. According to the least estimated figures, the real exploitation of four species alone in Periyar lake could be anything between 24 and 36 tonnes. Now consider that the 4 species form a maximum of about 35% of the total fish production and at a maximum rate of fish

production of about 62 tonnes, these 4 species can contribute only about 22 tonnes. But at the rate of 24 - 36 tonnes of fish caught, the question of the sustainability of the existing fishery in Periyar lake emerges.

Considering the market values for evaluating the economic importance of a particular fish species is imperative that we count other values of these natural capitals like fish populations and unique aquatic ecosystems (Moyle and Moyle, 1995) *viz.* existence values, ecosystem values and intergenerational values. So while evaluating the economics of commodities like fish, wildlife and forests, it has become inevitable that we add price-tags, like ecosystem value for its ecological services, existence value for its intangible benefits; and intergenerational value as the economic costs of environmental degradation caused by us to the future generations, other than their mere market values.

CONCLUSION AND MANAGEMENT IMPLICATIONS

The fish assemblages in the lake and streams of Periyar are ecologically structured on macrohabitat, diet and morphological attributes. The fish species are highly segregated on the above-mentioned resource axes. The water quality parameters show the pristine nature of water in the lake and streams, while the production estimates are rather relatively low in the lake system. More than half of the species in the system are endemic and/or threatened and warrants attention for lugh priority conservation strategies. The introduced/exotic fish species have potentially affected the native fish fauna of the lake and streams. The highly protected water sheds and conservative land use practices in the catchment coupled with the existence of diverse and unmodified habitats enhanced the ichthyofauna diversity in the system. The selective fishing practices of the indigenous may affect the sustainability of the existing fishery of the lake in long-run unless certain management strategies are adopted.

The managers or policy makers of the Protected Area (PA) may consider the following aspects while preparing management plans or designing management strategies for the system.

1. Considering the uniqueness and diversity of fishes present in the system, the lake and associated streams in Periyar Tiger Reserve (PTR) can be declared as a 'Fish Sanctuary'. More illustrations about the importance of each species of the system may be displayed at the interpretation centre in Thekkady along with the existing exhibits of fishes. This should enrich the knowledge of visitors on the importance of the existence value of this aquatic ecosystem
2. The endemic, rare and the threatened fishes of Kerala/india may be incorporated into the schedule of the Wildlife (Protection) Act, 1972, in order to enhance the current measures of protection of these fishes in their natural habitats. Moreover, strict measures may be imparted to curb any further introduction of exotic fishes into the system even by any government agencies without proper understanding on the possible impact of the species to the native fish fauna
3. The fishery by tribes on the exotic fishes like tilapia and common European carp may be promoted while strict measures may be taken to control the fishery by endemic and threatened species like mahseer and curmuca barb. The sale of mahsers (Kuyil) may be banned in the markets of Kumily/Thekkady. Moreover, the tribes may be made aware about the unsustainability of irrational fishing during breeding seasons as well as the importance of preserving the endemic and/or threatened fish stocks.
4. The commonly exploited fishes of the lake are normally large-sized. Regulation on the fishery of larger specimens by banning large-mesh gill nets may affect the marketing of fishes, since consumers do not prefer small fishes. Moreover most of the fishes in the inland waters breed during and soon after monsoon. Hence suspension of fishery activities in the lake during monsoon (June, July and August) may be tried (More studies on breeding patterns of fishes may be

encouraged). Furthermore, the fishery may be restricted only to the western and southern sections of the lake.

5. The dependency of tribes on the fish resources of the lake has to be studied in relation to their other income sources. Such a study would reveal the extent of dependency by tribes on the fishes for their livelihood and would also reveal the rationality of allowing fishery in the lake or the extent of issuing fishery licences to tribal fishermen. More scientific measures may be considered while issuing fishing licences like fishing skills of tribes, experience/involvement in the lake fishery as a primary income source, total income etc. Moreover, a pre-determined and limited number of licenses may be issued to the tribes on a rotation basis that every interested member of the group gets opportunity for a limited fishery in the lake.

References

Aleeve, Y.G. 1963. Function and gross morphology in fish. Israel Programme for Scientific Transactions, Jerusalem, Israel.

Angermier, P.L. and J.R. Karr 1983. Fish communities along environmental gradients in a system of tropical streams. - *Environmental Biology of Fishes*. 9:117-135.

APHA, 1985. Standard methods for the examination of water and waste water. American Public Health Association, Washington, D.C., USA.

Arun, L.K. 1992. Niche segregation in fish communities of a south Indian river. Ph.D. thesis, University of Kerala, Trivandrum, India.

Arun, L.K. 1996. Status and distribution of fishes in Periyar lake-stream system of southern Western Ghats. In: Das, P.A.G. Ponniah, and S.R. Verma. (Eds). Fish Genetics and biodiversity conservation for sustainable production. NATCON, Muzaffarnagar, India (in press).

Arun, L.K. 1997. Longitudinal variation in fish communities along a serially regulated river system of southern Western Ghats. P 96-99, In: Aiyengar, P.K. (Eds). Proceedings of the ninth Kerala Science Congress, State Committee on Science and Technology and environment, Trivandrum.

Arun, L.K. , C.P.Shaji and P.S. Easa. 1996. New reports of fishes from Periyar Tiger Reserve. *J.Bombay nut. Hist.soc.* 93: 103-104.

Asari, P.K.S. 1986. Periyar Tiger Reserve: Wildlife Management Plan Revised (1986-87 to 1995-96). Kerala Forest Department, Trivandrum, Kerala

Balon, E.K. 1992. How dams on the river Danube might have caused hybridisation and influenced the appearance of a new cyprinid taxon. *Environmental Biology of Fishes.* 33:167-180.

Barel, C.D.N., R. Dorit, P.H. Greenwood, G.Fryer, N.Hughes, P.B. N. Jackson, H. Kawanabe, R.H. Lowe-McConnel, M. Nagoshi, A.J. Ribbink, E.Trewavas, F. Witte and K. Yamaoka 1985. Distruction of fisheries in Africa's lakes. *Nature.* 315:19-20

Benton, A.H. and W.E. Werner. 1965. Mannual of field biology. Burgess publishing, Minneaplolis, MN, USA. 184p.

Chacko, P.I. 1948. Development of fisheries of Periyar lake. *J.Bombay nat. Hist.soc.* 48: 191-192.

Cross, J.N. 1985. Distribution of fish in the virgin river, a tributary of the lower Colarado river. *Environmental Biology of Fishes.* 12:13-21.

De-jalon, D.G. and P. Sanchez. 1994. Down stream effects of a new hydro power impoundment on macrophyte, macroinvertebrate and fish communities. Regulated rivers: *Research and Management.* 9:253-261.

de Silva, S.S. 1985. Status of the introduced cichilid, *Sarathrodon mossambicus* (Peters) in the fishery of Sri Lnka: A Management strategy and ecological implications. *Aquaculture and Fisheries Management.* 16:91-102.

de Silva, S.S. 1987. Impact of exotics on the inland fisheirs resources of Sri Lanka. *Archives fur Hydrobioiogie, Beiheft Ergebinnse der Lirnnologie* . 28:278-293.

Douglas, M.E. and W.J. Mattews. Does morphology predicts ecology?. Hypothesis testing within a fresh water stream fish assemblages. Oikos. 65: 213-225.

Easa, P.S. and S.C. Basha 1995. A survey of the habitat and distribution of stream fishes in the Kerala part of Nilgiri Biosphere Reserve. KFRI Research Report No. 104. Kerala Forest Research Institute, Peechi, Kerala. 87pp.

EPA, 1979. Methods of chemical analyses of water and wastes. United States environmental Protection Agency., EPA-600/4-79-20. USA.

Fenando, C.H. and J.Holcik. 1991. Some impacts of fish introductions in to tropical freshwaters. 103-129p, In: Ramakrishnan, P.S. (Eds). Ecology of biological invasions in the tropics, International scientifc publications, New Delhi.

Flecker, A S. 1992. Fish tropic guilds and the structure of a tropical stream, weak direct Vs. strong indirect effects. *Ecology.* 73: 927-940.

Gadgil, M. 1996. Documenting diversity: an experiment. *Current science.* 70:36-44.

Ganesh, T., R. Ganesan, M. Soubadra Devi, P. Davidar and K.S. Bawa. 1996. Assessment of plant diversity at a mid-elevation evergreen forest of Kalakkad-Mundanthurai Tiger Reserve, Westrn Ghats, India. *Current science.* 71:379-392.

Gatz, A.J.Jr. 1979a. Ecological morphology of fresh water stream fishes. *Tulane studies in Zoology and Botany.* 21: 91-124.

Gatz, A.J.Jr. 1979b. Community organisation of fishes as indicated by morphological features. *Ecology.* 60:711-718.

Goldsmith, E. and N. Hildyard 1984. The social and environmental effects of large dams. Vol I, II & III. Wadebridge ecological centre, Comwall, UK.

Gopinath, P. and T.N. Jayaknshnan. 1984. A study on the Pisci fauna of the Idukki reservoir and catchment area. *Fishery technology.* 21:131-136.

Gregor, P.D. and J.E. Deacon. 1988. Food partitionig among the fishes of the virgin river. *Copeia.* 1988: 314-323.

Harris, J.E. 1938. The role of fins in the equilibrium of the swimming fish.II. The role of pelvic fins. *J. Experimental Biology.* 15: 32-47.

Hynes, H.B.N. 1950. The food of freshwater sticklebacks *(Gasterosteus aculeatus* and *Pygosteus pungitus)* with review of methods used in the studies of food of fishes. *Journal of Animal Ecology.* 19: 36-88.

Hyslop, E.J. 1980. Stomach content analyses: a review of methods and their applications. *Journal of Fish Biology.* 17: 4 11-429.

Jayaram, K.C. 1981. The fresh water fishes of India, Pakistan, Bangladesh, Burma and Sri Lank: A Hand book. Zoological Survey of India. Calcutta, India. 475pp+ xiii pls.

Keast, A.and D. Webb. 1966. Mouth and body form relative of feeding ecology in the fish fauna of a small lake, Lake Opinicon, Ontario. *Journal of the Fisheries Research Board of Canada.* 23: 1845-1874.

Knoppel, H.A. 1970. Food of central Amazonian fishes. *Amazonia.* 2: 257-352

Kurup. B. M. 1994. An account on threatened fishes of river systems flowing through Kerala. 121-126p, In: Dehadri, P.V., P.Das and S.R. Verma (Eds). Threatened fishes of India. NATCON publications, Muzaffarnagar, India.

Langford, T.E. 1983. Electricity generation and ecology of natural waters. Liverpool University press, Liverpool, UK. 342pp.

Lowe-McConnel, R.H. 1975. Fish communities in tropical fresh waters. Longmann, London, UK.

Lowe-McConnel, R.H. 1987. Eological studies in tropical fish communities. Cambrodge University press, Cambridge UK.

Mahanata, P.C., D. Kapoor, R. dayal and A.G. Ponniah. 1994. Prioritsation of Indian fish species for conservation. 379-385Pp, In: Dehadri, P.V., P.Das. and S.R. Verma (Eds). Threatened fishes of India. NATCON publications, Muzaffarnagar, India.

Menon, A.G.K. and K.Rema Devi. 1995. *Hypselobarbus kurali* (Pisces:Cyprinidae): A new large barb from the south western rivers of Peninsular India. *J.Bombay nat. Hist. Soc.* 92: 389-393.

Menon, A.G.K. and P. C. Jacob. 1996. *Crossochilus periyarnesis,* a new cyprinid fish from Thannikudy (Thekkady), Kerala *J.Bombay nat. Hist. soc.* 93: 62-64.

Moyle, P.B. and F.R. Senanayake. 1984. Resource oartitioning among fishes rain forests streams in Sri Lanka *Journal of Zoological Society of London.* 202: 195-223.

Moyle, P.B. and B. Vondracek. 1985. Persistence and structure of fish assemblages in a small California stream. *Ecology*. 66: 1-13.

Moyle, P.B. and J.J. Cech, Jr. 1982. Fishes: an introduction to ichthyology in Englewood cliffs, N.J.: Prentice Hall Inc., USA.

Moyle, P.B. and P.B. Moyle. 1995. Endangered fishes and economics. Intergenerational obligations. *Environmental Biology of Fishes.* 29:

Nair, K.S.S. and P.S. Easa. 1997. Animal biodiversity in Kerala forests. 87-102p., In: Pushpangadan, P., K.S.S. Nair (Eds). Biodiversity and tropical forests: The Kerala Scenario Science, Technology and Environment Committee, Trivandrum.

Nair, S.C. 1991. The southern Western Ghats: A biodiversity conservation plan. INTACH, New Delhi, 92p.

Nikolski, G.V. 1933. On the influence of the rate of flow on the fauna of the rivers of central Asia. *Journal of Animal* Ecology. 2: 266-,281.

Owuor, 0.1996. Perchid atop an abyss. *Down to Earth.* 5(9): 22-23.

Pascal J.P. 1982. Bioclimates of the Western Ghats. French Institute of Pondicherry, Pondicherry. 2 Maps (Scale 1150,000).

Pascal, J.P. 1988. Wet evergreen forests of the Western Ghats of India. French Institute of Pondicheny, Pondicherry. 305 p.

Pascal, J.P. 1996. Wild and fragile. *Down to Earth.* 5(6): 28-32.

Platts, W.S. W.F. Meghan and G.W. Minshall. 1983. Methods for evaluating stream, riparian and biotic condition. General Technical Report. INT-138, USDA, Ogdn, Utah, USA. 70p.

Ponniah, A,G, 1994. Categorisation of India's threatened fishes. 365-377. In: Dehadn, P.V., P.Das. and S.R. Verma (Eds). Threatened fishes of India. NATCON publications, Muzaffarnagar, India.

Power, M.E. 1983. Grazing responses of tropical Fresh water fishes to different scales of variations in their food *Environmental Biology of Fishes.* 9: 103-115.

Qadri, M.Y., S. Mir and A.R. Yousaf. 1983. Breeding biology of Schizothorax richardisonii Gray and Hard. *Journal of Indian institute of Science.* 64: 73-81.

Ramachandran, KK. P.S. Easa and P.V. Nair. 1987. Management of Periyar Tiger Reserve: Problems and perspectives. *Tiger Paper,* 14: 25-33.

Ross, S.T. 1986. Resource partitioning in fish assemblages: a review of field studies. *Copiea* 1986: 352-328

Ross, R.A. 1965. A method for estimating the potential fish production of north temperate lakes. Transactions of American Fisheries Society 94: 214-218

Schoener, T.W. 1970. Non-synchronomous spatial overlap of lizards in patchy habitats. *Ecology* 51: 408-418.

Shaji, C.P., L.K. *Arun* and P.S. Easa, 1996. *Garra Surendranathanii* – A new cyprinid fish from the Southern Western Ghats, India. *J. Bomaby nut. Hist. Sco.* 93: 572-575.

Sreenivasan, A. 1991. Transfer of freshwater fishes into India. p. 131-138. In: Ramakrishnan, P.S. (Editor) Ecology of biological invasion in the tropics. International Scientific Publication, New Delhi.

Sreenivasan, A. 1992. Limnology and fisheries of some South Indian reservoirs P. 23 – 37. In: Desilva, S. (Editor) Reservoir fisheries of Asia. International Development Research Centre, Ottawa, Canada.

Swengal, F.B. 1990. Endemic vertebrates of the Western Ghats Region. P. 4-13. In: *Nilgiri Tahr, Stud. Book,* 1990. Minnessota Zoo, Minnessota, USA.

Swengal, F.B. 1993. Endemic vertebrates of the Western Ghats Region; an update. P. 12-13. In: *Nilgiri Tahr, Stud. Book,* 1990. Minnessota Zoo, Minnessota, USA.

Talwar, P.K. and A.G. Jhingran, 1991. Inland fishes of India and adjacent countries. Volume 1 & II. Oxford and IBH Publishing Company, New Delhi. 1158p.

The Wildlife (Protection) Act, 1972. 1994. Natraj Publishers, Debra Dun, India and WWF-TRAFFIC India. 154 p.

Vannote, RL., G.W. Minshal, K.W. Cummins, J.R. Sedell and C.E. Cushing, 1980. The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences.* 37: 130-137.

Watson, D.J. and E.K. Balon 1983. Structure and production of fish communities in tropical rain forest streams of northern Borneo. *Canadian Journal of Zoology* 62: 927-940.

Watson, D.J. and E.K. Balon, 1984. Ecomorphological analysis of fish taxocenes in rainforest streams of northern Borneo. *Journal of Fish Biology* 25: 371-384.

Welcomme, R.L. 1969. The biology and ecology of the fishes of a small torpical stream. *Journal of Zoological Society of London* 158: 485-529.

Wikramanayake, E.D. 1990. Ecomorphlogy and biogeography of a tropical stream fish assemblage: Evolution of assemblages structure *Ecology* 71 : 1756-1764.

Wikramanayake, E.D. and P.B. Moyle, 1989. Ecological structure of tropical fish assemblages in wetzone streams of Sri Lanka. *Journal of Zoological Society of London.* 218: 503-526.

Winberg, G.G. 1960. Primary productivity of the water bodies, Academik Nauske, USSR, Minsk. 328 p.

Winemiller, K.O. 1990. Spatial and temporal variation in tropical fish trophc networks. *Ecological Monographs* 60: 331-367.

Witte, F., T. Goldschmidt, J. Wanink, M. Van Oiijen, K. Gondswaard, E. Witte-Mass and N. Bouton. 1992. The destruction of an endemic species flock quantitative data on the decline of the haplochromine cichlids in Lake Victoria. *Environmental Biology of Fishes* 34: 1-28.

Zaret, T.M. and A S. Rand, 1971. Competition in tropical stream fishes; support for the competitive exclusion principle. *Ecology* 52: 336-342.

Zhong, Y and G.Power. 1996. Environmental impacts of hydroelectric projects in fish resources in China *Reguluted rivers; Research and Management* 12: 81-98.

APPENDIX

Food categories

LTV-Littoral vegetation

TEP-Higher terrestrial plant matter, their remains such as seeds, flowers *ctc*

SAL-Small algae including diatoms

FAL-Filamenous algae

WAT-Water mites

CHR-Chironomids

EPH-Ephemeropterans

TRI-Trichopterans

TEI-Insects of terrestrial origin such as ants

AQI-Adult aquatic insects

BEI-Benthic microinvertebrates

DET-Detritus including debris, mud/caly particles

FIS-Fish or parts of fishes likescales. fins etc

CRU-Crustaceans and its parts

MOL-Molluscs and parts

PHP-All phytoplankton species

ZOP-All zooplankton speceis

Morphological characters

REL/Relative length=Ratio of standard length to total length

RHL/Relative head length=Ratio of head length to standard length

FLT/flatness index=Ratio of maximum body depth to maximum body width

RCS/Relative cuadal span=Ratio of span of caudal fin to maximum body depth

RPF/Relative pectoral fin=Ratio of the length of longest pectoral fin ray to standard length

RVF/ Relative pelvic &=Ratio of the length of pelvic fm ray to standard length

RED/ Relative eye = Ratio of eye diameter to standard length

RMW/Relative mouth width =Ratio of maximum mouth width to standard length

RMD/Relative mouth deapth= Ratio of maximum mouth deapth to standard length

NBL = Total number of barbels

PES = Shape of the pectoral fins rated as rounded (A)/intermediate (B) and pointed(C.)

EPS =Eye position rated as lateral (A), slightly dorso-lateral (B)/ bulging on the top of the head (C)

MPS = Mouth position rated as supra terminal (A):terminal (B): subterminal (C):inferior (D) and ventral (E)