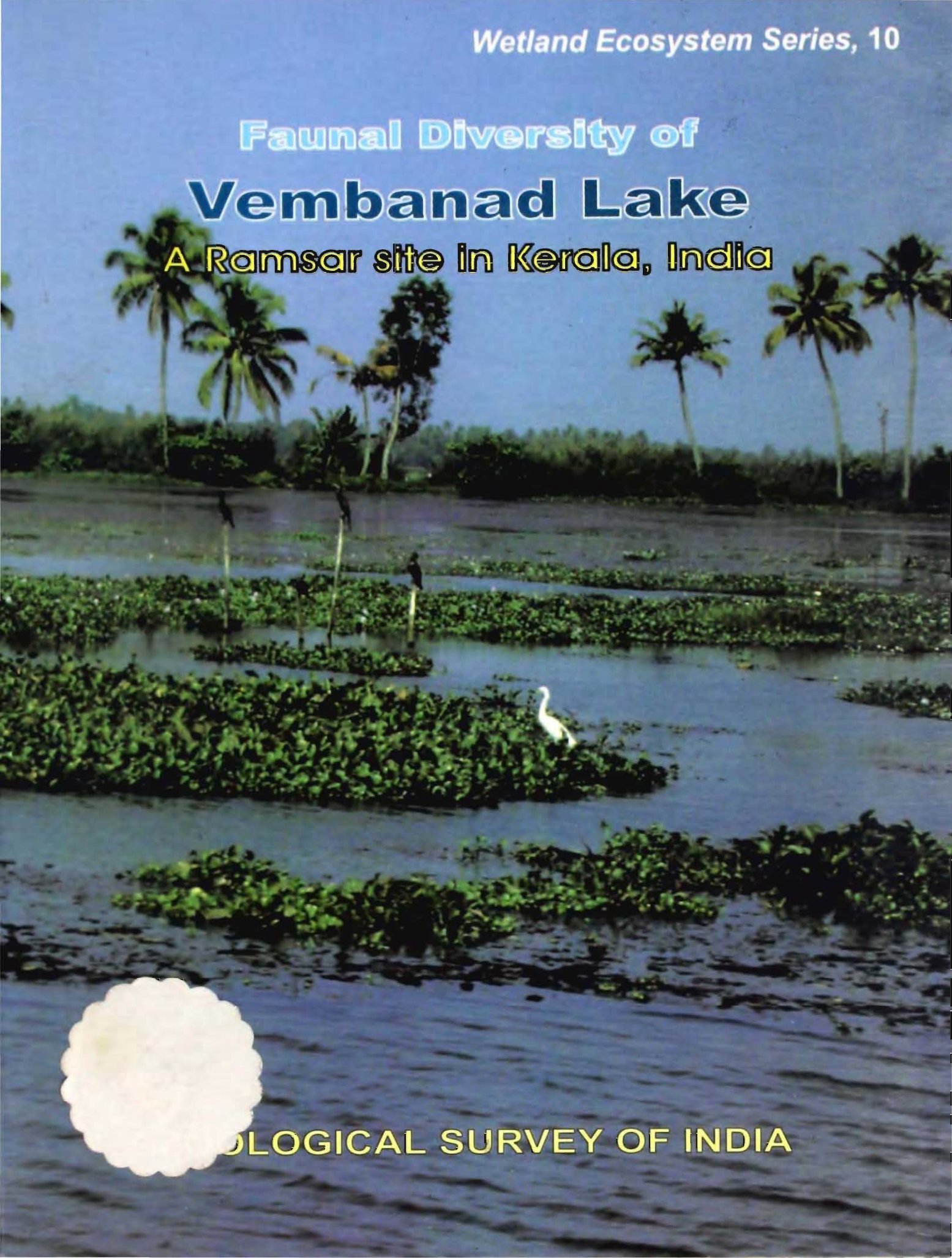
Wetland Ecosystem Series, 10

Faunal Diversity of Vembanad Lake

A Ramsar site in Kerala, India



OLOGICAL SURVEY OF INDIA

Wetland Ecosystem Series, 10

Faunal Diversity of
VEMBANAD LAKE
A Ramsar site in Kerala, India

Edited by the Director, Zoological Survey of India, Kolkata

Zoological Survey of India
Kolkata

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PREFACE

Kerala is blessed with beautiful backwaters. These backwaters and estuaries are rich in faunal elements. They offer an ideal *milieu* for the production and growth of faunal and fishery resources of the state, making it as one of the top sea-food producers of the country. Among the 30 backwaters, Vembanad Lake is the biggest in the state as well as the largest backwater lake in Asia. It is said to have originated during the post glacial era around 5000-6000 years ago. This lake has been studied by several investigators in different fields of science including animal science, but still, there is no comprehensive work on the faunal diversity of this important Ramsar site in India. For this reason, the present study pertains to make an inventory of the faunal diversity of Vembanad Lake along with ecological conditions of upstream and downstream sectors of the lake. Besides these, a brief account of fisheries and socio-economic aspects as well as threats, conservation and management aspects have been highlighted to facilitate future management plan of this lake, an important Ramsar site in South India.

The Vembanad Lake was surveyed twice as Rapid Assessment Surveys during 2002 and 2003 to understand and evaluate the overall hydrobiological status of this lake. Besides observations on vertebrates, fishes and shellfishes, collections of invertebrate specimens were made from the lake. The collected materials, though not exhaustive, are comprised of nine different groups, which were identified by experts of respective groups. As such it is aimed to prepare this document based on the collection and observations made during the course of survey as well as from literature. Thus, this document provides readers with adequate information on vertebrate and invertebrate faunal diversity and their distribution at upstream and downstream of the lake. It is hoped that this comprehensive document will serve as useful aid to lake researchers and managers for conservation and restoration of the lake. The readers are requested to inform us about errors and omissions in the faunal list of species, if any, for updating the document in future.

I, on behalf of the contributors of this document, would like to state that we are grateful to Dr. Ramakrishna, Director, Zoological Survey of India, Kolkata for the facilities provided to carry out this work. We are indebted to our collegues, namely, Dr. P. Mukhopadhaya, Dr. Animesh Bal, Dr. Rina Chakraborty, Dr. Aniruddha Dey, Dr. Amales Misra, Dr. (Mrs.) L. Bindu, Dr. Amal K. Karmakar, Dr. J.G. Pattanayak, Dr. Ch. Satyanarayana, Dr. R. Paliwal, Dr. S. Barua, Dr. Subrata Kar, Ms. Mousumi Roy, Ms. Lakshmi Ganesan, Ms. Chitra, and Mr. Santanu Mitra of this department for their various help and cooperation in identification of species, information and literature on lake aspects and checking of the inventory of invertebrate species occurring in the lake. Thanks are also due to Ms. Rituparna Nandi and Madhuparna Nandi for providing a

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Faunal Diversity of Vembanad Lake - A Ramsar site in Kerala, India

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FAUNAL DIVERSITY OF VEMBANAD LAKE : AN OVERVIEW

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INTRODUCTION

Vembanad Lake is an important Ramsar Site in India. Out of 19 Ramsar Sites, three Ramsar sites *viz.*, Vembanad Lake, Ashtamudi Lake and Sasthomcota Lake belong to Kerala State. Among these three sites, Vembanad and Ashtamudi lakes represent backwater ecosystems in India. Sasthomcota is a freshwater lake. The Vembanad Lake and particularly the Cochin backwaters is the seat of major port activities in Kerala. The lake plays a paramount role in the socio-economic and cultural history of this region. As a result, this backwater system, which supports many economically important marine as well as freshwater living resources, has attracted the attention of port engineers, planners, hydrobiologists and fishery scientists from the early part of twentieth century. During March-April 2002 and again in March 2003, two surveys were undertaken to study wetland faunal resources of Vembanad Lake, Kerala in connection with ecology and resource survey of macrozoobenthos and zooplankton of backwater ecosystems in Kerala. The significance of this study lies with the fact that an inventory of wetland fauna, both vertebrate and invertebrate is made herein along with some hydrobiological studies.

Studies on the physico-chemical and biological processes of the backwater systems in Kerala including Vembanad Lake have been made by several investigators (Bristow, 1938; Ramamritham and Jayaraman, 1963; Cherian, 1967; Desai and Krishnakutty, 1967; Qasim *et al.*, 1968; Qasim and Gopinathan, 1969; Sankaranarayanan and Qasim, 1969; Jasanto, 1971; Nair and Tranter, 1971; Wellershaus, 1972; Haridas *et al.*, 1973; Gopalan and Nair, 1975; Unnithan *et al.*, 1975; Balakrishnan and Shynamma, 1976; Remani, 1979; Qasim and Madhupratap, 1979; Gore *et al.*, 1979; Menon *et al.*, 2000). The fishery resources of this lake was also well documented (Pillay, 1960; Shetty, 1965; Kurup, 1982; Kurup and Samuel, 1980a, b, 1983, 1985, 1987; Kurup *et al.*, 1989, 1990a,b, 1993,1995). The system is subjected to serious stresses from anthropogenic activities, environmental degradation and shrinkage of habitat, Gopalan *et al.* (1983) and Gopalan (1984) have stressed the need for in-depth multidisciplinary

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studies, generation of adequate data-base and evolving legal measures to conserve this unique ecosystem of the country. Thus, Vembanad Lake for its uniqueness and international recognition as Ramsar site, an attempt is herein made to prepare a faunal inventory of this lake.

THE STUDY AREA

General

Kerala lies between 8°18' and 12° 48' North latitude and 74° 52' and 77° 25' East longitude and has a total area of 38,855 sq. km. The Vembanad Lake (Figs. 1.1a and 1.1b) is the largest brackishwater body in Kerala, measuring 80 km in length north to south from Kochi to Alapuzha. It is, in fact, a land-ward evagination of the Arabian Sea, which extends between Alleppey and Azhikode, located between latitude 9° 30' and 10° 12' and longitude 76° 10' and 76° 29' After intruding from the Arabian Sea, it extends to an area of 200 km^2, bordered by Alapuzha, Kottayam and Ernakulam districts. It enters inland through Ernakulam district in between Vypin Island and Cochin town, runs down the border between Alapuzha and Kottayam district ending in Alapuzha district town. The Vembanad Lake is trifurcated at Arur and Arkutti areas into Arur backwater, Vayalar backwater and Vembanad Lake proper. A salinity barrier was made in the lake ecosystem with the construction of Thanneermukkom bundh in the year 1976, which has resulted in partitioning the lake into two entirely different ecosystems, retaining estuarine conditions in the northern sector and transforming the southern sector into a freshwater habitat. The lake lies at sea level and is separated from the Arabian Sea by a narrow barrier island. There are three important islands *viz.*, Pathiramanal, Perumbalam and Pallippuram located within the lake. The town of Alapuzha is often referred to as the "Venice of the East" for its large network of canals linking the Vembanad Lake.

Genesis

Geologically, the Vembanad kayal (lake), a barrier-beach-lagoon system, was primarily a marine environment. It is believed to have had its origin during the post-glacial sea level rise, 5000-6000 years ago. The Vembanad Lake has taken its name from the ancient kingdom of Vempolinad sometime before 1200 A.D. Although interrupted by the Arabian Sea at intervals, geomorphologically all the sectors of the existing backwaters may not be of common origin. The present configuration of the Vembanad Lake has been attained in the 4th century A.D. (Anon., 1973), bounded by an alluvial bar parallel to the coastline. Some parts of Alleppey and Ernakulam districts and a number of islands arose due to the catastrophic deluge that took place in 1341 A. D. separating the water body from the sea with interconnecting channels at Thottapally, Andhakaranazhi and Cochin (Menon, 1913). The transformation of an originally marine environment into an estuarine system can be traced from the

deposition of large quantities of typically marine shells in the Vembanad region (Preston, 1916; Gopalan *et al.*, 1983).

The Vembanad Lake located in the low-lying area in Kuttanad region was originally a part of the shallow coastal area of the Arabian Sea. The geological uplift had formed a shallow bay in the area and the rivers were draining into it. The bay ultimately transformed into brackishwater lagoon extending from Alappuzha to Cochin. In 1976 the Thaneermukkam barrier was constructed to separate the lagoon into two to prevent saline water intrusion into the lake and to retain fresh water from the rivers flowing into it and thus cropping was successful in the Kuttanad region during the summer months. This has adversely affected the ecological health of the lake. The existing geomorphological features and estuarine characters of the lake have been brought about by natural and man-made alterations as well as freshwater discharge from major rivers.

Climate

Being situated in the humid tropical monsoon belt, the lowland regions of Vembanad Lake area experience high rainfall and humidity. There are two rainy seasons in Kerala, represented by the southwest and northeast monsoon. The former is characterized by heavy rainfall during June-September and the latter marked by precipitation of lesser magnitude occurring in between October and December. The mean annual rainfall varies from 2500 mm to 4000 mm. The rainfall mostly occurs during the southwest monsoon from May to September with average annual rainfall of 2812 mm. The thunderstorms generally occur between March and June. Dry season is short from December to March. The minimum and maximum temperatures are 21.0°C and 35.6°C respectively in the lowland region. The humidity is very high.

Soil

The soils of Kerala State are classified as alluvial soil, peaty soil, red soil, laterite and lateric soil, and forest soil. The soils are generally sandy to sandy loam with alluvial deposits in lowlands bordering the Arabian Sea. Mainly alluvial and peaty soils dominate the backwater tract of this state. In the lowland regions of Vembanad Lake area, soils belong to alluvial type in parts of Changancherry, Cherthala and Kottayam, being filled up by silt carried down by the Pamba and other rivers. The coastal alluvia types of soil with a low water-holding capacity as well as a low nutrient status are also found along near shore areas of this region. The peaty soils, also called *kari* soils, are found in areas like Vaikom and Cherthala that are generally submerged under water during monsoon season. These soils are black and heavy and acidic, pH sometimes being as low as 3.9 due to decomposition of organic matter under anaerobic conditions. Sometimes the soils are highly toxic to biota as they contain ferrous and aluminium sulphates in considerable amounts (Raychaudhuri *et al.*, 1963).

Vegetation

The entire backwater area including Vembanad Lake earlier had mangrove vegetation. Mangrove swamps originally occupied the whole of the backwater area, mainly with plants like *Rhizophora apiculata*, *Derris heterophylla*, *Sonneratia alba*, *Acanthus ilicifolius*, *Acrostichum aureum* and *Cerbera manghas*. Most of the mangroves have now been destroyed, and only a few isolated pockets of stunted *Rhizophora* and *Sonneratia* are still observed. In Kerala it has been estimated that there were 700 sq. km. of mangroves in the near past which has been reduced to 50 sq. km. What is left today are remnants of an over exploited system existing in isolated patches. Kumarakom Bird Sanctuary, situated on the bank of Vembanad Lake, is the largest of its kind in Kerala. Vaikom, Vechoor and Kulasekharamangalam areas of Kottayam district support some pockets of mangrove. Under Alapuzha district, Pathiramanal Island, which is on the other bank opposite to Kumarakom Sanctuary, is under Kerala Tourism Development Corporation (KTDC). The island is poor in mangrove vegetation due to human habitation. The extent of mangrove patches at Kumarakom includes 5 ha at KTDC area, 2.5 ha at Kari and 3 ha at Nalupanku areas dominated by *Rhizophora*, *Avicennia* and *Acanthus* species respectively. Patches of mangrove may be seen at Cherthala, Vayalar and Chanthirur along filtration ponds, canals and backwaters of Alapuzha district. In Ernakulam district, mangrove species mainly *Rhizophora*, *Avicennia*, *Acanthus* as well as *Candelia candal* occur in patches at several places like Vypin, Panangad, Marad, Kumbalam and Thripunithura. Both the national highway and the railway tract in this district traverse through the mangrove patches. However, Mangalavanam is unique in conservation of Cochin mangrove diversity.

In the Kumarakom areas on the eastern bank of Vembanad Lake mangrove and mangrove associates are well represented by species like *Acanthus ilicifolius* (Mulan chuli), *Acrostichum aureum*, *Ardisia littoralis*, *Avicennia officinalis*, *Barringtonia racemosa*, *Bruguiera gymnorrhiza*, *Cerbera odollam*, *Clerodendrum inerme*, *Derris trifoliata*, *Dolichandrone spathacea*, *Excoecaria agallocha*, *E. indica*, *Flagellaria indica*, *Heritiera littoralis*, *Hibiscus tiliaceus*, *Kandelia candel*, *Morinda citrifolia*, *Pandanus fascicularis*, *Pongamia pinnata*, *Premna serratifolia*, *Rhizophora apiculata*, *Sonneratia caseolaris*, *Stenochlaena palustris*, *Terminalia catapa* and *Thespesia populnea* besides the epiphytic *Dendrophothoe falcata* and *Viscum orientale*. (Ramachandran and Mohan, 1987).

The common freshwater inhabiting hydrophytes that occur in the lower reaches of Vembanad Lake at Kumarakom areas include species such as *Nymphoides indica, Pistia stratiotes, Salvinia molesta, Eichhornia crassipes, Ludwigia adscendens, Crinum defixum, etc.* (Ramachandran and Mohan, 1987). In the lower regions, coconut and arecanut platations are grown along with mango, jack, pepper, etc. Paddy and tapioca are the main cultivated crops. The coconut is the chief tree in the coastal areas.

Water resource

Several rivers flow into the lake (Fig. 1.2). Major rivers are Periyar (5400 km^2, 244 km) and Chalakudy (1700 km^2, 130 km) on the north and Pamba (2250 km^2, 176 km), Achankovil (1500 km^2, 128 km), Manimala (850 km^2, 90 km), Meenachil (1250 km^2, 78 km) and Moovattupuzha (1550 km^2, 121 km) in the southern region (Mallik and Suchindan, 1984). The river basins spread over an area of about 16200 km^2 out of which lowland, midland and highland areas constitute 22%, 23% and 55% respectively. While flowing down the highlands these rivers bring about an estimated total of 10074 million m^3 of water to the southern sector of the lake.

The Vembanad Lake and the districts of Alapuzha, Kottayam and Ernakulam bordering the lake fall under the broad physiographic division, the lowland regions/ backwater basins stretching along the coastal plain on the western side of Kerala State. The physiographic features of Kerala State and the Vembanad lake environs are summarized in Table 1. Gopalan *et al.* (1983) had shown that the Vembanad estuary which had an area of 36,500 ha in the last century had undergone man-made shrinkage to only 23,350 ha indicating an alarming rate of diminution due to various agricultural, aquacultural, retting and other activities. According to Nair (1990) the diminution in surficial area of Vembanad backwater reveals shrinkage of 51.0 sq. km in 15 years from 230 km^2 in 1968 to 179.25 km^2 in 1983. The physiographic features of Kerala State and Vembanad environs that support and influence the occurrence and distribution of fauna are presented in Table 1.

Table 1. Physiographical features of Kerala State and Vembanad Lake environs

Parameters	Kerala State	Vembanad Lake
Area (in sq km)	38,863	204
Number of districts	14	3
Altitude	1800 m	0–15 m
Latitude	8°18'–12°48' N	9°30'–10° 12'
Longitude	74°52'–77°25' E	76°10'–76°29'
Highest hills	Anamudi – 2695 m	Highland above 100 m
Population	3,18,39,000 (2001 census)	66,46,724 (1991 census)
Population density (per sq km)	819	Above 800
Temperature (°C)		
Summer (av.)	24-33	22-32
Winter (av.)	22-28	21-30

Table-1. Contd.

Parameters	Kerala State	Vembanad Lake
Rainfall	180–380 cm	Around 300 cm
Humidity	35–71 %	40–70 %
Landscape type	Highland, midland and lowland	Lowland
Soil type	Ten soil types such as red loams, laterites, coastal and riverine grayish onallukara, brown hydromorphis, hydromorphic saline, acid saline, black soils forest loams	Acid saline (*kari* soils) and riverine alluvium
Vegetation type	Tropical wet evergreen and semievergreen forests, Tropical moist deciduous and dry deciduous forests, Montane subtropical and temperate, Grasslands, Mangroves forest plantations	Mangrove and aquatic vegetation
Gross cropped area	2969002 ha	50% of 3 adjoining districts
Forest cover (in ha.)	1081509 ha	9000 ha including 295 ha (mangroves)
Water resource (in ha)	4,66,046 ha	23,350 ha
Number of rivers	44	6

MATERIALS AND METHODS

During the course of survey work, a total of 12 stations, 8 from the upstream region or northern sector (Cochin to Thanneeermukkom) and 4 from the downstream region or southern sector (Thanneermukkom) of Thanneermukkam bund of Vembanad Lake surroundings, belonging to 4 districts were surveyed once a year in March, 2002 and 2003. Of the four districts three districts, namely, Ernakulam, Alapuzha and Kottayam are typically adjacent districts, while Azhikode locality of Thrissur district is at the upper extreme tip of the lake. Being an extended part and confluent with the lake, two stations *viz.*, Azhikode and Kottapuram were brought under survey work. The locations of these field collection stations are arranged as upstream and downstream stations as follows and also shown in Fig. 1.3.

Downstream region : (Northern sector : Estuarine type)

1. Azhikode, Thrissur district
2. Kottapuram, Thrissur district
3. Vypin Island, Ernakulam district
4. Kumbalam, Ernakulam district
5. Vaikom, Kottayam district
6. Vayalar, Alapuzha district
7. Cherthala, Alapuzha district
8. Thavenakadave, Alapuzha district

Upstream region : (Southern sector : Nearly Freshwater)

9. Thanneermukkam, Kottayam district
10. Kumarakam, Kottayam district
11. Muhama, Alapuzha district
12. Punnamada, Alapuzha district

Field observations as well as some environmental parameters were noted (Figs. 1.4-1.13). Some water quality parameters were also recorded. The collection of faunal samples of zooplankton, macrozoobenthos, fishes and amphibians were made using plankton net, drag net, cast net, etc. The major higher vertebrates and cultivable fishes were observed in the field. The inventory of vertebrate and invertebrate faunal elements inhabiting the Vembanad lake environs including Cochin backwaters are presented in two articles, while ecological studies, zooplankton, macrozoobenthos, fisheries and socioeconomic aspects are also dealt in this document.

COLLECTION LOCALITIES

1. Azhikode, Thrissur district : This station is situated close to the upper tip/ extension of the lake and the seacoast. It is an important jettyghat of the state, located ca. 52 km north of Cochin town. The edge of the lake bank resembling river bank at this area is protected by concrete work and boulders. The lake bottom is sandy mixed with some amount of a somewhat black sediment. The water surface indicates a thin film of oil spillage from ferry boat and cargo boats carrying bricks, grocery goods, etc. of the Azhikode market. The collections were made on this bank for about one kilometer stretch of the area. Shore collections were mainly made from a sheltered,

semi-exposed and extended area used for harbouring country boats. Semi-aquatic isopods, molluscs and crabs abound the shore area.

2. Kottapuram, Thrissur district : This station, resembling an estuarine river, is located below a paired bridge, 37 km north of Cochin town. Due to high tide and unexposed condition of the shore, mainly plankton collection was made in addition to testing of some water quality parameters. *Nerita,* gastropod molluscs, which were found to be common in occurrence here, were collected from cemented estuarine bank as well as from boulders by handpicking. A few Chinese fishing nets and some non-mechanised fishing boats were seen here.

3. Vypin Island, Ernakulam district : The Vypin island is at the mouth of Vembanad Lake meeting the Arabian Sea. It is one of the most densely populated islands of the state. The jetty area at the southern tip as well as the lighthouse was surveyed at this island. The jetty area at the Vypin island, located about 11 km away from Ernakulum town, is extensively protected by dumping huge boulders. Collections were made at both the places using plankton net, drag net, box-type sampler as well as by handpicking. The lighthouse area is located about 7 km away from Vypin jetty. There are mangrove plants in and around this area. A number of small backwater pools were faunistically explored of which one was in bloom with phytoplankton and having a variety of fish. In general these pools were found to harbour sesarmine and fiddler crabs. The Chinese fishing nets at the jetty area add scenic beauty to the place, while the vast sandflats of the lighthouse area afford inspiring view for the tourists. The island is accessible by boat services. The Chinese fishing nets are huge cantilevered fishing gears set up on teak wood and bamboo poles. During high tide a group of four fishermen operates the system dipping the net in high tide water and lifting it soon after with the fishes in the hold of the net. A huge shoal of sardines was sighted jumping on water as well as on the bank following a motor vessel. Children as well as aged local folk of the Kochi Fort area were seen busy collecting these fishes on the bank of the river.

4. Kumbalam, Ernakulam district : Kumbalam is an important inland fishing village of Ernakulam district, located about 9 km south of Ernakulam town, inhabited by more than 3000 fishermen population. The bank area of the backwater is muddy with scattered mangrove vegetation *Avicennia officinalis* and *Acanthus ilicifolius.* Small sesarmine crabs abounds in this station. Collection was made at low tide from degraded, very sparsely distributed, mangrove mudflats as well as from bag nets operated at this site. Beside a variety of fishes and prawns, etc., a single specimen of echiurid worm was also collected from this locality.

5. Vaikom, Kottayam district : Vaikom is an important fish landing centre. It is the temple town of Kottayam district, situated about 40 km south of Ernakulum town. The legendary Shiva temple here is believed to have been constructed by Lord Parasuram. The embankment of the backwater here is made up of concrete structure with boulder. The water along the backwater edge is deep and difficult for macrobenthic collection. Mainly zooplankton samples were collected along the shore and also from open water using a hired country boat.

6. Vayalar, Alapuzha district : This station is situated 5 km north of Cherthala. The lake here could conveniently be approached from a villager's courtyard. The lake bottom was sandy. Aquatic insects comprising of water bugs and odonate larvae were collected beside crustaceans and mollusks from amongst the aquatic algae and other weeds. A coconut coir factory was located close to the lake and retting of coconut coir was noticed in the lake water. As a result, the lake water turns black in colour.

7. Cherthala, Alapuzha district : This taluk, is an important centre of Christianity since 1st century. The church here at Kokkomangalam was one of the seven churches founded by St. Thomas, one of the twelve disciples of Jesus Christ. This station is located about 10 km north of Thavenakadave. Collection was made from a private garden using plankton net and drag net. Blackish water, decomposition of water hyacinth and breeding of mosquitoes were observed at this station. Brahminy kite, cormorant and gastropod molluscs were found common in occurrence.

8. Thavenakadave, Alapuzha district : This station is situated on the other side of Vaikom jetty. It is a rural village area with *Pandanus* plants and coconut garden. Backwater canals, salt marsh habitats as well as the main backwater course were surveyed. Wetland loving plants like *Acrostichum*, *Alternanthera* and water hyacinth were encountered along the water edges. Both plankton net and drag net collections were made at this station. An interesting semi-decomposed, semi-floating *phumdi* habitat dominated by *Alternanthera*-like plant was observed as the suitable habitat for spider crab.

9. Thanneermukkam, Kottayam district : This station is located at Thanneermukkam bund proper, about 10 km north of Muhamma. The dyke was recently constructed across the lake to reclaim low-lying areas of this wetland for paddy cultivation. Survey was made on either side of the bundh. Salinity measured was 7‰ downstream of the bundh, while it was as high as 14‰ immediately upstream of the bundh. However, collection was made mainly below the bundh. A fisherman was seen collecting fishes using a cast net.

10. Kumarakam, Kottayam district : Located 12 km west of Kottayam town, Kumarakom is a beautiful place for tourists. This is an ideal place for enjoying backwaters and boat cruise. Boats are available on hire around the lake. Salinity at a canal used for ferry services from Kumarakom to Muhamma and the lake proper were tested. The water in the canal showed no salinity, while it increases from zero to 2‰, then 6‰ and 7‰ near the middle of the lake and 8‰ at all the three points tested towards Muhamma side. Sand mining as well as shell collection was observed at a number of places inside the lake using country boats. Both dead and live shell harvesters with their non-mechanised boats were noted. The lake bank at the collection site was steep and concrete-structured and lake margins were highly weed infested. Mainly macrophyte-associated macrofauna were collected at this station using water net. A bird sanctuary is set up here on the eastern bank of Vembanad Lake. The sanctuary

extends over 14 acres of luxuriant vegetation, inhabited by resident and migratory birds like waterfowl, cuckoo, cormorant, owl, storks and ducks. The best time to visit this place is between June and August.

11. Muhamma, Alappuzha district : This station is located 13 km west of Kumarakom. It is an important jettyghat on Vembanad Lake for ferry services between Kumarakom and Muhamma. The jetty area and a nearby canal were surveyed along with testing of some water quality parameters. Due to washing and spilling probably from boat and motor launches, a thin film of oil on surface water was noticed in the jetty area. The lake bottom at this area is sandy, while the canal bottom is both sandy and leaf-littered. Sand mining and shell collection were quite common features here.

12. Punnamada, Alapuzha district : This station is located about 7 km away from Alapuzha town. The Sports Authority of India is located here. At this place an adjacent marsh was surveyed for wetland fauna, yielding a good collection of insects, frogs and weed fishes. Collection in the marsh and also in the lake was made using plankton net, drag net as well as hand picking, especially from marginal weeds of the lake. Though water hyacinth was in abundance, the presence of Phragmites, Ipomoea, Lemna, Lotus, Water lily were not uncommon. Semi-decomposed water hyacinth at the lake margin was found to harbour polychaete worms.

PHYSICOCHEMICAL PARAMETERS

The physicochemical parameters of lake water at various upstream and downstream stations tested in March 2002 and 2003 are pooled and presented in Table 2.

Table 2. Water quality parameters of of Vembanad Lake at different stations.

Parameters	Collecting stations											
	Downstream								Upstream			
	1	2	3	4	5	6	7	8	9	10	11	12
Air temperature	34	31	28	32	32	34	32	32	34	32	33	34
Water temperature	35	35	27	31	31	35	35	32	36	32	34	36
PH	7.3	7.5	7.2	7.4	7.3	6.8	6.7	6.8	6.5	6.8	6.8	6.7
Alkalinity	-	0.2	1.2	0.5	0.7	-	-	0.4	-	-	0.3	0.3
D. O.	6.0	5.8	8.3	7.0	6.0	4.5	3.8	6.2	6.0	3.6	5	4.5
Salinity	31	27	30	30	32	11	12	33	7.0	1.8	8	5

Note : 1. Azhikode, 2. Kottapuram, 3. Vypin Island, 4. Kumbalam, 5. Vaikom, 6. Vayalar, 7. Cherthala, 8. Thavenakadave, 9. Thanneermukkam, 10. Kumarakam, 11. Muhamma, 12. Punnamada

FAUNAL COLLECTIONS

Besides observations on vertebrate fauna and commercially important fishes and shellfishes, collections of invertebrate specimens were made from the lake. The collected materials are comprised of nine different groups (Table 3).

Table 3. Group-wise collections of specimens of Vembanad Lake at different stations.

Groups	Number of specimens collected at different stations											
	Downstream								Upstream			
	1	2	3	4	5	6	7	8	9	10	11	12
Amphibia	-	-	-	-	-	-	-	-	-	-	-	4
Pisces	9	-	12	16	7	4	-	17	1	14	3	65
Crustacea	13	2	19	42	3	18	24	29	39	39	98	94
Insecta	-	-	-	-	-	12	4	-	-	45	9	25
Arachnida	-	-	-	-	-	-	-	-	-	4	1	2
Annelida	-	-	2	-	-	-	1	-	4	5	3	15
Echiura	-	-	-	1	-	-	-	-	-	-	-	-
Mollusca	18	22	16	6	-	6	35	18	2	8	2	10
Zooplankton (lots)	2	2	3	2	4	2	3	4	3	5	4	5

Note : 1. Azhikode, 2. Kottapuram, 3. Vypin Island, 4. Kumbalam, 5. Vaikom, 6. Vayalar, 7. Cherthala, 8. Thavenakadave, 9. Thanneermukkam, 10. Kumarakam, 11. Muhamma, 12. Punnamada

CONSOLIDATED SUMMARY

1. This document deals with 7 chapters, viz., 1. Overview; 2. Ecology; 3. Vertebrate diversity; 4. Invertebrate diversity; 5. Macrozoobenthos; 6. Fisheries and Socioeconomic aspects, and 7. Conservation and Management aspects.

2. Some environmental and water quality parameters were ascertained along with collection of faunal samples as depicted in chapters 1 and 2.

3. The inventory of vertebrate and invertebrate faunal elements inhabiting the Vembanad lake including Cochin backwaters are presented in chapters 3 and 4.

4. In all, 429 species of vertebrates (Pisces -177, Amphibia 10, Reptilia – 23, Aves 198 and Mammalia 21) have been listed.

5. A total of 550 species of invertebrates comprising of Sarcomastigophora (37 species), Ciliophora (8 species), Porifera (3 species), Cnidaria (48 species), Ctenophora (3 species), Nemertina (1 species), Rotifera (13 species), Platyhelminthes (1 species), Nematoda (6 species), Sipuncula (1 species) Mollusca (84 species), Echiura (1 species) Annelida (74 species), Arthropoda (245 species), Bryozoa (18 species), Echinodermata (1 species) and Chaetognatha (6 species) have been collated from this lake ecosystem. Six species of crustacea and nine species of insecta have been recorded for the first time from this backwater ecosystem.

6. Besides 429 species of vertebrates and 550 species of invertebrates, a single species of pelagic turicate, *Doliolum* sp. was also recorded from Vembanad Lake.

7. A composite list of 169 species of macrozoobenthos has been provided in chapter 5 along with occurrence and distribution of 27 crustacean and molluscan benthic species from 12 upstream and downstream stations of this lake.

8. Fisheries and socioeconomic aspects of the Vembanad lake ecosystem have been dealt in chapter 6 to indicate the commonly occurring fish diversity of the lake system as well as biotic resource, abiotic resource and socioeconomic relations pertaining to the lake.

9. Conservation and management aspects of this lake ecosystem have been discussed briefly in chapter 7 of this document.

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Fig. 1.1a. Map of Kerala showing location of Vembanad Lake.

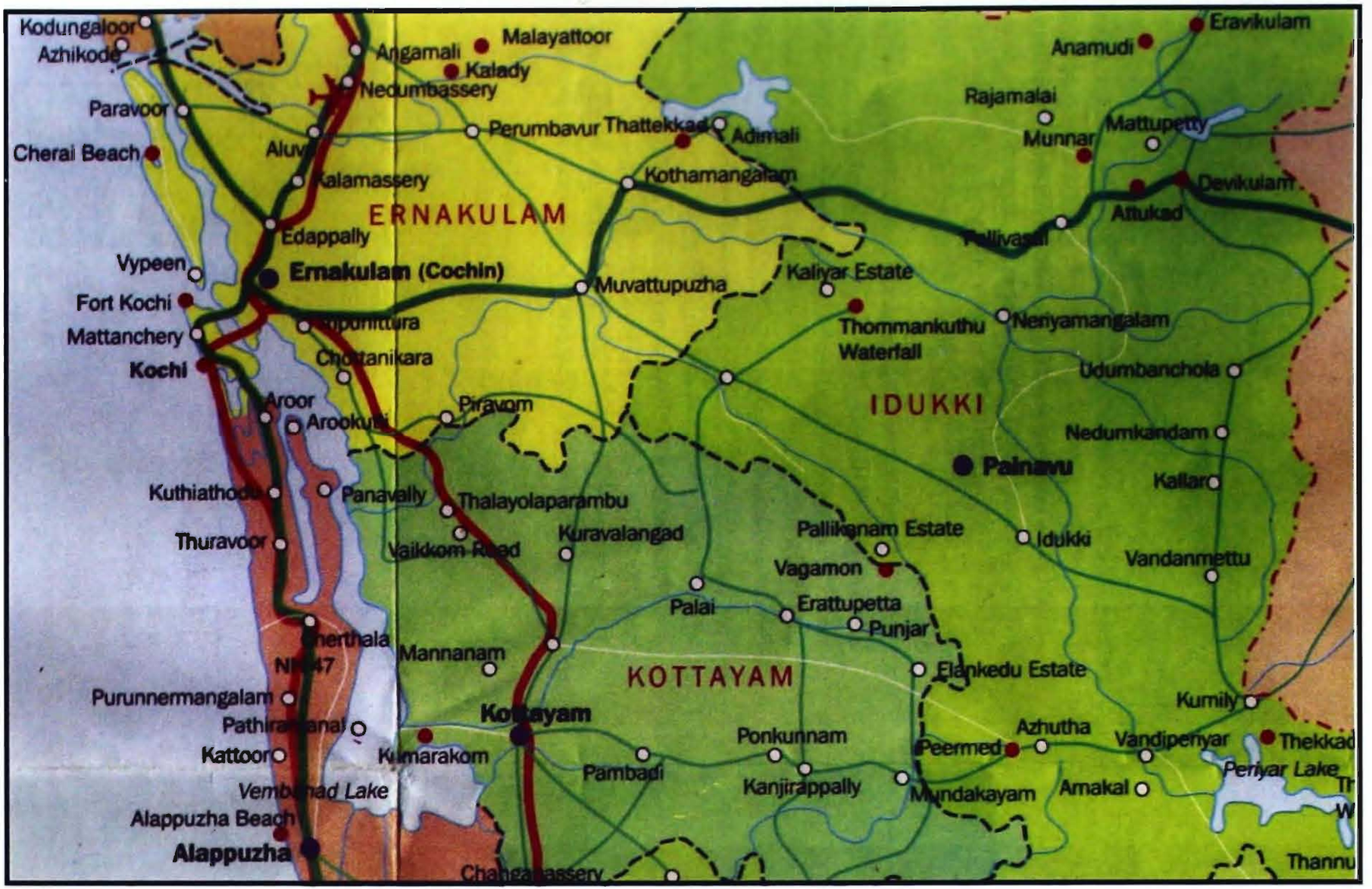

Fig. 1.1b. Map of localities of Vembanad Lake surroundings.

Fig. 1.2. Rivers and Lakes of Kerala including Vembanad Lake.

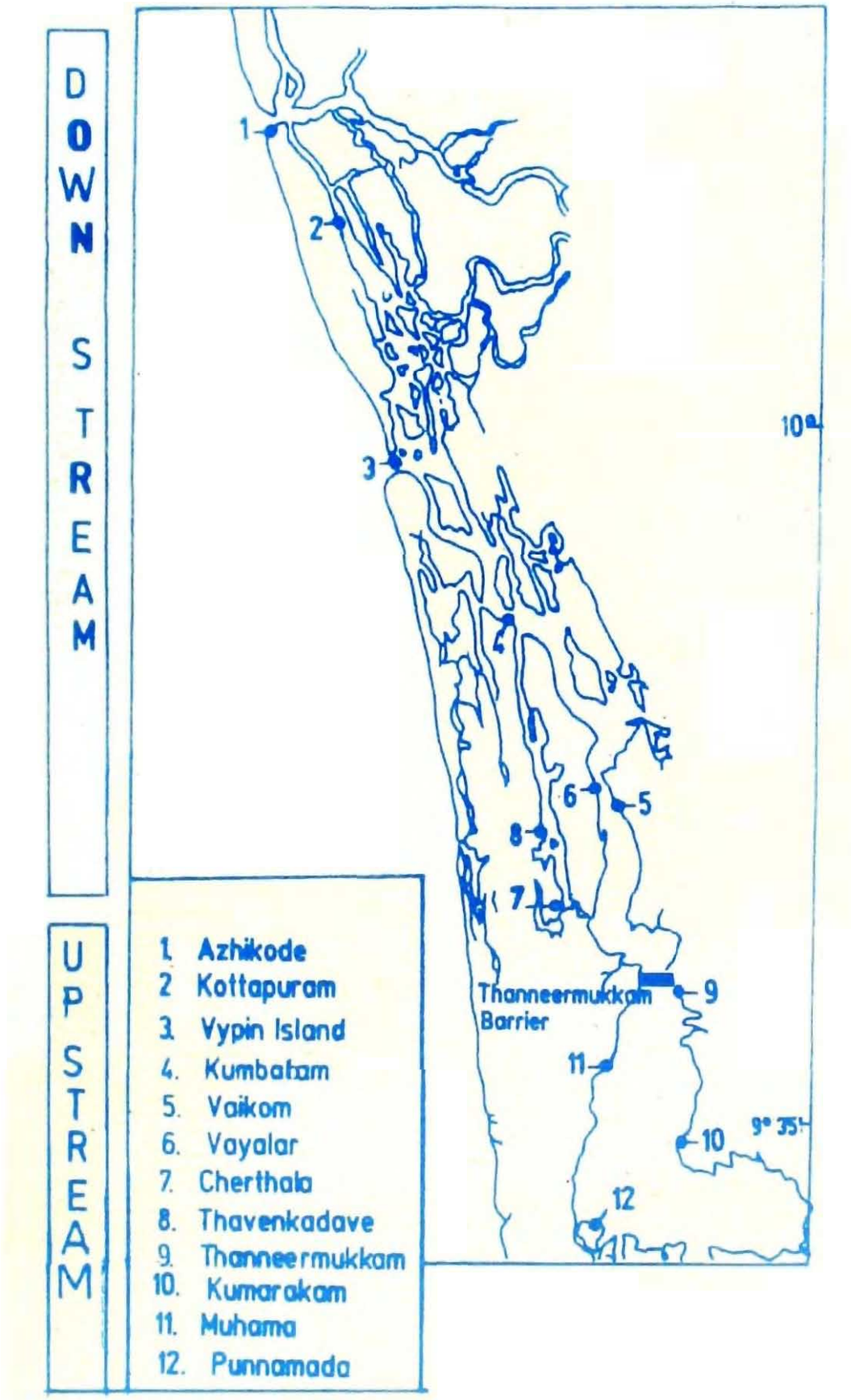

Fig. 1.3. Map of Vembanad Lake showing field collecting stations.

Fig. 1.4. Vembanad estuary/backwater habitat with houseboat and coconut orchard beside backwater

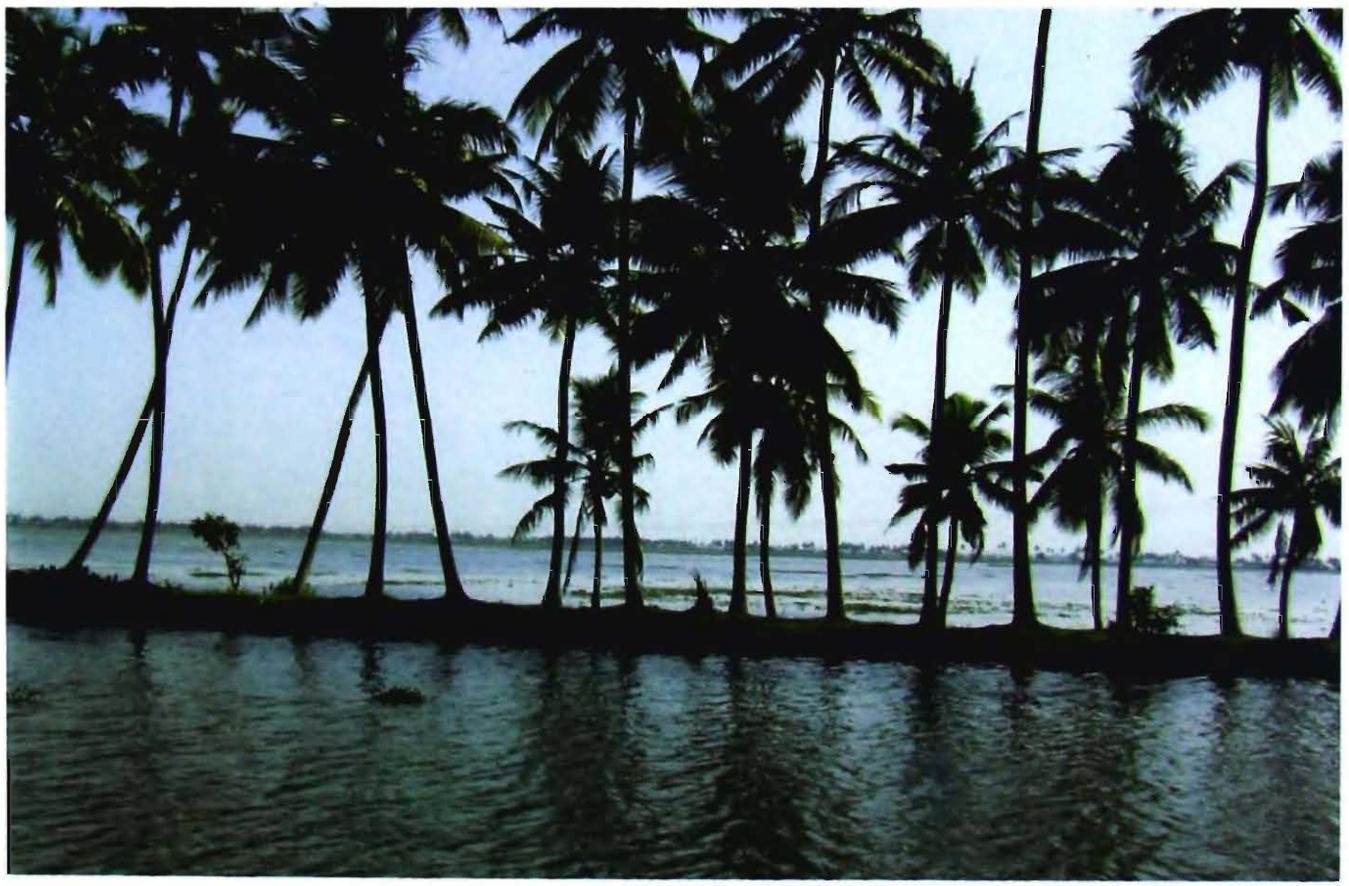

Fig. 1.5. Vembanad estuary and brackishwater impoundment.

Fig. 1.6. Vembanad backwater at Vypin island showing batteries of Chinese fishing nets.

Fig. 1.7. Vembanad Lake at Punnamada showing Sports Authority of India.

Fig. 1.8. Vembanad backwater showing water birds and infestation of water hyacinth.

Fig. 1.9. Kumarakom Lake Resort surrounding beside Vembanad Lake.

Fig. 1.10. Pathiramanal Island mangrove planted area within Vimbanad Lake.

Fig. 1.11. Pathiramanal Island – a side view.

Fig. 1.12. Kumarakom Bird Sanctuary showing luxuriant vegetation.

Fig. 1.13. Weed infestation in Kumarakom backwater.

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GENERAL ECOLOGY

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INTRODUCTION

Vembanad Lake is the largest backwater lake in Asia. The lake stretches along the west coast of India in which Cochin backwaters is situated at the northern tip. The lake has a length of 80 km and a width varying between 500 m and 4000 m. Two channels, one at Azhikode and another at Cochin of 450 m wide connect permanently with the Arabian Sea. Thaneermukkom salinity barrier divides this lake into two entirely different ecosystems *viz.*, northern estuarine sector (downstream region) and southern freshwater sector (upstream region). As such this chapter is incorporated to indicate the general ecology of this lake.

ECOLOGY OF LAKE WATER

Downstream

The northern estuarine sector also known as Cochin backwaters covering an area of 12440 ha extends with its northern boundary at Azhikode and southern boundary at Thaneermukkom bund. Historically, the Cochin estuary is famous for its trade, commerce and cultural activities with countries like Arabia, Portugal and Holland (Menon *et al.*, 2000). The Cochin harbour area has three dredged Channels *viz.*, Approach channel, Ernakulam channel and Mattancherry channel, located around Wellingdon Island and maintained at a depth of 10-13 m for navigation. Being an admixture of freshwater and seawater, this estuarine sector provides nursery ground for marine organisms (Remani *et al.*, 1983; Nair *et al.*, 1988; Sarala Devi *et al.*, 1991). Joseph and Kurup (1989) and Ajith (1996) have studied the stratification and extent of freshwater mixing in Cochin tidal inlet. Extensive studies have been made on the physical, chemical and biological aspects of Cochin estuary as well as impacts due to dredging are also discussed by several investigators (Gopinathan and Qasim, 1971; Anto *et al.*, 1977; Sundaresan, 1989; Rasheed and Balchand, 1995; Rasheed, 1997). However, Cochin backwaters suffer from serious environmental threat due to intertidal land reclamation, pollution, dredging activities and urbanization, etc. (Qasim and Gopinathan, 1969; Qasim and Madhupratap, 1979; Gopalan and Nair, 1975; Gopalan *et al.*, 1983).

Upstream

The southern freshwater sector covers an area of 8610 ha from Thaneermukkom to Kumarakom. Although detailed investigations on the physico-chemical parameters of the Vembanad Lake were documentad in the literature (Ramamritham and Jayaraman, 1963; Cherian, 1967; Jasanto, 1971; Balakrishnan and Shynamma, 1976; Kurup and Samuel, 1987), but most of these studies are confined to the northern estuarine sector of the lake. Before the construction of Thanneermukkom bund, the salinity values of this sector reached 23 ppt (Jasanto, 1971), while Kurup and Samuel (1987) observed that the salinity values were below 3.48 ppt in different seasons. During the course of present survey in March-April month in 2002 and 2003 the salinity values were mostly recorded in the range of 0.5-2 ppt in the near shore/ littoral region at Kumarakom areas.

ECOLOGY OF LAKE SEDIMENT

Sediment chemistry defines and dictates the distribution and abundance of benthic forms. So, the sediment parameters of two different substratum types such as sandy and clayey sand substratum from mangrove region of Cochin backwaters are collected, pooled and presented in Table 1. These are depicted season-wise as follows :

Table 1. Sediment chemistry of soil substratum from mangrove region of Cochin backwaters.

Parameters	**Premonsoon (February-May)**	**Monsoon (June-September)**	**Postmonsoon (October-January)**
Sandy substratum			
Sand	87.44 (86.34-88.76)	84.15 (80.92-85.86)	81.89 (77.24-88.76)
Silt	7.93 (5.19-10.38)	9.30 (4.97-11.56)	4.99 (2.66-9.02)
Clay	4.83 (2.4-8.47)	6.53 (2.75-9.17)	13.11 (7.93-20.10)
pH	6.9 (6.65-7.30)	7.20 (7.10-7.25)	6.5 (6.4-6.6)
Organic carbon	0.54 (0.42-0.77)	0.45 (0.35-0.55)	7.8 (0.64-0.89)
Clayey sand substratum			
Sand	68.55 (62.37-73.33)	61.07 (47.77-74.40)	59.91 (51.86-64.12)
Silt	12.88 (11.10-14.07)	28.01 (19.29-44.28)	14.98 (12.81-17.10)
Clay	19.24 (15.57-23.61)	10.91 (7.95-15.67)	25.10 (19.15-35.33)
pH	6.72 (6.63-6.80)	7.30 (6.90-7.59)	6.33 (6.3-6.4)
Organic carbon	2.01 (1.53-2.35)	1.84 (1.44-2.37)	1.94 (1.65-2.36)

Note : Except pH, all other values are in percentage.
Source : Sunil Kumar (2002)

Texture plays the key role in the distribution of benthic biota. The drastic changes in other ecological factors, especially salinity also play important role in the occurrence, distribution and population pattern of benthos as revealed from researches of several investigators (Sunil Kumar, 2002). The nature and texture of soil substratum presented in Table 1 vary relatively widely in two different substratum types. Among the three other soil factors given, salinity fluctuated most in relation to seasons.

ECOLOGY OF LAKE AND LAKE SURROUNDINGS

A few centuries ago, Kerala backwaters including Vembanad Lake were fringed with rich mangrove vegetation. It has been estimated that there were about 70,000 ha of mangroves in Kerala coast. This has now reduced to a few hundred hectares of area of isolated stands of a few species, which could be widely attributed to encroachment and human interference. Like Kerala coast, the present state of mangrove habitat is same all along the Vembanad estuary except the remnant silver lining of Kumarakom mangroves. The existence of a few hectares of Kumarakom mangrove greenary is the only extensive mangrove habitat left untouched by man in the Vembanad estuary (Ramachandran and Mohan, 1987). However, climbers and semi-parasitic plants predominates the area and the existing mangrove is threatened by the drastic ecological change brought about by human interference particularly for the prevention of saline intrusion in the southern sector after the construction of Thanneermukkom barrage. As a result, paddies are widely grown in the low lying areas (Fig. 2.1) of Vembanad estuary, while freshwater macrophytes have flourised in lake water birds (Fig. 2.2-2.4).

IMPACT OF THANNEERMUKKOM BARRIER

Thanneermukkom barrier divides the Vembanad Lake into two different ecosystems, downstearm region (Cochin backwaters) retaining estuarine character and upstream region (Kumarakom backwaters) transforming into freshwater habitat. The construction of a 1402 m long barrier at Thanneermukkom, preventing saltwater intrusion into the southern part of the lake has resulted in the conflicting interests of the agriculturists and fishermen (Batcha and Damodaran, 1987; Kurup *et al.*, 1990b). In the southern sector, Kurup and Samuel (1985) recorded fluctuations of salinity and dissolved oxygen in the range of 0.34 to 3.79 ppt and 1.98 to 5.90 ml/l respectively. In this sector, the salinity value could not be observed beyond 10 ppt. This finding corroborates with that of Kurup *et al.* (1990) who reported the occurrence of maximum saline condition (6 ppt) during March in a relatively deeper area (5 m), just south of the barrier. In the southeastern extensive shallow areas (1-2 m), the salinity did not exceed 4 ppt, in the southwestern regions, the highest salinity of 2 ppt was recorded, while the region running parallel to the southern and eastern borders remained fresh (less than 0.5 ppt), even during the dry season.

Before the commissioning of the Thanneermukkom barrier in 1976, the entire lake was a single waterbody for free movement of marine fishes, prawns and other aquatic animals. Due to the closure of the shutters of the Thanneermukkom barrage, such free movement for foraging purpose becomes restricted. The salt water incursions as well as tidal flow have been completely arrested leading to unfavourable environment of the upstream regions for marine fauna. Reclamation of land and construction of bund and bridges on the lake and approach roads destroy floodplain, which is the breeding ground of many fish species. It may be mentioned that the Cochin backwater has been severely suffering from anthropogenic stresses over the last five decades. The construction of Cochin port between 1930 and 1940 and the reclamation of Wellingdon Island caused major changes in this backwater system. The port activities had resulted in circulation blockages and reduced water flow. The construction of spillway channel in 1955 for flood control at Thottapally for increasing the agricultural production of Kuttanad region was another human activity in the area. It has been reported that out of 33 fish species the catches of several species have declined. Absence of *Scylla serrata* crab fishry in the southern sector of the lake was recorded after the construction of the bund. The prawn catches have also dwindled. The growth of the weed, *Salvinia* has become phenomenal which has created problem for paddy cultivation, water transport and fishing (Menon *et al.*, 2000).

A wide variety of faunal elements, particularly fishes, plankton and benthos, inhabit the Vembanad Lake. Several studies were made to evaluate the faunal diversity and seasonal and regional distribution of fishes (Shetty, 1965; Kurup, 1982; Kurup and Samuel, 1983; 1985; 1987) and crustaceans (Menon and Raman, 1961; George, 1965; Kuttyamma, 1975; Kuttyamma and Antony, 1975; Devasia and Balakrishnan, 1985) including assessment of fishery resources of the lake due to impact of the barrier (Kurup *et al.*, 1990a,b). Unnithan *et al.* (2001) recorded a substantial change in the faunal composition, indicating new entrants and disappearance of fishes and prawns from Vembanad Lake (Table 2). The southern sector of the lake, which was an ideal habitat for heterogenous assemblages of euryhaline marine fishes and crustaceans, has become completely devoid of euryhaline as well as stenohaline marine species (Menon *et al.*, 2000). The production level in the upstream sector was 10.96% of the downstream estuarine sector. The very low production in the southern freshwater sector was accredited due to the general scarcity of commercial fishes. The total absence of *Liza macrolepis*, *Sillago sihama*, *Ambassis commersoni*, *Penaeus indicus*, *P. monodon* and *P. semisulcatus* was recorded. More than 99.5% of the commercially important fishes (*Daysciaena albida*, *Gerres filamentosus*, *Tachysurus maculatus*, *Mugil cephalus*, *Ambassis gymnocephalus*, *Glossogobius giuris*, *Leiognathus brevirostris* and *L. equulus*) were harvested in addition to more than 95% catch of *Ehirava fluviatilis*, *Liza parsia*, *Caranx ignobilis* and *Mystus gulio* from the northern sector. Besides bulk landings of *Amblypharyngodon mola*, *Ambassis dayi*, and *Hyporhamphus xanthopterus*, the pearl spot showed slight dominance (55%) in the southern sector (Kurup *et al.*, 1990b).

Table 2. Alteration in species composition of fishes in the southern sector of the Lake consequent to to the barrage construction.

New entrants to the system (Fish)	Species disappeared (Fish and prawn)
Anguilla bicolor	**Fish**
Puntius sarana	*Nematolosa nasus*
P. filamentosus	*Tachysurus falcatus*
P. mahecola	*Ophichtyus microcephalus*
Labeo dussumieri	*Haplochilus lineatus*
L. rohita	*Mugil troscheli*
Catla catla	*Eleutheronema* sp.
Tetradactylum sp.	*Therapon puta*
Wallago attu	*Lutianus johnii*
Ompok bimaculatus	*Leognathus* sp.
Amblypharyngodon mola	*Gerres oblongus*
Heteropneustes fossilis	*Trichogaster brevirosteris*
Clarius batrachus	
Mastacembelus armatus	**Prawn**
Macrognathus guentheri	*Palaemon carcinus*
Channa striatus	
Anabas testudineus	

Source : Unnithan *et al.* (2001)

Like-wise, 98.2% of the penaeid prawns were landed from the northern sector. *Metapenaeus dobsoni* and *M. monoceros* were the only species sporadically obtained from the southern sector (less than 2%), while fishery of *Penaeus indicus*, *P. monodon* and *P. semisulcatus* were exclusively contributed by the northern sector. The edible crab, *Scylla serrata* was recorded from southern sector as migrant species and it is surprising that the freshwater prawns, *Macrobrachium rosenbergi* (58.57%) and *M. idella* (78%) also showed dominance in the northern sector (Kurup *et al.*, 1990).

IMPACT OF POLLUTION

Besides the impact of barrier, water pollution resulting from retting of coconut husk (Fig. 2.4), industrial effluents, pesticides, chemical fertilizers, market wastes, natural wastes from decay and decomposition of dense algal growth at certain areas of the lake

and domestic wastes all that are dumped into the lake interfere with the water quality of the lake ecosystem. The retting activities in the lake have resulted in extensive pollution causing a large scale depletion of resources in the retting zones along with health problems faced by the workers engaged in retting of coconut husk and related operations (Bijoy Nandan and Unnithan, 1998). Unnithan *et al.* (1975), Vijayan *et al.* (1975) and Sarala Devi *et al.* (1979) studied the effect of organic pollution on the water quality of Cochin backwaters, while Sarala Devi (1986) assessed the impact of industrial pollution on benthic communities in the backwaters. subsequently, Sunil Kumar and Antony (1994) identified the polychaete worm, *Paraheteromastus tenuis* Monro as an indicator species of pollution in Cochin backwaters.

Units causing water pollution at the upstream regions in and around Kottayam surroundings are listed as follows (Table 3) :

Table 3. Units causing Vembanad lake water pollution.

Sl. No.	Name of Block/ Panchayat	Name of the unit	Nature of effluents
1.	Vaikom : Chempu	HNL	–
2.	Kaduthuruthy : Velloor	Velloor HPC	Paper, pulp & Rayon
3.	Ettumanoor : Kumaranalloor	1. Premier Tyres, Nattassery 2. Popular Automobiles 3. South Indian Timber Depot	Rubber Oil & Rubber Chemicals and woods
4.	Ettumanoor : Athirampuzha	1. Market 2. Jass Flour Mills	Fishery wastes Wheat wastes
5.	Pallom : Nattakom	1. Electrochemicals 2. Travancore cements 3. Creep Mills (40 Nos) 4. Rubber factories	Chemicals Alkaline wastes Rubber wastes Rubber wastes
6.	Pallom : Vijayapuram	1. MRF 2. Fertilizer factory	Rubber wastes Bone wastes

Source : Panfish Book, Kottatyam District, Dept. of Fisheries, Kerala, 2001.

In Vembanad Lake including Cochin backwaters a list of 150 fishes inhabiting the backwater system is available (Kurup, 1982). In Cochin backwaters, the scientific literature of different trophic communities like plankton (George, 1958; Menon *et al.*, 1971; Silas and Pillai, 1975; Madhupratap, 1978; Madhupratap and Rao, 1979), benthos (Sunil Kumar, 1995), meio- and microfauna (Jayasree,1971; Sunil Kumar, 1995), biofoulers (Menon and Nair, 1967; Menon, 1971; Meenakumari and Nair, 1994),

bivalves (Salih, 1977; Nair, 1985; Kattickaran, 1989; Sreedhar, 1991), wood borers (Cherian, 1977; Nair, 1994), are also available. The declining trend of fish production as well as fish kills has also been recorded (Kurup *et al.*, 1990a, b, 1993; Kurup, 1992). However, the precise information on productivity fluctuations of fishery resources and population distribution of different faunal groups in the past as well as in the present are highly insufficient to understand the impact of large scale industrialization and the consequent effluent discharge around the lake. Extensive sand mining activity in the upstream southern region also contributes to turbidity, substratum erosion leading to the destruction of ecological niche of native organisms. Besides these, higher inflow of pesticides from the surrounding region affects the health of the ecosystem. At present, fishery productivity at various fishing zones of the lake seems to be critically altered. A detailed information on the trophic structure of the lake system including plankton, benthos, periphyton, shellfish and finfish resources etc., is essential particularly pertaining to abundance and spatial distributions for ecorestoration and formulating appropriate management measures.

CONCLUSION

It is revealed that Vembanad Lake has been subjected to a lot of made-made alterations in both the sectors of this backwater. The port activities and construction of barrage, spillway channel, roads etc., along and across the lake have affected the life support system. Thus it is high time to check and monitor the limnological and biological features of the lake so that further deterioration of lake environment may be prevented and naturalness of the ecosystem is restored

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Fig. 2.1. Vembanad estuary with low-lying paddy fields.

Fig. 2.2. Vembanad estuary showing a wide variety of lake vegetation.

Fig. 2.3. Vembanad estuary offering ideal habitat for water birds.

Fig. 2.4. Vayalar backwater of Vembanad lake showing coconut husk industry effluent affected area.

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VERTEBRATE DIVERSITY OF ENVIRONS

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INTRODUCTION

The Vembanad Lake, located between latitude 9°28' and 10°10' North and longitude 76°13'and 76°31', is the largest brackish water body in South India, spread over Ernakulam, Kottayam and Alapuzha districts of Kerala State. It has got a geographical extent of about 21050 ha, stretching from Cochin bar-mouth to Alappuzha, for a distance of 83 km, at widths ranging from about 15 km to a few hundred meters. The south-north stretching lake wetland, formerly a single, unitary water body, presently remains bifurcated as a result of the construction of a 1402 m long barrier at Thannermukkom to prevent salt water intrusion, thus forming two artificially isolated lake-water bodies : the northern brackish water sector, the low-reach areas (12440 ha) from Cochin to Thannermukkom (Cochin backwaters area), and the southern freshwater sector, up-reach areas (8610 ha) from Thanneermukkom to Alappuzha. The lake along with the adjacent Kole wetlands form one of the newly designated Ramsar sites of Kerala.

Four major rivers originating in the Western Ghats drain into the lake. The numerous small islands, mangrove forests, mudflats and the adjacent paddy fields provide good shelter and foraging grounds for many birds and animals.

Apart from the ornithological explorations (Nameer, 1993; Sreekumar, 2001, 2002, 2003 & 2004), no comprehensive work on the fauna of the lake is available in scientific literature. Hence an attempt is made to collate the information on the major vertebrate faunal elements so far recorded from the area.

PISCES

The Vembanad lake system exhibits a high diversity of fishes, which is a feature, primarily, linked to the lake-habitat characteristics, the tropical conditions, including its primal placement in the threshold of the vast open Indian Ocean. The lake system formed of the estuarine/brackish water habitats functions as a primary reservoir of the nutrients that are brought into it by the feeding river systems. Part of this nutrient load

gets discharged to the marine system mainly when the lake receives intense river run offs during monsoon, thereafter rest of the nutrient stock is retained within the lake system, becoming integrated with the biological recycling processes, which gets up-heaved and disturbed in the next wet season. The apparent 'calm-phase' of the lake during the pre and post monsoon seasons facilitates rich biomass production of the phytoplankton, zooplankton and benthos (Desai and Krishnankutty, 1967; Silas and Pillay, 1975). At the same time, during the off-season, the tidal inflows alter the lake environment to make it yet again diverse in its physiochemical and biological habitat parameters. As for example, the salinity as one key parameter component, which invariably acts in a gradient pattern, during the off-season, between the extremes of marine/estuarine habitat system on one side and the freshwater habitat system (the inland rivers) on the other, becomes the main limiting factor that determines the diversity or evenness of the biotic communities, including fishes, during the off-season. Its effect as a limiting factor gets diluted or nullified in the heavy inflows from the rivers during the monsoon. The congenial conditions provided by the fresh inflows, nutrients and other parameters altogether usher into the making of a different fish-diversity composition during this period. Thus, the lake's aquatic faunal communities, like fishes, obviously exhibit a better diversity in their morphology, in the habitat environment they occupy, and in their biology.

The freshwater fish species in the diversity list is only an estimate of the species found only in freshwater areas of the lake, especially the river openings (or inland limnetic waters with channeled ducts to the lake), or virtually so regardless of weak salinity (i.e., they may rarely occur in weak brackish waters). The diadromous species, like the eel, *Anguilla bengalensis bengalensis*, and semi-anadromous forms, like the freshwater herring, *Dayella malabarica*, may establish landlocked populations, with little or no direct effect on them by their continued occupation in freshwater habitats.

Some salient studies on the diversity and seasonal distribution of fishes of Vembanad Lake system have come from the works of Pillay (1960), Shetty (1965), Kurup (1982), Kurup and Samuel (1983, 1985, 1987). Kurup and Samuel (1987), with reference to the fish-diversity feature of the Vembanad Lake, have made a systematic listing with 139 species, and their seasonal occurrence and frequency in the lake waters, based on fish catches and their composition. The fish life harboured by the Lake includes not only those species that are perennially present or 'resident' forms, but also the seasonal, migrant visitors to the estuarine or brackish waters, and occasional vagrant forms from the sea. The combination of these categories among the fish diversity becomes apparently evident to observation when the season based catch composition from fish-landing sites, or from collection samples, obtained annually, are subjected to analysis.

Among the physiographic conditions or factors that seems to have a well-perceptible or observable influence on the diversity feature of the fish fauna of the lake system, are mainly the features of salinity and the monsoon-linked annual floods, followed by temperature and sedimentation factors.

The fishery information on inland fishes from Vembanad Lake is often subject to fragmentary statistics of data from the fish landing centers. According to one detailed study (Kurup *et al.*, 1989) on the fishery potential of Vembanad Lake, based on fish landing data, out of a total fishery production of 7202 t for the year (1989), the finfish output constituted only 3297. 2 t, and the rest of the stock being shellfish, comprising mainly prawns and crabs. However, the corresponding fishery data from the earlier period - 26,858 t in 1968 (Rasalam & Sebastian, 1976), 21,490 t in 1984 (Achary, 1987) - evidently suggest a declining trend of the fishery stock/potential of the lake system.

A systematic list of fishes comprising 176 species belonging to 113 genera, under 61 families of 16 orders reported from the Vembanad Lake system is presented below (Table, 1).

Table 1 : Systematic List of Fishes of Vembanad Lake System, Kerala.

No.	Classification/Species	Remarks
	Order ELOPIFORMES	
	Family ELOPIDAE	
1.	*Elops machnata* (Forsskal)**	BW~FW
	Family MEGALOPIDAE	
2.	*Megalops cyprinoides* (Broussonet)**	,,
	Order ANGUILLIFORMES	
	Family ANGUILLIDAE	
3.	*Anguilla bengalensis bengalensis* (Gray)**	,,
4.	*Anguilla bicolor bicolor* McClelland***	BW
	Family MURAENIDAE	
5.	*Lycodontis tile* (Hamilton-Buchanan)***	,,
6.	*Thyrsoidea macrura* (Bleeker)***	,,
	Family: OPHICHTHIDAE	
7.	*Lamnostoma orientalis* (McClelland) ***	,,
8.	*Pisodonophis boro* (Ham.-Buch.)	BW~FW
	Family MURAENESOCIDAE	
9.	*Congresox talabon* (Cuvier)***	BW
10.	*Congresox talabonoides* (Bleeker)***	,,

No.	Classification/Species	Remarks
11.	*Muraenesox bagio* (Ham.-Buch.)***	BW
12.	*Muraenesox cinereus* (Forsskal)***	,,
	Order CLUPEIFORMES	
	Family ENGRAULIDIDAE	
13.	*Stolephorus commersonii* Lacepede***	BW
14.	*Stolephorus indicus* (van Hasselt)***	,,
15.	*Thryssa kammalensis* (Bleeker)***	,,
16.	*Thryssa malabarica* (Bloch)***	,,
17.	*Thryssa mystax* (Schn.)***	,,
18.	*Thryssa purava* (Ham.)***	,,
19.	*Thryssa setirostris* (Brouss.)***	,,
	Family CLUPEIDAE	
20.	*Sardinella gibbosa* (Bleeker)***	,,
21.	*Sardinella longiceps* Val.***	,,
22.	*Escualosa thoracata* (Val.)***	,,
23.	*Nematalosa nasus* (Bloch)***	,,
24.	*Anodontostoma chacunda* (Ham.)***	,,
25.	*Dussumieria acuta* Val.***	,,
26.	*Dayella malabarica* (Day)**	BW~FW
27	*Ehirava fluviatilis* Deraniyagala**	,,
	Family PRISTIGASTERIDAE	
28.	*Ilisha melastoma* (Schneider)***	,,
	Order GONORHYNCHIFORMES	
	Family CHANIDAE	
29.	*Chanos chanos* (Forsskal)**	,,
	Order: CYPRINIFORMES	
	Family: CYPRINIDAE	
30.	*Horadandia atukorali* Deraniyagala	FW
31	*Rasbora daniconius* (Hamilton)	,,

No.	Classification/Species	Remarks
32.	*Amblypharyngodon mola* (Ham.)	,,
33.	*Puntius amphibius* (Valenciennes)	,,
34.	*Puntius filamentosus* (Valenciennes)	BW
35.	*Puntius sarana subnasutus* (Valenciennes)	,,
36.	*Puntius vittatus* Day	,,
37.	*Labeo dussumieri* (Val.)	,,
	Order SILURIFORMES	
	Family BAGRIDAE	
38.	*Horabagrus brachysoma* (Gunther)**	BW~FW
39.	*Mystus gulio* (Hamilton-Buchanan)**	,,
40.	*Mystus malabaricus* (Jerdon)**	,,
41.	*Mystus oculatus* (Valenciennes)**	,,
42.	*Mystus vittatus* (Bloch)**	,,
	Family SILURIDAE	
43.	*Ompok bimaculatus* (Bloch)	FW
44.	*Ompok malabaricus* (Valenciennes)**	FW~BW
45.	*Wallago attu* (Bloch & Schneider)**	,,
	Family HETEROPNEUSTIDAE	
46.	*Heteropneustes fossilis* (Bloch)	FW
	Family ARIIDAE	
47.	*Arius arius* (Hamilton-Buchanan)***	BW
48.	*Arius maculatus* (Thunberg)***	,,
49.	*Arius subrostratus* Val.***	,,
	Family PLOTOSIDAE	
50.	*Plotosus canius* Ham.***	,,
51.	*Plotosus lineatus* (Thunberg)***	,,
	Order AULOPIFORMES	
	Family SYNODONTIDAE	

No.	Classification/Species	Remarks
52.	*Saurida undosquamis* (Richardson)***	,,
	Order BATRACHOIDIFORMES	
	Family BATRACHOIDIDAE	
53.	*Austrobatrachus dussumieri* (Val.)***	,,
	Order MUGILIFORMES	
	Family MUGILIDAE	
54	*Liza macrolepis* (Smith)**	BW
55.	*Liza parsia* (Hamilton-Buchanan)**	,,
56.	*Liza subviridis* (Valenciennes)**	,,
57	*Liza vaigiensis* (Quoy & Gaimard)	,,
58.	*Mugil cephalus* Linnaeus**	BW~FW
59.	*Valamugil cunnesius* (Valenciennes)**	BW
60.	*Valamugil speigleri* (Bleeker)**	,,
	Order ATHERINIFORMES	
	Family ATHERINIDAE	,,
61.	*Atherinomorus duodecimalis* (Val.)**	BW~FW
	Order BELONIFORMES	
	Family ADRIANICHTHYIDAE	
62.	*Horaichthys setnai* Kulkarni**	,,
	Family BELONIDAE	
63.	*Strongylura leiura* (Bleeker**	,,
64.	*Strongylura strongylura* (van Hasselt)**	,,
65.	*Tylosurus crocodilus* (Peron & Le Sueur)**	,,
66.	*Xenentodon cancila* (Ham.-Buch.)	FW
	Family HEMIRAMPHIDAE	
67.	*Hyporhamphus limbatus* (Valenciennes**	BW
68.	*Hyporhamphus xanthopterus* (Val.)**	,,
69.	*Rhynchorhamphus malabaricus* Collette**	,,

No.	Classification/Species	Remarks
70.	*Zenarchopterus gilli* Smith**	,,
	Order CYPRINODONTIFORMES	
	Family APLOCHEILIDAE	
71.	*Aplocheilus blocki* (Arnold)	FW
72.	*Aplocheilus lineatus* (Valenciennes)	,,
	Family POECILIIDAE	
73.	*Gambusia affinis* (Baird &Girard) — Exotic	FW
	Order GASTEROSTEIFORMES	
	Family SYNGNATHIDAE	
74.	*Ichthyocampus carce* (Hamilton)**	BW~FW
75.	*Microphis brachyurus* (Bleeker)**	,,
76.	*Microphis cuncalus* (Hamilton)**	,,
	Order SYNBRANCHIFORMES	
	Family SYNBRANCHIDAE	
77.	*Ophisternon bengalense* McClelland**	BW
	Family MASTACEMBELIDAE	
78.	*Macrognathus guentheri* (Day)	FW
79.	*Mastacembelus armatus* (Lacepede)**	FW~BW
	Order SCORPAENIFORMES	
	Family PLATYCEPHALIDAE	
80.	*Platycephalus cantori* Bleeker***	BW
81.	*Platycephalus indicus* (Linnaeus)***	,,
	Order PERCIFORMES	
	Family CHANDIDAE (=AMBASSIDAE)	
82.	*Ambassis commersoni* Cuvier**	BW~FW
83.	*Ambassis dussumieri* Cuvier**	,,
84.	*Ambassis gymnocephalus* (Lacepede)**	,,
85.	*Ambassis nalua* (Hamilton-Buchanan)**	,,

No.	Classification/Species	Remarks
86.	*Parambassis dayi* (Bleeker)	FW
87.	*Parambassis ranga* (Hamilton)	,,
88.	*Parambassis thomassi* (Day)	,,
	Family SERRANIDAE	
89.	*Epinephelus malabaricus* (Schneider)***	BW
90.	*Epinephelus tauvina* (Forsskal)***	,,
	Family SILLAGINIDAE	
91.	*Sillago sihama* (Forsskal)***	BW
92.	*Sillago vincenti* McKay***	,,
	Family CARANGIDAE	
93.	*Alectis indicus* (Ruppell)***	,,
94.	*Alepes djedaba* (Forsskal)***	,,
95.	*Carangoides praeustus* (Bennett)	,,
96.	*Caranx carangus* (Bloch)***	,,
97.	*Caranx ignobilis* (Forsskal)***	,,
98.	*Caranx melampygus* Cuvier***	,,
99.	*Caranx sexfasciatus* Quoy & Gaimard***	,,
100.	*Megalaspis cordyla* (Linnaeus)***	,,
101.	*Scomberoides commersonianus* Lacepede***	,,
102.	*Scomberoides tala* (Cuvier)***	,,
103.	*Scomberoides tol* (Cuvier)***	,,
104.	*Trachinotus baillonii* (Lacepede)	,,
105.	*Trachinotus blochii* (Lacepede)***	,,
	Family LEIOGNATHIDAE	
106.	*Gazza minuta* (Bloch)***	,,
107.	*Leiognathus berbis* (Valenciennes)***	,,
108.	*Leiognathus bindus* (Valenciennes)***	,,
109.	*Leiognathus brevirostris* (Valenciennes)***	,,

No.	Classification/Species	Remarks
110.	*Leiognathus daura* (Cuvier)***	,,
111.	*Leiognathus equulus* (Forsskal)***	,,
112.	*Leioganthus splendens* (Cuvier)***	,,
113.	*Secutor insidiator* (Bloch)***	,,
114.	*Secutor ruconius* (Hamilton)***	
	Family LUTJANIDAE	
115.	*Lutjanus argentimaculatus* (Forsskal)	,,
116.	*Lutjanus fulviflammus* (Forsskal)***	BW
117.	*Lutjanus johni* (Bloch)***	,,
118.	*Lutjanus rivulatus* (Cuvier)***	,,
119.	*Lutjanus russelli* (Bleeker)***	
	Family GERREIDAE	
120.	*Gerreomorpha setifer* (Ham.-Buch)**	BW~FW
121.	*Gerres abbreviatus* Bleeker**	,,
122.	*Gerres filamentosus* Cuvier**	,,
	Family HAEMULIDAE (Pomadasyidae)	
123.	*Plectorhynchus nigrus* (Cuvier)***	BW
124.	*Pomadasys hasta* (Bloch)***	,,
	Family SPARIDAE	
125.	*Acanthopagrus berda* (Forsskal)***	,,
	Family LETHRINIDAE	
126.	*Lethrinus cinereus* Val.***	,,
127.	*Lethrinus microdon* Val.***	,,
	Family POLYNEMIDAE	
128.	*Eleutheronema tetradactylum* (Shaw)***	,,
	Family SCIAENIDAE	
129.	*Daysciaena albida* (Cuvier)***	,,
130.	*Dendrophysa russelli* (Cuvier)***	,,

No.	Classification/Species	Remarks
131.	*Johnius belangerii* (Cuvier)***	,,
132.	*Johnius carouna* (Cuvier)***	,,
133.	*Protonibea diacanthus* (Lacepede)***	,,
	Family MULLIDAE	
134.	*Parupeneus indicus* (Shaw)***	,,
135.	*Upeneus sulphureus* Cuvier***	,,
136.	*Upeneus vittatus* (Lacepede)***	,,
	Family DREPANIDAE	
137.	*Drepane punctata* (Linnaeus)***	,,
	Family NANDIDAE	
138.	*Nandus nandus* (Hamilton)**	BW~FW
	Family TERAPONIDAE	
139.	*Terapon jarbua* (Forsskal)**	,,
	Family CICHLIDAE	
140.	*Etroplus maculatus* (Bloch)**	FW~BW
141.	*Etroplus suratensis* (Bloch)**	,,
142.	*Oreochromis mossambica* (Peters) - Exotic**	,,
	Family ELEOTRIDIDAE	
143.	*Eleotris fusca* (Schneider)***	BW
144.	*Butis butis* (Hamilton-Buchanan)***	,,
145.	*Bunaka gyrinoides* (Bleeker)***	,,
	Family GOBIIDAE	
146.	*Acentrogobius viridipunctatus* (Val.)***	,,
147.	*Acentrogobius caninus* (Val.)***	,,
148.	*Awaous gutum* (Hamilton)**	BW~FW
149.	*Glossogobius biocellatus* (Val.)***	BW
150.	*Glossogobius giuris* (Hamilton)**	BW~FW
151.	*Gobiopsis macrostoma* Steindachner***	BW

No.	Classification/Species	Remarks
152.	*Oxyurichthys formosanus* Nichols***	,,
153.	*Oxyurichthys microlepis* (Bleeker)***	,,
154.	*Oxyurichthys tentacularis* (Val.)***	,,
155.	*Stenogobius gymnopomus* (Bleeker)***	,,
	Family GOBIOIDIDAE	
156.	*Taenioides buchanani* (Day)***	,,
157.	*Taenioides cirratus* (Blyth)***	,,
	Family TRYPAUCHENIDAE	
158.	*Trypauchen vagina* (Bloch & Schneider)***	,,
	Family SCATOPHAGIDAE	
159.	*Scatophagus argus* (Linnaeus)**	BW~FW
	Family SIGANIDAE	
160.	*Siganus canaliculatus* (Park)***	BW
161.	*Siganus javus* (Linnaeus)***	,,
	Family ACANTHURIDAE	
162.	*Acanthurus xanthopterus* Val.***	,,
	Family SPHYRAENIDAE	
163.	*Sphyraena jello* Cuvier***	,,
	Family ANABANTIDAE	
164.	*Anabas testudineus* (Bloch)**	FW~BW
	Family BELONTIIDAE (=OSPHRONEMIDAE)	
165.	*Pseudosphromenus cupanus* (Valenciennes)	FW
	Family CHANNIDAE	
166.	*Channa marulius* (Hamilton)	,,
167.	*Channa striatus* (Bloch)	,,
	Order PLEURONECTIFORMES	
	Family BOTHIDAE	
168.	*Pseudorhombus arsius* (Ham.)***	BW

No.	Classification/Species	Remarks
	Family SOLEIDAE	
169.	*Euryglossa orientalis* (Bloch and Schneider)**	BW~FW
170.	*Solea ovata* Richardson***	BW
171.	*Synaptura commersoniana* (Lacepede) ***	,,
	Family CYNOGLOSSIDAE	
172.	*Cynoglossus bilineatus* (Lacepede)***	,,
173.	*Cynoglossus puncticeps* (Richardson)***	,,
	Order TETRAODONTIFORMES	
	Family TRIACANTHIDAE	
174.	*Triacanthus biaculeatus* (Bloch)***	,,
	Family TETRAODONTIDAE	
175.	*Chelonodon fluviatilis* (Ham.)***	,,
176.	*Chelonodon patoca* (Ham.)***	,,
177.	*Tetraodon travancoricus* Hora & Nair**	BF~FW

Total = 177 species under 113 genera, 62 families of 16 orders

Note : BW : Brackish water sector; FW : Freshwater sector.

** Common in brackish waters, often migrate to freshwaters (BW~FW) or to brackish-waters (FW~BW).

***Occasional visitors or vagrants from marine/coastal waters to brackish waters.

[The systematic classification followed is after Nelson (1994), except incorporating Gobioididae and Trypauchenidae as separate families (instead of treating them under one family Gobiidae), with appropriate inputs from Jayaram (1999), and as well from Talwar and Kacker (1984) supplemented with species having fishery potential].

AMPHIBIA

A total of 10 species of amphibians have been reported from the Vembanad Lake area (Table 2). The Malabar Gliding Frog (*Rhacophorus malabaricus*), The Golden Frog (*Rana aurantiaca*) and the Common Tree Frog, (*Polypedates maculatus*) were rarely sighted from the locality. Bush frogs (*Philautus sp.*) are heard during monsoon months from the bushes adjoining the lake area. A decline in population of common species such as *Hoplobatrachus tigerinus* and *Euphlyctis hexadactyus* are noticed in the region.

Table 2 : Systematic list of Amphibians known from the Vembanad Lake area.

Sl. No.	Scientific Name	Common Name	Status
	Class AMPHIBIA		
	Order ANURA		
	Family RANIDAE		
1.	*Rana aurantiaca* Boulenger	Golden Frog	Rare
2.	*Rana malabarica* Tschudi	Fungoid Frog	Common
3.	*Hoplobatrachus tigerinus* (Daudin)	Indian Bull Frog	Common
4.	*Fejervarya limnocharis* Garvenhorst	Indian Rice Frog	Uncommon
5.	*Euphlyctis cyanophlyctis* (Schneider)	Skipper Frog	Common
6.	*Euphlyctis hexadactyus* (Lesson)	Indian Green Frog	Uncommon
	Family RHACOPHORIDAE		
7.	*Polypedates maculatus* (Gray)	Common Tree Frog	Uncommon
8.	*Rhacophorus malabaricus* Jerdon	Malabar Gliding Frog	Rare
9.	*Philautus* sp.	Bush Frog	Uncommon
	Family BUFONIDAE		
10.	*Bufo melanosticus* Schneider	Common Indian Toad	Common

REPTILIA

A total of 23 species of reptiles under 11 families belonging to 2 orders have been reported from Vembanad lake region (Table 3). The order Tesdudines (Turtles and tortoises) is represented with 2 species and the Squamata (Lizards and snakes) with 21 species. There are five species of lizards observed from the region. The Southern Green Calotes (*Calotes calotes*), a forest dwelling species was recorded from Kumarakom and Ramankary areas of the lake. (Narayanan *et al.*, 2004). A good population of Monitor Lizard, *Varanus bengalensis* has also been recorded from the wetlands adjoining the Vembanad Lake. 15 species of snakes are reported from the region. Wetland dwelling snake species like Checkered Keelback (*Xenochrophis piscator*), Siebold's Smooth Water Snake (*Enhydrina sieboldi*) and Dog-faced Water Snake (*Cerberus rhynchops*) are well represented. On many occasions, the Common Russel's Kukri Snake (*Oligodon taeniolatus)* has been sighted from the locality (Shibhu Bhaskar. Pers. commn.). Poisonous snakes represented in the area, and occasionally

seen, are the Indian Cobra (*Naja naja*), Russel's Viper (*Vipera russellii*) and the Common Krait (*Bungarus caeruleus*).

Table 3 : Systematic List of Reptiles of Vembanad Lake and its environs

Sl. No.	Scientific Name	Common Name	Remarks
	Class REPTILIA		
	Order TESDUDINES		
	Family EMYDIDAE		
1.	*Melanochelys trijuga* (Schweigger)	Indian Black Turtle	Common The status as per IUCN is LR/nt
	Family TESTUDINIDAE		
2.	*Lissemys punctata* (Lacepede)	Indian Flap-shelled Turtle	Uncommon
	Order SQUAMATA		
	Suborder SAURIA		
	Family GEKKONIDAE		
3.	*Hemidactylus brooki* Gray*	Spotted House gecko	Common
4.	*Hemidactylus frenatus* Schlegel*	Tic-Ticky House Gecko	Common
	Family AGAMIDAE		
5.	*Calotes versicolor* (Daudin)*	Indian Garden Lizard	Common
6.	*Calotes calotes* (Linnaeus)*	Green Forest Lizard	Uncommon
7.	*Cnemaspis* sp*	Palli Day Gecko	Uncommon
	Family SCINCIDAE		
8.	*Mabuya carinata* (Schneider)*	Common Indian Skink	Common
	Family VARANIDAE		
9.	*Varanus bengalensis* (Linnaeus)*	Indian Monitor Lizard	Uncommon
	Suborder SERPENTES		
	Family TYPHLOPIDAE		
10.	*Ramphotyphlops braminus* (Daudin)*	Common Blind Snake	Uncommon

Sl. No.	Scientific Name	Common Name	Remarks
	Family BOIDAE		
11.	*Python molurus* (Linnaeus)*	Indian Rock Python	Rare
	Family COLUBRIDAE		
12.	*Ptyas mucosa* (Linnaeus)*	Indian Rat Snake	Common
13.	*Dendrelaphis tristis* (Daudin)*	Common Indian Bronze-back	Uncommon
14.	*Oligodon taeniolatus* (Jerdon)*	Russel's Kukri Snake	Common
15.	*Lycodon aulicus* (Linnaeus)*	Common Wolf snake	Uncommon
16.	*Xenochrophis piscator* (Schneider)	Checkered Keelback	Common
17.	*Amphisema stolata* (Linnaeus)*	Striped Keelback	Common
18.	*Cerberus rhynchops* (Schneider)	Dog-faced Water Snake	Uncommon
19.	*Enhydris sieboldi* (Schlegel)	Siebold's Smooth Water Snake	Common
20.	*Ahaetulla nasuta* (Lacepede)*	Green Vine Snake	Uncommon
	Family ELAPIDAE		
21.	*Bungarus caeruleus* (Schneider)*	Common Krait	Uncommon
22.	*Naja naja* (Linnaeus)*	Indian Cobra	Uncommon
	Family VIPERIDAE		
23.	*Daboia russellii* (Shaw)*	Russel's Viper	Uncommon

Note : Asterisks (*) indicate dryland associates of Vembanad Lake environs.

AVES

A total of 198 species of birds belonging to 50 families have been reported from Vembanad Lake region (Nameer, 1993; Sreekumar, 2001, 2002, 2003& 2004) [Table 4]. Of these, 54 species are winter migrants. Four species of birds, Spot-billed Pelican (*Pelecanus philippensis*), Oriental Darter (*Anhinga melanogaster*), Black-headed Ibis (*Threskiornis melanocephalus*), Ferruginous Pochard (*Aythya nyroca*), listed in the globally threatened category as per the Red Data Book (Birdlife International, 2001) and NT as per IUCN (2007) are found here.

Table 4 : Systematic list of Birds of Vembanad Lake and its environs.

Nomenclature and classification after Mankadan & Pitte (2001).

Sl. No.	Order/Family/Scientific Name	Common Name	Remarks
	ORDER PODICIPEDIFORMES		
	FAMILY PODICIPEDIDAE		
1.	*Podiceps ruficollis capensis* Salvadori	Little Grebe	A
	ORDER PELECANIFORMES		
	FAMILY PELECANIDAE		
2.	*Pelecanus philippensis philippensis* Gmelin	Spot-billed Pelican	A
	FAMILY PHALACROCORACIDAE		
3.	*Phalacrocorax niger* (Vieillot)	Little Cormorant	A
4.	*Phalacrocorax fuscicollis* Stephens	Indian Shag	A
5.	*Phalacrocorax carbo sinensis* (Shaw)	Great Cormorant	A
6.	*Anhinga rufa melanogaster* Pennant	Oriental Darter	A
	FAMILY ARDEIDAE		
7.	*Egretta garzetta garzetta* (Linnaeus)	Little Egret	WD
8.	*Egretta gularis schistacea* (Hemprich & Ehrenberg)	Western Reef-Heron	WD
9.	*Ardea cinerea rectirostris* Gould	Grey Heron	WD
10.	*Ardea purpurea manilensis* Meyen	Purple Heron	WD
11.	*Casmerodius albus* (Linnaeus)	Large Egret	WD
12.	*Mesophoyx intermedia* (Wagler)	Median Egret	WD
13.	*Bubulcus ibis coromandus* (Boddaert)	Cattle Egret	WA
14.	*Ardeola grayii grayii* (Sykes)	Pond Heron	WD
15.	*Ardeola striatus chloriceps* (Bonaparte)	Little Green Heron	WD
16.	*Nycticorax nycticorax nycticorax* (Linnaeus)	Black-crowned Night Heron	WD
17	*Ixobrychus sinensis* (Gmelin)	Yellow Bittern	WD
18.	*Ixobrychus cinnamomeus* (Gmelin)	Chestnut Bittern	WD

Sl. No.	Order/Family/Scientific Name	Common Name	Remarks
19.	*Dupetor flavicollis* (Latham)	Black Bittern	WD
	FAMILY CICONIIDAE		
20.	*Anastomus oscitans* (Boddaert)	Asian Openbill-Stork	WD
21.	*Ciconia episcopus episcopus* (Boddaert)	White-necked Stork	WD
	FAMILY THRESKIORNITHIDAE		
22.	*Plegadis falcinellus falcinellus* (Linnaeus)	Glossy Ibis	WD
23.	*Threskiornis melanocephalus* (Latham)	Oriental White Ibis	WD
24.	*Platalea leucorodia* Linnaeus	Eurasian Spoonbill	WD
	ORDER ANSERIFORMES		
	FAMILY ANATIDAE		
25.	*Dendrocygna javanica* (Horsfield)	Lesser Whistling-Duck	A
26.	*Nettapus coromandelianus* (Gmelin)	Cotton Teal	A
27.	*Anas poecilorhyncha* J.R. Forster	Spot-billed Duck	A
28.	*Anas acuta* Linnaeus	Northern Pintail	A
29.	*Anas qurquedula* Linnaeus	Garganey	A
30.	*Anas crecca* Linnaeus	Common Teal	A
31.	*Aythya nyroca* (Guldenstadt)	Ferruginous Pochard	A
	ORDER FALCONIFORMES		
	FAMILY ACCIPITRIDAE		
32.	*Elanus caeruleus* (Desfontaines)	Black-shouldered Kite	
33.	*Milvus migrans* (Boddaert)	Black Kite	
34.	*Haliastur indus* (Boddaert)	Brahminy Kite	WA
35.	*Ichthyophaga ichthyaetus* (Horsfield)	Greater Grey-headed Fish-Eagle	WD
36.	*Circus aeruginosus* (Linnaeus)	Western Marsh-Harrier	WD
37.	*Accipiter badius* (Gmelin)	Shikra	
38.	*Hieraaetus pennatus* (Gmelin)	Booted Eagle	WA

Sl. No.	Order/Family/Scientific Name	Common Name	Remarks
39.	*Aquila nipalensis* Hodgson	Steppe Eagle	
	FAMILY PANDIONIDAE		
40.	*Pandion haliaetus* (Linnaeus)	Osprey	WD
	FAMILY FALCONIDAE		
41.	*Falco tinnunculus* Linnaeus	Common Kestrel	
42.	*Falco peregrinus* Tunstall	Peregrine Falcon	WA
	FAMILY RALLIDAE		
43.	*Rallina eurizonoides* (Lafresnaye)	Slaty-legged Crake	WD
44.	*Gallirallus striatus* Linnaeus	Blue-breasted Rail	WD
45.	*Amaurornis phoenicurus* (Pennant)	White-breasted Waterhen	WD
46.	*Porzana pusilla* (Pallas)	Baillon's Crake	WD
47.	*Porzana fusca* (Linnaeus)	Ruddy-breasted Crake	WD
48.	*Gallicrex cinerea* (Gmelin)	Water Cock	WD
49.	*Porphyrio porphyrio* (Linnaeus)	Purple Moorhen	WD
50.	*Gallinula chloropus* (Linnaeus)	Common Moorhen	WD
51.	*Fulica atra* Linnaeus	Common Coot	A
	ORDER CHARADRIIFORMES		
	FAMILY JACANIDAE		
52.	*Hydrophasianus chirurgus* (Scopoli)	Pheasant-tailed Jacana	WD
53.	*Metopidius indicus* (Latham)	Bronze-winged Jacana	WD
	FAMILY ROSTRATULIDAE		
54.	*Rostratula benghalensis* (Linnaeus)	Greater Painted-Snipe	WD
	FAMILY CHARADRIIDAE		
55.	*Pluvialis fulva* (Gmelin)	Pacific Golden Plover	WD
56.	*Charadrius dubius* Scopoli	Little Ringed Plover	WD
57.	*Vanellus malabaricus* (Boddaert)	Yellow-wattled Lapwing	
58.	*Vanellus indicus* (Boddaert)	Red-wattled Lapwing	WA

Sl. No.	Order/Family/Scientific Name	Common Name	Remarks
	FAMILY SCOLOPACIDAE		
59.	*Gallinago gallinago* (Linnaeus)	Common Snipe	WD
60.	*Limosa limosa* (Linnaeus)	Black-tailed Godwit	WD
61.	*Numenius phaeopus* (Linnaeus)	Whimbrel	WD
62.	*Numenius arquata* (Linnaeus)	Eurasian Curlew	WD
63.	*Tringa totanus* (Linnaeus)	Common Redshank	WD
64.	*Tringa stagnatilis* (Bechstein)	Marsh Sandpiper	WD
65.	*Tringa nebularia* (Gunner)	Common Greenshank	WD
66.	*Tringa ochropus* Linnaeus	Green Sandpiper	WD
67.	*Tringa glareola* Linnaeus	Wood Sandpiper	WD
68.	*Actitis hypoleucos* Linnaeus	Common Sandpiper	WD
	FAMILY RECURVIROSTIDAE		
69.	*Himantopus himantopus* (Linnaeus)	Black-winged Stilt	WD
70.	*Recurvirostra avosetta* Linnaeus	Pied Avocet	WD
	FAMILY DROMADIDAE		
71.	*Dromas ardeola* Paykull	Crab-Plover	WD
	FAMILY BURHINIDAE		
72.	*Esacus magnirostris* (Vieillot))	Great Stone-Plover	WD
	FAMILY GLAREOLIDAE		
73.	*Glareola lactea* Temminck	Small Pratincole	WD
	FAMILY LARIDAE		
74.	*Larus heuglini* Bree	Hueglin's Gull	WD
75.	*Larus ichthyaetus* Pallas	Pallas's Gull	WD
76.	*Larus brunnicephalus* Jerdon	Brown-headed Gull	WD
77.	*Larus ridibundus* Linnaeus	Black-headed Gull	WD
78.	*Gelochelidon nilotica* (Gmelin)	Gull-billed Tern	WD
79.	*Sternae caspia* (Pallas)	Caspian Tern	WD
80.	*Sterna bengalensis* Lesson	Lesser-Crested Tern	WD

Sl. No.	Order/Family/Scientific Name	Common Name	Remarks
81.	*Sterna bergii* Lichtenstein	Large Crested Tern	WD
82.	*Sterna saundersi* Hume	Saunder's Little Tern	WD
83.	*Sterna fuscata* Linnaeus	Sooty Tern	WD
84.	*Sterna sumatrana* Raffles	Black-naped Tern	WD
85.	*Sterna repressa* Hartert	White-cheeked Tern	WD
86.	*Chlidonias hybrida* (Pallas)	Whiskered Tern	WD
87.	*Chlidonias leucopterus* (Temminck)	White-winged Black Tern	WD
	ORDER COLUMBIFORMES		
	FAMILY COLUMBIDAE		
88.	*Columba livia* Gmelin	Blue Rock Pigeon	
89.	*Streptopelia chinensis* (Scopoli)	Spotted Dove	
90.	*Chalcophaps indica* (Linnaeus)	Emerald Dove	
91.	*Treron aenea* (Linnaeus)	Green Imperial-Pigeon	
	ORDER PSITTACIFORMES		
	FAMILY PSITTACIDAE		
92.	*Loriculus vernalis* (Sparrman)	Indian Hanging Parrot	
93.	*Psittacula krameri* (Scopoli)	Rose-ringed Parakeet	
94.	*Psittacula cyanocephala* (Linnaeus)	Plum-headed Parakeet	
	ORDER CUCULIFORMES		
	FAMILY CUCULIDAE		
95.	*Clamator jacobinus* (Boddaert)	Pied Crested Cuckoo	
96.	*Hierococcyx varius* (Vahl)	Brainfever Bird	
97.	*Cuculus micropterus* Gould	Indian Cuckoo	
98.	*Eudynamys scolopacea* (Linnaeus)	Asian Koel	
99.	*Centropus sinensis* (Stephens)	Greater Coucal	
	ORDER STRIGIFORMES		
	FAMILY TYTONIDAE		
100.	*Tyto alba* (Scopoli)	Barn Owl	

Sl. No.	Order/Family/Scientific Name	Common Name	Remarks
	FAMILY STRIGIDAE		
101.	*Otus bakkamoena* Pennant	Collared Scops-Owl	
102.	*Ketupa zeylonensis* (Gmelin)	Brown Fish-Owl	WA
103.	*Strix ocellata* (Lesson)	Mottled Wood Owl	
104.	*Glaucidium radiatum* (Tickell)	Jungle Owlet	
105.	*Athene brama* (Temminck)	Spotted Owlet	
106.	*Ninox scutulata* (Raffles)	Brown Hawk Owl	
	ORDER APODIFORMES		
	FAMILY APODIDAE		
107.	*Cypsiurus balasiensis* (J.E. Gray)	Asian Palm Swift	
108.	*Tachymarptis melba* (Linnaeus)	Alpine Swift	
109.	*Apus affinis* (J.E. Gray)	House Swift	
	ORDER CORACIIFORMES		
	FAMILY ALCEDINIDAE	Kingfishers	
110.	*Alcedo atthis* (Linnaeus)	Small Blue Kingfisher	WD
111.	*Halcyon capensis* (Linnaeus)	Stork-billed Kingfisher	WD
112.	*Halcyon smyrnensis* (Linnaeus)	White-breasted Kingfisher	WA
113.	*Halcyon pileata* (Boddaert)	Black-capped Kingfisher	WD
114.	*Ceryle rudis* (Linnaeus)	Lesser-Pied Kingfisher	WD
	FAMILY MEROPIDAE		
115.	*Merops orientalis* Latham	Small Bee-eater	
116.	*Merops philippinus* Linnaeus	Blue-tailed Bee-eater	WA
117.	*Merops leschenaulti* Vieillot	Chestnut-headed Bee-eater	
	FAMILY CORACIIDAE		
118.	*Coracias benghalensis (*Linnaeus)	Indian Roller	
	FAMILY: UPUPIDAE		
119.	*Upupa epops* Linnaeus	Common Hoopoe	

Sl. No.	Order/Family/Scientific Name	Common Name	Remarks
	ORDER PICIFORMES		
	FAMILY CAPITONIDAE		
120.	*Megalaima viridis* (Boddaert)	White-cheeked Barbet	
121.	*Megalaima haemacephala* (P.L.S. Muller)	Coppersmith Barbet	
	FAMILY PICIDAE		
122.	*Dandrocapus nanus* (Vigors))	Brown-capped Pigmy Woodpecker	
123.	*Dinopium benghalense* (Linnaeus)	Lesser Golden-backed Woodpecker	
	ORDER PASSERIFORMES		
	FAMILY PITTIDAE		
124.	*Pitta brachyura* (Linnaeus)	Indian Pitta	
	FAMILY ALAUDIDAE		
125.	*Eremopterix grisea* (Scopoli)	Ashy-crowned Sparrow Lark	
126.	*Galerida malabarica* (Scopoli)	Malabar Crested Lark	
127.	*Alauda gulgula* Franklin	Eastern Skylark	
	FAMILY HIRUNDINIDAE		
128.	*Hirundo rustica* Linnaeus	Common Swallow	WA
129.	*Hirundo tahitica* Gmelin	House Swallow	
130.	*Hirundo smithii* Leach	Wire-tailed Swallow	WA
131.	*Hirundo daurica* Linnaeus	Red-rumped Swallow	
132.	*Hirundo fluvicola* Blyth	Streak-throated Swallow	
	FAMILY MOTACILLIDAE		
133.	*Dendronanthus indicus* (Gmelin) (=*Motacilla indica*)	Forest Wagtail	
134.	*Motacilla alba* Linnaeus	White Wagtail	WA
135.	*Motacilla maderaspatensis* Gmelin	Large Pied Wagtail	WA
136.	*Motacilla citreola* Pallas	Citrine Wagtail	WA

Sl. No.	Order/Family/Scientific Name	Common Name	Remarks
137.	*Motacilla flava* Linnaeus	Yellow Wagtail	WA
138.	*Motacilla cinerea* Tunstall	Grey Wagtail	WA
139.	*Anthus richardi* Vieillot	Richard's Pipit	
140.	*Anthus rufulus* Vieillot	Paddyfield Pipit	
	FAMILY CAMPEPHAGIDAE		
141.	*Coracina macei* (Lesson)	Large Cuckoo-Shrike	
142.	*Coracina melanoptera* (Rüppell)	Black-headed Cuckoo-Shrike	
143.	*Pericrocotus cinnamomeus* (Linnaeus)	Small Minivet	
144.	*Pericrocotus flammeus* (Forster)	Scarlet Minivet	
145.	*Tephrodornis pondicerianus* (Gmelin)	Common Woodshrike	
	FAMILY PYCNONOTIDAE		
146.	*Pycnonotus jocosus* (Linnaeus)	Red-whiskered Bulbul	
147.	*Pycnonotus cafer* (Linnaeus)	Red-vented Bulbul	
	FAMILY IRENIDAE		
148.	*Aegithia tiphia* (Linnaeus)	Common Iora	
149.	*Chloropsis cochinchinensis* (Gmelin)	Jerdon's Chloropsis	
	FAMILY LANIIDAE		
150.	*Lanius cristatus* Linnaeus	Brown Shrike	
151.	*Lanius schach* Linnaeus	Rufous-backed Shrike	
	FAMILY MUSCICAPIDAE		
	SUBFAMILY TURDINAE		
152.	*Zoothera citrina* (Latham)	Orange-headed Ground-Thrush	
153.	*Luscinia svecica* (Linnaeus)	Bluethroat	WA
154.	*Copsychus saularis* Linnaeus	Oriental Magpie-Robin	
155.	*Saxicoloides fulicata* (Linnaeus)	Indian Robin	
156.	*Saxicola torquata* (Linnaeus)	Common Stonechat	WA

Sl. No.	Order/Family/Scientific Name	Common Name	Remarks
157.	*Saxicola caprata* (Linnaeus)	Pied Bushchat	
	SUBFAMILY TIMALIINAE		
158.	*Turdoides striatus* (Jerdon)	Jungle Babbler	
159.	*Turdoides affinis* (Jerdon)	White-headed Babbler	
	SUBFAMILY SYLVINAE		
160.	*Cisticola juncidis* (Rafinesque)	Streaked Fantail-Warbler	WA
161.	*Prinia hodgsonii* Blyth	Franklin's Prinia	
162.	*Prinia socialis* Sykes	Ashy Prinia	
163.	*Prinia inornata* Sykes	Plain Prinia	
164.	*Acrocephalus dumetorum* Blyth	Blyth's Reed-Warbler	
165.	*Acrocephalus stentoreus* (Hemprich & Ehrenberg)	Indian Great Reed-Warbler	WA
166.	*Orthotomus sutorius* (Pennant)	Common Tailorbird	
167.	*Phylloscopus trochiloides* (Sundevall)	Greenish Leaf-Warbler	
	SUBFAMILY MUSCICAPINAE		
168.	*Muscicapa daurica* Pallas	Asian Brown Flycatcher	
	SUBFAMILY MONARCHINAE		
169.	*Terpsiphone paradisir* (Linnaeus)	Asian Paradise-Flycatcher	
	SUBFAMILY RHIPIDURINAE		
170.	*Rhipidura aureola* Lesson	White-browed Fantail-Flycatcher	
	FAMILY PARIDAE		
171.	*Parus major* Linnaeus	Great Tit	
	FAMILY DICAEIDAE		
172.	*Dicaeum erythrorhynchos* (Latham)	Tickell's Flowerpecker	
	FAMILY NECTARINIIDAE		
173.	*Nectarinia zeylonica* (Linnaeus)	Purple-rumped Sunbird	
174.	*Nectarinia asiatica* (Latham)	Purple Sunbird	

Sl. No.	Order/Family/Scientific Name	Common Name	Remarks
175.	*Nectarinia lotenia* (Linnaeus)	Loten's Sunbird	
	FAMILY ESTRILDIDAE		
176.	*Lonchura striata* (Linnaeus)	White-rumped Munia	
177.	*Lonchura punctulata* (Linnaeus)	Spotted Munia	
178.	*Lonchura malacca* (Linnaeus)	Black-headed Munia	
	FAMILY PASSERIDAE		
	SUBFAMILY PASSERINAE		
179.	*Passer domesticus* (Linnaeus)	House Sparrow	
180.	*Petronia xanthocollis* (Burton)	Yellow-throated Sparrow	
	SUBFAMILY PLOCEINAE		
181.	*Ploceus manyar* (Horsfield)	Streaked Weaver	WA
182.	*Ploceus philippinus travancoreensis* Whistler	Baya Weaver	
	FAMILY STURNIDAE		
183.	*Sturnus malabaricus* (Gmelin)	Grey-headed Starling	
184.	*Sturnus pagodarum* (Gmelin)	Brahminy Starling	
185.	*Sturnus roseus* (Linnaeus)	Rosy Starling	
186.	*Acridotheres tristis* (Linnaeus)	Common Myna	
187.	*Acridotheres fuscus* (Wagler)	Jungle Myna	
	FAMILY ORIOLIDAE		
188.	*Oriolus oriolus* (Linnaeus)	Eurasian Golden Oriole	
189.	*Oriolus chinensis* Linnaeus	Black-naped Oriole	
190.	*Oriolus xanthornus* (Linnaeus)	Black-headed Oriole	
	FAMILY DICRURIDAE		
191.	*Dicrurus macrocercus* Vieillot	Black Drongo	
192.	*Dicrurus leucophaeus* Vieillot	Ashy Drongo	
193.	*Dicrurus aeneus* Vieillot	Bronzed Drongo	

Sl. No.	Order/Family/Scientific Name	Common Name	Remarks
194.	*Dicrurus paradiseus* (Linnaeus)	Greater Racket-tailed Drongo	
	FAMILY ARTAMIDAE		
195.	*Artamus fuscus* Vieillot	Ashy Swallow-Shrike	WA
	FAMILY CORVIDAE		
196.	*Dendrocitta vagabunda* (Latham)	Indian Treepie	
197.	*Corvus splendens* Vieillot	House Crow	
198.	*Corvus macrorhynchos* Wagler	Jungle Crow	

Note : Classification and nomenclature followed after Manakadun and Pittie (2001).

Key : A = Aquatic, WD = Wetland Dependant, WA = Wetland Associated. Rest of the species are dryland birds of the lake areas.

MAMMALIA

Altogether 21 species of mammals under 13 families are reported from the area Table 5). Smooth- coated Otter (*Lutra perspicillata*) is the only large mammal found in the lake environs of Vembanad. According to the local fisher folk, their number has declined alarmingly in the recent past. Earlier, otters were regularly sighted near the mangrove patches at Kumarakom and Vypeen areas, but their sightings have become scarce in recent times. Manu (2004) reported a live Madras Hedge Hog, *Hemiechinus nudiventris*, a rare, endangered small mammal species from the Kumarakom area of the Vembanad Lake. Many roosts of the Indian Flying Fox are found within Mangalavanam and Kumarakom mangrove sites. A systematic account of the mammals reported from the Vembanad Lake and its adjacent environs is given below :

Table 5 : Systematic List of mammals of Vembanad Lake System, Kerala.

Sl. No.	Family and species (Scientific name)	Common name
	ORDER INSECTIVORA	
	FAMILY ERINACEIDAE	
1.	*Hemiechinus nudiventris* (Horsfield)	South Indian Hedgehog
	FAMILY SORICIDAE	
2.	*Suncus murinus* (Linnaeus)	Grey Musk Shrew

Sl. No.	Family and species (Scientific name)	Common name
	ORDER CHIROPTERA	
	FAMILY PTEROPODIDAE	
3.	*Cynopterus sphinx* (Vahl)	Short-nosed Fruit Bat
4.	*Pteropus giganteus* (Brünnich)	Indian Flying Fox
	FAMILY MEGADERMATIDAE	
5.	*Megaderma lyra* Geoffroy	Greater False Vampire
6.	*Megaderma spasma* (Linnaeus)	Lesser False Vampire
	FAMILY RHINOLOPHIDAE	
7.	*Rhinolophus rouxii* Temminck	Penninsular Horseshoe Bat
	FAMILY VESPERTILIONIDAE	
8.	*Kerivoula picta* (Pallas)	Painted Bat
9.	*Pipistrellus* sp.	Bat
	ORDER CARNIVORA	
	FAMILY CANIDAE	
10.	*Canis aureus* Linnaeus	Asiatic Jackal
	FAMILY MUSTELLIDAE	
11.	*Lutra perspicillata* (I. Geoffroy Saint Hilaire)*	Smooth-coated Otter
	FAMILY VIVERRIDAE	
12.	*Paradoxurus hermaphroditus* (Pallas)	Common Palm Civet
13.	*Viverricula indica* (Desmarest)	Small Indian Civet
	FAMILY HERPESTIDAE	
13.	*Herpestes edwardsii* (E. Geoffroy Saint-Hilaire)	Indian Gray Mongoose
	FAMILY FELIDAE	
	15. *Felis chaus* Schreber	Jungle Cat
	ORDER RODENTIA	
	FAMILY SCIURIDAE	
16.	*Funambulus palmarum* (Linnaeus)	Indian Palm Squirrel

S. No.	Family and species (Scientific name)	Common name
	FAMILY MURIDAE	
17.	*Bandicota bengalensis* (Gray & Hardwicke)	Lesser Bandicoot Rat
18.	*B. indica* (Bechstein)	Greater Bandicoot Rat
19.	*Rattus rattus* (Linnaeus)	House Rat, Roof Rat
20.	*Mus musculus* Linnaeus	House Mouse
21.	*M. booduga* (Gray)	Common Indian Field Mouse

Note : The Smooth-coated Otter marked with (*) is truly wetland dependent species, while others are dry land species.

SUMMARY

429 species of vertebrates (Pisces 177, Amphibia - 10, Reptilia - 23, Aves - 198 and Mammalia - 21) known to occur in Vembanad Lake and its environs are check-listed in this article.

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INVERTEBRATE DIVERSITY

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INTRODUCTION

Faunal resources of Vembanad Lake are very vast and varied. Among the vertebrate and invertebrate faunal elements, invertebrate diversity is high. An attempt is made to collate and compile this diversity from literature on these aspects to prepare a consolidated list of species including the findings of the present survey works undertaken during the years 2002 and 2003. This inventory of invertebrate fauna is prepared to incorporate aquatic invertebrate species covering from Protozoa to Arthropoda that are reported from this lake including other invertebrate elements directly dependent and/ or associated with this backwater system as an integral part of the ecosystem.

Among the lacustrine ecosystems of India, Vembanad Lake has attracted most of the naturalists, limnologists and scientists, and consequently has been subjected to intense biological research. The salinity gradient of the lake supports an assemblage of diversified fauna in accordance to their tolerance to saline environments. Invertebrate faunal diversity of this lake covering distribution, species composition, abundance, biomass, etc., have been investigated by a number of workers (Desai and Krishna Kutty, 1967; Cheriyan, 1968; Silas and Pillai, 1975; Kurian *et al.*, 1975; Pillai, 1977; Antony, 1980; Batcha, 1984; Sunil Kumar and Antony, 1994; Varghese *et al.*, 2006; Dev Roy and Nandi, 2008). Menon *et al.* (2000) reviewed the hydrobiology of Cochin backwater system and dealt with different groups of invertebrates without supplementing a total list of species. However, even though a good deal of baseline data on various zoological taxa is available including *Doliolum* sp., a tunicate species recorded from plankton samples, a compendious compilation of total invertebrate fauna of this lake was lacking and hence the present communication.

INVENTORY OF INVETEBRATE SPECIES

The aquatic invertebrate elements comprising of 550 species belonging to 17 phyla are listed in Table 1 and their phylum- and family-wise distribution in Table 2 and Fig. 1, mainly based on available literature as well as the specimens collected from upstream and downstream areas during the course of faunistic survey from Vembanad Lake. The first two phyla viz., Sarcomastigophora (37 species) and Ciliophora (8 species) belong to the subkingdom Protozoa under Kingdom Protista, while the remaining 15 phyla belonging to the Kingdom Animalia represent 506 metazoan invertebrate species. Among the phyla, Arthropoda represents the highest diversity (245 species), followed by Mollusca (84 species), Annelida (74 species), Cnidaria (48 species) and Sarcomastigophora (37 species) from this lake ecosystem (Figs. 4.1(A) and 4.1(B); 4.2-4.7).

4.2.1. The Phylum Sarcomastigophora

Thirty seven species of foraminiferans and one species of arcellinid rhizopods belonging to the phylum Sarcomastigophora have so far been recorded from Vembanad Lake (Antony, 1975, 1980; Antony and Kurian, 1975; Desai and Krishna Kutty, 1967). Antony (1980) studied the foraminiferans of the Vembanad estuary and observed eight calcareous and 24 chitinous and siliceous forms. These species are primarily epibenthic forms, preferring oxygenated upper layer (1 cm) of the sediment. The calcareous species were predominant in the lower reaches of the estuary, particularly near the barmouth, whereas the siliceous and chitinous species prevailed in the upper reaches of the estuary, probably due to greater freshwater admixture in the water.

4.2.2. The Phylum Ciliophora

Eight species of hymenostomatid, peritrichous and spirotrichous endocommensal ciliates belonging to the phylum Ciliophora have been reported from this lake (Santha Kumari and Nair, 1970-1975). Among these, the ciliates *viz.*, *Boveria teredinidi*, *Trichodina balakrishnia*, *Nucleocorbula adherans*, *Thigmozoon fencheli* and *Nyctotherus marina* inhabit in the shipworm *Nausitora hedleyii* during monsoon and post-monsoon seasons.

4.2.3. The Phylum Porifera

Two named and an unnamed species of sponges belonging to the class Demospongiae have been known to occur in this lake.

4.2.4. The Phylum Cnidaria

Forty eight species of hydromedusae, scyphomedusae and actinarians have been found to occur mainly as holoplakters in this lake as reported by several investigators

(Vannucci *et al.*, 1970; Santhakumari, 1970; Santhakumari and Vannucci, 1972; Nair and Tranter, 1972; Menon *et al.*, 1972; Silas and Pillai, 1975). Amongst these species, Santhakumari (1970) has recorded *Eutima comensalis* as endemic to Cochin backwater. Cheriyan (1964) reported *Phytocoeteopsis ramunni* from Cochin backwaters during November to May, when salinity values were higher than 20%. The scyphomedusae *Achrometes* sp. has been reported as common during the premonsoon months in the estuary. Rengarajan (1974) recorded five species siphonophores and stated that high salinity plays an important role in the influx of these organisms. The number of siphonophores showed an increase in the backwater during post monsoon months when salinity increases and zooplankton standing crop was on the declining trend.

4.2.5. The Phylum Ctenophora

Three species of ctenophores inhabit this lake (George, 1958; Nair and Tanter, 1972). Of these, George (1958) recorded *Pleurobrachia globosa* as a common component of holoplankters during January to April. The occurrence of these planktonic ctenophores was found in considerable numbers in some downstream stations (Northern sector) of this lake.

4.2.6. The Phylum Nemertina

Unnithan *et al.* (2001) recorded an undetermined species of nemertean worm as rare occurrence in the benthic fauna of Vembanad Lake. During the present survey an undetermined specimen of nemertean was only once observed at Vypin Island adjacent to mangrove habitat.

4.2.7. The Phylum Rotifera

Varghese *et al.* (2006) recently recorded thirteen species of rotifers from Cochin backwaters. All of them belong to a single genus *Brachionus* under the family Brachionidae.

4.2.8. The Phylum Platyhelminthes

One underterminated species of planaria was encountered from Kumbalam area. Mention may be made that planaria was also recorded along with barnacles and also from teredinid burrows by Santhakumari and Nair (1975).

4.2.9. The Phylum Nematoda

Six species of nematodes have so far been reported from this backwater system. Thomas *et al.* (1999) recorded three species of nematodes *viz.*, *Sabatieria* sp., *Desmodora* sp. and *Theristus* sp. in the kayal land of Kuttanad region. In the

meiobenthic samples, Desai and Krishnankutty (1967) and Jayasree (1971) recorded nematodes as one of the major component out of 11 taxonomic groups.

4.2.10. The Phylum Mollusca

Thirty nine species of gastropods belonging to 24 families and forty five species of bivalve belonging to 17 families have been recorded from Vembanad Lake including the doubtful occurrence of three bivalves, namely *Tellina* (*Angulus*) *rhodon*, *Pandora flexosa* and *Nuculona mauritiana*. These include a few species of freshwater *viz*., *Bellamya bengalensis*, *Melanoides* (=*Thiara*) *tuberculata*, *Thiara scabra* and *Indoplanorbis exustus* from Kumarakom areas of the lake in Kottayam district of Kerala. Preston (1916) made malacological studies from this lake. Cheriyan (1968) recorded 51 species of mollusks from Cochin harbour area. Nair (1975) and Unnithan *et al.* (2001) studied the growth rate of an important species of clam *viz*., the black clam, *Villorita cyprinoides* var. *cochinensis* from Cochin backwater, which forms the major molluscan fishery in Vembanad Lake and sustains a regular fishery in Kerala. The species attained a length of 30 mm during the first year and only 11 mm in the second year, and also showed two peak periods of breeding activity in a year, one from late May to August and the other from January to late March. George (1958) and Nair and Tranter (1972) enumerated various groups existing in the Vembanad estuary and mentioned that molluscan larvae dominated by two species of gastropod (*Thais* sp. and *Neritina* sp.) during the post-monsoon period and bivalve larvae in varying numbers during October to May, with peak periods during November-December and April-May. Unnithan *et al.* (2001) recorded *Melanoides tuberculata* (=*Thiara tuberculata*), *Indoplanorbis exustus*, *Melampus* sp., and *Bellamya* (=*Viviparus*) sp. from this lake.

Cheriyan (1964) recorded wood-boring mollusks belonging to the Pholadidae (*Martesia striata*) and Teredinidae (*Teredo* and *Bankia* species) at Cochin harbour. Fresh attacks of these pholads and teredinids appeared in January, reaching maximum in May and then disappearing in June. Nair (1994) reported on the distribution of wood borers in the Vembanad backwaters.

4.2.11. The Phylum Sipuncula :

In the benthic samples of Cochin harbour, small sipunculids were recorded by Desai and Krishnankutty (1967) and Pillai, (1977) without giving the identity of the species.

4.2.12. The Phylum Echiura

A single specimen of echiurid worm (undetermined) was observed in the fish landing centre of Kumbalam area. Pillai (1977) also recorded echiuroids from this backwater.

4.2.14. The Phylum Annelida

Seventy four species of annelids comprising of sixty five species of polychaetes and nine species of oligochaete have been recorded from this lake. George (1958) recorded pelagic polychaetes belonging to the family Nereidae from Cochin backwater throughout the year with their maximum occurrence in October. Cheriyan (1966) reported 8 species of polychaetes from a depth ranging from 3.05 m to 9.14 m from the Cochin harbour area. Thomas *et al.* (1999) recorded polychaetes representing *Dendronereis aestuarina* and *Namalycastis indica* (=*Lycastis indica*) as the the largest population amongst the benthic fauna in the Kuttanad area. Sunil Kumar and Antony (1994) reported 33 species of polychaetes belonging to 20 genera and 10 families from the mangrove areas of Cochin. Of these, *Marphysa gravelyi*, *Paraheteromastus tenuis*, *Nereis glandicincta*, *Dendronereis heteropoda* and *Dendronereis aestuarina* were predominant and occurred throughout the year.

Thomas *et al.* (1999) recorded three species of oligochaetes, such as, *Pristina* sp., *Tubifex* sp. and *Dero* sp. in greater population in the entire Kuttanad area. Unnithan *et al.* (2001), however, reported three species of tubifiid worms *viz.*, *Aulodrilus* sp., *Aulodrilus remex* and *Limnodrilus hoffmeisteri* and also three species of the family Naididae such as *Dero* sp., *Dero cooperi* and *Hanochaeta* sp., as well as seven polychaetes species, namely, *Dendronereis* sp., *D. aestuarina*, *D. arborifera*, *Ceratonereis* sp., *C. mirabilis*, *Prionospio* sp., and *Namalycastis indica*.

4.2.13. The Phylum Arthropoda

4.2.14. Crustacea : A total of 214 species of crustaceans, either adults or larval forms, belonging to Copepoda, Ostracoda, Cladocera, Amphipoda, Isopoda and Decapoda have been recorded from Vembanad Lake (by several investigators (Sewell, 1919; George, 1958; Rao, 1968; Sankarankutty, 1969, 1975; Rao and Kathirvel, 1972; Achuthankutty and George, 1973; Radhakrishnan and Samual, 1982 and others). Of these, 83 species (41.9%) are represented by copepods. Other groups include nine species, decapods, three species by ostracods and two species each of cladocerans, mysids, cumaceans and tenaidaceans, while one species *viz.*, *Cyclestheria hislopi* Baird belongs to Conchostraca. Pillai and Pilai (1973) recorded two species of cladocerans *viz.*, *Evadne tergestina* and *Penilia avirostris* from the Cochin backwater and investigated their abundance, seasonal distribution and temperature-salinity relationship. These two species were high during the post-monsoon months from September to November.

Several investigators have studied the diversity and distribution of calanoid copepods in and around Cochin backwater since 1910's (Sewell, 1919; George, 1958; Wellerhaus, 1969, 1970, 1974; Abraham, 1970a, b, 1972; Tranter and Abraham, 1971; Pillai, 1970; Pillai, 1972; Nair and Tranter, 1972; Menon *et al.*, 1971; Pillai *et al.*, 1973; Pillai and

Pillai, 1973). Madhupratap (1978) reported 49 species of copepods belonging to 22 genera from Cochin backwaters. Out of 49 copepod species, 41 represent calanoid copepods belonging to 11 families and among these, Acartidae constitutes the dominant family comprising of 10 species. Earlier Pillai *et al.* (1973) recorded thirtythree species of calanoid copepods in zooplankton samples of Cochin backwater and connected estuarine waters, while Silas and Pillai (1975) reported eleven species of cyclopoid copepods, which occurred in abundance during November to April period in the Cochin backwater.

George (1958) recorded mysids (*Mesodopsis orientalis* and *Mesodopsis* sp.), cumaceans (*Paradyastylis culicoides* and *Eucoma* sp.), tenaidaceans (*Apseudes gymnophobia* and *Apseudes* sp.) and one species of isopod (*Sphaeroma* sp.) from Cochin backwater and also recorded maximum numbers of planktonic ostracods during September-October period. Thomas *et al.* (1999) reported *Tanais* sp. from Kuttanad area. Silas and Parameswaran Pillai (1975) encountered one species of ostracod, *Cypridina* near the mouth of the estuary during high salinity period. Thomas *et al.* (1999) reported three species of ostracods representing *Cypris* sp., *Stenocypris* sp. and *Candocypria* sp. in the bottom fauna of Kuttanad region. George (1958) and Nair and Tranter (1972) reported a few species of gammarid amphipods during the pre- and post-monsoon periods from this backwater system. Two species of amphipods, *Ampelisca pusilla* and *Talorchestia martensii* were recorded from freshwater zone of the lake. In the Kuttanad area the amphipod population representing *Melita* sp., *Gammaropsis* sp. and *Parhyela* sp. were recorded throughout the year (Thomas *et. al.*, 1999). Unnithan *et al.* (2001), reported two species of caprillid amphipods, two species of gammarids, *viz.*, *Eriopisa chilkensis* and *Quadrivisio bengalensis* (Gammaridae), a single talitrid species and *Parhyela hawaiensis* (Hyalidae) from the Cochin backwater. Mathew *et al.*, (1994) reported the occurrence of the isopod crustacean, *Cirolona fluviatilis* in Cochin backwater. Kathirvel and Gopalakrishnan (1974) recorded the occurrence of *Charybdis hellerii* in the trawl net collection from Cochin backwaters.

George (1958) and Menon *et al.* (1971) recorded cirripede larvae of *Balanus amphitrite* from Cochin backwater in almost all seasons. John (1964) reported that *Balanus amphitrite communis* (Darwin) was capable of infesting fresh surface throughout the year with peak period of settlement during north east monsoon season (September to December). Caridean larvae (*Pereclimenes* sp. and *Palaemon* sp.) occurred during August to February (George, 1958), stomatopod larvae (*Alima* sp.) during the pre-monsoon periods (George, 1958), penaeid larvae showed four peaks in a year (George, 1958; Mohammed and Rao, 1972), brachyuran larvae exhibited maximum numbers during December to February (Nair and Tranter, 1972; Menon *et al.*, 1972). Mohammed and Rao (1972) reported on relevance of the estuarine phase in the life cycle of the commercially important prawns and stated that except

Parapenaeopsis stylifera, the larvae and and juveniles of all other commercially important prawns are available in the estuary. Kuttyamma and Antony (1975) studied the relatve abundance, size variation and sex difference on the penaeid prawns of the stake net catches *viz.*, *Metapenaeus dobsoni*, *M. monoceros* and *Penaeus indicus* and observed comparatively larger-sized prawns in the southern part of the Cochin backwaters. George (1962) studied the breeding and recruitment of post-larvae of penaeids into the backwaters of Cochin, while Kuttyamma (1980) observed the dominance of post larvae and juveniles of *Metapenaeus dobsoni* over other species such as *M. monoceros* and *Penaeus indicus* in the Cochin backwaters during 1972-73 throughout the year.

4.2.14.2. Insecta : In all, 26 species of insects belonging to 5 orders and 10 families have been recorded/ observed from Vembanad Lake. These include adult insects belonging to the orders Hemiptera (11 species) and Coleoptera (8 species) and larval forms representing orders Ephemeroptera (1 species), Odonata (1 species) and Diptera (5 species). Among the above five insect orders, Hemiptera represents the highest diversity of 11 species followed by Coleoptera (8 species) and Diptera (5 species)

4.2.14.3. Arachnida : Three species of spiders belonging to three genera (*viz.*, *Tetragnatha*, *Lycosa* and *Zygaballus*) were found to be associated with aquatic weeds of the lake, while two species of water mites were reported from the lake water.

4.2.15. The Phylum Ectoprocta (Bryozoa)

Eighteeen species of bryozoans belonging to 12 families were reported from this lake. Menon and Nair (1971) observed the larval settlement of bryozoans during all seasons but preferred low salinity periods in the Cochin backwater.

4.2.16. The Phylum Echinodermata

One undetermined species of echinodermata was recorded by Pillai (1977) from this backwater ecosystem. Sarala Devi (1991) also reported echinoderms from this lake.

4.2.17. The Phylum Chaetognatha

Six species chaetognaths *viz.*, *Sagitta enflata*, *S. bedoti*, *S. oceania*, S. *pulchra*, *S. robusta* and *Krohnitta pacifica* have so far been recorded from this backwater ecosystem (Nair, 1971; Srinivasan, 1972; Silas and Pillai, 1975).

Table 1. Inventory of invertebrate diversity recorded from Vembanad Lake.

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	1. Phylum SARCOMASTIGOPHORA (PROTOZOA)		
	Subphylum SARCODINA		
	Superclass RHIZOPODA		
	Class LOBOSEA		
	Subclass TESTACEALOBOSIA		
	Order ARCELLINIDA		
	Family DIFFLUGIIDAE		
1.	*Difflugia* sp.	+	-
	Class GRANULORETICULOSEA		
	Order FORAMINIFERIDA		
	Family GLOBIGERINIDAE		
2.	*Globigerina bulloides* d'Orbigny, 1826	+	-
	Family SACCAMMINIDAE		
3.	*Saccammina sphaerica* Brady, 1871	+	-
	Family REOPHACIDAE		
4.	*Reophax scottii* Chaster, 1892	+	-
5.	*Reophax cattella* Hoglund,1947	+	-
	Family LITUOLIDAE		
6.	*Ammobaculites foliaceous* (Brady, 1884)	+	-
7.	*Ammobaculites taylorensis* Cushman and Waters, 1948	+	-
8.	*Ammobaculites dilatatus* Cushman and Bronniman	+	-
	Family TEXTULARIIDAE		
9.	*Textularia agglutinans* d'Orbigny, 1839	+	-
10.	*Textularia conica agglutinans* d'Orbigny, 1839	+	-
11.	*Textularia* sp.	+	-
	Family RHEHAKINIDAE		
12.	*Miliammina fusca* Brady, 1870	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Order TROCHAMMINIDA		
	Family TROCHAMMINIDAE		
13.	*Trochammina inflata* Montagu, 1808	+	-
14.	*Trochammina nitida* Brady, 1884	+	-
15.	*Trichammina* sp.	+	-
	Family MILIOLIDAE		
16.	*Quinqueloculina agglutinans* d'Orbigny, 1839	+	-
17.	*Quinqueloculina seminulum* (Linnaeus, 1758)	+	
18.	*Quinqueloculina bicornis* Walker and Jacob, 1798	+	
19.	*Triloculina oblonga* (Montagu, 1803)	+	
	Family NONIONIDAE		
20.	*Nonion boueanum* (d'Orbigny, 1846)	+	-
21.	*Nonion scaphum* (Fichtel and Moll, 1798)	+	
22.	*Nonion sloani* d'Orbigny	+	
23.	*Nonion* sp.	+	
	Family ELPHIDIIDAE		
24.	*Elphidium advenum* (Cushmann, 1922)	+	
25.	*Elphidium craticulatum* (Fichtel and Moll, 1798)	+	
26.	*Elphidium crispum* (Linnaeus, 1758)	+	
27.	*Elphidium macellum* (Fichtel and Moll, 1798)	+	-
	Family NUMMULITIDAE		
28.	*Operculina granulosa* Leymerie, 1846	+	-
29.	*Operculina complanata* (Defrance, 1822)	+	
30.	*Operculinella cumingii* (Carpenter)	+	
	Family BULIMINIDAE		
31.	*Bolivina nobilis* Hantken-MacFadyen, 1931	+	
32.	*Bolivina striatula* Cushmann, 1922	+	
	Family ROTALIIDAE		
33.	*Discorbis orbicularis* d'Orbigny	+	

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
34.	*Discorbis rosacea* d'Orbigny, 1839	+	-
35.	*Rotalia beccarii* (Linnaeus, 1758)	+	-
36.	*Rotalia calcar* (d'Orbigny)	+	-
	Family ANOMALINIDAE		
37.	*Cibicides lobatulus* (Walker and Jacob, 1798)	+	-
	2. Phylum CILIOPHORA (PROTOZOA)		
	Class KINETOFRAGMINOPHORA		
	Subclass HYMENOSTOMATA		
	Order SCUTICOCILIATIDA		
	Suborder PHILASTERINA		
	Family CRYPTOCHILIDAE		
38.	*Thigmozoon fencheli* Santhakumari and Nair, 1973	+	-
	Suborder THIGMOTRICHINA		
	Family ANCISTRIDAE		
39.	*Boveria teredinidi* Nelson, 1923	+	-
	Family NUCLEOCORBULIDAE		
40.	*Nucleocorbula adherens* Santhakumari and Nair, 1970	+	-
	Class OLIGOHYMENOPHOREA		
	Subclass PERITRICHIA		
	Order PERITRICHIDA		
	Suborder SESSILINA		
	Family VORTICELLIDAE		
41.	*Vorticella campanula* Ehrenberg, 1831	+	-
42.	*Zoothamnium rigidum* Precht, 1935	+	-
	Suborder MOBILINA		
	Family URCEOLARIIDAE		
43.	*Trichodina balakrishnia* Santhkumari and Nair, 1973	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Class POLYMENOPHOREA		
	Subclass SPIROTRICHIA		
	Order HETEROTRICHIDA		
	Suborder CLEVELANDELLINA		
	Family NYCTOTHERIDAE		
44.	*Nyctotherus marina* Santhkumari and Nair, 1973	+	-
	Suborder COLIPHORINA		
	Family FOLICULINIDAE		
45.	*Folliculina* sp.	+	-
	3. Phylum PORIFERA		
	Class DEMOSPONGIAE		
	Order HAPLOSCLERIDA		
	Family CHALINIDAE		
46.	*Haliclona tenuiramosa* Burton, 1930	+	-
	Order POECILOSCLERIDA		
	Family TEDANIIDAE		
47.	*Tedania nigrescens* (=*Tedania* (*Tedania*) *anhelans* (Lieberkuhn, 1859)	+	
	Family ?		
48.	Sponge (undetermined)	+	
	4. Phylum CNIDARIA		
	Class HYDROZOA		
	Order HYDROIDA		
	Family CAMPANULARIIDAE		
49.	*Obelia bicuspidata* Clarke, 1876	+	
50.	*Obelia* sp.	+	
51.	*Phialidium brunescens* (Bigelow, 1904)	+	
52.	*Phialidium hemisphericum* (Linnaeus, 1767)	+	
53.	*Phialidium rangireae* (Agassiz and Mayer, 1902)	+	

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Family BLACKFORDIIDAE		
54.	*Blackfordia virginica* Mayer, 1910	+	-
	Family CLYTIIDAE		
55.	*Clytia hendersoni* Torrey,1904	+	-
	Family LOVENELLIDAE		
56.	*Eucheilota ceylonensis* Kramp, 1959	+	-
57.	*Eucheilota menoni* Kramp, 1959	+	-
	Family EIRENIDAE		
58.	*Eirene ceylonensis* Browne, 1905	+	-
59.	*Eirene menoni* Kramp, 1953	+	-
60.	*Eutima brownie*	+	-
61.	*Eutima commensalis* Santhakumari, 1970	+	-
62.	*Eutima hartlaubi* Kramp, 1958	+	-
63.	*Eutima japonica* Uchida, 1925	+	-
64.	*Eutima neucaledonia* Uchida, 1964	+	-
	Family TUBULARIIDAE		
65.	*Ectopleura* sp.	+	
	Family HALOCORDYLIDAE		
66.	*Pennaria disticha* (Goldfuss, 1820)	+	-
67.	*Halocordyle* sp.	+	-
	Family CYTAEIDAE		
68.	*Cytaeis tetrastyla* Eschscholtz, 1829	+	-
	Family BOUGAINVILLIIDAE		
69.	*Bimeria franciscana* Torrey, 1902	+	-
70.	*Bougainvilla fulva* Agassiz and Mayer, 1899	+	-
	Family PANDEIDAE		
71.	*Pandea rubra* Bigelow, 1913	+	-
72.	*Leuckartiara octona* (Fleming, 1823)	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Family AEQUOREIDAE		
73.	*Aequorea aequorea* (Forskål, 1775)	+	
74.	*Aequorea conica* (Browne, 1905)	+	
75.	*Aequorea macrodactyla* (Brandt, 1825)	+	
	Family RHOPALONEMATIDAE		
76.	*Aglaura hemistoma* Péron and Lesueur, 1809	+	
77.	*Aglaura elata* (Haeckel, 1877)	+	
	Family GERYONIIDAE		
78.	*Liriope tetraphylla* (Chamisso and Eisenhardt, 1821)	+	-
79.	*Geryonia proboscidalis* (Forskål, 1775)	+	
	Family CUNINIDAE		
80.	*Cunina peregrina* Bigelow, 1909	+	
	Family AEGINIDAE		
81.	*Solmundella bitentaculata* (Quoy and Gaimard, 1833)	+	
	Family ZANCLEIDAE		
82.	*Zanclea costata* Gegenbaur, 1857	+	
	Family MITROCOMIDAE		
83.	*Tiaropsidium japonicum* Kramp, 1932	+	
	Family PHIALUCIIDAE		
84.	*Phialucium carolinae* Mayer, 1900	+	
85.	*Phialucium taeniogonia* Chow and Huang, 1958	+	
	Family HYDRACTINIIDAE		
86.	*Podocoryne carnea* M. Sars, 1864	+	
	Order SIPHONOPHORA		
	Family DIPHYIDAE		
87.	*Lensia subtiloides* (Lens and van Riemsdijk, 1908)	+	
88.	*Lensia hotspur* Totton, 1941	+	
89.	*Muggiaea delsmani* Totton, 1954	+	

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
90.	*Diphyes chamissonis* Huxley, 1859	+	-
91.	*Eudoxoides mitra* (Huxley, 1859)	+	-
	Class SCYPHOZOA		
	Order RHIZOSTOMEAE		
	Family CATOSTYLIDAE		
92.	*Acromitus* sp.	+	-
93.	Scyphomedusae (Undetermined)	+	-
	Class ANTHOZOA		
	Order ACTINARIA		
	Family HALIACTIDAE		
94.	*Phytocoetopsis ramunni* Panikkar, 1936	+	-
	Family ACTINIIDAE		
95.	*Anthopleura nigrescens* (Verill, 1869)	+	-
	Family EDWARDSIIDAE		
96.	*Edwardsia* sp.	+	-
	5. Phylum CTENOPHORA		
	Class TENTACULATA		
	Order CYDIPPIDA		
	Family PLEUROBRANCHIIDAE		
97.	*Pleurobrachia globosa* Moser, 1903	+	-
98.	*Pleurobrachia* sp.	+	-
99.	*Beroe sp.*	+	-
	6. Phylum PLATYHELMINTHES		
	Class TURBELLARIA		
100.	*Planarian* (undetermined species)	+	-
	7. Phylum NEMATODA		
	Class ADENOPHOREA		
	Order ENOPLIDA		
	Family ANTICOMIDAE		
101.	*Anticoma* sp.	+	-
102.	*Trichoma* sp	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Order CHROMADORIDA		
	Family COMESOMATIDAE		
103.	*Chromodora* sp.	+	
104.	*Sabatieria* sp.		+
	Order DESMODORIDA		
	Family DESMODORIDAE		
105.	*Desmodora* sp.	+	+
	Family XYLIDAE		
106.	*Theristus* sp.	-	+
	8. Phylum ROTIFERA		
	Family BRACHIONIDAE		
107.	*Brachionus plicatilis* Muller, 1780	+	
108.	*Brachionus rotundiformis* Tschugunoff, 1921	+	-
109.	*Brachionus angularis* (Gosse, 1851)	+	
110.	*Brachionus urceolaris* (Muller, 1773)	+	
111.	*Brachionus rubens* Ehrenberg, 1838	+	
112.	*Brachionus calyciflorus* Pallas, 1776	+	
113.	*Brachionus caudata* Barrois and Daday, 1894	+	-
114.	*Brachionus falcatus* Zacharias, 1898	+	
115.	*Brachionus forficula* Wiezejski, 1891	+	
116.	*Brachionus quadridentatus* Hermann, 1783	+	
117.	*Brachionus patulus* Muler, 1786	+	
118.	*Brachionus bidentata* Anderson, 1889	+	
119.	*Brachionus mirabilis* Daday, 1897	+	
	9. Pyhlum NEMERTINA		
120.	Undetermined species	+	
	10. Phylum ANNELIDA		
	Class POLYCHAETA		
	Family SIGALIONIDAE		
121.	*Sthenelais boa* (Johnston, 1933)	+	

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Family GLYCERIDAE		
122.	*Glycera alba* Rathke, 1788	+	-
123.	*Glycera convoluta* Keferstein,1862	+	-
124.	*Glycera longipinnis* Grube, 1878	+	-
	Family ONUPHIDAE		
125.	*Diopatra neapolitana* Delle Chiaje, 1847	+	-
	Family LUMBRINERIDAE		
126.	*Lumbrinereis latreilli* Audouin and Milne Edwards, 1834	+	-
127.	*Lumbrinereis simplex* Southern, 1921	+	-
128.	*Lumbrinereis notocirrata* Fauvel, 1932	+	-
129.	*Lumbrinereis pseudobifilaris* Fauvel, 1932	+	-
130.	*Lumbrinereis* sp.	+	-
	Family NEPHTYIDAE		
131.	*Nephtys oligobranchia* Southern, 1921	+	-
132.	*Nephtys polybranchia* Southern, 1921	+	-
	Family NEREIDIDAE		
133.	*Ceratonereis costae* (Grube, 1840)	+	
134.	*Ceratonereis mirabilis* Kingberg, 1865	+	-
135.	*Ceratonereis* sp.	+	-
136.	*Neanthes chingrighattensis* (Fauvel, 1932)	+	-
137.	*Neanthes glandicincta* (Southern, 1921)	+	-
138.	*Nereis chilkaensis* Southern	+	-
139.	*Nereis kauderni* Fauvel	+	-
140.	*Perinereis cavifrons* Ehlers, 1920	+	-
141.	*Perinereis nuntia* (Savigny, 1818)	+	-
142.	*Perenereis* sp.	+	-
143.	*Namalycastis indica* Southern, 1921 (Syn. *Lycastis indica* Southern)	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
144.	*Dendronereis arborifera* Peters, 1854	+	
145.	*Dendronereis aestuarina* Southern, 1921	+	-
146.	*Dendronereides heteropoda* Southern, 1921	+	-
147.	*Dendronereis* sp.	+	-
	Family CAPITELLIDAE		
148.	*Branchiocapitella singularis* Fauvel, 1932	+	
149.	*Capitella capitata* (Fabricius, 1780)	+	-
150.	*Capitella* sp.	+	
151.	*Pulliella armata* Fauvel, 1930	+	
152.	*Scyphoproctus djiboutiensis* Gravier, 1906	+	
153.	*Paraheteromastus tenuis* Monro, 1937	+	
154.	*Heteromastides bifidus* Augener, 1914	+	-
155.	*Heteromastus similis* Southern, 1921	+	-
	Family SPIONIDAE		
156.	*Minuspio cirrifera* Loew, 1869	+	-
157.	*Prionospio pinnata* Ehlers, 1901	+	-
158.	*Prionospio polybranchiata* Fauvel, 1929	+	-
159.	*Prionospio* sp.	+	
160.	*Minuspio cirrifera* (Wirén, 1883)	+	
161.	*Polydora* sp.	+	
162.	*Pseudopolydora kempi* (Southern, 1921)	+	
	Family PILARGIDAE		
163.	*Ancistrosyllis constricta* Southern, 1921	+	
	Family SYLLIDAE		
164.	*Odontosyllis gravelyi* Fauvel, 1930	+	
165.	*Sthenelais boa* (Johnston, 1833	+	
	Family EUNICIDAE		
166.	*Eunice tubifex* Crossland, 1904	+	
167.	*Eunice* sp.	+	
168.	*Marphysa gravelyi* Southern, 1921	+	

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
169.	*Marphysa stragulum* (Grube, 1878)	+	-
	Family GONIADIDAE		
170.	*Goniada emerita* Audouin and Milne Edwards, 1833	+	-
	Family TEREBELLIDAE		
171.	*Pista indica* Fauvel, 1940	+	-
172.	*Loimia medusa* (Savignyi, 1818)	+	-
	Family OWENIIDAE		
173.	*Owenia* sp.	+	-
	Family PECTINARIIDAE		
174.	*Lagis abranchiata* (Fauvel, 1932)	+	-
175.	*Amphictene crassa* (Grube, 1870)	+	-
	Family AMPHINOMIDAE		
176.	*Notopygos* sp.	+	-
	Family POLYNOIDAE		
177.	*Gaudichaudius cimex* (Quatrefages, 1866)	+	-
178.	*Lepidonotus tenuisetosus* (Gravier, 1901)	+	-
	Family SABELLARIIDAE		
179.	*Sabellaria cementarium* Moore, 1906	+	-
	Family SERPULIDAE		
180.	*Ficopomatus macrodon* Southern, 1921	+	-
181.	*Mercierella enigmatica* Fauvel, 1923	+	-
182.	*Serpula vermicularis* Linnaeus, 1767	+	-
	Family TALEHSAPIIDAE		
183.	*Talehsapia annandalei* Fauvel, 1932	+	-
	Family PHYLLODOCIDAE		
184.	*Phyllodoce* sp.	+	-
	Family AMPHARETIDAE		
185.	*Amphicteis gunneri* (Sars, 1838)	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Class OLIGOCHAETA		
	Order LIMICOLAE		
	Family NAIDIDAE		
186.	*Dero cooperi* Stephenson, 1932		+
187.	*Dero* sp.		+
188.	*Hanochaeta* sp.	-	+
189.	*Nais* sp.		+
190.	*Pristina* sp.		+
	Family TUBIFICIDAE		
191.	*Aulodrilus pigueti* Kowalewski, 1914		+
192.	*Aulodrilus remex* Stephenson, 1921		+
193.	*Limnodrilus hoffmeisteri* Claparède, 1862		+
194.	*Tubifex* sp.		
	11. Phylum MOLLUSCA		
	Class GASTROPODA		
	Order ARCHAEOGASTROPODA		
	Family TROCHIDAE		
195.	*Clanculus clanguloides* (Wood, 1856)	+	
	Family NERITIDAE		
196.	*Nerita (Theliostyla) albicella* Linnaeus, 1758	+	
197.	*Neritina (Dostia) violacea* (Gmelin, 1791)		+
	Order MESOGASTROPODA		
	Family VIVIPARIDAE		
198.	*Bellamya bengalensis* (Lamarck, 1822)		+
199.	*Bellamya dissimilis* (Müller, 1774)		+
200.	*Bellamya* sp.		+
	Family AMPULLARIIDAE		
201.	*Pila virens* (Lamarck 1882)		+
202.	*Pila* sp.		+

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Family HYDROBIIDAE		
203.	*Hydrobia* sp.	+	-
	Family PATELLIDAE		
204.	*Cellana radiata radiata* (Born, 1778)	+	-
	Family LITTORINIDAE		
205.	*Littorarina littoraria* (Linnaeus, 1758)	+	-
206.	*Littoraria (Littoraria) undulata* (Gray, 1839)	+	-
207.	*Littorina (Littorinopsis) scabra scabra* (Linnaeus, 1758)	+	-
	Family IRAVADIIDAE		
208	*Iravadia annandalei* Preston, 1916		
209.	*Iravadia funerea* Preston, 1916		
	Family THIARIDAE		
210.	*Thiara (Thiara) scabra* (Müller, 1774)	-	+
211.	*Melanoides tuberculata* (Müller 1774)	-	+
	Family CERITHIDAE		
212.	*Bittium* sp.	+	-
	Family NATICIDAE		
213.	*Natica gualteriana* Recluz, 1844	+	-
214.	*Natica tigrina* (Roeding, 1798)	+	-
215.	*Natica vitellus* (Linnaeus, 1758)	+	-
	Family BURSIDAE		
216.	*Bursa (Bufonaria) crumena crumena* (Lamarck, 1816)	+	-
217.	*Bursa (Bufonaria) rana* (Linnaeus, 1758)	+	-
	Family TURITELLIDAE		
218.	*Turritella attenuata* Reeve, 1899	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
219.	*Turritella duplicata* (Linnaeus, 1758)	+	
	Order NEOGASTROPODA		
	Family MURICIDAE		
220.	*Murex carbonnieri* (Jousseaume, 1881)	+	
221.	*Murex* sp.	+	
222.	*Thais* sp.	+	
	Family BUCCINIDAE		
223.	*Babylonia zeylonica* (Bruguiere, 1789)		
	Family NASSARIIDAE		
224.	*Nassarius subconstrictus* (Sowerby, 1899)	+	
225.	*Nassarius (Niotha) livescens* (Philippi, 1840)	+	
	Family CONIDAE		
226.	*Conus* sp.	+	-
	Family VASIDAE		
227.	*Turbinella rambhaensis* (Preston)		
	Subclass HETROBRANCHIA		
	Family PYRAMIDELLIDAE		
228.	*Pyrgulina rambhaensis* (Preston)	+	
	Subclass OPISTHOBRANCHIA		
	Family HAMINEIDAE		
229.	*Haminea elegans* A. Adams		+
	Subclass PULMONATA		
	Order ARCHAEOPULMONATA		
	Family ELLOBIIDAE		
230.	*Melampus* sp.		+
	Order BASOMMATOPHORA		
	Family LYMNAEIDAE		
231.	*Lymnaea (Pseudosuccinea) luteola* Lamarck, 1822		+

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Family PLANORBIDAE		
232.	*Indoplanorbis exustus* (Deshayes, 1834)	-	+
	Class BIVALVIA		
	Subclass PTERIOMORPHIA		
	Order NUCULOIDA		
	Family NUCULANIIDAE		
233.	*Nuculana mauritiana* (Sowerby, 1825)	+	-
	Order ARCOIDA		
	Family ARCIDAE		
234.	*Arca* sp.	+	-
235.	*Trisidos tortuosa* (Linnaeus, 1758)	+	-
236.	*Anadara granosa* (Linnaeus, 1758)	+	-
237.	*Scapharca inequivalvis* (Bruguiere, 1792)	+	-
	Order MYTILOIDA		
	Family MYTILIDAE		
238.	*Perna viridis* (Linnaeus, 1758)	+	-
239.	*Modiolus tulipa* (Lamarck, 1836)	+	-
240.	*Modiolus striatulus* (Hanley, 1844)	+	-
241.	*Modiolus undulatus* (Dunker, 1856)	+	-
242.	*Musculista senhausia* Benson	+	-
	Subclass HETERODONTA		
	Order VENEROIDA		
	Family CARDIIDAE		
243.	*Acanthocardia coronata* (Schroeter, 1786)	+	-
	Family OSTREIDAE		
244.	*Crassostrea cuttackensis* (Newton and Smith, 1912)	+	-
245.	*Saccostrea cucullata* (Born, 1778)	+	-
246.	*Ostrea forskalli*	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Family MACTRIDAE		
247.	*Meropesta pellucida* (Gmelin, 1782)	+	
	Family SOLENIDAE		
248.	*Solen lamarckii* Deshayes, 1839	+	-
	Family CULTELLIDAE		
249.	*Neosolen aquae-dulcioris* Ghosh, 1920	+	-
	Family TELLINIDAE		
250.	*Tellina (Angulus) rhodon* Hanley, 1844	+	-
251.	*Tellina tenuis* da Costa	+	-
	Family SEMELIDAE		
252.	*Theora opalina* (Hinds, 1843)	+	-
253.	*Theora* sp.	+	-
	Family CORBICULIDAE		
254.	*Villorita cornucopia* Prashad, 1921	+	
255.	*Villorita cyprinoids* var. *cochinensis* Preston	+	+
256.	*Batissa* sp.	+	-
	Family UNIONIDAE		
257.	*Lamellidens marginalis* (Lamarck, 1819)	-	+
	Family VENERIDAE		
258.	*Sunetta solanderii* Gray, 1825	+	
259.	*Timoclea imbricata* (Sowerby, 1853)	+	
260.	*Meretrix meretrix* (Linnaeus, 1758)	+	-
261.	*Meretrix casta* (Gmelin, 1791)	+	
262.	*Dosinia insularum* Fischer-Piette and Deloma, 1967	+	-
263.	*Paphia ala-papilionis* Roeding, 1798	+	-
264.	*Pandora flexosa* Sowerby, 1820	+	-
	Order MYOIDA		
	Family PHOLADIDAE		
265.	*Martesia fragilis* Verrill and Bush, 1898	+	

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
266.	*Martesia striata* (Linnaeus, 1758)	+	-
	Family TEREDINIDAE		
267.	*Dicyathifer manni* (Wright, 1866)	+	-
268.	*Lyrodus pedicillatus* (Quatrefages, 1849)	+	-
269.	*Nausitora hedleyi* Schepman, 1919	+	-
270.	*Bankia campanellata* Moll and Roch, 1831	+	-
271.	*Bankia carinata* (Gray, 1827)	+	-
272.	*Teredo clappi* Bartsch, 1923	+	-
273.	*Teredo furcifera* von Martens, 1894	+	-
274.	*Teredora princisae* (Sivickis, 1928)	+	-
275.	*Teredothyra smithi* (Bartsch, 1927)	+	-
	Order POROMYOIDA		
	Family CUSPADARIIDAE		
276.	*Cuspidaria* sp.	+	-
	Family CAVOLINIIDAE		
277.	*Cavolinia* sp.	+	-
	Class SCAPHOPODA		
	Order DENTALIIDAE		
278.	*Dentalium* sp.	+	-
	12. Phylum ARTHROPODA		
	Subphylum CRUSTACEA		
	Class BRANCHIOPODA		
	Subclass DIPLOSTRACA		
	Order CLADOCERA		
	Family PODONIDAE		
279.	*Evadne tergestina* Claus, 1877	+	-
280.	*Podon* sp.	+	-
	Family SIDIDAE		
281.	*Penilia avirostris* Dana, 1852	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Class MAXILLOPODA		
	Subclass CIRRIPEDIA		
	Family BALANIDAE		
282.	*Balanus amphitrite* Darwin, 1854	+	
283.	*Balanus tintinabulum tintinabulum* Linnaeus,1758	+	
284.	*Balanus amphitrite communis* (Darwin, 1854)	+	
285.	*Balanus amphitrite amphitrite* (Darwin, 1854)	+	
286.	*Balanus amphitrite cochinensis* Nilsson-Cantell, 1938	+	
287.	*Balanus amphitrite insignis* Nilsson-Cantell, 1938	+	-
	Family LEPADIDAE		
288.	*Lepas* sp.	+	
	Subclass COPEPODA		
	Order CALANOIDA		
	Superfamily CENTROPAGOIDEA		
	Family ACARTIIDAE		
289.	*Acartia bilobata* Abraham, 1979	+	
290.	*Acartia centrusa* Giesbrecht, 1889	+	
291.	*Acartia erythraea* Giesbrecht, 1889	+	
292.	*Acartia pacifica* Steuer, 1915	+	
293.	*Acartia plumosa* T. Scott, 1894	+	
294.	*Acartia spinicauda* Giesbrecht, 1889	+	
295.	*Acartiella gravelyi* Sewell, 1919	+	
296.	*Acartiella keralensis* Wellershaus, 1969	+	
	Family CANDACIDAE		
297.	*Candacia bradyii* A. Scott, 1902	+	
	Family CENTROPAGIDAE		
298.	*Centropages alcocki* Sewell, 1912	+	
299.	*Centropages furcatus* Dana, 1849	+	

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
300.	*Centropages tenuiremis* Thompson and Scott, 1903	+	-
301.	*Centropages trispinosus* Sewell, 1914	+	-
302.	*Isias cochinensis* Pillai, 1975	+	-
	Family DIAPTOMIDAE		
303.	*Heliodiaptomus cinctus* Gurney1907	+	-
304.	*Allodiaptomus mirabilipes* Kiefer, 1936	+	-
	Family PSEUDODIAPTOMIDAE		
305.	*Pseudodiaptomus annandalei* Sewell, 1919	+	-
306.	*Pseudodiaptomus aurivilli* Cleve, 1901	+	-
307.	*Pseudodiaptomus binghami malayalus* Wellershaus, 1969	+	-
308.	*Pseudodiaptomus jonesi* Pillai, 1970	+	-
309.	*Pseudodiaptomus mertoni* Früchtl, 1924	+	-
310.	*Pseudodiaptomus serricaudatus* T. Scott, 1894	+	-
311.	*Pseudodiaptomus tollingarae* Sewell, 1919	+	-
	Family PONTELLIDAE		
312.	*Labidocera acuta* Dana, 1849	+	-
313.	*Labidocera orsinii* (Giesbrecht, 1889)	+	-
314.	*Labidocera pectinata* Thompson and Scott, 1903	+	-
315.	*Labidocera kroyeri* Brady, 1883	+	-
316.	*Labidocera minutum* Giesbrecht, 1889	+	-
317.	*Labidocera pavo* Giesbrecht, 1889	+	
	Family TEMORIDAE		
318.	*Temora discaudata* Giesbrecht, 1889	+	-
319.	*Temora stylifera* Dana, 1849	+	-
320.	*Temora undulata* Dana, 1849	+	-
	Family TORTANIDAE		
321.	*Tortanus gracilis* Brady, 1883	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Superfamily EUCALANOIDEA		
	Family EUCALANIDAE		
322.	*Eucalanus crassus* Giesbrecht, 1888	+	-
323.	*Eucalanus subcrassus* Giesbrecht, 1888	+	-
	Superfamily MEGACALANOIDEA		
	Family CALOCALANIDAE		
324.	*Calocalanus pavo* Dana, 1852	+	
	Family PARACALANIDAE		
325.	*Acrocalanus monachus* Giesbrecht, 1888	+	
326.	*Acrocalanus undulata* Sewell, 1914	+	
327.	*Paracalanus aculeatus* Giesbrecht *f. major* Sewell, 1929	+	-
328.	*Paracalanus crassirostris* Dahl *f. cochinensis* Wellershaus, 1969	+	
	Suborder HARPACTICOIDA		
	Family EUTEROPINIDAE		
329.	*Euterpina acutifrons* Dana, 1847	+	
	Family LAOPHONTIDAE		
330.	*Laophonte* sp.	+	
	Order CYCLOPOIDA		
	Family CYCLOPIDAE		
331.	*Mesocyclops* sp.	+	
	Family CYCLOPINNIDAE		
332.	*Cyclopina* sp.	+	-
	Family AMEIRIDAE		
333.	*Nitocra spinipes* Boeck, 1864	+	
	Family OITHONIDAE		
334.	*Oithona attenuata* Farran, 1913	+	
335.	*Oithona brevicornis* Giesbrecht, 1892	+	
336.	*Oithona hebes* Giesbrecht, 1891	+	

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
337.	*Oithona nana* Giesbrecht, 1892	+	-
338.	*Oithona oculata* Farran, 1913	+	
339.	*Oithona plumifera* Baird, 1843	+	-
340.	*Oithona rigida* Giesbrecht, 1896	+	-
341.	*Oithona simplex* Farran, 1913	+	-
342.	*Oithona similis* Claus, 1866	+	-
	Order POECILOSTOMATOIDA		
	Family CORYCAEIDAE		
343.	*Corycaeus (Corycaeus) crassiusculus* Dana, 1849	+	
344.	*Corycaeus (Corycaeus) speciosus* Dana, 1849	+	-
345.	*Corycaeus (Ditrichocorycaeus) affinis* McMurrich, 1916	+	-
346.	*Corycaeus (Ditrichocorycaeus) andrewsi* Farran, 1911	+	
347.	*Corycaeus (Ditrichocorycaeus) asiaticus* F. Dahl, 1894	+	-
348.	*Corycaeus (Ditrichocorycaeus) undula* Tanaka, 1957	+	
349.	*Corycaeus (Ditrichocorycaeus) dubius* Farran, 1911	+	-
350.	*Corycaeus (Ditrichocorycaeus) subtilis* M. Dahl, 1912	+	
351.	*Corycaeus (Onychocorycaeus) agilis* Dana, 1849	+	
352.	*Corycaeus (Onychocorycaeus) giesbrechti* F. Dahl, 1894	+	-
353.	*Corycaeus (Onychocorycaeus) ovalis* Claus, 1863	+	
354.	*Corycaeus (Onychocorycaeus) pacificus* F. Dahl, 1894	+	-
355.	*Corycaeus (Onychocorycaeus) pumilus*	+	-
356.	*Corycaeus (Agetus) typicus* Kroyer, 1849	+	-
357.	*Farranula gibbulus* (Giesbrecht, 1891)	+	-
	Family ONCAEIDAE		
358.	*Oncaea clevi* Fruchtl, 1923	+	-
359.	*Oncaea concifera* Giesbrecht, 1891	+	-
360.	*Oncaea media* Giesbrecht, 1891	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
361.	*Oncaea mediterranea* (Claus, 1863)	+	-
362.	*Oncaea venusta* Philippi, 1843	+	-
	Family SAPPHIRINIDAE		
363.	*Sapphirina intestinata* Giesbrecht, 1891	+	-
364.	*Sapphirina nigromaculata* Claus, 1863	+	-
365.	*Sapphirina opalina* Dana, 1849	+	-
366.	*Sapphirina ovatolanceolata* Dana, 1849	+	
367.	*Sapphirina metallina* Dana, 1849	+	
368.	*Sapphirina scarlata* Giesbrecht, 1891	+	
369.	*Sapphirina stellata* Giesbrecht, 1891	+	
370.	*Copilia mirabilis* Dana, 1849	+	
371.	*Copilia quadrata* Dana, 1849	+	
	Order OSTRACODA		
	Family CYPRIDINIDAE		
372.	*Cypridina dentata* (Muller, 1906)	+	-
	Family CYPRIDIDAE		
373.	*Cypris* sp.		
374.	*Stenocypris* sp.		
375.	*Candocypria* sp.		
	Class MALACOSTRACA		
	Subclass EUMALACOSTRACA		
	Superorder PERACARIDA		
	Order MYSIDACEA		
	Family MYSIDAE		
376.	*Mesopodopsis orientalis* (W.M. Tattersall, 1908)	+	
377.	*Mesodopsis* sp.	+	
378.	*Pseudomysidetes cochinensis* Panampunnayil, 1977	+	

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Order AMPHIPODA		
	Suborder GAMMARIDEA		
	Family COROPHIIDAE		
379.	*Corophium triaenonyx* Stebbing, 1904	+	-
380.	*Grandidierella bonnieri* Stebbing, 1908	+	-
381.	*Grandidierella gravipes* Barnard, 1935	+	-
382.	*Grandidierella gilesi* Chilton, 1921	+	-
383.	*Grandidierella magne* (Giles, 1888)	+	-
	Family CALLIOPIIDAE		
384.	*Paracalliope indica* Barnard, 1935	+	-
	Family GAMMARIDAE		
385.	*Eriopisa chilkensis* (Chilton, 1921)	+	-
386.	*Maera othonides* Walker, 1904	+	-
387.	*Quadrivisio bengalensis* Stebbing, 1907	+	-
388.	*Eriopisella sechellensis* (Chevreux, 1901)	+	-
389.	*Melita zeylanica* Stebbing, 1904	+	-
390.	*Melita* sp.	+	-
391.	*Gammarus* sp.	+	-
	Family ISAEIDAE		
392.	*Gammaropsis* sp.	+	-
393.	*Parorchestia notabilis* Barnard, 1935	+	-
	Family TALITRIDAE		
394.	*Orchestia platensis* Kroyer, 1845	+	-
395.	*Talorchestia martensii* (Weber, 1892)	+	-
396.	*Hyale brevipes* Chevreux, 1901	+	-
	Family AMPELISCIDAE		
397.	*Ampelisca pusilla* Sars, 1891	+	-
	Family PODOCERIDAE		
398.	*Podocerus brasiliensis* (Dana, 1853))	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Family OEDICEROTIDAE		
399.	*Perioculoides longimanus* (Bate & Westwood, 1868)	+	-
	Suborder HYPERIIDEA		
	Family HYPERIIDAE		
400.	*Hyperia* sp.	+	-
	Suborder CAPRELLIDAE		
	Family CAPRELLIDAE		
401.	*Caprella* sp.	+	-
	Family HYALIDAE		
402.	*Parhyela hawaiensis* (Dana, 1953	+	
403.	*Parhyela* sp.	+	-
	Family PHOTIDAE		
404.	*Photis digitata* Barnard, 1935	+	
405.	*Photis longicaudata* (Bate & Westwood, 1862)	+	-
	Order TANAIDACEA		
	Family TANAIDAE		
406.	*Tanais philetaerus* Stebbing, 1904	+	-
407.	*Tanais* sp.	+	
	Family APSEUDIDAE		
408.	*Apseudes chilkensis* Chilton	+	-
409.	*Apseudes gymnophobia* Barnard, 1935	+	
	Order ISOPODA		
	Family ONISCIDAE		
410.	*Exalloniscus coecus* (Dollfus, 1898)		
	Family ANTHURIDAE		
411.	*Apanthura sandalensis* Stebbing, 1900	+	
412.	*Cyathura indica* Barnard, 1935	+	
	Family IDOTEIDAE		
413.	*Synidotea variegata* Collinge, 1917	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Family LIGIIDAE		
414.	*Ligia exotica* Roux,1828	+	-
415.	*Ligia* sp.	+	-
	Family CYMOTHOIDAE		
416.	*Anilocra leptosoma* Bleeker, 1857	+	-
417.	*Alitropus typus* Milne Edwards, 1840	+	-
	Family SPHAEROMATIDAE		
418.	*Sphaeroma annandalei* Stebbing, 1911	+	-
419.	*Sphaeroma annandalei travancorensis* Pillai, 1955	+	-
420.	*Sphaeroma terebrans* Bate, 1866	+	-
421.	*Sphaeroma walkeri* Stebbing, 1890	+	-
422.	*Cymodoce longistylis* Miers, 1884	+	-
	Family CIROLANIDAE		
423.	*Cirolana willeyi* Stebbing, 1904	+	-
424.	*Cirolana fluviatillis* Stebbing, 1902	+	-
425.	*Cirolana bovina* Barnard, 1940	+	-
426.	*Cirolana elongata* Milne Edwards, 1840	+	-
427.	*Cirolana nodosa* Schioedte and Meinert, 1879		
428.	*Cirolana* sp.	+	-
	Family CORALLANIDAE		
429.	*Corallana nodosa* Schioedte and Meinert, 1879	+	-
	Family BOPYRIDAE		
430.	*Schizobopyrina cochinensis* (Chopra, 1923)	+	-
	Family JANIRIDAE		
431.	*Iais singaporensis* Menzies and Barnard, 1951	+	-
	Order CUMACEA		
	Family DIASTYLIDAE		
432.	*Paradyastylis culicoides* Kemp, 1916	+	-
433.	*Eucoma* sp.	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Family BODOTHRIIDAE		
434.	*Iphinoe* sp.	+	-
	Order DECAPODA		
	Family PENAEIDAE		
435.	*Penaeus* (*Fenneropenaeus*) *indicus* Milne-Edwards, 1837	+	-
436.	*Penaeus* (*Penaeus*) *semisulcatus* (De Hann, 1844)	+	-
437.	*Metapenaeus affinis* (Milne-Edwards, 1837)	+	-
438.	*Metapenaeus dobsoni* (Miers, 1878)	+	-
439.	*Metapenaeus monoceros* (Fabricious, 1798)	+	
440.	*Parapenaeopsis stylifera* (Milne-Edwards, 1837)	+	-
	Family SERGESTIDAE		
441.	*Acetes indicus* H. Milne Edwards, 1830	+	
442.	*Acetes japonicus* Kishinouye, 1905 (Syn. *A. cochinensis* Rao)	+	
443.	*Acetes sibogae* Hansen, 1919	+	
444.	*Acetes sibogalis* Achuthankutty and George, 1973	+	-
	Family ATYIDAE		
445.	*Caridina nilotica* (Roux, 1833)	+	-
446.	*Caridina pseudogracilirostris* Thomas, Pillai and Pillai, 1973	+	
447.	*Caridina weberi* var. *sumatrensis* De Man, 1892)	+	
	Family PALAEMONIDAE		
448.	*Leandrites celebensis* (De Man, 1881)	+	
449.	*Leptocarpus fluminicola* (Kemp, 1917)	+	
450.	*Leptocarpus kempi* Jayachandran, 1992	+	
451.	*Leptocarpus potamiscus* (Kemp, 1917)	+	-
452.	*Macrobrachium divakarani* Jayachandran, 2001	+	-
453.	*Macrobrachium equidens* (Dana, 1852)	+	-
454.	*Macrobrachium idae* (Heller, 1862)	+	
455.	*Macrobrachium idella idella* (Hilgendorf, 1878)	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
456.	*Macrobrachium rosenbergii* (De Man, 1879)	+	-
457.	*Macrobrachium sulcatus* (Henderson and Matthai, 1910)	+	-
458.	*Macrobrachium veliense* Jayachandra and Joseph, 1985	+	-
459	*Palaemonetes hornelli* Kemp, 1925	+	-
460.	*Periclimenes grandis* (Stimpson, 1860)	+	-
	Family ALPHEIDAE		
461.	*Alpheus malabaricus* Fabricius, 1775	+	-
462.	*Alpheus strenuus* Dana, 1952	+	-
463.	*Alpheus* sp.	+	-
464.	*Synalphaeus acanthitelsonis* (Bate, 1888)	+	-
	Family LUCIFERIDAE		
465.	*Lucifer hanseni* Nobili, 1905	+	-
466.	*Lucifer typhus* H. Milne Edwards, 1837	+	-
	Family OGYRIDIDAE		
467.	*Ogyrides striaticauda* Kemp, 1915	+	-
	Family PANULIRIDAE		
468.	*Panulirus polyphagus* (Herbst, 1793)	+	-
	Section BRACHYURA		
	Family ERIPHIIDAE		
469.	*Eriphia smithi* MacLeay, 1838	+	-
	Family LEUCOSIIDAE		
470.	*Philyra* (= *Ebalia*) *malefactrix* (Kemp, 1915)	+	-
	Family GONEPLACIDAE		
471.	*Litochira* sp.	+	-
	Family HYMENOSOMATIDAE		
472.	*Elamenopsis alcocki* (Kemp, 1917)	-	+
473.	*Elamenopsis tuberculata* (Chopra and Das, 1930)	+	+

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
474.	*Halicarcinus* sp.	+	-
	Family PORTUNIDAE		
475.	*Scylla serrata* (Forskål, 1775)	+	-
476.	*Scylla tranquebarica* (Fabricius, 1798)	+	-
477.	*Portunus pelagicus* (Linnaeus, 1758)	+	
478.	*Charybdis (Charybdis) lucifera* (Fabricius, 1798)	+	
	Family PILUMNIDAE		
479.	*Benthopanope indica* (De Man, 1887)	+	-
480.	*Viaderiana* sp.	+	-
	Family GRAPSIDAE		
481.	*Grapsus albolineatus* Lamarck, 1818	+	
482.	*Metopograpsus messor* (Forskål, 1775)	+	-
	Family SESARMIDAE		
483.	*Clistocoeloma balansae* A. Milne Edwards, 1873	+	
484.	*Parasesarma plicatum* (Fabricius, 1798)	+	
485.	*Pseudosesarma edwardsi* (de Man, 1887)	+	+
	Family XENOPHTHALMIDAE		
486.	*Neoxenophthalmus garthii* (Sankarankutty, 1969)	+	-
	Family OCYPODIDAE		
487.	*Uca lactea* (De Haan, 1835)		
488.	*Uca* sp.	+	
	Family DOTILLIDAE		
489.	*Dotilla intermedia* De Man, 1888	+	-
490.	*Dotilla* sp.	+	-
	Family MACROPHTHALMIDAE		
491.	*Macrophthalmus* sp.	+	
	Family PARATHELPHUSIDAE		
492.	*Spiralothelphusa hydrodroma* (Herbst, 1794)	-	+

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Class INSECTA		
	Order EPHEMEROPTERA		
	Family BAETISAE		
493.	*Baetis* sp.	-	+
	Order ODONATA		
	Family ?		
494.	Damsel fly larvae	-	+
	Order COLEOPTERA		
	Family DYTISCIDAE		
495.	*Cybister convexus* Sharp, 1882	-	+
496.	*Cybister tripunctatus asiaticus* Sharp, 1882	-	+
497.	*Hydaticus* sp.	-	+
	Family HYDROPHILIDAE		
498.	*Hydrous unguicularis* Regimbart	-	+
499.	*Helochares anchoralis* Sharp, 1890	-	+
500.	*Amphiops pedestris* Sharp	-	+
501.	*Coelostoma* sp.	-	+
	Family GYRINIDAE		
502.	*Dineutus indicus* Aube	-	+
	Order HEMIPTERA		
	Family BELOSTOMIDAE		
503.	*Diplonychus rusticus* (Fabricius, 1803)	-	+
504.	*Diplonychus* sp.	-	+
505.	*Lethocerus indicus* (Lepeletier and Serville, 1825)	-	+
	Family NEPIDAE		
506.	*Ranatra filiformis* Fabricius, 1790	-	+
507.	*Ranatra elongata* Fabricius, 1790	-	+
508.	*Laccotrephes griseus* (Guerin, 1829)	-	+

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Family CORIXIDAE		
509.	*Micronecta quadristrigata* Breddin, 1905	-	+
	Family NOTONECTIDAE		
510.	*Anisops* sp.	-	+
	Family GERRIDAE		
511.	*Limnogonus nitidus* (Mayr, 1865)		+
	Family MESOVELIIDAE		
512.	*Mesovelia vittigera* Horvath, 1895		+
	Family HYDROMETRIDAE		
513.	*Hydrometra greeni* kirkaldy, 1898		+
	Order DIPTERA		
	Family CULICIDAE		
514.	*Anopheles* larvae	-	+
	Family CHIRONOMIDAE		
515.	*Cricotopus sylvestris* (Fabricius, 1794		+
516.	*Diamesa* sp.		+
	Family CERATOPOGONIDAE		
517.	*Bezzia* sp.	-	+
	Family SIMULDAE		
518.	*Simulium* sp.		+
	Class ARACHNIDA		
	Order ARANEAE		
	Family TETRAGNATHIDAE		
519.	*Tetragnatha* sp.		+
	Family LYCOSIDAE		
520.	*Lycosa* sp.		+
	Family SALTICIDAE		
521.	*Zygoballus narmadaensis* Tikader, 1975	-	+

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Order ACARI		
	Family HALACARIIDAE		
522.	*Copidognathus balakrishnani* Chatterjee, 2000	-	+
523.	*Copidognathus sideus* Bartsch, 1982	-	+
	13. Phylum SIPUNCULA		
524.	Indeterminate species	+	-
	14. Phylum ECHIURA		
525.	*Echiurus* sp.	+	-
	15. Phylum ECTOPROCTA (BRYOZOA)		
	Class GYMNOLAEMATA		
	Order CTENOSTOMATA		
	Family MEMBRANIPORIDAE		
526.	*Membranipora savartii* (Audouin, 1826)	+	-
527.	*Membranipora* sp.	+	-
	Order CHEILOSTOMATA		
	Family BUGULIDAE		
528	*Bugula cucullata* Busk, 1867	+	-
529.	*Bugula neritina* (Linnaeus, 1758)	+	-
530.	*Bugula* sp.	+	-
	Family SCHIZOPORELLIDAE		
531.	*Schizoporella cochinensis* Menon and Nair, 1967	+	-
532.	*Schizoporella unicornis* Johnston, 1874	+	-
533.	*Schizomovella linearis* var. *inarmata* (Hincks)	+	-
	Family VESICULARIIDAE		
534.	*Bowerbankia gracilis* Leidy, 1855	+	-
	Family VICTORELLIDAE		
535.	*Victorella pavida* Saville Kent, 1870	+	-

Sl. No.	Groups and species	Occuurrence in	
		Downstream	Upstream
	Family ELECTRIDAE		
536.	*Electra bengalensis* (Stoliczka, 1869)	+	-
537.	*Electra crustulenta* (Pallas, 1776)	+	-
	Family CALLOPORIDAE		
538.	*Alderina arabianensis* Menon and Nair, 1975	+	-
	Family NOLELLIDAE		
539.	*Nolella papuensis* (Busk, 1886)	+	-
	Family WALKERIIDAE		
540.	*Aeverrilla setigera* (Hincks)	+	-
	Family SAVIGNYELLIDAE		
541.	*Savignyella lafonti* (Audouin, 1826)	+	-
	Family WATERSIPORIDAE		
542.	*Watersipora subovoidea* (d' Orbigny, 1852)	+	-
	Family THALAMOPORELLIDAE		
543.	*Thalamoprella* sp.	+	-
	16. Phylum ECHINODERMATA		
	Family ?		
544.	*Echinoderm* (Undetermined)	+	-
	17. Phylum CHAETOGNATHA		
	Family SAGITTIDAE		
545.	*Sagitta bedoti* Beraneck, 1895	+	-
546.	*Sagitta undulat* Grassi, 1881	+	-
547.	*Sagitta oceania* Gray, 1930	+	-
548.	*Sagitta pulchra* Doncaster, 1902	+	
549.	*Sagitta robusta* Doncaster, 1902	+	
	Family KROHNITTIDAE		
550.	*Krohnitta pacifica* Tokoika, 1940	+	-

Table 2. Group and familywise distribution of genera and species of invertebrate fauna of Vembanad Lake

Sl. No.	Family	Genus	Species
	Phylum SARCOMASTIGOPHORA	**17**	**37**
1.	Diffugidae	1	1
2.	Globigerinidae	1	1
3.	Saccamminidae	1	1
4.	Reophacidae	1	2
5.	Lituolidae	1	3
6.	Textulariidae	1	3
7.	Rzehakinidae	1	1
8.	Trichamminidae	1	3
9.	Miliolidae	2	4
10.	Nonionidae	1	4
11.	Elphidiidae	1	4
12.	Nummulitidae	1	3
13.	Buliminidae	1	2
14.	Rotaliidae	2	4
15.	Anomalinidae	1	1
	Phylum CILIOPHORA	**8**	**8**
16.	Cryptochilidae	1	1
17.	Ancistridae	1	1
18.	Nucleocorbulidae	1	1
19.	Vorticellidae	2	2
20.	Urceolariidae	1	1
21.	Nyctotheridae	1	1
22.	Foliculinidae	1	1
	Phylum PORIFERA	**3**	**3**
23.	Chalinidae	1	1

Sl. No.	Family	Genus	Species
24.	Tedaniidae	1	1
25.	Undetermined	1	1
	Phylum CNIDARIA	**34**	**48**
	HYDROIDA		
26.	Campanulariidae	2	5
27.	Blackfordiidae	1	1
28.	Clytiidae	1	1
29.	Lovenellidae	1	2
30.	Eirenidae	2	7
31.	Tubulariidae	1	1
32.	HalocordylIdae	2	2
33.	Cytaeidae	1	1
34.	Bougainvilliidae	2	2
35.	Pandeidae	2	2
36.	Aequoreidae	1	3
37.	Rhopalonematidae	1	2
38.	Geryoniidae	2	2
39.	Cuninidae	1	1
40.	Aeginidae	1	1
41.	Zancleidae	1	1
42.	Mitrocomidae	1	1
43.	Phialuciidae	1	2
44.	Hydractiniidae	1	1
	SIPHONOPHORA		
45.	Diphyidae	4	5
	SCYPHOZOA		
46.	Catostylidae	2	2
	ANTHOZOA		
47.	Haliactidae	1	1

Sl. No.	Family	Genus	Species
48.	Edwardsiidae	1	1
49.	Actiniidae	1	1
	Phylum CTENOPHORA	**2**	**3**
50.	Pleurobranchiidae	2	3
	Phylum NEMERTINA	**1**	**1**
51.	Undetermined	1	1
	Phylum ROTIFERA	**1**	**13**
52.	Brachionidae	1	13
	Phylum PLATYHELMINTHES	**1**	**1**
53.	Undetermined	1	1
	Phylum NEMATODA	**6**	**6**
54.	Anticomidae	2	2
55.	Comesomatidae	2	2
56.	Desmodoridae	1	1
57.	Xylidae	1	1
	Phylum SIPUNCULA	**1**	**1**
58.	Undetermined	1	1
	Phylum MOLLUSCA	**65**	**84**
	ARCHAEOGASTROPODA		
59.	Trochidae	1	1
60.	Neritidae	2	2
	MESOGASTROPODA		
61.	Patellidae	1	1
62.	Littorinidae	3	3
63.	Iravadiidae	1	2
64.	Thiaridae	2	2
65.	Hydrobiidae	1	1
66.	Cerithidae	1	1

Sl. No.	Family	Genus	Species
67.	Naticidae	1	3
68.	Viviparidae	1	3
69.	Ampullariidae	1	2
70.	Bursidae	1	2
71.	Turitellidae	1	2
	NEOGASTROPODA		
72.	Nassariidae	1	2
73.	Vasidae	1	1
74.	Muricidae	2	3
75.	Buccinidae	1	1
76.	Conidae	1	1
	HETEROBRANCHIA		
77.	Pyramidellidae	1	1
	OPISTHOBRANCHIDA		
78.	Hamineidae	1	1
	PULMONATA		
79.	Ellobiidae	1	1
80.	Lymnaeidae	1	1
81.	Planorbidae	1	1
	BIVALVIA		
	NUCULOIDA		
82.	Nuculaniidae	1	1
	ARCOIDA		
83.	Arcidae	4	4
	MYTLLOIDA		
84.	Mytilidae	3	4

Sl. No.	Family	Genus	Species
	VENEROIDA		
85.	Cardiidae	1	1
86.	Mactridae	1	1
87.	Ostreidae	3	3
88.	Solenidae	1	1
89.	Cultellidae	1	1
90.	Tellinidae	1	2
91.	Semelidae	1	2
92.	Corbiculidae	2	3
93.	Veneridae	6	7
94.	Unionidae	1	1
	MYOIDA		
95.	Pholadidae	1	2
96.	Teredinidae	7	9
	POROMYOIDA		
97.	Cuspadariidae	1	1
98.	Cavolinidae	1	1
	SCAPHOPODA		
99.	Dentalidae	1	1
	Phylum ECHIURA	**1**	**1**
100.	Undetermined	1	1
	POLYCHAETA		
101.	Sigalionidae	1	1
	Phylum ANNELIDA	**51**	**74**
102.	Glyceridae	1	3
103.	Onuphidae	1	1
104.	Lumbrineridae	1	5
105.	Nephtyidae	1	2

Sl. No.	Family	Genus	Species
106.	Nereididae	6	15
107.	Capitellidae	7	8
108.	Spionidae	5	7
109.	Pilargidae	1	1
110.	Syllidae	2	2
111.	Eunicidae	2	4
112.	Goniadidae	1	1
113.	Terebellidae	2	2
114.	Oweniidae	1	1
115.	Pectinariidae	2	2
116.	Amphinomidae	1	1
117.	Polynoidae	2	2
118.	Sabellariidae	1	1
119.	Serpullidae	3	3
120.	Talhespiidae	1	1
121.	Phyllodocidae	1	1
	OLIGOCHAETA		
122.	Naididae	4	5
123.	Tubificidae	3	4
124.	Ampharetidae	1	1
	Phylum ARTHROPODA	**121**	**214**
	CRUSTACEA		
	CLADOCERA		
125.	Podonidae	2	2
126.	Sididae	1	1
	CIRRIPEDIA		
127.	Balanidae	1	6
128.	Lepadidae	1	1
	COPEPODA		
129.	Acartiidae	2	8

Sl. No.	Family	Genus	Species
130.	Candaciidae	1	1
131.	Centropagidae	2	5
132.	Diaptomidae	2	2
133.	Pseudodiaptomidae	1	7
134.	Pontellidae	1	6
135.	Temoridae	1	3
136.	Tortanidae	1	1
137.	Eucalanidae	1	2
138.	Calocalanidae	1	1
139.	Paracalanidae	2	4
	HARPACTICOIDA		
140.	Euteropinidae	1	1
141.	Laophontiidae	1	1
	CYCLOPOIDA		
142.	Cyclopidae	1	1
143.	Cyclopinnidae	1	1
144.	Ameiridae	1	1
145.	Oithonidae	1	9
	POECILOSTOMATOIDA		
146.	Corycaeidae	2	15
147.	Oncaeidae	1	5
148.	Sapphirinidae	2	9
	OSTRACODA		
149.	Cyprididae	3	3
150.	Cypridinidae	1	1
	MYSIDACEA		
151.	Mysidae	2	3
	AMPHIPODA		
152.	Corophiidae	2	5

Sl. No.	Family	Genus	Species
153.	Calliopiidae	1	1
154.	Gammaridae	6	7
155.	Isaeidae	2	2
156.	Talitridae	3	3
157.	Ampeliscidae	1	1
158.	Podoceridae	1	1
159.	Oedicerotidae	1	1
160.	Hyperiidae	1	1
161.	Caprellidae	1	1
162.	Hyalidae	1	2
163.	Photidae	1	2
	TANAIDACEA		
164.	Tanaidae	1	2
165.	Apseudidae	1	2
	ISOPODA		
166.	Oniscidae	1	1
167.	Anthuridae	2	2
168.	Idoteidae	1	1
169.	Ligiidae	1	2
170.	Cymothoidae	2	2
171.	Sphaeromatidae	2	5
172.	Cirolanidae	1	6
173.	Corallanidae	1	1
174.	Bopyridae	1	1
175.	Janiridae	1	1
	CUMACEA		
176.	Diastylidae	2	2
177.	Bodothriidae	1	1

Sl. No.	Family	Genus	Species
	DECAPODA		
178.	Penaeidae	3	6
179.	Sergestidae	1	4
180.	Palaemonidae	5	13
181.	Atyidae	1	3
182.	Alpheidae	2	4
183.	Luciferidae	1	2
184.	Ogyrididae	1	1
185.	Panuliridae	1	1
	BRACHYURA		
186.	Eriphiidae	1	1
187.	Goneplacidae	1	1
188.	Leucosiidae	1	1
189.	Hymenosomatidae	2	3
190.	Portunidae	3	4
191.	Pilumnidae	2	2
192.	Grapsidae	2	2
193.	Sesarmidae	3	3
194.	Dotillidae	1	2
195.	Macrophthalmidae	1	1
196.	Ocypodidae	1	2
197.	Xenophthalmidae	1	1
198.	Parathelphusdae	1	1
	Class INSECTA	**23**	**26**
	EPHIMEROPTERA		
199.	Baetidae	1	1
	ODONATA		
200.	Family ?	1	1

Sl. No.	Family	Genus	Species
	COLEOPTERA		
201.	Dytiscidae	2	3
202.	Hydrophilidae	4	4
203.	Gyrinidae	1	1
	HEMIPTERA		
204.	Belostomatidae	2	3
205.	Nepidae	2	3
206.	Corixidae	1	1
207.	Notonectidae	1	1
208.	Gerridae	1	1
209.	Mesoveliidae	1	1
210.	Hydrometridae	1	1
	DIPTERA		
211.	Culicidae	1	1
212.	Simulidae	1	1
213.	Ceratopogonidae	1	1
214.	Chironomidae	2	2
	ARACHNIDA	**3**	**3**
215.	Tetragnathidae	1	1
216.	Lycosidae	1	1
217.	Salticidae	1	1
	ACARI		
218.	Halacariidae	1	2
	ECTOPROCTA (BRYOZOA)	**12**	**18**
219.	Membraniporidae	1	2
220.	Bugulidae	1	3
221.	Schizoporellidae	1	3
222.	Vesiculariidae	1	1
223.	Victorellidae	1	1
224.	Electridae	1	2

Sl. No.	Family	Genus	Species
225.	Calloporidae	1	1
226.	Nolellidae	1	1
227.	Walkeriidae	1	1
228.	Savignyellidae	1	1
229.	Watersiporidae	1	1
230.	Thalamoporellidae	1	1
	ECHINODERMATA		
231.	Family ?	1	1
	CHAETOGNATHA	**2**	**6**
232.	Sagittidae	1	5
233.	Krohnittidae	1	1

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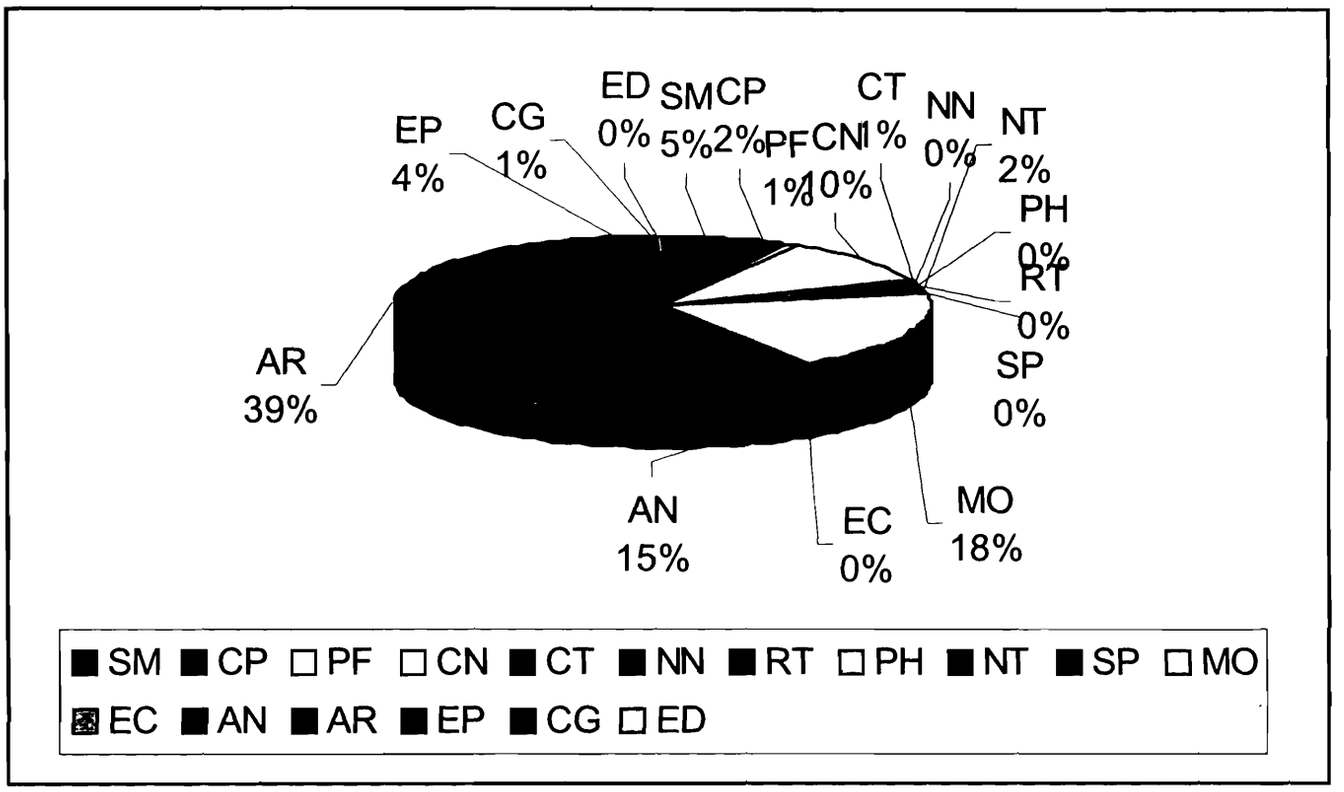

Fig. 4.1(A). Invertebrate Generic Diversity of Vimbanad Lake.

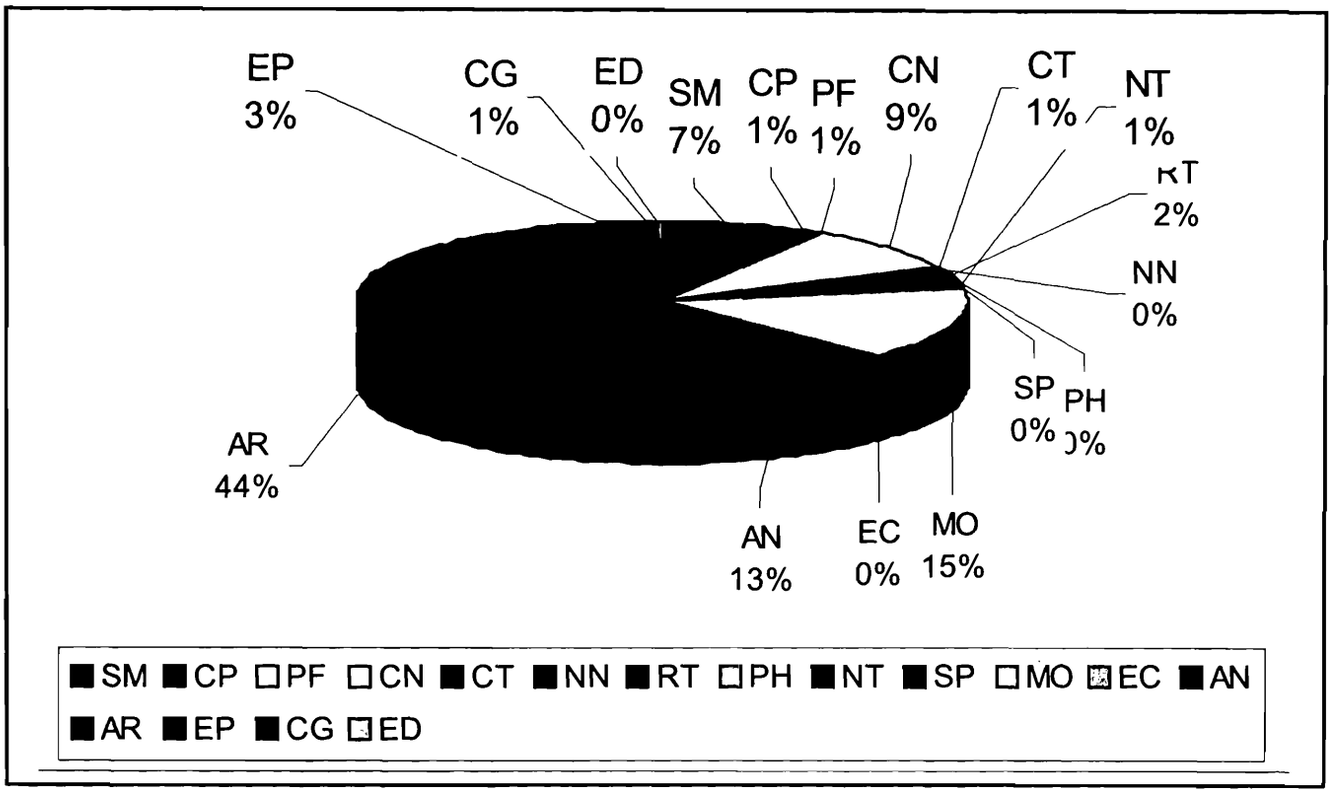

Fig. 4.1(B). Invertebrate Species Diversity of Vimbanad Lake.

ABBREVIATIONS USED IN FIG. 4.1(A) AND FIG. 4.1(B)

SM=Sarcomastigophora

CP=Ciliophora

PF=Porifera

CN=Cnidaria

CT=Ctenophora

NN=Nemertina

RT=Rotifera

PH=Platyhelminthes

SP= Sipuncula

MO=Mollusca

EC=Echiura

AN=Annelida

AR= Arthropoda

EP=Ectoprocta (=Bryozoa)

CG=Chaetognatha

Fig. 4.2 *Penaeus* (*Fenneropenaeus*) *indicus* Milne Edwards

Fig. 4.3 *Metapenaeus monoceros* (Fabricius)

Fig. 4.4 *Metapenaeus affinis* Milne Edwards

Fig. 4.5 *Macrobrachium rosenbergii* (De Man)

Fig. 4.6. *Scylla serrata* (Forskål)

Fig. 4.7. *Portunus pelagicus* (Linnaeus)

Fig. 4.8. *Benthopanope indica* (De Man)

Fig. 4.9. *Metopograpsus messor* (Forskål)

Fig. 4.10. *Parasesarma plicatum* (Fabricius)

Fig. 4.11. *Pseudosesarma edwardsi* (De Man)

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MACROBENTHOS

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INTRODUCTION

Investigations on benthic community of aquatic ecosystem have considerable relevance as they occupy an intermediate position in the trophic structure and for their role in the energy cycle. They provide important clues on the available organic matter and are known to reflect the past and the present environmental condition of an ecosystem more efficiently than physical and chemical indices of water and soil (Hynes, 1960; Hofmann, 1978). They are also regarded as best indicators of pollution because of their constant presence, relatively long life, sedentary habit and different tolerance to stress. The present study on macrobenthos of Vembanad Lake is made to determine the qualitative composition of the benthic fauna both in the upstream and downstream of Thaneermukkom bund. In addition to the typically benthic forms, several species like *Balanus* spp. and *Sphaeroma* spp. which are associated with cemented and wooden structures at the bottom of the lake are also included in the paper

In India, studies on ecology and diversity of brackishwater macrobenthic animal communities have received appreciable attention. Annandale (1907) and Annandale and Kemp (1915) earlier studied the ecology of Gangetic delta and Chilka Lake respectively, while several investigators studied the benthic fauna of Cochin backwater (Desai and Krishnan Kutty, 1967; Kurian, 1967, 1972; Ansari, 1974; Kurian *et al.*, 1975; Pillai, 1977: Batcha, 1984; Sarala Devi and Venugopal, 1989a; Sunil Kumar, 1995).

MATERIALS AND METHODS

Mainly qualitative and in some suitable sites quantitative samplings were done from Vembanad Lake by hand picking, drag netting and by a box type sampler. The materials collected using samplers were washed thoroughly in a standard sieve of 0.5 mm mesh size. Samples were sorted in large enamel trays and preserved in 4% formalin or 70% alcohol. A few water parameters were also measured.

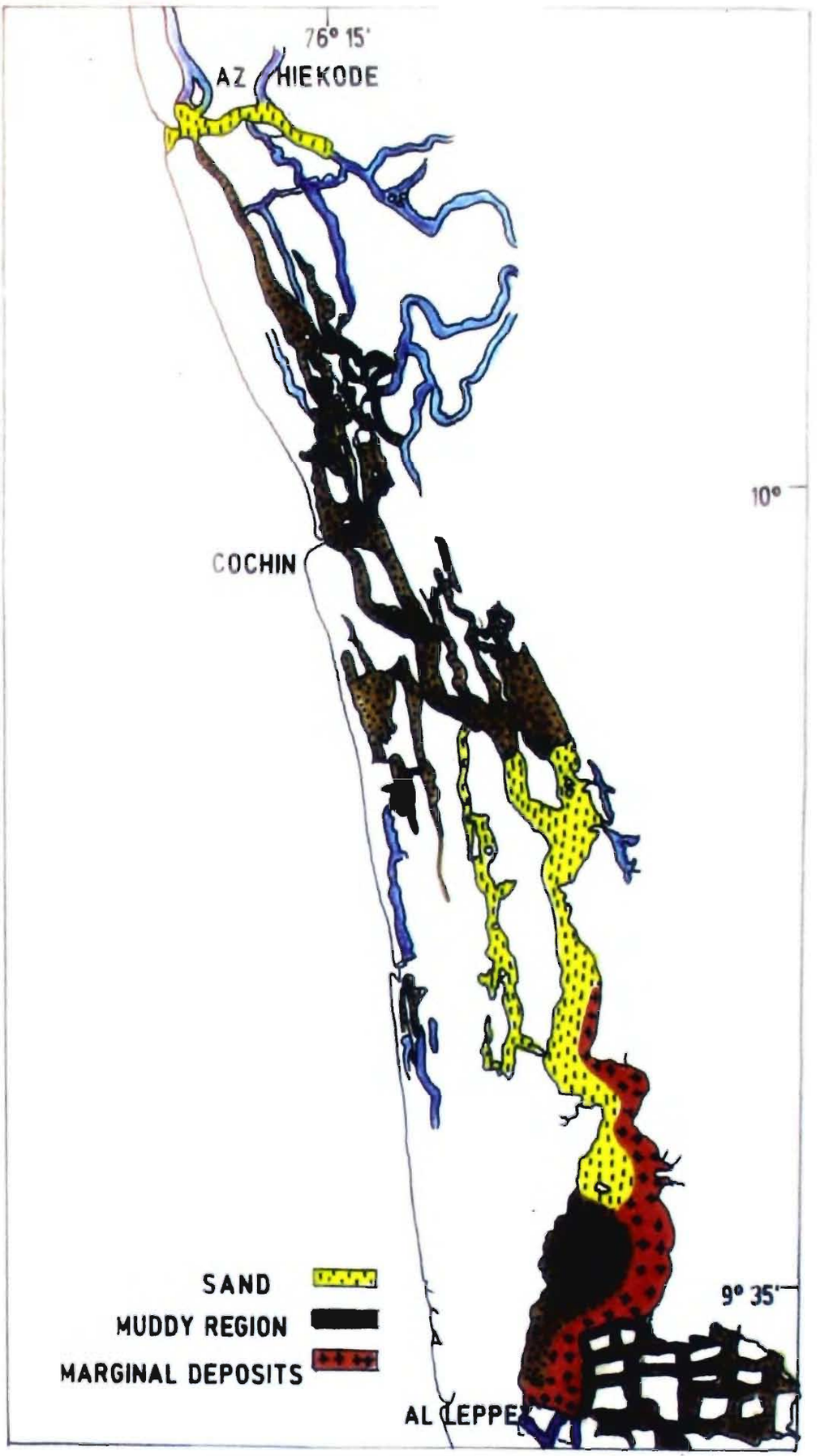

Fig. 5.1. Soil profile of Vembanad Lake.

RESULTS

Water quality

During the course of two survey works, both in March 2002 and 2003, the collected physicochemical parameters of water of upstream and downstream stations are pooled and presented in Table 1, which indicates lower salinity level in the upstream stations. The lake water is widely used for coir retting where physico-chemical conditions differ considerably from the non-retting areas (Table 2).

Table 1. Water quality parameters of of Vembanad Lake at different stations.

Parameters	Collecting stations	
	Downstream Stations (1-8)	Upstream Stations (9-12)
Air temperature (°C)	28-34	32-34
Water temperature (°C)	27-35	32-36
pH	6.7-7.5	6.5-6.8
Alkalinity (mg/l)	0.2-1.2	0.3
D. O. (mg/l)	3.8-8.3	3.6-6.0
Salinity (ppt)	11-32	2.0-8.0

Note : 1. Azhikode, 2. Kottapuram, 3. Vypin Island, 4. Kumbalam, 5. Vaikom, 6. Vayalar, 7. Cherthala, 8. Thavenakadave, 9. Thanneermukkam, 10. Kumarakam, 11. Muhamma, 12. Punnamada.

Table 2. Mean values of physico-chemical characteristics of retting and non-retting zones in the backwaters

Parameters	Retting site	Non-retting site
Depth (m)	1.88	2.88
Transparency (m)	0.60	0.69
pH	6.92	7.99
Dissolved oxygen (mg/l)	2.43	7.60
Total sulfides (mg/l)	8.80	3.01
Turbidity (NTU)	2.62	1.60
Free carbon dioxide (mg/l)	6.4	3.5
Alkalinity (MO) (mg/l CaCO3)	103	91
Alkalinity (Ph) (mg/l CaCO3)	6.7	10
Inorganic phosphate	40.6	36.5

Source : Bijoy Nandan (2004)

Sediment characteristics

Several reports are available on the sediment characteristics of Vembanad Lake (Murty and Veeryya, 1972; Padmalal and Seralathan, 1991; Sundaresan, 1991; Sunil Kumar, 1995; Nair *et al.*, 1995). It may be mentioned that sediment, interstitial water and overlying water of Vembanad between Thaneermukkom bund and Fort Cochin have been studied by Padmalal and Seralathan (1991), which indicate that lake sediments are associated with organic matter, exhibiting a general increase towards the estuarine mouth, while lower salinity value prevails in the southern part of the Cochin backwaters. Sundaresan (1991) studied the textural distribution of surface sediments of the Cochin harbour and reported fine sediment in the inner channels and coarse fraction in the approach channel, and also indicated that littoral transport played a major role in the sedimentation of Cochin harbour. Nair *et al.* (1995) analysed the surficial sediment (Table 3) and reported that the concentration of petroleum hydrocarbon was higher in the estuarine areas of high salinity than at the riverine area of low salinity. Similarly, Sunil Kumar (1995) assessed the percentage of sand-silt-clay and organic carbon contents in the mangrove ecosystem of Cochin backwaters and encountered lower percentage of silt, clay and organic carbon particularly in the fringe areas exposed to the constant flushing (Table 4).

Table 3. Sediment characteristic of Cochin estuary during monsoon and non-monsoon season

Parameters	Monsoon	Non-monsoon
Salinity	0.15-21.35 x 10^{-3}	4.64-31.00^{-3}
pH	6.50-7.40	6.60-7.59
Texture	Sand/ Sand-silt-clay/ Clayey-silt	Sand/Sand-silt/Clayey-silt/ Silt-clay
Organic carbon (mg.g $^{-1}$)	0.98-33.53	2.56-33.03
Petroleum hydrocarbon ($\mu g.g^{-1}$)	275.00-306.43	249.10-570.09

Source : Nair *et al.* (1995)

Table 4. Sediment characteristics of Cochin mangrove ecosystem at low, mid and high tide level areas

Parameters	Low tide level	Mid tide level	High tide level
Sand (%)	56.29-85.99	64.56-85.04	55.32-86.68
Silt (%)	7.92-24.62	5.51-20.87	6.68-27.30
Clay (%)	5.85-19.09	8.58-14.58	6.64-17.45
Organic carbon (%)	0.48-2.23	0.51-1.96	0.73-2.35

Source : Sunil Kumar (1995)

Substratum condition

The substratum condition of sampling stations at Kumbalam, Cherthala and Kumarakam was mainly muddy, while rest of the stations were predominately sandy mixed with mud though varying from station to station. Even within the mixed sandy station there were areas with or without vegetation, vegetable matter, humous, silt, sand, cemented structures, boulders, etc., in various proportions. The sediment characteristics of Vembanad Lake after Josanto (1971) is shown in Fig. 5.1.

Composition and diversity

Based on literature as well as survey work, a total of 169 macrobenthic invertebrate species belonging to 10 major groups have been listed from Vembanad Lake and presented in Table 5. During the course of survey work nemertean worm was once observed in the mangrove mudflat at Vypin Island only. Similarly echiurid worm was encounterd in the mudflat at Kumbalam. The species-wise data so far obtained and recorded for different groups indicate the composition of species at the upstream and downstream regions of this lake. It is evident that downstream stations represent higher diversity of species (141 species) over upstream stations (36 species). Similarly, the crustacean and molluscan macrobenthic species collected and/or observed from each of the 12 stations surveyed from this lake are depicted in Table 6. It has been found that among the downstream stations, Vypin was inhabited by 10 species, while among the upstream stations, maximum of 8 species was recorded from Punnamada.

Macrobenthic crustaceans were mainly represented by amphipods, isopods, tanaidaceans and decapods. Amphipods were represented *Gammarus* and *Corophium* species, while isopods were predominated by *Sphaeroma* species. The mussel, ***Musculista senhausia*** (Bivalvia : Mytilidae), which is used as poultry feed and fertilizer, occurs in large quantity ranging in size from 10-29 mm in length in certain areas of Cochin backwaters (Sreedhar and Radhakrishnan, 1995).

Sarala Devi and Venugopal (1989a) recorded 10 species of polychaetes from Cochin backwaters. Subsequently, Sarala Devi *et al.* (1991) reported 30 species of polychaetes in northern limb of Cochin backwaters, of which *Capitella capitata* showed high density near the effluent discharge site perhaps being pollution indicator species. ***Dendronereis aestuarina*** was present at all sites but with high densites in polluted areas apparently being pollution resistant species and species like *Lycastis indica*, ***Paraheteromastus tenuis*** and *Telehspia annandalei* including chironomid larvae and ***Penora flexosa*** in very low numbers in the effluent discharged site indicating their existence as pollution tolerant species. Sunil Kumar (1995) recorded 53 species of macrobenthos in the mangrove ecosystem of Cochin backwaters of which the bulk of bottom fauna was constituted by polychaetes (33 species). Among these polychaetes the prominent species were *Paraheteromastus tenuis*, *Marphysa gravelyi*, *Nereis glandicincta*, *Dendronereides heteropoda* and *Dendronereis aesturina* in the mangrove ecosystem of Cochin backwaters. In the coconut husk retting areas, four species of

polychaetes viz., *Branchiocapitella* sp., *Ceratonereis* sp., *Nereis chingrighattensis* and *Prionospio cirriferra* have been recorded, while in the non-retting areas another four species such as, *Ceratonereis* sp., *Lycastis indica*, *Nereis chingrihattensis* and *Prionospio cirriferra*, were observed. It is mentioned that *Branchiocapitella* sp. occurred exclusively in the retting sites and *Lycastis indica* encountered in non-retting locations.

Table 5. List of macrobenthic invertebrate species recorded fromVembanad Lake.

Sl. No.	Group and Species	Stations	
		Downstream (1-8)	Upstream (9-12)
	Cnidaria		
1.	*Bimeria franciscana*	+	-
	Nemathelminthes		
2.	*Desmodora* sp.	+	-
3.	*Trichoma* sp.	+	-
	Echiurida		
4.	Undetermined species	+	-
	Polychaeta		
5.	*Amphicteis gunneri*	+	-
6.	*Ancistrosyllis constricta*	+	-
7.	Aphroditids (undetermined)	+	-
8.	*Branchiocapitella singularis*	+	-
9.	*Capitella capitata*	+	-
10.	*Capitella* sp.	+	-
11.	*Ceratonereis costae*	+	-
12.	*Ceratonereis mirabilis*	+	-
13.	*Ceratonereis* sp.	+	-
14.	*Dendronereis aestuarina*	+	-
15.	*Dendronereis arborifera*	+	-
16.	*Dendronereis* sp.	+	-
17	*Dendronereides heteropoda*	+	-
18.	*Diopatra neapolitana*	+	-

Sl. No.	Group and Species	Stations	
		Downstream (1-8)	Upstream (9-12)
19.	*Eunice tubifex*	+	-
20.	*Eunice sp.*	+	-
21.	*Ficopomatus macrodon*	+	-
22.	*Glycera alba*	+	-
23.	*Glycera convoluta*	+	-
24.	*Glycera longipinnis*	+	-
25.	*Glycera papillosa*	+	-
26.	*Goniada emerita*	+	-
27.	*Heteromastides bifidus*	+	-
28.	*Heteromastus simiis*	+	-
29.	*Lumbrinereis latrelli*	+	-
30.	*Lumbrinereis notocirrata*	+	-
31.	*Lumbrinereis pseudobifilaris*	+	-
32.	*Lumbrinereis simplex*	+	-
33.	*Lumbrinereis* sp.	+	-
34.	*Nemalycastis indica*	+	-
35.	*Marphysa gravelyi*	+	-
36.	*Marphysa stragulum*	+	-
37.	*Mercierella enigmatica*	+	-
38.	*Nephtys oligobranchia*	+	-
39.	*Nephtys polybranchia*	+	-
40.	*Nereis chingrighattensis*	+	+
41.	*Nereis chilkaensis*	+	-
42.	*Neanthes glandicincta*	+	-
43.	*Nereis kauderni*	+	-
44.	*Notopygos* sp.	+	-
45.	*Odontosyllis gravelyi*	+	-

Sl. No.	Group and Species	Stations	
		Downstream (1-8)	Upstream (9-12)
46.	*Owenia* sp.	+	-
47	*Paraheteromastus tenuis*	+	-
48.	*Perinereis cavifrons*	+	-
49.	*Perinereis* sp.	+	-
50.	*Phyllodoce* sp.	+	-
51.	*Pista indica*	+	-
52.	*Pseudopolydora kempi*	+	-
53.	*Polydora* sp.	+	-
54.	*Prionospio pinnata*	+	-
55.	*Prionospio polybranchiata*	+	-
56.	*Prionospio* sp.	+	-
57.	*Pulliella armata*	+	-
58.	*Serpula vermicularis*	+	-
59.	*Sthenelais boa*	+	-
60.	*Talehsapia annandalei*	+	-
	Oligochaeta		
61.	*Aulodrilus remex*	-	+
62.	*Aulodrilus* sp.	-	+
63.	*Dero cooperi*	-	+
64.	*Dero* sp.	-	+
65.	*Hanochaeta* sp.	-	+
66.	*Limnodrilus hoffmeisteri*	+	+
67	*Nais* sp.	-	+
	Mollusca : Gastropoda		
68.	*Bellamya benglensis*	-	+
69.	*Bittium* sp.	-	+
70.	*Haminea elegans*	+	-

Sl. No.	Group and Species	Stations	
		Downstream (1-8)	Upstream (9-12)
71.	*Hydrobia* sp.	+	-
72.	*Indoplanorbis exustus*	-	+
73.	*Littorina littorea*	+	-
74.	*Littoraria (Littoraria) undulata*	+	-
75.	*Littorina (Littorinopsis) scabra scbra*	+	-
76.	*Melampus* sp.	+	
77.	*Neritina (Dostia) violacea*	-	+
78.	*Pila* sp.	-	+
79.	*Thiara (Thiara) scabra*	-	+
80.	*Melanoides tuberculata*	-	+
	Mollusca : Bivalvia		
81.	*Anadara granosa*	+	-
82.	*Arca* sp.	+	-
83.	*Bankia campanellata*	+	-
84.	*Bankia carinata*	+	-
85.	*Batisa sp.*	+	-
86.	*Crassostrea cuttackensis*	+	-
87.	*Dicyathifer manni*	+	-
88.	*Lamellidens marginalis*	-	+
89.	*Lyrodus pedicellatus*	+	-
90.	*Martesia striata*	+	-
91.	*Martesia fragilis*	+	-
92.	*Meretrix casta*	+	-
93.	*Meretrix meretrix*	+	-
94.	*Modiolus striatulus*	+	-
95.	*Modiolus undulata*	+	-
96.	*Musculista senhausia*	+	-

Sl. No.	Group and Species	Stations	
		Downstream (1-8)	Upstream (9-12)
97.	*Nasutora hedleyi*	+	-
98.	*Ostrea forskalli*	+	-
99.	*Paphia ala-papillionis*	+	-
100.	*Pandora flexosa*	+	-
101.	*Perna viridis*	+	-
102.	*Saccostrea cuculata*	+	-
103.	*Tellina tenuis*	+	-
104.	*Tellina* sp.	+	-
105.	*Teredo clappi*	+	-
106.	*Teredo furcifera*	+	-
107.	*Teredora princesae*	+	-
108.	*Villorita cyprinoids cochinensis*	+	+
109.	*Cuspidaria* sp.	+	-
	Crustacea		
110.	*Acetes* sp.	+	-
111.	*Alpheus* sp.	+	-
112.	*Apseudes chilkensis*	+	-
113.	*Balanus amphitrite*	+	-
114.	*Balanus tintinnabulum tintinnabulum*	+	-
115.	*Balanus* sp.	+	-
116.	*Benthopanope indica*	+	-
117.	*Charybdis (Charybdis) lucifera**	+	-
118.	*Cirolina fluviatilis*	+	-
119.	*Clistocoeloma balansae**	+	-
120.	*Corophium triaenonyx*	+	-
121.	*Dotilla intermedia**	+	-
122.	*Dotilla* sp.	+	-

Sl. No.	Group and Species	Stations	
		Downstream (1-8)	Upstream (9-12)
123.	*Philyra malefactrix**	+	-
124.	*Eriopisa chilkensis*	+	-
125.	*Grandideirella bonnieri*	+	-
126.	*Grandideirella gilesi*	+	-
127.	*Grapsus albolineatus**	+	-
128.	*Gammarus* sp.	+	-
129.	*Halicarcinus* sp.	+	-
130.	*Matuta victor*	+	-
131.	*Melita zeylanica*	+	-
132.	*Metopograpsus messor*	+	-
133.	*Macrobrachium* sp.	+	+
134.	*Palaemon* sp.	+	+
135.	*Parhyale hawaensis*	+	-
136.	*Parasesarma plicatum*	+	-
137.	*Spiralothelphusa hydrodroma*	-	+
138.	*Photis digitata*	+	-
139.	*Photis longicauda*	+	-
140.	*Portunus pelagicus*	+	-
141.	*Pseudosesarma edwardsi**	+	+
142.	*Quadrivisio bengalensis*	+	-
143.	*Elamenopsis alcocki*	+	
144.	*Scylla serrata**	+	+
145.	*Scylla tranquebarica**	+	+
146.	*Sphaeroma annandalei*	+	
147.	*Sphaeroma terebrans*	+	
148.	*Sphaeroma annandalei travancorensis*	+	
149.	*Sphaeroma walkeri*	+	

*New record from Vembanad Lake.

Sl. No.	Group and Species	Stations	
		Downstream (1-8)	Upstream (9-12)
150.	*Sphaeroma* sp.	+	-
151.	*Uca lactea**	+	-
152.	*Uca* sp.	+	-
153.	*Viaderiana* sp.	+	-
154.	*Neoxenophthalmus* sp.	+	-
	Insecta		
155.	*Amphiops pedestris**	-	+
156.	*Baetis* sp.	-	+
157.	*Cybister convexus**	-	+
158.	*Cybister tripunctatus asiaticus**	-	+
159.	*Cybister* sp.*	-	+
160.	*Hydrous unguicularis**	-	+
161.	*Helochares anchoralis**	-	+
162.	*Simulium* sp.	-	+
163.	Chironomid larvae	-	+
164.	Mayfly larvae	-	+
165.	Mosquito larvae	-	+
166.	Odonata larvae	-	+
167.	Water beetle larvae	-	+
	Bryozoa		
168.	*Bugula* sp.	+	-
169.	*Membranipora* sp.	+	-

Note : Species marked with asterisk (*) indicates new record from Vembanad Lake. Genus and species have been arranged alphabatically irrespective of their systematic position.

Table 6. List of some macrobenthic species recorded from selected stations of Vembanad Lake

Sl. No.	Group and species	Downstream stations								Upstream stations			
		1	2	3	4	5	6	7	8	9	10	11	12
	Crustacea												
1.	*Apseudes chilkensis*				+								
2.	*Corophium triaenonyx*	+											
3.	*Quadrivisio bengalensis*					+			+				
4.	*Gammarus sp.*	+	+						+				
5.	*Photis digitata*					+			+				
6.	*Scylla tranquebarica*			+									
7.	*Matuta victor*	+		+									
8.	*Grapsus albolineatus*			+		+			+				
9.	*Metopograpsus messor*			+	+								
10.	*Parasesarma plicatum*	+	+	+									
11.	*Pseudosesarma edwardsi*								+			+	
12.	*Dotilla intermedia*			+						-			
13.	*Uca lactea*		+	+									
14.	*Spiralothelphusa hydrodroma*										+		+

Sl. No.	Group and species	Downstream stations								Upstream stations			
		1	2	3	4	5	6	7	8	9	10	11	12
	Mollusca												
15.	*Neritina (Dostia) violacea*	-			+								
16.	*Littoraria (Littoraria) undulata*			+									
17	*Bellamya benglensis*						-					+	
18.	*Thiara (Thiara) scabra*										+	+	+
19.	*Melanoides tuberculata*						-	-			+	+	+
20.	*Indoplanorbis exustus*										+		+
21.	*Pila* sp.									-	+		+
22.	*Anadara granosa*					+			+	-	-		-
23.	*Perna viridis*	+		+			-						-
24.	*Modiolus striatulus*	+		+									-
25.	*Villorita cyprinoides cochinensis*								-	-	+	+	+
26.	*Meretrix meretrix*					-	-				-		+
27	*Paphia ala-papilionis*			-					-		-	-	+

1= Azhikode; 2= Kottapuram; 3= Vypin; 4= Kumbalam; 5= Vaikom; 6= Vayalar; 7= Cherthala; 8= Thavenakadave

9= Thannermukham; 10= Kumarakom; 11= Muhama; 12= Punnamada

FOULERS

Fouling organisms settle on the substratum at the bottom or around rocks and erect concrete structures submerged in water. Menon and Nair (1971), Nair and Saraswathy (1971) and Meenakumari and Nair (1994) studied the foulers of Cochin backwaters (Table 7). Among protozoans, the stalked ciliates *Vorticella*, *Zoothamnium* and folliculinids are the common fouling communities. They show a preference to brackish water in heavily polluted situations. The fouling bivalves belong to the genera *Mytilus*, *Modiolus* and *Ostrea* at Cochin harbour. Among these bivalves at Cochin harbour, *Modiolus* is an important fouling organism being represented by *M. undulatus* and *M. striatulus*. *Ostrea forskalii* and *Perna viridis* are the other important bivalves. They assume paramount importance during certain seasons due to their size and occurrences in large numbers.

At Cochin, polychaete like *Perinereis cavifrons* is very common. *Ficopomatus macrodon* is the most important serpulid at Cochin. It breeds throughout the year with a minor peak during April to June. A total of 14 species of fouling bryozoans have been reported to occur in Cochin Backwaters. Ecology of fouling bryozoans of Cochin backwaters has been investigated by Menon and Nair (1971). On the basis of test panel studies they grouped these organisms in to three categories: (i) species occurring exclusively in brackish water, e. g., *Victorella pavida* (ii) typical marine forms never occurring during low saline conditions, e.g., *Nolella papuensis*, *Bowerbankia gracilis*, *Aeverrillia setigera*, *Electra bengalensis*, *Membranipora savartii*, *Alderina arabianensis*, *Bugula neritina*, *B. cucullata*, *Savignyella lafontii*, *Watersipora subovoidea*, *Schizoporella cochinensis* and *Schizomavella linearis* var. *inarmata* (iii) typical brackish water forms also appearing in marine localities, e.g., *Electra crustulenta*.

Table 7. Fouling communities of Cochin backwaters.

Substratum/Group	Occurring organisms
A. Wooden Structures	
Protozoa	*Folliculina* sp., *Zoothamnium rigidum*, *Vortcella companula*
1. Bryozoa	*Membranipora savertii*, *Bugula cucullata*, *B. neritina*, *Schizoporella cochinensis*, *S. unicornis*, *Bowerbankia gracilis*, *Victorella pavida*, *Electra bengalensis*, *E. crustulenta*, *Alderina arabianensis*, *Nolella papuensis*, *Aeverrillia setiger*, *Savignyella lafonti* and *Watersipora subovoidea*
2. Mollusca	*Modiolus undulatus*, *M. striatulus*, *Perna viridis*, *Ostrea forskalii*

Substratum/Group	Occurring organisms
3. Crustacea	*Balanus amphitrite amphitrite, Balanus amphitrite cochinensis, Balanus amphitrite communis, Balanus amphitrite insignis, Balanus tintinnabulum tintinnabulum*
4. Amphipoda	*Corophium triaenonyx, Melita zeylanica*
5. Polychaeta	*Ficopomatus macrodon, Perinereis cavifrons*
6. Hydroid	*Bimeria franciscana*
B. Cemented structure	
1. Bryozoa	Undetermined species
2. Mollusca	*Crassostrea cuttackensis*, *Modiolus* sp.
3. Crustacea	*Balanus amphitrite*

Among crustaceans, amphipods and isopods are the other important crustaceans from the fouling point of view. *Melita zeylanica* is an important fouler at Cochin. *Corophium triaenonyx* was found to occur on long term panels. It is moderately common during high saline period. Cirripeds belonging the genus *Balanus* are the most important fouling organisms at Cochin. Among these, *Balanus amphitrite amphitrite* is the most common cirriped of this area exhibiting wide tolerance to salinity fluctuations. Nair (1967) has shown that *Balanus amphitrite* settles most abundantly during the monsoon period with a distinct peak of settlement during November-December. It is most abundant during pre-monsoon period and their settlement was minimum during the monsoon. They occurred very sparsely during July-August. The other important barnacle of Cochin is *Balanus tintinnabulum tintinnabulum.*

DISCUSSION

Benthic animal communities play an important role in the trophic dynamics as they assume significant relations in the determination of fishery potentials of aquatic ecosystems. A preliminary appraisal of the nature of the bottom biota may help relate as to how best they can be utilised as food by fish populations in the backwater. In general, major macrobenthic groups of Vembanad Lake include Polychaeta, Crustacea and Mollusca, while in the sediment samples bivalves, gastropods and polychaetes were the most predominant forms (Desai and Krishnan Kutty, 1967; Ansari, 1974; Kurian *et al.*, 1975; Pillai, 1977; Sarala Devi and Venugopal, 1989a, Sarala Devi *et al.*, 1991; Sunil Kumar, 1995, 1997; Unnithan *et al.*, 2001).

Before the commissioning of the barrage, several investigators studied the distribution and diversity of benthic fauna from Cochin backwaters (Unnithan *et al.*, 2001). .In the intertidal habitat, especially in the mangrove fringed areas of the lake, the molluscan taxa form an important group among these benthic organisms (Sunil Kumar, 1997, 1998). Molluscs occur in the top soil as well as in the subsoil, and also as epibionts, attached to the submerged roots and shoots of mangrove vegetation. Tidal influence acts as a cardinal factor, if not as limiting factor, in so far as the distribution of various intertidal fauna is concerned.

Villorita cyprinoides var. *cochinensis* is an important species of backwater clam, which occur conjointly with other species of *Villorita* along the west coast of India, from Goa to South Kerala (Prashad, 1921). Extensive dense beds of this species are found in all the major backwaters of Kerala *viz.*, Vembanad, Kayankulam and Ashtamudi. This species sustains a regular fishery in Kerala, providing a cheap source of protein food for a large section of people and shells as raw material for the manufacture of cement and lime.

The penaeid prawns constitute an important fishery in the backwaters of Cochin, of which, *Metapenaeus dobsoni*, *M. momoceros* and *P. indicus* are the most important. These prawns enter the backwaters quite early in life in the larval and post-larval phases, and after a few months of growth there, return to the sea for breeding (Menon, 1951; Panikkar and Menon, 1956; George, 1959; Kuttyamma, 1975).

The present study shows that macrozoobenthos of Cochin backwater environment are primarily marine in origin with some freshwater components occurring at freshwater marine interface in the lower reaches. The backwater fauna is dominated by polychaeta, crustacea and mollusca. According to their mode of habitat, the macrozoobenthos can be broadly divided into four groups : sedentary form, substrate epifauna, substrate infauna and woodborers. The composition of fauna within each of these categories is governed by the physical environment such as sediment structure, tidal and salinity fluctuations and period of inundation.

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FISHERIES AND SOCIOECONOMIC ASPECTS

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INTRODUCTION

Kerala is blessed with extensive estuaries and beautiful backwaters, which are important not only with respect to fish production but also offer most important waterfront for tourist attraction of the state. The Vembanad Lake and its adjoining rivers and estuaries particularly play a paramount role in the socio-economic life as well as cultural canvas of this region. In the inland sector, there are 41 west flowing and 3 east flowing rivers, 84 estuaries and 53 backwaters covering an area of 46,129 ha. The total inland fishermen population was estimated at 2, 49,105 in 2002-03 and estimated annual inland fish production of the State in the same year was around 75 thousand tonnes. As such, the inland sector including the Vembanad Lake and other backwater systems of Kerala has a great potential for fisheries and ecotourism development. Vembanad Lake being an integral part of the lake dependent communities an attempt is herein made to reflect the extent of dependency of the local populace including fishermen population and their association with the lake ecosystem.

Vembanad Lake harbours a variety of marine, estuarine and freshwater fishes. Day (1865a,b, 1878) had initiated investigations on the freshwater fish fauna of Kerala and several investigators (Silas, 1951, 1977; Menon and Jacob, 1996) have continued the work. From Vembanad Lake several researchers studied faunal resource diversity and distrbution of fishes (Shetty, 1965; Kurup, 1982; Kurup and Samuel, 1980-1991; Kurup *et al.*, 1989-1995; Unnithan *et al.*, 2001) and crustaceans (Menon and Raman, 1961; George, 1965; Kuttyamma, 1975, 1980; Kuttyamma and Antony, 1975; Devasia and Balakrishnan, 1985; Preetha and Noble, 1993). Kurup (1982) made a systematic list of 150 species of fishes belonging to 100 genera under 56 families. Menon *et al.* (2000) studied the impact of fluctuation of temperature from premonsoon to monsoon on the seasonal distribution and abundance of fishes in this estuarine system. Besides fishes the lake supports several species of prawns, crabs and molluscs of commercial importance. Menon and Raman (1961) reported 7 species of penaeid prawns from the lake. Kathivel *et al.* (1978) and Kurup *et al.* (1991) reported *Portunus pelagicus* and *Portunus sanguinolentus* from the lake during high salinity periods.

KEY INFORMATION

The largest backwater stretch in Kerala is the Vembanad Lake, which flows through three districts and open out into the sea at the Cochin Port. The key statistics of inland fisheries, prepared by the Department of Fisheries, Government of Kerala in 2004, is presented in Table 1. It is revealed that there are 113 inland fishing villages inhabited by 2,49,105 fishermen population. Three districts *viz.*, Alapuzha, Ernakulam and Kottayam districts border the Vembanad Lake, which include 47 inland fishing villages with a total of 1,59,284 fishermen mostly dependent on this lake ecosystem for their livelihood (Table 2). This suggests that 63.94% of the total inland fishermen population of the State is concentrated arround the Vembanad Lake. A list of fish markets located around the lake and their estimated landings (in kg.) as revealed from the study of Kurup *et al.* (1995) is presented in Table 3 to indicate the extent of fishery potential and fish trade involved mostly from this lake. Kurup *et al.* (1990) had also estimated annual landings of commercially important fishes (21 species) and crustaceans (8 species) from Vembanad Lake (Tables 4 & 5). The data obtained by Kurup *et al.* (1990) suggests that northern marine and estuarine sector yielded appreciably very high production than the southern nearly freshwater sector of the lake. Besides these, lists of freshwater fishes as well as marine and estuarine fishes with their scientific, common and vernacular names have been provided in Tables 6 and 7 to indicate the commonly occurring fish diversity of the lake system. Biotic resource, abiotic resource and socioeconomic relations pertaining to the lake have been discussed hereunder.

Table 1. Key statistics of inland fisheries of Kerala.

Features	Figures
1. Number of inland fishing villages	113
2. Estimated inland fishermen population (2002-03)	
a. Male	82,101
b. Female	79,812
c. Children	87,192
d. Total	2,49,105
3. Estimated inland fish production (2002-03)	0.75 lakh M. T.
4. Number of active inland fishermen (2002-03)	44,053
5. Estimated area of freshwater lakes (in ha)	1620
6. Estimated area of river system (in ha)	85,000
7. Estimated area of reservoirs (in ha)	42,890
8. Estimated area of brackishwater resources (in ha)	65,213
9. Estimated area of backwaters (in ha)	46,129
10. Estimated area of Vembanad Lake (in ha)	21,050

Source : Department of Fisheries: Inland Fisheries Statistics of Kerala 2004.

Table 2. Fishing villages and fishermen population inhabiting around Vembanad Lake.

District and fishing villages	Population in 2002-03	District and fishing villages	Population in 2002-03
ERNAKULAM		ALAPPUZHA	
Kadamakudi	1109	Kayamkulam	2439
Ezhikkara	10719	Kochiyard jetty	3164
Mulavukadu	4210	Chodatheruvu	2969
Cheranellor	1674	Payippadu	2413
Maradu	1652	Karuvatta	2405
Kumbalam	5202	Chenkola	1987
Udayamperoor	9920	Muhamma	2501
Ernakulam (West)	1253	Thirunellur	2639
Poonithura	3915	Panavally	2633
Nedamagramam	2786	Arukutty	2918
Ernakulam (East)	2637	Perumpalam	2356
Kumpalangi	2492	Aroor	2645
Palluruthy	5884	Thuravoor (North)	3210
Vadallellara	8052	Thuravoor (South)	2741
Puthenvelikkara	6139	Vayalar (East)	2945
Total	67638	Mannar Sangham	3417
KOTTAYAM		Thalavady	2887
Changanassery	4851	Noornadu	2533
Kumarakom	3744	Eraviperoor	2207
Thiruvarpu	1728	Marakkattu Ward	2945
Vaikom (Town)	6678	Ramamkary	3428
Thalayazhom	1809	Kavalam	2512
Chempu	2165	Thevarvattom	2834
Kaduthuruthy	3456	Thanneermukkom	2712
Kottayam	1775	**Total**	65440
Total	26206		

Source : Department of Fisheries : Inland Fisheries Statistics of Kerala, 2004.

Table 3. List of fish markets located around Vembanad Lake and their estimated annual landings (in kg).

Name of markets	Annual landings	Name of markets	Annual landings
ERNAKULAM DISTRICT		26. T.V. Puram	72484.75
1. Thevra	154701.90	27. Ullala	131505.90
2. Kumbalangi	78269.30	28. Ambika Market	12253.80
3. Palluruthy	152943.00	29. Achinakam	17008.00
4. Chullickal	72329.90	30. Chandakavala	45953.41
5. Pazhangzd	28812.05	31. Kumarakom Jetty	103993.80
6. Eda Cochin	15560.95	32. Attipedika	2169.10
7. Ernakulam	125822.50	ALAPUZHA DISTRICT	
8. Champakara	118851.60	33. Aroor	124442.70
9. Fort Cochin	84640.00	34. Chandiroor	211291.40
10. Kadavanthara	42715.50	35. Kuthiathodu	101196.00
11. Kaloor	100176.30	36. Ponnamvely	147883.60
12. Nemoor	23382.15	37. Chavady	151691.90
13. Pamangad	26055.65	38. Valiathodu	53199.05
14. Udayamperoor	220361.40	39. Perumbalam	27921.80
15. South Parur	151728.10	40. Shertallai	317805.00
16. Poothotta	26103.00	41. Poochakkal	96697.00
17. Murinjhapazha	14424.35	42. Kadakkarapalli	63444.00
KOTTAYAM DISTRICT		43. Pallipuram	13595.50
18. Chempu	80313.50	44. Muttathiparambu	7680.00
19. Kalothumkadavu	323105.30	45. Ottapunna	9009.00
20. Nandom	73547.46	46. Thanneermukkom	98253.46
21. Kaduthuruthy	59451.05	47. Puthamangadi	10728.25
22. Vadayar	15389.05	48. Muhamma	36697.75
23. Chemmanathkara	42557.10	49. Mannanchery	24430.95
24. Puthenthodu	29900.30	50. Komalapuram	32543.30
25. Appaochira	12328.60	51. Alleppey	119166.80

Source : Kurup *et al.* (1995)

Table 4. Annual yeild/ha of commercially important fishes and crustaceans from Vembanad Lake

Commercially important species	Average catch/ha/yr (kg)	
	Northern sector	Southern sector
FISHES		
1. *Daysciaena albida*	53.22	0.15
2. *Ambassis gymnocephalus*	39.93	0.12
3. *Etroplus suratensis*	14.37	17.51
4. *Tachysurus maculatus*	23.62	0.13
5. *Tachysurus subrostratus*	12.85	1.52
6. *Ehirava fluviatilis*	13.03	1.05
7. *Gerres filamentosus*	8.11	0.15
8. *Liza parsia*	10.13	0.34
9. *Mystus (M) gulio*	8.60	0.24
10. *Hyporhamphus (H) xanthopterus*	0.69	4.27
11. *Ambassis commersoni*	5.56	0.00
12. *Ambassis dayi*	1.97	3.08
13. *Leiognathus brevirostris*	4.41	0.03
14. *Sillago sihama*	4.46	0.00
15. *Mugil cephalus*	4.39	0.16
16. *Amblypharyngodon mola*	0.05	5.24
17. *Glossogobius giuris*	3.35	0.00
18. *Megalops cyprinoides*	3.20	0.89
19. *Caranx ignobilis*	3.89	0.13
20. *Leiognathus equulus*	2.48	0.01
21. *Liza macrolepis*	2.73	0.00
CRUSTACEANS		
1. *Metapenaeus dobsoni*	202.50	5.52
2. *Penaeus indicus*	42.96	0.00
3. *Metapenaeus monoceros*	28.21	0.16
4. *Penaeus monodon*	0.97	0.00
5. *Penaeus semisulcatus*	0.81	0.00
6. *Macrobrachium idella*	5.73	2.22
7. *Macrobrachium rosenbergii*	2.53	1.75
8. *Scylla serrata*	23.96	0.19

Source : Kurup *et al.* (1990)

Table 5. Annual landing of *Scylla serrata* crabs from Vembanad Lake during 1970s and 1980s.

Year	Quantity (tons)	Year	Quantity (tons)
1976	350.0	1982	352.0
1977	345.0	1983	389.0
1978	321.0	1984	398.0
1979	357.0	1985	392.0
1980	370.0	1986	376.0
1981	343.0		

Table 6. Scientific, common and vernacular names of freshwater fishes of Vembanad Lake

Scientific name	Common name	Vernacular name
FISHES		
Ambassis spp.	Glass fishes	Nanthan/Nandan
Anabas testudineus	Climbing perch	Kalladamutti/aringil
Anguilla bengalensis	Indian Long Fin Eel	Maninjil/Vilang/Aarel
Arius spp./ *Mystus* spp.	Cat fish	Koori
Catla catla	Catla	Catla
Channa marulius	Murrels	Varal
Channa striatus	Murrels	Vaka Varal/Cherumeen
Channa spp.	Murrels	Varal
Cirrhinus mrigala	Mrigal	Mrigul
Clarias sp.	Air breathing catfish	Kari/Koori/Mushi
Cyprinus carpio	Common carp	Carp
Dayella malabarica	Herring	-
Etroplus maculatus	Pear spot	Pallathi

Table 6. Contd.

Scientific name	Common name	Vernacular name
Heteropneustes fossilis	Stinging catfish	Kari
Labeo dussumieri	Carp	Thuli/Pulan/Pullan
Labeo fimbriatus	Carp	Chundan
Labeo rohita	Rohu	Rohu
Mastacembelus armatus	Spiny eels	Aaral
Mastacembelus guentheri	Spiny eels	Aaral
Nandus nandus (=*marmoratus*)	Mud perch/Nandus	Nandan/Mootahree
Ompok bimaculatus	Butter catfish	Manjivala
Ompok malabaricus	Butter catfish	-
Oreochromis mossambica	Tilapia	Thilapia/Silopia/Philoppi
Puntius amphibius	Barb	Urulan paral/Oolee-perlee
Puntius filamentosus	Barb	Paral
Puntius sarana	Barb	Paral
Puntius sp.	Barb	Kaipa/Paral
Stenogobius malabaricus	Gobiid fish	-
Wallago attu	Freshwater shark	Vala/Kanambu/Vatta/ Kurichil
Xenentodon cancila	Freshwater gars	
PRAWNS		
Macrobrachium spp.	Freshwater prawn	Konchu
Macrobrachium rosenbergi	Scampi/Giant Freshwater prawn	Attukonchu/konchu

Table 7. Scientific, common and vernacular names of marine and estuarine fishery resources of Vembanad Lake.

Scientific name	Common name	Vernacular name
FISHES		
Anchoviella commersoni	Anchovies	Anchovy Kozhuva
Chanos chanos	Milk fish	Poomeen
Elops sp.	Lady fish	Polankanni
Ertroplus suratensis	Pearl spot	Karimeen
Hemiramphus sp.	Half beaks	Kolan
Hilsa sp.	Hilsha shad	Kathiran
Lates calcarifer	Giant perch	Kalanchi
Lepturacanthus savala	Ribbon fish	Vala
Liza parsia	Mullet	Kanambu
Megalaspis cordyla		Vankada
Megalops cyprinoide	Tarpons	Palamkanni
Mugil cephalus	Mullet	Molan/Thirutha
Mugil spp.	Mullet	Thirutha
Nemipterus sp.	Threadfin bream	Kilimeen
Pampus spp.	Pomfrets	Avoli
Rastrelliger kanagurta	Mackerel	Ayala/ Ayila
Sardinella longiceps	Oil Sardine	Chala/Neichala/Nallamathi
Sardinella fimbriatus	Lesser Sardine	Chalamathi/Karichala
Scatophagus argus	Butter fish	Nachaka
Scoliodon sp.	Shark	Choraku
Saurida tumbil	Lizard fish	Pallimeen/ Veloori
Solea/Cynoglossus sp.	Flat fish	Manthal
Sphyraena jello	Baracauda	Sheelavu/ Vazhumeen
Arius (=Tachysurus) spp.	Catfish	Koori
Thunnus sp.	Tuna	Choora

Table 7. Contd.

Scientific name	Common name	Vernacular name
PRAWNS		
Metapenaeus affinis	Indian Prawn	Kazhanthan
Metapenaeus brevicornis	Yellow Prawn	Kazhanthan
Metapenaeus dobsoni	Brown shrimp	Thelly / Poovalan
Metapenaeus monoceros	Brown shrimp	Choodan
Metapenaeus spp.	Shrimp	Chemmeen
Parapenaeopsis stylifera	Marine shrimp	Kaikkodi
Penaeus monodon	Tiger prawn	Kara chemmeen
Penaeus indicus	Indian White prawn	Naran
Penaeus semisulcatus	Green Tiger Prawn	Kuzhikara Chemmeen
Penaeus merguiensis	Banana Prawn	Kuzhikara Chemmeen
CRABS		
Scylla serrata	Mud crab	Njandu
SQUIDS/ CLAM		
Loligo duvaucelli	Squid	Squid/ Koonthal
Sepia spp.	Cuttle fish	Koonthal
Villorita cyprinoids	Clam	Kakka

Note : All marine fishes are not truly backwater inhabiting species but are availble in the fish landing centres of Ernakulam district.

RESOURCE PRODUCTION RELATIONS

The meandering Vembanad estuary is typically palm-fringed and networked by canals. The production of coconut and coconut husk is an important livelihood activity of the local people beside fishing and sand mining, etc. (Figs. 6.1-6.16). In fact Vembanad Lake has a rich resource of both biotic and abiotic elements as follows :

Biotic resource

Vembanad Lake harbours a wide variety of marine and estuarine fishes, prawns, crabs, lobsters, mussel, clams as well as squids in the estuarine region and around bar mouth. Tasty fishes like Pearlspot, Palankanni, Kanambu, Thirutha, Koori, etc. are

caught in large quantities along with a variety of shell fishes which includes crab, prawn, *konchu* etc. Innumerable number of non-motorized country boats are engaged in such purposes.

Finfish resource

A complete systematic list of the fishes of Cochin backwater and their frequency of occurrence was presented by Kurup (1982). 150 species of fishes belonging to 100 genera under 56 families were identified. Out of this 23 species were oligohaline. Kurup and Samuel (1987) observed 89 species of marine fishes in Cochin backwaters of which 41 species were euryhaline and 48 stenohaline. The fluctuation of temperature from pre- monsoon to monsoon influences the seasonal distribution and abundance of fishes in this estuarine system (Menon *et al.*, 2000). Gopinath (1953), Shetty (1965), Kurup and Samuel (1980a, b, 1983, 1985, 1987), Kurian and Sebastian (1982), Kurup *et al.* (1990a) and Unnithan *et al.* (2001) studied the fishery resource, species-wise and gear-wise landings of fishes from Vembanad Lake. The species-wise fish landing from three districts surrounding the lake is shown in Table 8.

Shellfish resource

Kuttyamma (1980) studied the distribution and abundance of prawns and prawn larvae in Cochin backwaters, while Raman (1967, 1976) contributed to the biology and fishery aspects of the Giant freshwater prawn, *Macrobrachium rosenbergii* in the lake. Traditional shrimp culture has been practiced in the low-lying areas of Kerala since time immemorial. There has been steady growth in the area of culture from about 4,000 ha in 1960 to 13,000 ha in 1990, and 81.6% of the total shrimp culture area at present is in Ernakulam district located on the eastern bank of Vembanad Lake. Vypin Island near the mouth of the lake accounts for a very large concentration of both perennial and seasonal fields. Soon after the paddy harvest in October (the variety is called "Pokkali", and hence the fields are called Pokkali fields, the bunds of the fields are strengthened and sluices are installed. Besides shrimp production, harvesting of crab and clam occupies an important position from this backwater system. The edible crabs (*Scylla serrata, Portunus pelagicus and P. sanguinolentus*) constitute 4% of the exploited fishing resources of Vembanad lake yielding an annual production of 288.16 tonnes (Kurup *et al.*, 1990b). The edible clam, *Villorita cyprinoides* var. *cochinensis* from Cochin backwater sustains a regular fishery in Kerala, providing a cheap source of protein food for a large section of people and a raw material for the manufacture of cement and lime. Laxmilatha and Alloycious (2001) reported organized fishing of the black clam, *Villorita cyprinoides* in Vembanad Lake. Kurup and Samuel (1976), Achary (1987) and Kurup *et al.* (1990) studied about this major molluscan fishery resource from Vembanad Lake. Nasser and Noble (1991) discussed about the economics of clam exploitation from backwaters at Azhicode.

Table 8. Species-wise inland fish landings in three districts around Vembanad Lake in 2002-03. (Quantity in tonnes).

Name of fish	Name of districts and quantity			Value in Rs./Kg
	Ernakulam	Kottayam	Alapuzha	Av. Price Rs./Kg
1. Etroplus	1349	317	1758	56.90
2. Murrels	1225	430	772	34.64
3. Mullets	1192	375	911	36.94
4. Cat fish	1187	376	890	25.21
5. Jew fish	961	181	712	25.95
6. Tilapia	2606	420	1642	24.30
7. *Labeo fimbriatus*	-	248	197	31.05
8. Barbus	64	55	40	27.25
9. Mrigal	197	-	716	35.54
10. Common carps	472	251	536	26.35
11. Catla	1034	138	542	37.33
12. Gourami	-	-	-	
13. Chanos	220	30	132	33.64
14. Eels	23	2	12	25.21
15. *Labeo rohita*	166	734	667	35.54
16. Prawns	11086	409	2108	66.00
17. Crabs	12	2	190	33.24
18. Miscellaneous	1544	216	662	24.76
Total	**23338**	**4184**	**12487**	**40.00**

Source : Department of Fisheries : Inland Fisheries Statistics of Kerala 2004.

Other living resource

This includes mangrove plant resources used as fuel, firewood and timber purpose. Aquatic edible vegetable plants that grow naturally in the lake are collected for domestic consumption by the poorer section of local community. Besides plant resource of economic importance, the faunal elements like frogs, insects and worms are often used as fish bait. These living plant and animal resources are also useful source of food for

domestic live stocks and poultry birds. Duckery is one of the important economic activities of the people living in and around the lake.

Fish disease

Epizootic Ulcerative Syndrome (EUS) was reported from Vembanad Lake in August in 1991 initially from upstream areas. Soon, the disease spreaded over the other areas of Vembanad backwaters situated in the adjoining areas of Alappuzha and Ernakulam (Kurup, 1992). Incidence of fish mortality was reported from Cochin backwaters by Unnithan *et al.* (1977).

Abiotic resource

Sand mining : Sand mining at various places of the lake is a common feature. The number of persons, number of boat involved for extraction of sand and the estimated quantity of extraction from this lake could not be gathered. However, from the Periyar river belt extraction of sand reached alarming proportions during the recent construction boom in Kerala. A study by some geologists on the sand mining problems of certain rivers of Kerala showed that the quantity of sand that could be extracted safely without causing environmental damage to Periyar was 19178 tonnes. The actual extraction was found to be more than thirty times of this quantity (Pratapan, 1999). Due to persistent pressure from various voluntary organizations, the Kerala Government has fixed 18375 tonnes as the ceiling on the quantity that can be removed from 175 mining points on the river in Ernakulam district. The mining activity was entrusted to Gramapanchayats and the sale is done at prices fixed by the District Collector. However, so far no standard system has been formulated to implement these norms effectively.

Extensive sand mining from the lakebed affects the bottom fauna. It may be mentioned that indiscriminate sand mining from the river basin of Periyar cause serious and far reaching repercussions like destruction of ecological niche and habitat of various biotic forms. Besides bottom fauna, indiscriminate sand mining is likely to pose considerable threat to bird population. The stagnation and trapping of saline water in the regions of mining due to artificial deepening of river basin interfere in the free flow of water, etc.

SOCIOECONOMIC RELATIONS

Fishermen involved : Fishermen communities traditionally inhabit mangrove areas along the coast in Kerala. They lived as an integral part of this ecosystem, making temporary embankments and exploiting fishery and forestry resources in the area. Due to high rate of population growth in the coastal Kerala and intensive exploitation and development of human settlements and industries mangrove habitats are destructed all along the west coast including areas adjoining Vembanad Lake. The

distribution of fishermen population as well as fishing crafts and gears is depicted in Tables 9 & 10.

In Ernakulam district, 39 fishermen colonies are located under 8 blocks and 3 municipalities inhabited by *Dheevara*, *Pulayas*, *Harijan Pulaya*, *Kudumbies*, *Ezhavas*, *Vala*, *Valan Ezhava*, *Vala Arya*, *Vettuvans*, Anglo Indian, Latin Catholics and Muslim communities. In Vypin island 1125 fishermen of 250 households represent muslim community only (Panfish Book, Ernakulam District, Department of Fisheries, Kerala, 2001). Fishermen colonies and settlements of Vaikom areas under Kottayam district include Nikarthil of T. V. Puram Panchayat, Ayyanttu of Vechoor Panchayat and Vaikom Fisherman Colony and Nikarthil Colony under Vaikom Municipality. These fishermen belong to Dheevara and Ezhava communities comprising of 570 fisherfolk from 117 households mostly using traditional fishing equipments like drift net (*ozhukuvala*), gill net (*udakkuvala*), dip net (*thanguvala*), cast net (*veeshuvala*), stake net, encircling net, ottal, vattavala, koruvala, undavala, kampavala, spear, hook and line, bow and arrow, pole and line etc., are used indigenous fishes such as *Ertroplus*, *Mystus*, *Ambassis*, anchovies, *Mugil*, *Macrobrachium* and crab (*njendu*) species from Vembanad Lake and its connecting canals, rivers and other waterbodies. Fishermen at night can be seen to glide over the dark waters carrying aloft a flaming torch on the left hand and a butterfly net in the right hand to scoop up the surfacing fish attracted by the light. The local people including women immersed up to their necks in water are often found to be searching for tasty *karimeen* fish (Pearl spot). Some other local names associated with traditional fishing equipments are *Adakkomkolli*, *Choonda*, *Koodu*, *Thettali*, *Padala*, *Pantharanduvala*, etc.

Integrated farming practices such as Duck-cum-Fish culture, Pig-cum-Fish culture, Pig-Fish culture and Pig-Duck-Fish culture have been encountered in and around Vembanad Lake. Detrimental fishing practices using dynamite, nanchu, nanchukalakal, thottapottikal have been reported. Department of Fisheries, Government of Kerala, often organized backwater-sea ranching, while fish distribution programmes are arranged to augment fish production in Vembanad Lake under social fisheries programmes of the department, implemented by RARS Research Station, Kumarakom (Funded by Fisheries Dept.). The fish species include under the scheme are crustaceans (Scampy, *Machrobrachium* spp.) and fishes (*Cyprinus*, *Cirrhinus*, *Catla*, *Etroplus*, *Mugil*, *Labeo rohita*, *L. fimbriatus*, *L. dussumieri*. Exotic fish *viz.*, Silver carp, Grass carp, *Cyprinus* carp and African Catfish introduced into pond ecosystem surrounding the Vembanad Lake may reach the lake ecosystem during monsoon when the pond become flooded with water. It is mentioned that the District administration, Ernakulam, granted financial assistance to 13 crab farmers and trained them. Each beneficiary with an average pond area of 20 cents was provided with 175 crabs, each weighing 150-200 g. The crabs attained a size of 600-800 g. after a culture of 2 months. Scientific monitoring was rendered by CMFRI, Cochin (*vide* CMFRI Newsletter, 200, No. 92, p.1).

Table 9. Distribution of inland fishermen population around Vembanad Lake (1995-96)

District	Male	Female	Total	Active fishermen
Ernakulam	31763	30961	62724	16116
Kottayam	12291	12010	24301	6067
Alapuzha	30797	29890	60687	15136

Source : Department of Fisheries, Kerala : Facts and Figures-2000.

Table 10. Crafts and gears used by the fisherfolk Ernakulam district around Vembanad Lake.

Categories of crafts and gears	Local names of crafts and gears
CRAFTS	
Non mechanised : Country Boats, Country Canoes (Plank built and Dug out)	Choonda Vanchi, Oonivala Vanchi, Pachil Vanchi, Kakka Vanchi, Kettu Vallam, Thara Vallam, Kochu Vallam, Muri Vallam, etc. (Total=8109)
Motorised (OBM Fitted)	Same as above (Total=7855)
Mechanised	Trawl Boats, Plywood Boats, Gill Net Boats, etc. (Total = 3387)
GEARS	
Fixed gears	Stake Net, Chinese Net, Mada vala, (Total=2426)

Source : Pan Fish Book : Ernakulam District (2001). Department Fisheries, Government of Kerala.

Ferry services available : The water transport service is operated by Kerala State Water Transport Corporation and also by private agencies. The State Water Transport Corporation is operating 11 boats and 19 routes of about 218.08 km, which carried 9559273 passengers during 1977-78. The Kerala State Road Transport Corporation operates ferry service in Cochin Harbour area as an ancillary service. There are 11 boats operating in Ernakulam-Cochin, Ernakulam-Vypeen, Ernakulam-Vallarpadom, Ernakulam-Port Cochin, Terminus-Cochi, Terminus-Vypeen routes. About 31,000 passengers make use of this service everyday (Bhatt, 1998). There are boat services from Kottayam town to other places viz., Alappuzha, Mannar, Ambalapuzha, Edatua,

Champakulam and Pulinkinnu. Kottayam town is connected by a canal to the Vembanad Lake and because of its centralised location, it has become the centre of water communication to Ernakulam, Alappuzha and Kollam. In all there are 48 Government passenger carrying boats, connecting different places of the lake. These big boats undertake daily cruises carrying more than 75 passengers, usually more than once per day depending on the distance of the trip concerned. Besides these, there are about 600 registered House boats traveling all over the length and breadth of the lake. In addition, there are 370 private boats of small types. These are tour boats, carrying tourists. The capacity is 25-40, which are also taking regular trips during the season.

Retting of coconut husk : The coir industry in Kerala is one of the most organised traditional industries in the state. The total labour force in coir industries accounts for the highest number of 4,30,000 workers (43%) when compared to other traditional industries. The womenfolk (84%) constitute the major chunk of the workers in this sector. There are 2,22,886 coir workers household in the state of which 99,146 are concentrated in Alappuzha District (Table 11; Government of Kerala, 1990) which shows the extent and intensity of coir retting around Vembanad Lake.

Table 11. Distribution of coir worker families in Kerala

District	Number of families	Percentage
Thiruvanantapuram	21,667	9.7
Kollam	35,400	15.9
Alappuzha	99,146	44.5
Kottayam	6,850	3.1
Ernakulam	15,118	6.8
Trishoor	6,324	2.8
Malappuram	8,350	3.7
Kozhikode	27,000	12.2
Kannur	2,076	0.9
Kasargod	955	0.4
Total	**2,22,886**	**100**

Note : * Districts located around Vembanad Lake (Source: Govt. of Kerala, 1990)

The backwater ecosystems of Kerala are important coconut coir processing ground in India. These kayals serve as extensive natural nursery of prawn and shrimp resources of Kerala. However, retting of coconut husk in backwaters has led to extensive pollution and large-scale depletion of the fishery resources of this region. Huge quantities of coconut husks are kept in water for several months for organic decomposition. The organic load in the retting zones remains high resulting in greater microbial decomposition leading to total depletion of oxygen. Consequently biochemical oxygen demand values become high in the retting zones as observed by Remani (1979) in Cochin backwaters (0 to 513.76 mg/l). Remani (1979) had also reported the presence of sulphur bacteria, *Desulphovibrio* sp. and *Thiobacilli* sp. in the retting zone mud of Cochin backwaters. During microbial softening of the husk, a wide spectrum of aerobic and anaerobic bacteria, fungi and yeast are involved in the process. These include bacteria such as *Aerobactor*, *Pseudomonas*, B*acillus*, *Paracolobacterium*, *Escherichia* and *Micrococcus* (Bhat and Nambudiri, 1971); fungi *viz.*, *Aspergillus flavus*, *A. niger*, *Trichoderma*, *Penicillium* sp. (Jayasanker, 1961) and yeasts like *Rhodotorula flava*, *Saccharomyces fructum* (Bhat and Nambudiri, 1971) (cited from Bijoy Nandan and Unnithan, 1998). Ambika Devi (1988) reported prolonged periods of anoxic condition associated with high BOD values and low pH as well as high organic carbon content (3.04 to 7.51%) and higher phosphate concentration in the retting zones of Cochin backwaters.

In the Vembanad backwater alone about 157 million husks are retted every year covering an area of 247 ha. Fish kills have been reported from several areas in the state. This has been widely incriminated due to extensive depletion of dissolved oxygen in the kayals. The fishermen organizations claim that retting poses to be the greatest threat to capture fisheries in kayals of Kerala. Remani *et al.* (1989) reported intense pollution due to retting of coconut husk in the waterbodies of Kozhikode district, Kerala. The air adjoining the retting area gets charged with hydrogen sulfide gas as encountered in the Vayalar backwater during the present study. In Vayalar and Cherthala backwaters both water and sediment samples of the retting zones were black, emittng smell of hydrogen sulphide. The studies conducted by Abdul Azis (1978) and Bijoy Nandan (1991) on the ecology of retting grounds have clearly indicated that the retting activity in the backwaters has caused grave pollution problems.

Retting of coconut husk in the backwaters has been a major source of health problem to workers engaged in the retting operations. The skin diseases and asthma were common ailments in people engaged in actual retting operations. Since retting is done in unhygenic and dirty water conditions, fungal infections on various parts of the body, leading to itching problems were very common health hazards. Bensam (1990) and Bijoy Nandan (1991), based on personal interview and discussions with workers engagaged in retting activity, reported skin, throat and eye irritation, knee swelling and

red eyes while standing inside retting pits, muscular weakness, sleeplessnes and swelling in various parts of the body. It is believed that the high amount of toxic gases like carbon dioxide and hydrogen sulphide produced in the retting grounds may act as simple chemical asphyxiants causing discomfort, muscular weakness and other problems. The high organic content in the retting grounds serve as breeding ground of various species of mosquitoes including vectors of filariasis.

ECOTOURISM RELATIONS

Tourism is a major source of income in Kerala. Backwater cruise plays a major role in this respect. The Vembanad Backwater Lake with its vast expanse of water, luxuriant greenery and very vibrant nature around the lake attract tourists from India and abroad. The lake is bordered with lush green banana plantations and coconut palms. The lake is a tourist's paradise for calm and cool backwater cruises in houseboat plying at leisurely pace. It may be mentioned that to discover the delightful landscape and the enchanting lake a visit by houseboat is a must to unfold the rich tradition and culture of colourful Kerala. The Snake Boat Races in backwater have attained a wide popularity all over the world. The Nehru Boat Race that held on the second Saturday of August every year at the Vembanad Lake at Alapuzha is a major tourist event in Kerala. Neighbouring villages compete fiercely in this race. The "Chundan Vallam", 130 feet long boats, is the major attraction of this prestigious event. There are over 100 rowers, 4 helsmen and 25 cheerleaders, decorated with colourful silk umbrellas taking part in this event. Thousands of spectators from all over the world watch and enjoy this colourful competition. The race is also held during tourist season on the third day of the Great Elephant March in mid January and is known as Tourism Snakeboat Race. Onam and Tourist Week Boat Races in August-September at Alapuzha, Aramula and Kumarakom are added attractions for the tourists. As such, Alapuzha, a waterlocked district, has emerged as one of the major tourist destination of the country. It is referred to as the 'Venice of the East' due to the amazing backwaters. So, to have an eye-view of ecotourism only a few areas around Vembanad Lake are highlighted hereunder.

Alapuzha-Kollam backwater trip is organised by ATDC. Excellent boat services are available through the backwaters to Kollam, Kottayam, Kochi, Kumarakom, etc. The boat passes through exotic locations and gives a close view of the countryside. The eight-hour backwater cruise in the houseboat is soothing, calming and nourishing. Although time taken by boat is more but it is an enchanting experience to see many beautiful sights along the way, such as the Chinese fishing nets, which are believed to have been introduced into Kerala by the traders from Kublai Khan's court.

Pathiramanal is the first island resort of the State in the Vembanad Lake. The island is accessible only by boat from Kumarakom and Muhamma. The island is another tourist attraction and also attracts a considerable variety of migratory birds from various parts of the world. Kumarakom bird sanctuary located at 12 km west of Kottayam town is yet another place of tourist interest. The sanctuary is situated on the eastern bank of Vembanad Lake extending over 14 acres of greenery. It is referred to as an ornithologist's paradise as a wide variety of resident and migratory birds like egrets, darters, herons, teal, ducks including the Siberian stork are found here. Best time to visit the sanctuary is between June and August. This is also an ideal site for enjoying the backwaters and boat cruise, as boats are readily available on hire around the lake. Besides boating, backwater biking and canoeing, fishing facilities are available at Kumarakom.

Backwater cruise : Backwater cruises are operated in houseboats (*Kettuvallam*). These boats measuring 51 feet in length and 15 feet in width with a storage capacity of 45 tons were originally constructed 80 years ago for transporting a variety of goods mainly rice. These boats are at present well furnished, consisting of thatched covered lounge cum dinning area, a double bedroom (with mosquito net) and a bathroom. The most enchanting feature of this *kettuvallam* is the boat ride done in the evening when they are lit by the hurricane lamps. There is a kitchenette at the back where the chefs cook simple meals using traditional spices of Kerala. A guide always accompanies the trip to familiarize the foreign tourists with the local surroundings. En route one can witness and explore the beauty and tranquility of the Kerala backwaters comprising of a network of lakes, coconut shaded canals and estuaries with wooden houses that dot the embankments. The Vembanad Lake, narrow canals, paddy fields and sleepy villages, and bathing and swimming in backwater if it is reserved, make backwater cruise an amazing and enjoyable experience.

Tourism relies heavily on high quality backwater sites and biodiversity rich areas for continued enjoyment of the fast growing tourism industries. In tourism as well as in backwater cruise, interaction with lake environment and large number of people being direct and involve extensive infrastructure development on lake and adjacent land, it is inevitable that it has its own implications and impacts.

Educational excursion : Wetlands can be a very suitable place for educational excursion. Similarly, mangrove habitat may provide effective educational arena in the field of both plant and animal science. As such, Indian mangrove can be used in a more effective way for eco-tourism, education and research, and also for capture and captive fisheries. At present mangrove habitat in the country do not receive adequate attention to this aspect.

CONCLUDING REMARKS

Wetlands in India as well as in Kerala, if not entirely man-made, are predominantly human modified. Vembanad Lake is one such example in which naturalness is increasingly missing from the lake and also from both urban and rural surroundings of the lake. There is also considerable shrinkage of habitat, posing a great threat to biodiversity. This has resulted due to accelerated reclamation of littoral niches of the lake particularly for paddy cultivation. It appears that the "Thaneermukkom bund" system has shown that man should not interfere with the natural systems. Though the bund was constructed to increase the yield of paddy, it created environmental problems including eutrophication and growth of African Payal – *Salvinia* species in the southern sector of the lake. It may be mentioned that NATCOM has made a number of recommendations for the sustainable use and conservation of mangroves. So, it is suggested that these recommendations may be duly considered for management of mangrove fringed areas of the lake and socioeconomic development of coastal habitats including backwaters, based on CRZ rules applicable, if any, for the purpose.

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Fig. 6.1. Water route for boat among weeds in Kumarakom backwater.

Fig. 6.2. Country boat in Kumarakom backwater carrying goods.

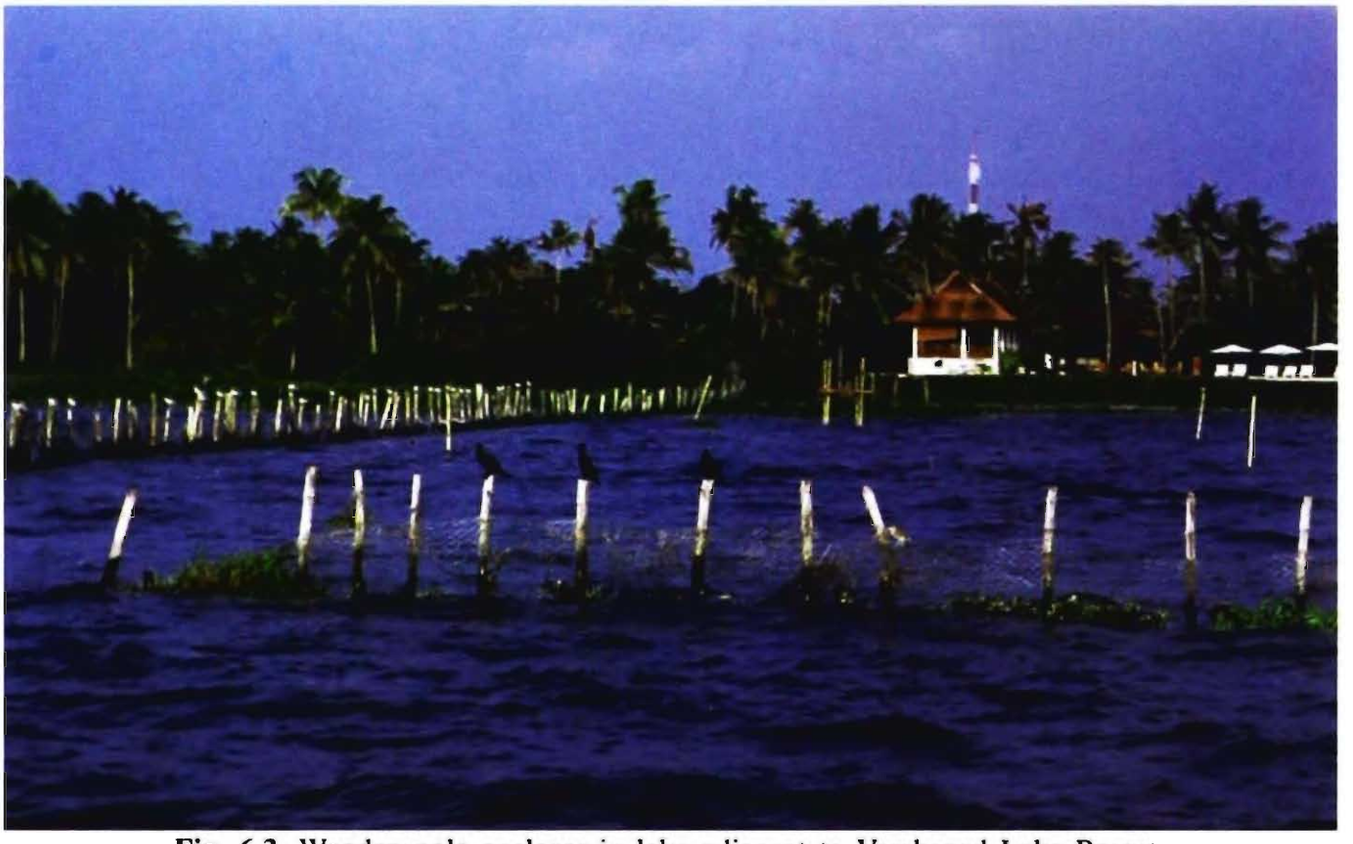

Fig. 6.3. Wooden pole encloser in lake adjacent to Vembanad Lake Resort.

Fig. 6.4. Fisherman resorting to line fishing in Kumarakom backwater.

Fig. 6.5. Boat carrying sand after sand mining in Vembanad Lake.

Fig. 6.6. Vembanad estuary showing coconut husk bundles stacked for transportation.

Fig. 6.7. Foreign tourist enjoying boat services in Vembanad Lake.

Fig. 6.8. Domestic tourist enjoying a walk inside Pathiramanal island.

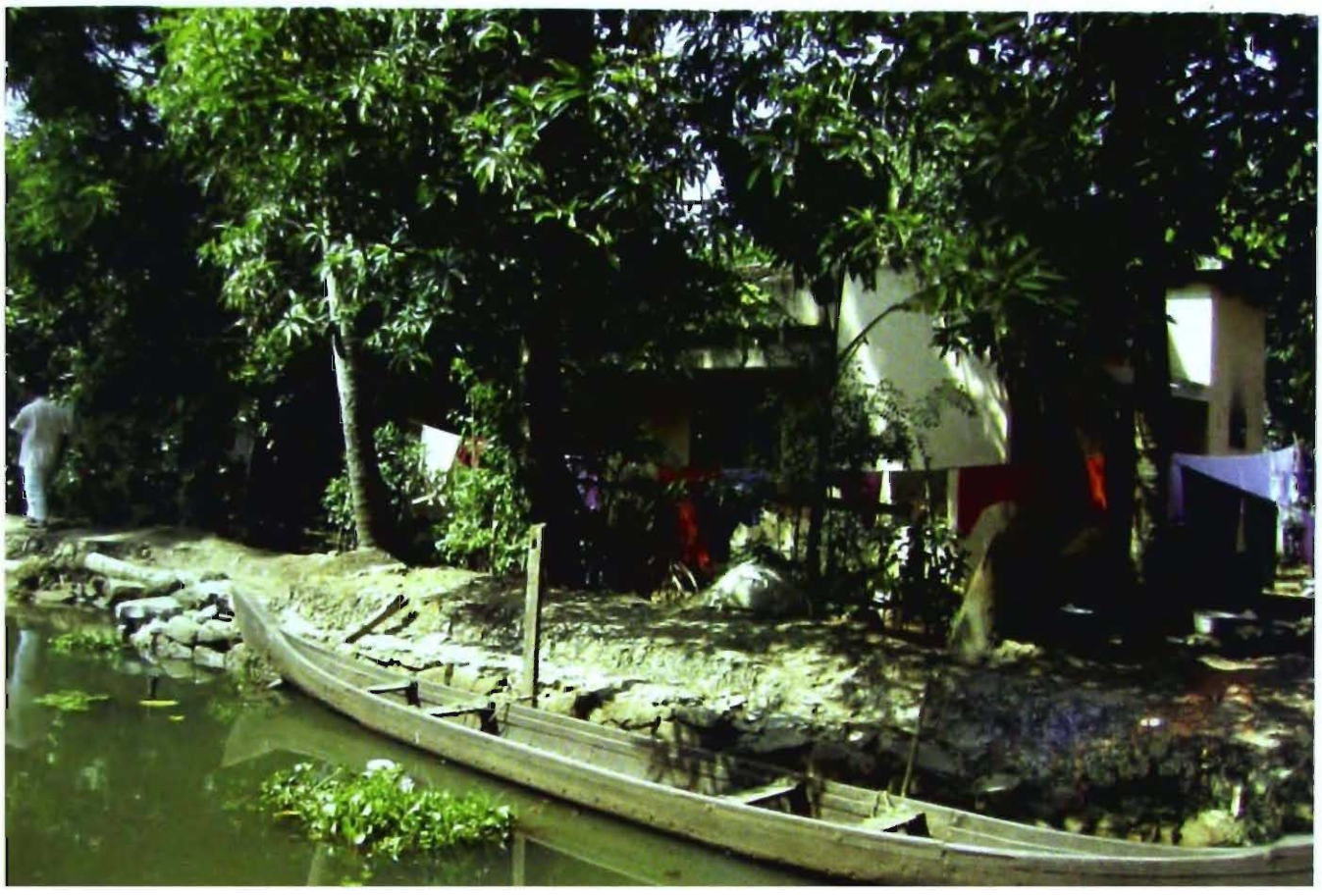

Fig. 6.9. Vembanad estuarine environment inhabited by local people.

Fig. 6.10. Vembanad estuary supporting mud crab culture.

Fig. 6.11. Local fisherfolk with their country boat in the Vembanad backwater.

Fig. 6.12. A row of wooden poles for setting fishing net in the Vembanad estuary.

Fig. 6.13. A view of crab banded in the local market.

Fig. 6.14. A view of local fish market.

Fig. 6.15. Another view of local fish market.

Fig. 6.16. Thaneermukkom barrage on Vembanad Lake.

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CONSERVATION AND MANAGEMENT ASPECTS

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INTRODUCTION

Lakes all over the world provide natural resources that are crucial for survival of all aquatic organisms, wildlife and man. Due to rising pressure on land, encroachment and reclamation of land continues from aquatic ecosystems like lakes, estuaries and backwaters over the years. As a matter of fact, Vembanad Lake has also undergone critical changes during the last three decades defying the benefits and ecosystem services rendered by this lake ecosystem. Studies on the Vembanad Lake, particularly the Cochin backwaters, have revealed high diversity of life forms as well as problems related to development of fisheries, navigation and recreation (Bristow, 1938; Desai and Krishnankutty, 1967; Qasim *et al.*, 1968, 1969; Qasim and Gopinathan. 1969; Sankarnarayanan and Qasim, 1969; Nair and Tranter, 1971; Wellershaus, 1972; Haridas *et al.*, 1973; Gopalan *et al.*, 1983). Studies have also shown the rapid rate of environmental deterioration and irrational economic exploitation in the backwater (Gopalan and Nair, 1975; Unnithan *et al.*, 1975; Sankarnarayan *et al.*, 1986; Qasim and Madhupratap, 1979; Gore *et al.*, 1979; Remani, 1979; Gopalan, 1984; Kurup *et al.*, 1990), while Gopalan *et al.* (1983) focused on various factors contributing to the horizontal and vertical shrinkage of Vembanad estuary.

CONSERVATION ISSUES

Horizontal shrinkage

Vembanad Lake has been reclaimed over the past 150 years for various purposes such as agricultural expansion for paddy cultivation and aquaculture practices particularly for paddy-cum-shrimp culture (Table 1), harbour and urban development activities (Table 2) and for some other public and private uses. It was earlier estimated that the lake had an area of 365 km^2 till 1834 and the farmers were encouraged by the

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then Government of Travancore to reclaim the backwaters based on interest-free loans (Anonymous, 1971). The reclamation of land in the Vembanad estuary, varying from 800 to 6900 ha, resulting in a total reclamation of 23104.87 ha up to 1975 was undertaken in different periods for agricultural and aquacultural purposes (Table 1). Of these, 1500 ha area was reclaimed by private owners for housing, agriculture and cottage industries along the banks, including 500 ha area for coconut husk retting ground enclosures alone. These reclamations were mainly confined to the Kuttanad region of the Vembanad Lake under the support from the then state Government (Pillai and Pannikkar, 1965; Kurien, 1978; KSSP, 1978). The government constructed a spillway for flood control at Thottapally in 1955 and also constructed and commissioned a barrier at Thanneermukkom in 1976. As a result, an area of 69 km^2 of brackishwater lying south of Thanneermukkom has been ecologically cut off from the backwaters (Gopalan *et al.*, 1983).

Harbour and urban development activities commenced in 1920 under the direction of an eminent harbour engineer Sir Robert Bristow and was completed in 1936 to develop Cochin into a major port on the West Coast of India. Due to constant dredging during this period an area of nearly 365 ha that comprised the present Wellington Island was reclaimed. Thereafter, there was no major reclamation till 1970s. During 1978 and 1981-1985, a total of 329.82 ha area was reclaimed for fishing harbour, shipyard, extension of island and port development purposes (Table 2). The shrinkage of habitat has resulted in the overcrowding of euryhaline species in the lower reaches.

Table 1. Reclammations in the Vembanad estuary for agricultural and aquacultural purposes.

Period	**Area reclaimed (ha)**	**% reclaimed**	**Purpose**
1834-1903	2226.72	6.100	Agricultural
1912-1931	5253.15	14.392	Agricultural
1941-1950	1325.00	3.600	Agricultural
Till 1970s	5100.00	13.972	Paddy-cum shrimp culture
1970-1984	800.00	2.191	Paddy-cum shrimp culture
1900-1984	1500.00	4.109	Housing, agriculture and traditional industries including coconut husk retting by private owners.
1975	6900.00	18.904	Ecologically severed from backwaters as a result of bunding at Thannermukkom
Total	**23104.87**	**63.298**	-

Table 2. Reclammation in the Vembanad estuary for harbour and urban development

Period	Reclaimed Area(ha)	Percent Reclaimed	Purpose and location
1920-1936	364.37	0.9982	Creation of Willington Island for harbour development.
1978	10.78	0.0295	Fishing harbour project
1981-1985	141.70	0.3882	Vallarpadam–Ramanthuruthu–Candle Island complex under Integrated Development Project. Southern extension to Willington Island.
-do-	23.91	0.0655	Foreshore urban development by GCDA and Cochin Town Planning Trust.
-do-	11.73	0.0321	Reclaimed for the use of Cochin Shipyard, CIFT, North Tanker Berthand other berths.
Total	**694.19**	**1.9017**	-

Vertical shrinkage

flow. Major changes in the ecosystem, however, occurred due to construction of Cochin port and Thaneermukkom bund between 1930 and 1940 and in 1974 respectively. This has resulted in the reduction in primary production and fishery resources, growth of sea weeds and degradation of lake water (Menon *et al.*, 2000).

Biodiversity depletion

The progressive shrinkage of the estuarine system has resulted in the decline of mangrove swamps as well as estuarine dependent fishery resources particularly pertaining to shrimp and shell fisheries. Blasco (1975) estimated that there were 70,000 hectares of mangrove marshes in Kerala, a few centuries ago. Vannucci (1984) stated that the whole backwater of Kerala was once a mangrove swamp. Now, there are remnants of mangrove vegetation in different places of the backwaters. The shrinkage of swampy areas (*kari* lands) was estimated to a total of 61 km^2 in the south Vembanad region representing black peaty soil, which suggests the presence of dense mangrove in the past. In the middle and northern sector, about 60 km^2 of paddy-cum shrimp culture fields were also converted from mangrove marshes (Gopalan *et al.*, 1983). It is believed that this large-scale shrinkage of mangrove habitats along the Vembanad Lake has resulted in the total extermination of estuarine crocodile *Crocodrilus porosus* from the lake. This may promote the growth of predatory fish populations and in turn affect the growth of certain commercially important fish species (Sidensticker and Hai, 1978). Out of 33 species in the Kuttanad region, the catch composition has revealed drastic decline of several species (Menon *et al.*, 2000).

The Vembanad Lake was full of life with innumerable species of aquatic flora and fauna representing various trophic levels. The adverse effect of unfavourable alterations has resulted in the lower yield of fish and shrimp resources over the decades. Before commissioning of Thanneermukkom bund, the average daily catch of shrimps was 5 tonnes during the summer months (Kannan, 1979). In 1950s, the averge rate of production of penaeid shrimp was estimated at 1131 kg/ha (Menon, 1954; Gopinath, 1956), while in 1960s and 1970s the production had declined to 600-700 kg/ha and 300-400 kg/ha respectively (Gopalan *et al.*, 1983). Bunding and prevention of saline incursion has led to the extinction of fishery of all migratory species, depending on both fresh and brackishwater for the completion of their life cycle. The giant freshwater prawn *Macrobrachium rosenbergii* which was earlier a lucrative fishery in the middle and lower half of the Vembanad Lake, producing 300-400 tonnes/year (Rao, 1981; Rabanol, 1982) has been disrupted and led to the near extinction of this fishery in Kerala (Gopalan *et al.*, 1983). Similarly ever since the commencement of dredging and spoil spillage activities in Cochin backwater for harbour development, the extensive beds of edible oysters *Crassostraea cuttackensis* (=*madrasensis*) and clams *(Villoritta cornucopia)* of appreciable economic importance were disrupted resulting in downward trend in oyster and clam fishery in this backwater system. Vembanad Lake is well known for its clam fishery, both live and dead, with an annual output estimated at 1,70,000 tonnes in 1970 (KSSP, 1978). Rasalam and Sebastian (1976) estimated subsoil

shell deposits around 2-4.5 million tonnes. Dredging, sand and shell mining, salt water extrusion projects, etc., have, however, hampered the regeneration of shell resources adversely affecting the existing the clam fishery of this lake.

POLLUTION PROBLEMS

Vembanad Lake is subjected to pollution from different sources during the last five decades. Serious impacts of industrial and organic pollution due to factory effluents, pesticides, hydrocarbons, sewage and domestic discharges, retting of coconut husks, etc., on the hydrography of Vembanad Lake have been reported by several workers. Besides shrinkage of habitat and indiscriminate exploitation, the discharge of both untreated or partially treated sewage and industrial effluents into the lake as well as increase in the sediment load have made an adverse impact on the aquatic productivity of the backwater. The sources of pollution and impact on the ecosystem including health hazards are briefly discussed hereunder.

Sources of pollution

Domestic sewage : Gopalan *et al.* (1983) estimated discharge of domestic effluents of 80 million litres/day in the Cochin region alone. At present with the increase in local population in all the three districts viz., Ernakulam, Alapuzha and Kottayam, bordering the lake, the discharge of sewage has gone manifold in the entire Vembanad Lake.

Industrial effluents : About 108 major and minor industrial units comprising of sugar mills, rubber factories and coir industries contribute to pollution in Kuttanad region. Unnithan *et al.* (1977) reported incidence of fish mortality due to industrial pollution in Cochin backwaters. During 1980s the rate of inflow of industrial effluents had increased from negligible level to 260 million litres/day in the span of past fifty years (Anonymous, 1982). The daily effluent discharge was estimated to about 33,000 cum. About 35 rubber factories were estimated to release 1500 cum/day of waste water with the total waste load of 50 kg/day of BOD, 190 kg of COD and 350 kg/day of suspended solids. Ten coir factories in Alapuzha generate about 530 cum/day of waste water with a waste load of 90 kg/day of BOD, 215 kg/day of COD and 200 kg/day of suspended solids (Kurup, 1992). The fishery related ancillary units like Fishing Harbours, Fish Collection Centres, Fish Auction Halls, Prawn Peeling Sheds, Ice Plants, Matsyabooth, etc., along the bank of Vembanad Lake also add to pollution in this lake system.

Retting of coconut husk : The retting activity in the lake has caused enormous anoxic properties and pollution, depleting the aquatic biodiversity of the retting zones (Bijoy Nandan and Unnithan, 1998).

Construction and harbour extension : The construction works particularly concerning harbour extension and oil terminal adversely have adversely affected the equilibrium of Cochin backwater ecosystem by altering the water flow pattern and adding silt load of the waters as well as by different forms of pollution.

Sediment load and organic enrichment : The sediment load, increased turbidity and organic enrichment derived from domestic sewage disposal have also adversely affected the ecosystem, growth and rearing of commonly available and commercially cultivable species including the experimental beds of *Crassostraea cuttackensis* (=*madrasensis*) reared in the backwaters. As a result, weed infestations by water hyacinth, *Eichhornia crassipes* and other aquatic weeds are quite evident these days.

Pesticide pollution and agricultural runoff : The drainage due to agricultural runoff was estimated to about 1000 tonnes/year of pesticides in the districts of Alappuzha and Kottayam in addition to runoff of huge quantity of inorganic fertilizers in the lake (Gopalan *et al.*, 1983). Ten types of pesticides mostly comprising of Dimicron, Monocrotophos, Henosan, Thymet, Femoxan and Nuvacron were regularly used in Kuttanad region. Of the 484.63 tonnes of pesticides used during 1988 in the area, 367.72 t were applied for the "Punja crop" also known as "summer crop" The very high levels of DDT were also detected in the water samples, sediments and clam from the region in the summer months (Kurup, 1992).

Eutrophication : Gopalan and Nair (1975) estimated that about 1 kg/m^2 of the macrophyte weed matter in decaying state was accumulated at the bottom of the backwater system. The floating vegetation smothered due to about 4 million tonnes/ year of petroleum oil handled in the Cochin Harbour. High BOD values (6.21 to 280.40 mg/l), low oxygen values (0.05 to 3.081 mg/l) and high sulphide content in the bottom water were reported from some sites in the backwater (Unnithan *et al.*, 1975). Qasim and Madhupratap (1979) also documented the eutrophication of Cochin backwater through reduction in the quantity and diversity of benthic organisms in the Cochin backwater.

Disease outbreak and Fish kill

Human interventions, indiscriminate application of pesticides and discharge of industrial efflents have altered the aquatic environment of Vembanad Lake. Large scale fish mortality was recorded on several occasions (Unnithan *et al.*, 1977; Azis and Nair, 1987). Fish kill and reports on the outbreak of Epizootic Ulcerative Syndrome (EUS) in the lake, for the first time in August 1991 near Kumarakom, were registered in murrels and other fishes. The environmental stresses appear to act as the predisposing factor for the outbreak of the disease (Joseph, 1990; Kurup, 1992).

Health hazards

In the industrial areas and also around sites of coconut husk retting the human health conditions suffer from various ailments with a significant increase in disease incidence in many body systems including cancer and skin disease. The large scale industrialization and the consequent effluent discharge have made the discharge site as well as retting sites unfit for bathing purpose. The report of Green Peace survey (Green Peace, 2003) conducted at Eloor on human health is as follows :

"The health assessment has discovered that there is an overwhelming increase in most types of systemic diseases across Eloor (Target village) when compared to Pindimana (Reference village). A stratified random sample of Eloor population when compared with those at Pindimana shows a significant increase in disease incidence in many body systems. The key systems affected are neoplasm, blood and blood forming organs, endocrine, nutritional and metabolic system, mental and behavioural, the nervous system, the eye and adenexa, the ear and mastoid process, the circulatory system, the respiratory system etc. Clinically confirmed cancer incidence is greater in Eloor, at a statistically significant rate——"

MANAGEMENT MEASURES

The Backwater areas in Kerala including Vembanad Lake and Cochin backwaters are now being converted more and more for various uses. These uses include construction and extension of harbours, human settlement, industrial estate activities, and salt production, retting of coconut husk, paddy cultivation and pokkali culture. These activities have begun to threaten the lake ecosystem in a serious way. Besides the direct effects of conversion, construction of Thaneermukkom bund causes additional stresses to the lake environment and mangrove forest ecosystem at Kumarakkom. The impact of tourism and recreation on the backwater ecosystem is mounting. It is, therefore, suggested to formulate proper management plan of this Ramsar site adopting/ considering the following baseline monitoring and management measures.

1. Ensure aerial photography and mapping of the Vembanad Lake and adjacent settlement for future monitoring purpose.
2. Ensure the welfare of local lake dwellers in the integrated planning process of the lake.
3. Investigate and document the natural and human induced stressors of the lake ecosystem.
4. Encroachment and reclamation of shallow shore regions of the backwater ecosystem should be prevented from further shrinkage of the lake.
5. Investigate the diseases and health problems of populations living in or near the lake especially of the coir retting workers.
6. Identify socio-economic and cultural issues associated with the lake and also relating to lake dependent and lake visiting man and animals.
7. Identify and quantify the interdependence of ecosystems, organisms, products and processes of the lake.
8. Regulate boating and fishing related activities to prevent oil spillage, overexploitation and decline in productivity of the lake.

9. Registration of all existing fishing crafts, gears and fishermen should be made compulsory to regulate fishing efforts in the lake along with regulation of mesh size.

10. Regulate organic and industrial pollution in the lake imposing pollution abatement measures.

11. Develop alternative technology for coconut husk retting practices to prevent organic pollution.

12. Develop techniques and methods to restore and rehabilitate degraded lake areas

13. Develop criteria and methodologies to undertake environmental impact assessment and long-term cost-benefit analysis to ensure continued productivity of the lake.

14. Regulatory or enforcement machinery should be made highly effective to arrest further degradation of the lake.

15. Formulate long-term management plan at least for twenty years incorporating management mission and/ or ideal objectives.

16. Formulate short-term management plan for a period of five years adopting time-bound operational objectives.

17. Design annual action plan incorporating phase-wise management activities towards achieving operational and ideal objectives.

18. Provide infrastructure for establishing Vembanad Lake Development Authority with adequate technical and managerial personnel.

19. Provide research support for ecological monitoring, biomonitoring and biomanipulation and also to develop effective management options internalising socio-economic issues.

20. Review of management measures at every two years' interval and, if required, restructure the annual action plan and short-term management plan.

CONCLUSION

Biodiversity depletion and its socio-economic impact are felt by the fisherfolk and the local community since the productivity at various levels and particularly the fish production has been critically shattered. Increased retting of coconut husk adding to pollution of lake water and hectic sand mining activity leading to the destruction of ecological niche of native organisms at the upstream areas are evident and well documented in the literature. However, assessment for a meaningful comparison of aquatic biodiversity seems to be difficult due to the lack of base line data on biodiversity

at various temporal levels with respect to different groups. From the present study it may be concluded that the production of commercially important fishes, prawns and crabs has to be restored for the sake of fishermen community as well as for the state and the country as it represents the largest backwater lake and Ramsar site of this subcontinent. However, an in-depth and integrated investigation essential for improvement should be conducted on unexposed but vital components of this river system which includes significant areas like fast disappearing biodiversity, sand mining and its effect on eco-degradation, dangerous level of industrial pollution and its multidimensional impacts on river system and local inhabited area, large scale destruction of fishery resources and its socio-economic impact on society, etc. However, it is felt that this lake warrants an ecosystem approach with a strong will and wisdom for proper management of the system for effective conservation and sustainable utilization of the living resources of this backwater ecosystem.

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