Status Report on Periyar River

The Declining trend of Biodiversity and Fish Production in consequence of pollution in the Lower Reaches of Periyar River

Introduction

Kerala, with an inimitable physiography, monsoon climate, variable land use pattern, is endowed with highly diverse and plentiful bounty of aquatic habitats. The inland water bodies in Kerala have been extensively investigated and more interest is shown in this regard due to ever increasing demand for water, fish and the necessity for maintaining water quality and productivity.

The river Periyar, the longest river of the state (PWD,1974; CESS,1984) is considered to be the life line of Central Kerala. It originates from the Sivagiri peaks (1800m MSL) of Sundaramala in Tamil Nadu. The total length is about 300Kms (244Kms in Kerala) with a catchment area of 5396Sq Kms (5284 Sq. Kms in Kerala). The total annual flow is estimated to be 11607cubic meters. During its journey to Arabian Sea at Cochin the river is enriched with water of minor tributaries like Muthayar, Perunthuraiar, Chinnar, Cheruthony, Kattappanayar and Edamalayar at different junctures. Periyar has been performing a pivotal role in shaping the economic prospects of Kerala, as it helps in power generation, domestic water supply, irrigation, tourism, industrial production, collection of various inorganic resources and fisheries. However, as in the case of many other inland water bodies, River Periyar is gradually undergoing eco-degradation throughout its course of flow due to various anthropogenic stresses, which include indiscriminate deforestation, domestic-agricultural-industrial water pollution, excessive exploitation of resources, large scale sand mining, various interferences in the flow of water etc.

The limnology of River Periyar ought to show considerable variations, as it flows through successive stretches, where the water shed area appears to be highly variable in the nature of vegetation, land use pattern, habitation, establishment of industrial units and other man

made developments. A probe into the published data on this aspect reveals paucity of information about many ecological parameters irrespective of its status as one of the major rivers in India. It was further noted that majority of the scientific investigations have been concentrated on Cochin backwater system, which receives the tributaries of Periyar river.

Length

Periyar is the longest river in Kerala with a length of 244 Km and stretching from Western Ghats to Lakshadweep Sea (PWD, 1974; CESS, 1984). However, length of Periyar in Kerala is recorded as 229Km in NEERI report, 1992. The distance that the river flows through the plane is only 23 Km (NEERI, 1992), (Fig.1)

Width

Maximum width is recorded as 405m (Joy, 1992).

Catchment Area

Total drainage area is 5398 sq Km, out of this 5284 in Kerala and 114 in the Western slope of the Anamalai hills in Tamilnadu (KSPCB,1981; KSPCB, 1985; PWD, 1986).

Origin and Tributaries

Periyar originates in the 'Sivagiri' group of hills in 'Sundara Malai' at an elevation of about 1830m. After about 48Km it receives the Mullayar and then turns west to flow into the Periyar lake at Thekkady. The renowned Periyar Wildlife Sanctuary, famous especially for elephants and tigers is situated there. From there it flows on and passes Vandiperiyar and after receiving River Perumthurai and River Kattappana, reaches the Idukki catchment. Afterwards, Idamalayar joins Periyar near Neriamangalam. After Neriamangalam the river flows into the Periyar Barrage and then on to the

Bhoothathankettu dam. The river then meanders through Malayattoor, Kalady and Alwaye.

At Alwaye, the river bifurcates into the Mangalapuzha branch and the Marthanadavarma branch. The former joins river Chalakudy and finally drains into the Lakshadweep Sea and the latter bisects the industrial belt at Eloor before discharging into the backwaters adjoining the Arabian Sea (KSPCB,1981)

Rainfall

The average rainfall in the basin may be considered as 3000mm. In most of the areas of the basin, about 60% of the rainfall is experienced during South West Monsoon and 25% during North East monsoon period. Maximum rainfall was experienced in 1981 ie. 3863mm (CWRDM,1993) and minimum in 1982 ie. 2130mm(IDRB,1988).

Lower basins have recorded an average rainfall of 3447mm with a maximum rainfall of 4525mm in 1978 and a minimum of 2157.5mm in 1976. The upper basin receive much more rain (CWRDM.1988).

Discharge Flow

The minimum rate of flow is 9.66 m^3 and the maximum is 1364.66 m^3 /Sec (Joy,1992). It may be observed that in most of the years the summer flows are only a fraction of the total runoff. This calls for the proper conservation and efficient management of water resources (CWRDM,1981). According to PWD(1974), the total runoff from the tributaries of Periyar amounts to 11607mm^3 of which 11341 mm^3 is the contribution from the catchments within Kerala.

Land Use

About 35% of the area of Periyar basin is forests. But some of these areas have already been cleared for various developmental activities. In the highland region, the major

human activities are connected with plantation, hydroelectric projects and new settlements and building activities in the Idukki district. While the plantation in the very high reaches such as Udumpenchola, Peerumedu and Devikulam are cardamom, tea and pepper, the foothills are cultivated with rubber, coconut and pepper. The midland belt has mainly paddy, coconut and plantains. The irrigation projects of the basin are intended to cater to the requirements of mainly the midland crops. The waste lands cover only 5-8% of the total basin area. These are situated in the highest peaks or the coastal saline belts in the low land. The major industries and settlements are in the lower reaches, especially in the Alwaye, Ernakulam belt. There are a number of islands in the lower reaches of the basin (Fig.2)

The major classification of forests in the basin is wet-evergreen, semi-evergreen, moist-deciduous, dry-deciduous and pure reed areas (Fig.3) The map also shows grass lands, forest plantation and unclassified areas. The vegetal cover classification of Periyar basin using the latest IRS (LISSII) CCT data (using the facilities at NRSA) shows that around 30% of the area is dense in vegetation (more than 75% canopy coverage), 50% is medium (35-75%) and the remaining low in vegetation (less than 35%)- (CWRDM, 1993) (Fig.4).

Demands on the River

Irrigation

There are 15 minor and one major hydroelectric projects, apart from nine irrigation schemes, which regulate and consume water for irrigation processes.

1. Periyar Valley Irrigation Project -32000Ha

2. Diversion of water from Periyar dam at Thekkady to Tamilnadu to irrigate-76890Ha.

Electricity Generation/ Hydro Electric Projects

The river flow has suffered because of impoundments upstream and the river basin diversion which has happened in the case of Idukki Hydel Power Project. The diversion from the power station at Moolamattom to Muvattupuzha river has resulted in the slimming of the river downstream of the dam.

The river has been rendered non-existent immediately downstream of Idukki and lower Periyar projects. However, replenishment through sources like many numbers of rivulets and streams further rejuvenates the river.

Major hydroelectric schemes in Periyar

Name	***Capacity***	***Catchment area***
Pallivasal HES	37.5MW	
Sengulam HES	48MW	
Panniyar HES	30MW	
Neriamangalam HES	45MW	81.6sq.Km
Idukki HES	700MW	649.3sq.Km
Edamalayar HES	75MW	380.7sq.Km
Lower Periyar HES	180MW	181.34sq.Km

Proposed schemes

Name	***Capacity***	***Catchment area***
Upper Edamalayar and Kudal Dam	90MW	84.48sq.Km
Anamalai Dam and Manali Dam	100MW	95.4sq.Km
Kadalur, Mankulam, Rajamalai weir	80MW	61.30sq.Km
Thottiyar Dam and Pooyamkutty Dam	480MW	266sq.Km

Potable Water Supply Schemes

The following is the list of major water supply schemes from Periyar river.
Scheme for Cochin corporation
Scheme for Alwaye town
Scheme for Perumbavoor town
Scheme for Parur town
Rural water supply scheme for panchayaths of Maradu, Mulanthuruthy, Kadamakudy, Udayamperur, Puthencruz etc.

The water supply scheme for Corporation of Cochin, started in 1914, has two head works and treatment plants ie. Alwaye and Chowara, with a capacity of 48 and 22.5 million litres/day respectively.

The total domestic supply covers a population of 32.27l akhs having a requirement of 520 million litres/day.

Navigation

Inland navigation through Cochin backwaters and lower reaches of Periyar river is a major means of transportation in this area. Boats owned by both Government and private agencies conduct regular services. It offers a smooth and comfortable journey for passengers when compared to the busiest roadways in Cochin area.

Fisheries

Lower reaches of Periyar was well known for easy availability of various types of tasty fishes like Pearlspot, Palankanni, Kanambu, Thirutha, Koori etc. Along with a variety of shell fishes which includes crab, prawn, konchu and so on. However, this has become an old story due to the severe impact of pollution from different sources which already inflicted large scale damage to aquatic life in this water body.

Industries

Angamaly to Kochi is the most industrialized zone of the Periyar river basin. There are over 50 large and medium industries and over 2500 small scale industries in this region. The southern branch of Marthandapuzha which cater to the needs of these industries is estimated to have a lean water flow of 8200 cum/sec which the monsoon flow is calculated as 150-250 cum/sec. The industries located in Edayar – Eloor atea consumes about 189343 cum per day water from the day and discharge about 75% as used water along with large quantity of effluents and pollutants.

The major types of these industries are fertilizers, pesticides, chemicals and allied industries, petroleum refining and heavy metal processing, radioactive mineral processing, rubber processing units, animal bone processing units, battery manufacturers, mercure products, acid manufacturers, pigment and latex producers etc. The wide spectra of pollutants that adversely affect the natural environmental quality of the water of the river include toxic and hazardous materials such as heavy metals, phenolics, hydrocarbons, pesticides, radionuclides, ammonia, phosphates, domestic and untreated waste water etc(Fig.5).

The details of industries coming under water act with their raw materials, products, effluent composition, effluent discharge rate and discharge points are furnished as Table-12 (KSPCB,2001).

Deforestation in the Periyar Valley

The systematic deforestation in the High Ranges of Idukki district which is a principal catchment of Periyar, began in 1870s when timber extraction started on a large scale on the hill tracts of Western Ghats. Extensive conversion of forests into tea estates in the last decade of 19^{th} centuary added to it. A labyrinth of roads increased deforestation. The formation of cardamom hill reserve area in Udumbenchola taluk in 1897 led to worsening

of the situation. According to the estimates of forest department some 10000 trees fell in 1989-90 alone because of soil erosion caused by undergrowth removal from 10sqKm of the Munnar forest division. Whatever forest cover has remained is now under tremendous pressure from encroachments. The settlements within the forested areas keep expanding. The forest department has not yet conducted a comprehensive survey to ascertain the forest boundaries conclusively and this deficiency is often exploited by encroachers (Pratapan,1999).

Tourism

The mountain ranges where Periyar originates and the serene beautiful lakes reflecting the nature around along with forest abounding in attractive wild life are all perennial attractions to the tourists. The Thekkady lake with boating facilities, the Bhoothathan reservoir and beautiful wild life sanctuary adjascent to it attracts nature lovers and tourists from all over the world. The famous Malayattoor church, the birth place of Adisankara (Kalady), Thattekad bird sanctuary, Sivarathri Manalpuram (Alwaye), the Queen of Arabian Sea(Kochi) etc are all spots of natural beauty along the banks of Periyar (Gopalan,1992).

Sand Mining

Sand mining from the river belt 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 districts. The mining activity was entrusted to Gramapanchayths and the sale is done at prices fixed by District Collector. However, so far no standard system has been formulated to implement these norms effectively.

The 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, stagnation and trapping of saline water in the regions of mining due to artificial deepening of river basin, interferences in he free flow of water etc.

Pollution

Sources of pollution in Periyar river can be categorized as

- Sewage and garbage
- Agricultural run-off
- Industrial pollution

Sewage and Garbage

The river directly receives civic effluents from townships like Vandiperiyar, Upputhara, Cheruthony, Munnar, Malayattoor, Kalady, Perumbavoor, Neriamangalam, Aluva and Parur. None of these bcal bodies possess proper sewage treatment facility. In the case of Cochin corporation sewage treatment system is inadequate and the untreated organic and inorganic refuse is being discharged into the backwaters (KSPCB,1981)(Fig.6).

Agricultural Run-off

Periyar river basin has an area of 5284sqkms. Out of this, 39000Ha are available as wet land and 166000 ha as garden land (KSPCB,1981). Major crops being cultivated in the river basin includes rice, coconut, arecanut, banana, rubber, vegetables etc. The upper reaches of the basin is utilized for plantation crops like tea, coffee, cardamom and rubber. This intensive agricultural practice all along the banks and watershed area has been enriching the river water with huge amounts of pesticides and fertilizers especially during surface run off in the rainy season. Besides, loosening of surface soil and removal of vegetation from catchment area generates problems related to soil erosion and siltation.

Industrial Pollution

Industrial pollution poise the most serious threat to the riverine ecosystem in lower reaches of Periyar ie aout 15 Kms upstream from the backwaters of Cochin, where a cluster of small and big industries are operating.

Pollution Status Assessments

A pioneer study on pollution aspects of Periyar river by Paul and Pillai (1976) provides valuable baseline information towards this direction. The study report discusses various important parameters like river discharges at different points, influence of tidal influx in the lower reaches, effluent dilution due to discharge of fresh water from unpolluted area, distribution of radioactivity in sediment-water- biota, concentration of other pollutants like heavy metals, inorganic compounds etc.

Jayapalan et al(1976) explored some aspects of physico-chemical and biological variations of Periyar water due to the effluent discharge from FACT. Remani et al(1980) analysed the chemical composition of sediments of Cochin backwaters in relation to the pollution. Further Remani et al(1983) listed the indicator organisms of pollution in the same water body.

Fluctuations in the spatial distribution of phytoplankton in the pollution affected zones of Periyar river in relation to certain physico-chemical parameters have been reported by Joseph et al (1984).

Joy(1989) made a detailed assessment of the water quality of Periyar river and observed growth response of phytoplankton community so as to predict the probable effect of continued discharge of complex effluents from industries on such organisms. The two major phases of this attempt was 1) Field observation of hydrological factors and its correlation to standing stock of phytoplankton and 2) Algal assays on pure cultures using industrial effluents.

Green Peace Reports (1999,2003) describe Eloor industrial area as one of the most vulnerable industrially polluted “hot spots” in the world. Recently they have appointed a full time river keeper to regularly monitor the industrial pollution load of river Periyar. The results of the analysis of various polluting factors of the river water from three stations revealed that Periyar is being continuously poisoned by factories leading to its death in all aspects. Following is the brief narration of various factors of contamination in the river, consolidated from available literature.

Radioactivity

The results of the analysis of radionuclides in sediment, water and biota in the lower reaches of Periyar river is documented in the study report of Paul and Pillai(1976). ^{228}Ra concentration near the IRE outfall area recorded as high. The levels of ^{228}Ra of river water were found to be above 0.3(MPC)w on 30% of the random samples analysed. The analysis of sediment has indicated beta activity of 248pCi/gm.

Rock phosphate processed in FACT was also registered beta radioactivity of 228pCi /gm. Comparing the gross beta activity levels of monazite(10pCi/gm) and rock phosphate(228pCi/gm), it is found that about 35 tonnes of rock phosphate contributes gross beta activity equivalent to 1tonne of monazite. Hence it may be concluded that a part of the environmental radioactivity is contributed by FACT operations also.

Gamma spectra analysis of body parts of three species of edible fishes ie. Aries(Koori), Clupea(Palankanny) and Etroplus(Karimeen) showed significant level of radioactive contamination due to ^{232}Th . Similar incidence was noted in the case of analysis of certain aquatic weeds like *Eichornia crassipus*. Roots of the plants which are submerged in water exhibited twice the activity as compared with the rest. It was further noticed that the floating community of weeds could transport the radionuclides to distant places throughout the downstream (Paul and Pillai,1976).

Paul and Pillai(1986) probed the transportation of radium in the sediments of Periyar river. Again Paul and Pillai(1990) noted considerable reduction in the radioactivity by a factor of 3 to 5 during the post monsoon, base line, 1980 as compared to pre-monsoon mainly due to the better effluent treatment facility. The study concluded that $^{226}_{Ra}$ in the bottom sediments was due to leaching of the nuclides from the phosphogypsum dump sites of the fertilizer factory.

Trace/ Heavy Metals

Preliminary reports of the trace/heavy metal concentration in the pollution affected angles of Periyar river is given by Paul and Pillai(1976). Trace elements concentrations in the downstream locations were found to be higher than that of upstream. High Hg content near TCC, elevated concentrations of Copper, Zinc and Cadmium near Binani Zinc and TCC were some of the highlights of the data. Incidentally, slightly increased concentration of Hg was noted in some of the edible fishes, likewise, the levels of Mn, Cd and F were noted to be higher in sediments and water column of the affected areas of the river.

Interestingly, an extensive study by NEERI(1992) on water quality of Periyar river from Bhoothathankettu to Eloor ferry ie total 9 stations, recorded comparatively very low level of trace metals in water. Zn, Cd and Hg were reported to be below detectable level. Only the F level was found to be slightly higher.

The load of Hg in Periyar river from various sources was estimated as 0.6 kg per day(KSPCB,1981). Comparatively higher concentration of Cu and Zn in bottom sediments was recorded and it was considered as one of the reason for absence of bottom fauna in the polluted zone of Periyar river.

Nutrients

Periodical enrichment of water bodies with potential plant nutrients like PO4, NO3, SiO2, SO4 is considered as primary step towards 'Eutrophication' of aquatic habitats.

The concentration of these nutrients in the different stretches of Periyar river has been discussed elsewhere. Irrespective of the presence of higher quantities of the phosphate and nitrate in the lower reaches of Periyar, this area does not exhibit increase in primary production or profuse growth of algae.

Nitrate

Paul and Pillai(1976) observed considerably high concentration of nitrate in water samples from varapuzha to Alwaye ie.Methanam-8.57 ppm, IRE-8.53ppm and TCC-5.5ppm, whereas, a comparatively lesser quantity of nitrate was noted by Joseph et. al. (1984) from Alupuram(1.85 µg/l to 5.48µg/l/L), FACT(4.66µg/l to 6.10µg/l) and Eloor(4.66µg/l to 7.07µg/l).

CPCB (1995 and 2000)had given an estimate of nitrate with nitrite river water from three stations ie.Kalady, Sewage disposal zone and Alwaye(Table 5)

NEERI(1992) recorded a highest value of 0.55mg/l(Kodanadu) and lowest value of 1.9mg/l (Kuttikattukara) in river waters. The average value at Eloor Ferry was 1.54mg/l. Joy(1989) observed higher levels of nitrate in Periyar river (maximum of 406µg/l). Many investigators report a gradual rise nitrate concentration in Cochin backwaters (Sankaranarayanan and Qasim,1969; Devassi and Bhattathiri, 1974; Remani et al.,1980; Lakshmanan et al., 1987).

Phosphate

Higher phosphate values were recorded in polluted region of Periyar river by Paul and Pillai(1976) ie. 160µg/l(Varapuzha), 640µg/l to 910µg/l (Methanam) and 630µg/l (IRE) (Table 6).

In contrast, Jayapalan et al. (1976) observed only negligible amount of inorganic phosphate in the industrial zone of the river. However, later studies showed increasing trend of phosphate enrichment. Joseph et al. (1984) registered a peak value of 955µg/l in

polluted zone of the river and NEERI (1992) recorded phosphate level as 0.7ppm near Marthandavarma Bridge and 0.5 in the Eloor ferry region.

The rate of phosphate discharge from various sources has been given as 9500 kg per day(SPCB,1981). Joy(1989) recorded a maximum value of 64.58µg/l of phosphate from pollution affected region of the river.

Ammonia

Joseph et al (1984) observed considerably higher concentration of free ammonia in polluted area of Periyar river, especially in pre-monsoon period (288µg/l –FACT; 215µg/l –Eloor). Values showed very significant increase in FACT and Eloor area when cited against an immediate upstream, just above the discharge. Joy(1989) noted increased level of free ammonia in the regions of industrial discharge (Edayar-Eloor area) of the river, ranged between 0.14 to 65.71µg/l. Saraladevi et al (1979) noted the presence of ammonia in the effluents of many factories situated here, which ranged between 0.1 to 3.0ppm. It may be recalled that the unionized form of ammonia is poisonous to organisms.

According to KSPCB (2000) the range of free ammonia at sewage disposal point was 0.005 to 0.023mg/l. This report also gives an estimate of total kjeldahl nitrogen from three stations in river.(Table 4 and Table 7)

Nitrite

Joy (1989) noticed the range of nitrite in the Periyar river water as 0.0 to 48µg/l.

Sulphate

High level of sulphate in industrial zone of Periyar river water was recorded by Paul and Pillai(1976), ie. Varapuzha-460ppm; Methanam-160ppm and IRE-100ppm. According to KSPCB(1981) the daily sulphate load into the Periyar river was 7500Kg/day.

Biological Oxygen Demand (B O D)

BOD values from various studies indicates safe limits in the Periyar river (Table 3)

Chemical Oxygen Demand (COD)

Data on Chemical Oxygen Demand is furnished in the report of CPCB(1995 and 2000). Maximum values were 6.4 in 1995 (Kalady, sewage disposal point and Alwaye) and 11 in 2000 (Alwaye)

Physico-Chemical Factors

Water temperature

The temperature of surface water in Periyar river from Edamalayar to Vembanad lake ranged between 24.5^{0}C to 34.8^{0}C (Joy,1989). The lowest water temperature was noted in Edamalayar , can be due to the effect of high altitude. Joy(1989) noted highest water temperature at Edayar near effluent discharge points from FACT, TCC and Binani are situated. Saraladevi et al(1979) also noted elevated water temperature at areas of industrial discharge.

According to Green peace report, water temperature fluctuated between a highest of 35.9^{0}C downstream (01/06/03) and a lowest of 27.2^{0}C upstream (29/06/03 and 29/07/03).

pH

pH of the Periyar river water in industrial discharge area was fluctuated between 11.6 to 3.4; 12.2 to 3.1; 9.5 to 5.1 in the years 1972, 73 and 74 respectively (Paul and Pillai,1976).

Silas and Pillai(1976) reported large scale fish mortality in the region of river between FACT and TCC due to high acidity of water. Saraladevi et al (1979) noted erratic fluctuations in pH during non-monsoon months in industrial zone.

According to KSPCB reports(1981) the range of pH of Periyar water is 1.32 to 5.72. Green Peace report (1999) recorded acidic pH of 3 in areas like Muttinakam, Pallikadavu and Eloor ferry ie. downstream of industrial belt (Table.1)

Dissolved Oxygen (mg/l)

Saraladevi et al(1979) and Gopinathan et al(1984) did not observe variation in dissolved oxygen level in Periyar water. Joseph et al (1984) noted a range of 5.65 in post-monsoon to 2.28 in pre-monsoon in the pollution affected areas of river (Table 2).

Joy(1989) observed undersalinisation of dissolved oxygen in bottom layers at industrial discharge zone, whereas well oxygenated condition prevailed in other areas of river.

Records of KSPCB(1995 and 2000) did not show much variation or decrease in the dissolved oxygen level of Periyar river at Kalady, sewage discharge point and Alwaye. According to Green Peace reports comparatively higher dissolved oxygen was noted in downstream ie.12µg/l to 3µg/l.

Salinity

In a study by Joseph et al (1984), zero salinity was recorded for Periyar river upto Alupuram and FACT area. During the pre-monsoon period a nominal increase in salinity(3.1 parts per thousand) was noted in Eloor area. According to Joy(1989), Periyar river has fresh water regime upto Pathalam, in Eloor panchayath. The intrusion of sea water occurs upto 15Kms (Edayar) into the river during pre-monsoon months. Recently, earthern bunds are being constructed across the river to prevent salinity intrusion during pre-monsoon period. The alarmed mining activity in the river basin for sand collection has created another set of ecological imbalances including salinity incursion and stagnation of saline water in certain pockets of the river. It creates problems in the water supply scheme from Alwaye.

Hydro-biology

A perusal of literature shows plenty of information on hydrobiology of riverine systems in India, to mention a few (Rai,1974; John,1976; Prasad and Saxena,1980; Vasisht and Sarma,1986; Venkiteswarlu,1986; Negi,1993). Here an attempt is made to review the available literature on some of the hydro-biological aspects of river Periyar.

Primary Productivity

Rate of primary production in Cochin backwaters has been worked out by many authors. Quasim et al(1969) have estimated the phytoplanktonic production using chlorophyll measurement ^{14}C uptake and also by counting the microplankton retained by Heron-Tranter Net. According to them gross production ranged from 272 to 293g C/Sqm /year with an average of 280gC/sqm/year. Effect of various parameters like 1)Salinity and 2)flushing rate and nutrients on the phytoplanktonic growth also have been washed out by Quasim et al(1972) and Wyatt and Quasim(1973) respectively. Significant increase in primary production during post monsoon season was attributed to during post monsoon season was attributed to adequate supply and utilization of light and nutrients.

According to Nair et al (1975) the annual gross production ranges from about 1.5 to 2gC/sqm/day with maximum during pre and post-monsoon period. In this study the standing crop as measured by chlorophyll showed distinct spatial variation. Similarly the primary production measured by C^{14} registered wide fluctuation from station to station and season to season.

Joy(1989) noted poor chlorophyll concentration in the fresh water region of river (Edamalayar to Pathalam) ie.<5.45mg/cu.m, compared to that of polluted regions and backwaters. Eloor region showed highest chlorophyll value whereas Joseph et al (1984) reported very thin standing crop of primary producers (plankton) from FACT area and it was attributed to the inhibitory effect of high phosphate content in water.

Eventhough the studies of primary production in Indian fresh water were started much earlier (Sreenivasan,1960,1963) especially of lakes and reservoirs, not much works have been carried out on the river system (Gopal and Zutshi,1998).Similarly the rate of primary production in the fresh water region of Periyar river is found to be unavailable.

Phytoplankton

Joy(1989) made a detailed assessment of phytoplankton composition in three different regions of lower reaches of Periyar river (Table 11). The study revealed that the phytoplankton community comprised of chlorophyceae especially desmids and members of basillariophyceae in the fresh water region of river. In the industrial zone, members of cyanophyceae, chlorococcales were dominant. More number of diatoms were reported in backwater region. In another study on phytoplankton, Joy (1989) reported twenty species of diatoms, nine species of blue green algae, sixteen species of green algae, four species of dinoflagellates and Euglena viridis from different stations in Periyar river ie Edamalayar to the cochin backwaters, with striking variation in occurrence and abundance. Out of total 50 species reported in this study only 27 species have been registered from fresh water regions of the river, beyond the influence of estuarine waters.

Jayapalan et al (1976) have reported the bloom of Oscilllatoria sp. from Edayar region of river Periyar. Saraladevi et al(1979) also observed termination of an algal bloom in this region accompanied by increasing organic load.

Joseph and Pillai(1975) observed the composition and diversity of phytoplankton in the Periyar river mouth(Cochin backwater) for a period of one year and reported considerable seasonal and spatial variations both in magnitude and composition. The authors give an account of the seasonal and spatial variation of common phytoplankton in the 90Km long backwaters extending from Alapuzha in south and Azhikode in North, where, tributaries of Periyar river joins. They noted considerable seasonal and spatial variation both in magnitude and composition of phytoplankton. Gopinathan (1972) gave another account on the seasonal abundance of phytoplankton in Cochin backwater.

George(1958) in a pioneer study noted comparatively sparse amount of phytoplanktonic biomass, both in quality and quantity in Cochin backwaters. This study showed the role of diatoms as the major constituent with two successive peaks ie. In June- July (South West Monsoon) and November- December.

A quantitative study on the diatoms of Cochin backwater by Gopinathan (1975) revealed altogether 88 species of diatoms, among which 20 species were prominent and showed seasonal variations. The author also tried to relate the seasonal fluctuation in the planktonic diversity and abundance with some of the major hydrographic features like nutrients.

Gopinathan(1972) made quantitative and qualitative examination of phytoplankton of cochin backwaters and listed the occurrence of 120 species (excluding nanoplankton) and opined that the seasonal variability of nutrients, especially nitrates and phosphates, controls the production of phytoplankton (Table 9).

The role of nutrients and their seasonal variation in the Cochin backwaters have been discussed by Sankaranarayanan and Quasim(1969) also.

Seasonal and spatial distribution of phytoplankton in the pollution hit areas of Periyar river system near Industrial area of Alwaye have been studied by Joseph et al.(1984). In this study the station near FACT was registered the total absence or poor concentration of standing crop of phytoplanktonic biomass due to high concentration of NH_3-N (20 to 50 µg at l^{-1}). Considerable variation noted in the composition of phytoplankton among three different stations indicated significant changes in the quality of river due to contamination from various industrial pollutants.

It was noted from different studies that quantitative and qualitative changes in primary producers (phytoplankton) have been occurred in Periyar river eco-system as it enters into the pollution hit areas and estuarine system. Productivity level was reached to the

level of zero due to acute contamination from effluents. Presence of various contaminants in concentration far above the tolerable limits might have resulted in the extermination of many of the organisms. Joy(1989) arrayed the toxicity of the effluents to plankton species under different environmental conditions employing standard algal bioassay procedure.

In the estuarine region with the onset of monsoon and reduction of salinity, the phytoplankton progressively increases until salinity reaches the lower level of 10 and it was inferred that salinity is the prominent factor that controls diversity and succession (Menon et al., 2000).

Phytoplankton Vs Nutrients

The available studies on the nutrient uptake by aquatic plants have been reviewed in detail by Gopal(1990). The concentrations of different nutrients and their specific role in the proliferation of phytoplankton in river ecosystem have been carried out by many, to mention a few, (Chakrabarty et al, 1959; Chacko et al, 1953; Saraladevi et al, 1983; Rao and Sarma,1995).

Survey of literature indicated scarcity of data of the nutrient-energy-production relationship in Periyar river water. However reports of similar attempts are available on Cochin backwaters(George,1958; Gopinathan,1972; Joseph et al,1984; Quasim et al, 1972; Sankaranarayanan and Quasim,1969; Sankaranarayanan and Panampunnayil,1979; Saraladevi et al,1991).

Zooplankton

Zooplanktonic community constitute an integral part of any aquatic environment. Efforts are made to understand their distribution and magnitude in Cochin backwaters(Menon et al,1971; Nair and Tranter, 1971; Rao et al, 1975; Madhupratap,1977; Madhupratap and Rao, 1979).

A perusal of available literature showed scarcity of information about the distribution and abundance of zooplankton in Periyar river water. Identification and enumeration of plaktonic animals in the fresh water region and pollution affected region of the river is a prerequisite for any type of biodiversity analysis. However dearth of base line information gives no scope for a comparative assessment of this factor and also for the instances of disappearance or extinction (due to the pollution load) of riverine zooplanktonic fauna.

George(1958) conducted a study which gives a detailed account of various levels of zooplankton in Cochin backwaters, in which majority are purely marine and some are estuarine. However, not even a single genus/species of freshwater form was recorded throughout the year, except for the scanty appearance of certain larval form of Caridea.

Fish diversity

Rivers generally harbour a variety of fishes. The investigations of the fresh water fish fauna of Kerala had started with the works of Day (1865,1878)and continuing (Silas, 1951; Indira and Remadevi, 1981; Easa and Bashs,1996; Menon and Jacob,1996).

Chacko(1948) enlisted the fishes of periyar lake. A similar study by Arun(1998) exposed the disappearance of 16 species of fishes from the same aquatic system within a span of 50 years. The disappeared species include Eels, Catfishes, Goby and Cyprinides. According to Arun(1998) the presence of 56%(14) of the endemic fishes of Kerala in Periyar lake and river system makes it a unique and diverse Icthyofaunal regions in South India(Table 8 and Table 10).

Ponniah and Gopalakrishnan (2002), under the auspecies of NBFGR, listed all the 287 fresh water species of fishes found in Western Ghats including those in Periyar waters. While identifying a variety of endemic species it was proposed to declare the upper reaches of Periyar as potential fish sanctuary along with other centers. The author opined that regulation of Mullayar- Periyar streams by construction of the dam in 1895 might

have ceased the free upstream-downstream movements of many catadromous and anadromous fishes including a variety of eels. In the case of Periyar, many of the threatened or endemic fishes which are of high conservation status inhabit the forest streams or lake/ reservoirs in the forest. It was suggested to include the threatened or endemic species of India(as given in the list of Mehanta et al, 1994) in the schedule of Wild Life Protection Act 1972.

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 speciees 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).

In Cochin backwaters, the scientific literature of different trophic communities like Wood Borers(Nair,1994), Biofoulers (Menon and Nair, 1967;Menon ,1971; Meenakumari and Nair,1994), Bivalves(Salih,1977; Nair,1985; Kattickaran,1989; Sreedhar,1991), Meico and Microfauna(Jayasree,1971; Sunilkumar,1995) are available.

Biodiversity depletion and some of its socio-economic impact

The perusal of literature shows poor records on the biodiversity of Periyar river system barring a few attempts.

- Some account of the phytoplankton community, excluding nanoplankton, are documented in the works of Joy(1989) and Joseph et al (1984).
- Similarly, a list of fishes in Periyar lake (Arun,1998) and Cochin backwaters are also available.

However, the meager information on fishery resources and biodiversity are found to be insufficient in the light of following facts.

- The full fledged river waters of Periyar including the lower reaches upto backwaters(About 15-20Kms into the river from seaward end) once supported very rich biodiversity including various types of fin fishes and shell fishes of high economic value.
- Formerly, the river in this region was full of life with innumerable number of aquatic flora and fauna representing various trophic levels which constituted a vibrant tropical aquatic system
- Fishery resources from this region was major means for income for thousands of families belonging to this area and there was absolutely no scarcity of fish as their prime food item

However, inspite of the above mentioned facts, the present scenario of the river in this region draws a very grim situation.

- The large scale industrialization and the consequent effluent discharge has made this part of the river almost lifeless or dead
- Now a days the river has become a sewage canal carrying a myriad of hazardous and toxic industry-borne pollutants
- At present, fishery from this region is gradually vanishing; the different types of gears(Chinese net, cast net, dip net, gill net etc.) and crafts which were regularly operating in this area have been almost totally disappeared
- Thousands of people are deprived of their conventional labourhood
- The poor availability of fish lead to malnutrition and related health problems in economically weaker section of the people inhabiting here
- Massive destruction of fauna and flora ,including large scale fish kills, has become routine where the river resembles a graveyard of all types of biotic forms
- In fact, in many occasions, such incidents are repeating so frequently that the river ecosystem never gets adequate time to revive its natural community structure and order
- The productivity at various level seems to be critically shattered

However from the present review it is understood that there is no scope for a meaningful comparison of the biodiversity due to the following reasons

- Lack of base line data on biodiversity at various levels
- Preliminary level information about vital links in the trophic structure of the system like zooplankton, benthos, periphyton, micro-algae, fishes, shellfishes etc. are lacking
- In some cases, qualitative data of some organisms is available but their abundance and spatial variations are not properly looked into.
- It may be noted that the cruel destruction to various biotic forms in this region of the river is a mere truth as it is evident from the layman's point of view.

Health hazards of local people and river pollution

Following are the findings of Green Peace survey conducted in Eloor (2003) industrial area on human health conditions. "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--------".

The highlights of the data from the pollution angle are following (See Plates1-7)

- Significant level of radioactivity was noted in water, sediment and biota in Periyar river in the industrial area by investigators. It's present status is not known.

- High level concentration of heavy metals in the river including Manganese, Zinc, Cadmium and Mercury (chance for bioaccumulation and magnification at trophic levels eg. fishes, man).
- Elevated level of water nutrients like nitrate, phosphate, sulphate etc.(Chance for eutrophication and depletion of dissolved oxygen leading to dystrophic condition and total destruction of biocoenosis).
- Physical appearance of water body a) abnormal colouration like greenish brown, reddish brown, bluish brown which changes everyday b)chemical smell of water and appearance of oil layer coating on surface.
- Fluctuation in pH, ranging from 1.3 to 5.7
- Hectic sand mining activity leading to the destruction of ecological niche of native organisms
- Variability in the seasonal incursion of saline water and its further encroachment to fresh water region even upto Alwaye. Consequent problems associated to drinking water supply and industrial utilization of river water.
- According to official statistics, there are only 37 discharge points in the banks of the river in industrial area. The real estimate shows more numbers, including certain under water discharge points which open directly into middle portion of the river (Fig.7).
- Comparatively higher concentration of a wide spectrum of pesticides (Sujatha et al. 1999: Greenpeace, 1999), particularly trace metals (Ouseph,1992; Meenakumari and Nair,1996, Khurshid et al.1998) and heavy metals (Nair et al.1997) have been reported from Periyar waters and Cochin back water.

(see Plates 1-7)

Conclusion

In the present study an attempt is made to review the available literature on Periyar river ecology. The study reveals lack of scientific information on various ecological parameters of the river with reference to its alarming proportion of contamination from

sources like small and large industries, agricultural run-off and sewage cum garbage pollution from cities, towns and other local bodies.

Eventhough significant level of radioactivity was noted in water, sediment and biota in in the industrial area of Periyar river by investigators, it's present status is not known. High level concentration of heavy metals Manganese, Zinc, Cadmium, Mercury in the sediments and water (as reported in the earlier and recent studies) poise ample chance for their bioaccumulation and magnification at various trophic levels consisting of fish and man at the apex. Elevated level of water nutrients like nitrate, phosphate, sulphate etc. pointing towards development of eutrophication and consequent after effects like blooming of obnoxious algae, depletion of dissolved oxygen, deterioration of water quality leading to dystrophic condition and total destruction of biocoenosis.

Another observation is that, irrespective of its status as the life line of kerala, the hydrobiology of Periyar River is not completely explored. Basic information about several trophic communities like zooplankton, benthos, periphyton, decomposers etc are found to be lacking. Analysis of available literature on biology (eg. Data of fish diversity and phytoplankton) indicates that the unabated eco-degradation activities in Periyar river system have resulted in the disappearance/extermination of many of its endemic biodiversity at various trophic levels. However, a detailed comparative assessment seems to be impossible due to the lack of information.

From the present analysis of available data it may be concluded that more investigations should be conducted on unexposed but vital components of this river system which includes significant areas like fastly 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.

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List of Abbreviations

CESS	Centre for Earth Science Studies
CPCB	Central Pollution Control Board
CWRDM	Centre for Water Research Development and Management
FACT	Fertilizers and Chemicals of Travancore
HES	Hydro Electric Scheme
IRE	Indian Rare Earths
KSPCB	Kerala State Pollution Control Board
MSL	Mean sea level
NEERI	National Environmental Engineering Research Institute
ND	Not detectable
PWD	Public Works Department
TCC	Travancore Cochin Chemicals

Table1. Pollution indicators in lower reaches of Periyar river-pH

Source of information	Range observed	Place	Comments
Paul & Pillai,1974	3.1 to 12.2 (Average value of year 1973)	Industrial Zone	
KSPCB,1981	1.32 to 5.72	Industrial Zone	
Silas & Pillai,1976	Highly acidic water	Between FACT and TCC	
Joy, 1989	3.94 to 8.92	Edamalayar to Cochin backwaters	Exceptionally low pH in industrial zone
Green Peace,2003	3 to 7	Industrial Zone	Muttinakam region showed low pH constantly

Table 2. Pollution indicators in lower reaches of Periyar river-Dissolved oxygen

Source of information	Range observed	Place	Comments
Saraladevi et al, 1979			No variation throughout year
Gopinathan et al, 1984			No variation throughout year
Joseph et al, 1984	2.28 - 5.65	Alupuram to Eloor	Highest in post - monsoon
Joy,1989	3 - 12.95	Edamalayar to Cochin backwaters	Low values in bottom layers
CPCB,1995	5.6 – 8.6	Kalady to Alwaye	
CPCB,2000	4.4 – 7.4	Kalady to Alwaye	
Green Peace,2003	4 - 12	Industrial area	Highest in Edamula (Upstream of factories)

Table3. Pollution indicators in lower reaches of Periyar river - Biological oxygen demand (BOD)

Source	Range	Place
KSPCB, 1981	4600kg/day	Industrial area
Joy,1989	0.23 -6.11mg/l	Edamalayar to Cochin backwaters
NEERI,1992	0.1 mg/l 0.2 mg/l 0.5 mg/l	Kodanad Eloor Alwaye
CPCB,1995	0.3 -0.7mg/l	Kalady to Alwaye
CPCB,2000	0.2 – 0.4mg/l	Kalady to Alwaye
Green Peace,2003	2 – 6 mg/l	Edamalayar

Table 4. Pollution indicators in lower reaches of Periyar river-Free ammonia

Source	Range	Place	Comments
Joseph et al,1984	Trace-288µg/l	Alupuram to Eloor	Higher values in pre-monsoon
Joy,1989	0.0–65.71µg/l	Edamalayar-backwaters	Persistent high values in industrial zone
NEERI,1992	Not detected		Not detected in any station
CPCB,2000	0.060-0.005µg/l	Sewage discharge point (Near Alwaye)	

Table5. Pollution indicators in lower reaches of Periyar river-Nitrate

Source	Range	Place	Comments
Paul & Pillai,1974	5.5-8.57ppm	Industrial zone	Highest value from Methanam
Joseph et al,1984	1.85-7.07µg/l	Industrial zone	Highest value from Eloor
Joy,1989	Highest-406µg/l	Industrial area	
Green Peace,2003	1-100.5mg/l	Industrial zone	Very high level at Pallikadavu and Muttinakam

Table 6. Pollution indicators in lower reaches of Periyar river-Inorganic phosphate

Source	Range	Place	Comments
Paul& Pillai, 1974	160-910 µg/l	Industrial zone	Highest value in Methanam
KSPCB,1981	9500Kg/day		
Joseph et al,1984	Trace-148.14µg/l		
Joy,1989	0-64.58µg/l	Edamalayar to backwaters	Highest in industrial zone
NEERI,1992	0.5 – 0.7ppm	Alwaye to Eloor ferry	
Green Peace,2003	1 – 2.5ppm	Industrial zone	

Table 7. Pollution indicators in lower reaches of Periyar river-Data given by Central Pollution Control Board

Indicator	Year 1995			Year 2000		
	Kalady	Sewage discharge point	Alwaye	Kalady	Sewage discharge point	Alwaye
DOmg/l	7.9	7.5	7.2	6.9	6.7	6.3
BODmg/l	0.5	0.6	0.6	0.3	0.2	0.4
CODmg/l	7.3	8.2	9.6	4.3	4.5	4.8
No2+No3mg/l	0.252	0.483	0.943	0.514	0.457	0.663
Total N (Kjeldahl) mg/l	0.585	0.669	0.756	0.160	0.117	0.217
Free ammonia mg/l	ND	ND	ND	ND	0.023	ND

Table 8. Status of the fish encountered in Periyar lake-stream system

Scientific name	Common name	Status
Aplocheilus lineatus	Top minnow	EW
Bhavania australis	Western Ghat Loach	EW
Noemacheilus denisoni	Denison's loach	EW
N. guentheri	Guenther's loach	EW
N. keralaensis	Kerala loach	EW
Travancoria jonesi	Travancore loach	EW,TT(Rare and Endemic – Kurup,1994
Channa gachua	Brown Snake hand	TT(Endangered,Kurup,1994)
C. striatus	Striped snake head	TT(Endangered,Kurup,1994)
Oreochromis mossambicus	Tilapia	XO
Lepidocephalis thermalis	Malabar loach	
Barilius bakeri	Malabar baril	EW,TT(Rare and Endemic – Kurup,1994
Crossocheilus periyarensis	Periyar latia	EP,TT- limited distribution
Cyprinus carpio communis	European carp	XO
Danio aquepinnatus	Giant danio	
Garra mcClellandi	Cauvery garra	EW
G. mullya	Common stone sucker	
Lepidopygopsis typus	Preiyar trout	EP.TT-Indeterminate-Mahanta et al.,1994
Puntius curmuca	Curmuca barb	EW,TT(Endangered,Kurup,1994)
P. ophiocephalus	Periyar barb	EW,TT-Limited distribution
P.micropogan periyarensis	Periyar barb	EW,TT-Limited distribution
P. melanampyx	Tiger barb	EW,TT(Endangered,Kurup,1994)
Rasbora danicornius	Common rasbora	
Tor khudree	Mahseer	TT-Indeterminate-Mahanta et al.,1994
Mastacemblus armatus	Spiny eel	TT-Indeterminate-Mahanta et al.,1994
Heteropneustes fossilis	Stinging Catfish	
Ompok bimaculatus	Indian butter catfish	TT-Vulnerable -Mahanta et al.,1994
Glyptothorax madraspatanam	Travancore sucker catfish	EW,TT(Rare and Endemic – Kurup,1994

EW-endemic to Western ghats;EP-endemic to Periyar;TT-threatened;XO-exotic
Source-Arun,1998

Table 9. Phytoplanktonic species- identified from Cochin backwaters

BACILLARIOPHYCEAE

Melosira sulcata	Hyalodiscus subtilis
Stephanopyxis turris	Stephanopyxis palmariana
Coscinocira polychorda	Thalassiosira decipiens
Thalassioria subtilis	Cyclotella meneghiniana
Coscinodiscus marginatus	Astermphalus flabilatus
C. granii	Schroderella delicatula
C. concinnus	Leptocylindrus danicus
C. perforatus	Guinardia flaccida
C. asteromphalus	Bacterastrum hyalinum
C. aculus-iridis	B.varians
C. gigas var.praetexta	Chaetoceros coarctatus
Rhizosolenia stolterfothii	C. denticulatum
R. robusta	C. decipiens
R. imbricate	C. lorezianens
R. styliformis	C. affinis
R. calcar-avis	C. curvisetus
R. alata	Eucampia zoodiacus
Climacodium frauenfeldianum	Streptotheca indica
Ballerochea malleus	Lithodesmium undulatum
Triceratium reticulatum	Biddulphia aurita
B. heterceros	Cerataulina bergonii
Hemiaulus sinensis	Hemidiscus hardmannianus
Grammatophora undulate	Thalassionema nitzchioides
G. marina	Fragilaria intermedia
Thalassiothrix frauenfeldii	Asterionella japonica
Gyrosigma balticum	Pleurosigma elongatum
T. longissima	P.directum
Navicula hennedyii	Amphiprora gigantea var. sulcata
Cymbella marina	Nitzschia closterium
Bacillaria paradoxa	Nitzschia longissima
Nitzschia sigma var. indica	Nitzschia seriata

DINOPHYCEAE

Prorocentrum micans	Dinophysis miles
Amphisolenia bidentata	D. caudate
Ornithocercus magnificus	Gymnodinium sp.
Peridinium oceanicum	Ceratium fusus
P. steinii	C. tripos
p. pentagonum	C. macroceros
P. claudicans	C. breve
P. divergens	C. vulture

Table 9 (contd---)

Cladopyxis caryophyllum
Ceratocorys horrida
Goniaulax sp.
Pyrocystis fusiformis
Podolampas bipes
Phalacroma roundatus
Pyrophacus horologium

MYXOPHYCEAE

Trichodesmium theibautii
Katagnymene spiralis
Oscillatoria sp.

SILICOFLAGELLATAE

Dictyocha fibula
Distephanus speculum

Source -Gopinathan,1972

Table.10. The disappeared fish species of Periyar lake-stream system

Common name	Scientific name
Anguillidae	
1. Anguilla bengalensis	Indian longfin eel
2. A. bicolor	Shortfin eel
Bagridae	
3. Macrones cavasius	Gangetic mystus
4. M. vittatus	Stripped dwarf catfish
Cyprinidae	
5. Barillius bendelisis	Hamilton's baril
6. B. gatensis	River carp- baril
7. Chela boopis	Razorbelly minnow
8. Garra lampta	Lampta garra
9. Puntius amphibius	Scarlet banded barb
10.P. arulius	Longfin barb
11.P. melanostigma	Wynaad barb
12.P. pinnaratus	Olive barb
Gobidae	
13.Glossogobius giuris	Tank goby
Mastacembelidae	
14.Rhyncobdella aculeate	One stripe spiny eel
Notopteridae	
15.Notopterus notopterus	Grey-feather back
Schibeidae	
16.Silundia sykesii	White catfish

Source- Arun,1998

Table 11. Species composition of phytoplankton at lower reaches of Periyar river

Diatom

Amphora coffeaeformis	Fragilaria sp.
Asterionella japonica	Melosira sulcata
Cerataulina bergonii	Navicula gracilis
Chaetoceros sp.	Nitzchia closterium
Cosinodiscus gigas	Nitzchia palea
Cyclotella maneghiniana	Pinnularia sp.
Pleurosigma ungulatum	Rhizosolenia sp.
Skeletonema costatum	Surirella ssp.
Synedra sp.	Thalassionema pseudonana

Blue-green algae

Anabaena sp.	Anacystis sp.
Lyngbya sp.	Microcystis sp.
Nostoc sp.	Oscillatoia sp.
Rivularia sp.	Spirulina sp.
Synechocystis sp.	

Green algae

Volvox sp.	Staurastrum sp.
Spirotaenia sp.	Scenedesmus quadricauda
Pleodorina sp.	Pediastrum duplex
Pandorina sp.	Oocystis pusilla
Netrium sp.	Mougeotia sp.
Hydrodictyon sp.	Eudorina sp.
Cosmarium sp.	Closterium sp.
Chlorella sp.	Chlamydomonas sp.

Dinoflagellate

Ceratium furca	Gymnodinium sp.
Gonyaulax sp.	Peridinium sp.
Euglena viridis	

Source -Joy,1989

List of Abreviations

CESS	Centre for Earth Science Studies
CPCB	Central Pollution Control Board
CWRDM	Centre for Water Research Development and Management
FACT	Fertilizers and Chemicals of Travancore
HES	Hydro Electric Scheme
IRE	Indian Rare Earths
KSPCB	Kerala State Pollution Control Board
MSL	Mean sea level
NEERI	National Environmental Engineering Research Institute
ND	Not detectable
PWD	Public Works Department
TCC	Travancore Cochin Chemicals

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