3.1. STUDY AREA

Kerala state, situated in the humid tropics lies between 8°18’ and 12°48’ N and 74°52’ and 77°22’ E. It extends along the south western part of India to a length of about 560 km. The state is a narrow strip of land with width varying from 30 km in the north and south to about 130 km in the central region. The Western Ghats forms continuous mountain wall on the eastern border of the state while Arabian Sea is the border to the west.

44 rivers, with length more than 15 km, originate from the Western Ghats, out of which 41 flow towards west and the other 3 rivers towards east. Periyar, Bharathapuzha (Nila River) Pamba and Chaliyar are the major rivers of the state. The drainage basin area and the discharge carried by these rivers are small compared to the other major rivers in India. In Kerala a river is defined as a drainage channel of more than 15 km in length. According to the national norms rivers with drainage area of more than 20000 and 2000 sq km are called major and medium rivers respectively. Rivers with less than 2000 sq km are termed as minor rivers (Rao, 1979). According to this norm there are only four medium rivers (Chaliyar, Nila River Periyar and Pamba) in Kerala. The remaining 40 are minor rivers.

Thutha River is one of the main tributary of the Bharatha puzha (Nila River), the second longest river on the south west coast of India. Kunthi puzha, Nelli puzha,
Kanjira puzha, Ambakadavu River, and Thuppanadu puzha are the tributaries of the Thutha River. Kunthi puzha originates from the north eastern side of the Silent valley National Park. The remarkable feature of this river is its water which remains crystal clear in all seasons. The river falls from the hills and flows through Manarkkad Taluk (crossing NH 213 once) and ends up at a location called Njettarkkadavu in Mannarkkad and joins with another two rivers, Nellipuzha and Kanjirapuzha. Then it flows through the Ottappalam Taluk under the name Karimpuzha. Another small river the (Thuppanadupuzha) joins it at Koottilakadavu and flows to Malappuram district under the name Thuthapuzha. The river flows through Mudukurissi, Pulumanthol, Angadippuram Thiruvegappura and joins Bharathapuzha at Velikulum village in Irimbiliyam panchayath and finally empties in to the Arabian Sea.

Nellipuzha, Kanjirapuzha and Thuppanadpuzha originate from the hills of Palakkad district. Thuthapuzha water shed lies between $10^050'$ to $11^015'$ north latitude and $70^014'$ to $76^00'$ East longitude. The watershed has a total area of 1018 sq kms and covers 27 panchayats 6 blocks and two districts. Thutha River is the main tributary which supplies water to Nila River especially during summer. The higher contribution from the River Thutha may be due to the large stretches of comparatively less disturbed evergreen forests such as Silent valley, Siruvani and Muthikkulam on the upper reaches of the river basin. The forested area may be a significant factor for the consistently high discharge of water round the year. Moreover, the basin falls under 'slightly disturbed area' according to the classification proposed by Gordon et. al (1992). The richly forested area acts as a
sponge sucking the rain water, retaining it and promoting percolation and recharge of ground water, thus allowing slow release to the river. Thick vegetation cover also reduces the evapo- transpiration loss.

Compared to the other parts of Nila basin agriculture is less extensive in this region, illicit water diversion from the river basin is less and urban pressure is much lower. All the other tributaries of Nila River are dammed up for irrigation projects and exploitation of water for agriculture and other human uses is rather high.

The River Thutha has a glorious cultural legacy. It is inseparably connected with the traditions and culture of the people living near the river. Thiruvegappura a small village on the bank of Thutha River is famous for its historical importance. The Rayiranellur mountain-temple where Naranath Bhranthan of the Parayipetta Panthirukulam lived and taught his philosophy to society in his own way. The Braanthaachalam temple and Thiruveggappura temple are historical attractions of this area. Thiruvegappura Anayath Krishna Pisharody was considered as the Guru of Manavedan Raja.

Several other temples located on the bank of Thutha river are also famous. The Ashta Vaidy temple (Rudra Dhanananthiri Kshethram). Thutha Bagavatty temple etc. are two of the temples which have close connection with the culture of people living near the river. There are several 'Mana' (Ancestrol and 'Illam' on the bank of the river which were once the pillars of Ayurveda treatment (Ashtavaida) and centre of famous literary works including Ithihyamala, Kerala Sahitya Charithram, Surya Kalady etc.
In the present work, Thutha River in the Karimpuzha village from (Koottakadavu) to Irimbiliyam (Velikulam) where it joins Nila River was selected as the study area. Five stations with an approximately 13 to 20 kms distance were selected. The total distance from the 1st station to the last station is about 68 kms. Water samples, sediment samples, fishes and other organisms were collected monthly for analysis.

**Station I: Koottakadavu**

This station is located in the Irimbiliyam Panchayath close to the old railway bridge across Thutha river. This station lies 10°to.428' North latitude and 76°05.439' East longitude. The station has only 2 meter elevation from sea level. The fallow land on the right side of the river has different types of vegetation. In the left side there are banana plantations. The bottom of the river is sandy. Local people use this area for bathing and washing. Sand mining has created many deep gorges in the river. At this site Thutha river joins Bharathapuzha, hence the name Koottakadavu.

**Station II: Thiruvegappura**

Located in Thiruvegappura Panchayath, this station is approximately 12 kms from the 1st station. It lies 10° 52.768' north latitude and 76° 06.876' East longitude. The river has about 510 m width here. Thiruvegappura temple is located near the bank of the river. The river bed has uniformly graded sand. A pump house which provides drinking water to the nearby Panchayaths is located at this station. Intensive sand mining is going on here. The river is very shallow here during
summer season and the river bottom is clearly visible. As a result of sand mining the river bottom has became muddy in some areas. On the river margin vegetation is not very thick. Coconut plantations border the river.

**Station III: Mavundirikkadavu.** This station belongs to Nellaya Panchayath of Mudukurissi, Palakkad district. The station is located at an elevation of 13 meter from sea level and is at 10° 58.757' north latitude and 76°15.570' east longitude. The river is very shallow here during summer with clear water. On either side of the river there are fallow paddy fields. The vegetation on the river margin is thick and is less disturbed. Rapid flow of water is seen at this station. River bottom is rocky and consist of stones and pebbles with patches of sand. Local people use this area for bathing, washing and fishing.

**Station IV: Thutha Kadavu**

This station lies at an elevation of 23 m from sea level. It is located 10° 54.926' north latitude and 76° 17.399' east longitude. The river forms sharp curve here. The river bottom is rocky. Water is deep and still here. Several rocky pools can be seen during summer. The Thutha Bagavathy temple is located on the bank of the river. Local people use this area for fishing, bathing and washing. A small fish market is located near this station. The Thutha town is very near to the station.

**Station V: Koottilakkadavu**

Situated in the Karimpuzha village of Sree Krishnapuram in Palakkad district, the station is about 46 m above sea level and is located 10° 55.087' North latitude and 76° 25.815' east longitude. From this site onwards the river acquires
the name Thutha. Thuppanadpuzha which originates from the hills of Palakkad district joins the Karimpuzha and flows as Thutha from here. Coconut plantations border the river. The river bottom has plenty of small, colourful pebbles. As a result of stone mining there is considerable degradation of the natural habitat. During summer the river is shallow here.

3.2. COLLECTION OF SAMPLES FOR PHYSICO-CHEMICAL ANALYSIS

3.2.1. WATER

Water samples for physico-chemical analysis were collected in triplicate in acid washed, dried, polyethylene bottles. Monthly samples were collected from the five stations between 5 a.m to 9 a.m in the morning during the second week of every month. The bottles were kept in an ice box and transported immediately to the laboratory. Specially designed glass bottles were used for dissolved oxygen sampling. The samples were fixed at the site and dissolved oxygen in the sample was estimated in the laboratory by modified Winkler’s method described by Strickland and Parsons (1972).

The pH of the sample was measured in the laboratory using a pH meter (Elico, Model No. L1-L10 pH meter, India) having ± 0.01 accuracy. The instrument is calibrated with buffers 7.0 and 9.0. Water quality parameters such as bicarbonate alkalinity, total hardness, and nutrients like phosphate, silicate, nitrite and nitrate were analysed in the laboratory following standard procedures given in the standard methods for the examination of water and waste water (APHA 1995); Strickland and
Parsons (1972). Temperature of water and sediment were recorded for all the stations. The recordings were made using a centigrade thermometer of range 0 - 50° C each division being 0.1° C. The water and sediment temperature was measured immediately after the collection of samples. Transparency was measured by using a Secchi disc of 20 cm diameter and the average depth at which the disc disappeared and reappeared was noted (Golterman et al., 1975) and usual precautions were taken while immersing the disc in to the water as given by Welch (1952) and the values were expressed in centimeters.

3.2.2. SEDIMENT

Bottom sediments were collected from all the five stations for analyses of the particle size and for analyses of physico-chemical parameters like temperature, pH, percentage of organic carbon available phosphate and available potassium. The samples were kept in polythene bags and transported to the laboratory as early as possible. Temperature and pH were analyzed immediately. For other parameters soil samples were air dried under the shadow in natural condition. Soon after drying, stones and similar objects were picked up and the soil was grounded in a mortar to break up aggregate or lumps, taking care not to break actual soil particle. The soil was then sieved through 2 mm sieve, to analyse particle density by international pippette method (Carver 1971).

The mesh size allow all the nutritionally important factors to pass through. Approximately 4 or 5 gm of soil was grounded to get more fine particles which can pass through mesh size of 0.5 mm. The chemical characteristics of the soil like, pH,
percentage of organic carbon, available phosphorous and potassium were analysed using standard methods (APHA, 1995), Trivedy and Goel (1986).

3.3. COLLECTION OF BIOTIC SAMPLES

3.3.1. PLANKTON

Monthly plankton samples were collected from five stations in Thutha River from June 2007 to May 2009. Plankton were collected by filtering 100 litre of water through a plankton net made of bolting silk (standard grade No.25 with a mesh size of 60 microns). The collections were made in the early hours of the day. The collected samples were preserved in 4% formaldehyde for analysis within a few days. The samples collected were transferred to a 100 ml borosil graduated centrifuge tube for about 24 hours so as to allow the organic elements to settle, and then the volume was noted. Macroplankton were removed from the sample. The sample was then stirred to ensure even distribution of the organism and from each, 1 ml was transferred with a narrow mouthed pipette to a Sedgwick Rafter counting cell and the phytoplankton number/m$^3$ were calculated (APHA, 1995, Davis, 1955). Identification of phytoplankton was made as per guidelines of Prescott (1962) and Needham and Needham (1962). Zooplankton were identified with the help of standard references Pennak (1953), Ward and Whipple (1992). The settling volume was noted and the plankton biomass was calculated using the formula: Biomass= (A*1000)/ V, where A is the settling volume and V is the volume of water filtered (Ward and Whipple, 1992)
3.3.2. BENTHOS

Sediment samples for analysis of benthic fauna were collected using a cylindrical corer having 12 cm inner diameter and 15 cm height. Three replicate samples were taken from each station from a radius of 2m and the results pooled. The sediment samples were washed and stirred thoroughly and the organic material was decanted. Then the samples were sieved through 40 mm and 100 mm sieves. Organisms visible to the naked eye were sorted and counted during the initial washing. The material retained in the sieve were preserved and stained in 10% neutralized formalin to which rose-bengal dye was added. The sorted benthic organisms were identified and counted under a scientific microscope. The number of benthic organisms was calculated as per (Welsch,1952). Benthic organisms were identified up to lowest possible taxonomic level using standard keys (Pierre Fauvel). The number of benthos obtained were converted into their percentage. The interpretation of the composition, distribution and abundance of benthic fauna were based on the percentage of each taxonomic category.

3.3.3. NEKTON

The nektonic forms primarily the fishes were collected by cast nets, gill nets and in some cases with the help of a special net made of mosquito net clothing. Fish samples were collected by 15 minute catch. Total no. of fishes collected for each catch was recorded. Colour, maturity condition and standard length were noted in the field itself. All fishes were preserved in 10% formaldehyde solution. Keys of Day (1865, 1878) Jayaram (1981, 1999) and Talwar and Jhingran (1991) were referred for confirmation of identification.
3.4. STATISTICAL ANALYSIS

The data relating to water and sediment parameters were subjected to statistical analysis. The SPSS (version 11.0) package was used for statistical analysis. Correlation coefficient (r) (Pearson's correlation coefficient) was calculated to find out the relationship between variables. The significance of correlation was reported at 5% level and 1% level based on the probability value. Statistical significance between stations and seasons were studied by General linear model ANOVA and Duncan test.

The diversity, dominance, richness and evenness which form the basis of a community structure were examined with the data collected during the present investigation. The computer programme PRIMER 60 (Plymouth Routines in Multivariate Ecological Research) was employed for the analysis of diversity indices.

Shannon – Wiener Diversity index (H’)

In the present study, the data were analysed for diversity index (H’) using the following Shannon – Wiener’s formula (1949):

\[
H' = -\sum_{i=1}^{S} P_i \log_2 P_i \\
\]

which can be rewritten as

\[
H' = \frac{3.3219 ( N \log N - \sum_{i} n_i \log n_i)}{N}
\]

Where, \(H\) = species diversity in bits of information per individual
\[ ni = \text{proportion of the samples belonging to the } i^{th} \text{ species} \]

\[ \text{(number of individuals of the } i^{th} \text{ species)} \]

\[ N = \text{total number of individuals of the collection and} \]

\[ \sum = \text{sum.} \]

**Species Dominance index (Simpson index) (Lambda)**

\[ D = 1 - C \]

where \[ C = \sum P_i^2 \]

\[ P_i = \frac{ni}{N} \]

\[ ni = \text{number of individuals of } i, i_2 \text{ etc. and} \]

\[ N = \text{total number of individuals} \]

**Species Richness index (Margalef index } d \text{ )**

\[ d = \frac{(S-1)}{\log N} \]

**Species Evenness index (Pielou’s evenness index } j \text{ )**

The equitability (\( J’ \)) was computed using the following formula of Pielou (1966):

\[ J’ = \frac{H'}{\log 2S} \text{ or } \frac{H'}{\ln S} \]

where, \[ J’ = \text{evenness,} \]

\[ H' = \text{species diversity in bits of information per individual and} \]

\[ S = \text{total number of species} \]