REPORT OF ACTIVITIES DONE UNDER THE PROJECT ON WETLAND CONSERVATION AND MANAGEMENT AWARENESS CAMPAIGN - 2018-19

BY

THE CENTRE FOR ENVIRONMENTAL STUDIES

DEPARTMENT OF ENVIRONMENTAL SCIENCE

SACRED HEART COLLEGE, THEVARA, KOCHI-13

TO

THE MEMBER SECRETARY

SWAK

Introduction

Under the project on Wetland Conservation and Management Awareness Campaign 2018-19, Department of Environmental Science, Sacred Heart College, Thevara was awarded a grant of Rs. 4, 00, 000 from State Wetland Authority, Kerala to carry out the activities to conserve the wetland ecosystem at Nettoor, adjacent to Vembanad Lake. The activities included awareness component as well as action components which were executed during the period from June 2019-February 2020.

Objectives

As per the project proposal titled 'Wetlands and Sustainability' submitted to SWAK by Department of Environmental Science, the following were the list of activities targeted to be completed by the end of the project period.

Awareness activities	Action components
Documentary on wetlands	Assessing the quality of wetland ecosystem
Preparation and distribution of resource material	Biodiversity assessment of the wetland
Awareness classes	Mangrove afforestation

Initiation of activity

The preparatory works of the awareness activities, in particular the video component were initiated on the month of April, 2019 itself. The other activities related to the action components which were done voluntarily involving students, was initiated on June 2019, when the college reopened after summer vacation. The activities culminated with the observance of World Wetland Day on February 3rd, 2020.

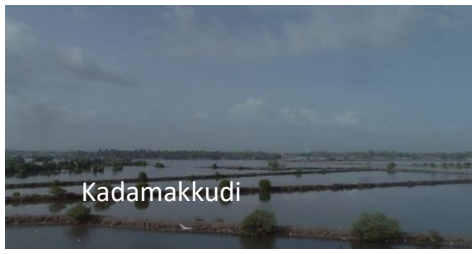
Activities done under Awareness component

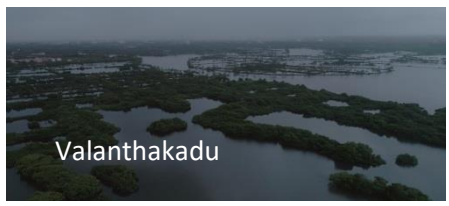
- Documentary

The major share of the fund was spent on creating a documentary on "Wetlands around Kochi" which was shot around wetlands *viz.*, Chathamma, Kadamakkudi, Kumbalam,

Kumbalangi, Nettoor, Valanthakkadu, Varappuzha and Vypin areas of Kochi. The documentary which is of 35 minutes duration also covers the unique vegetation found around wetlands, the mangroves. The common mangrove species found around the wetlands in Kochi has been described by various experts in the field. Even though there are many documentaries based on wetlands and mangroves, the present documentary is distinctive, as it has been shot in such a way, that the general public is made to understand the need to conserve wetlands by its simple, yet scientific narration and depictions. For example, through this documentary one can clearly understand how the wetlands of Kochi was being instrumental in saving the city from the recent 2018 floods which caused havoc to the entire Kerala state. Also, apart from the physical environment, the whole ecosystem including flora and fauna present in wetlands is also beautifully captured. An excellent view of the aerial The screening of documentary was done in various panchayats, colleges and schools around Kochi which received wide appreciation from all sectors irrespective of age. It was also uploaded in you tube (https://youtu.be/9xbOovrydFs) and shared in social media to gain public attention in a global level.

Fig. 1. Cover page of CD of documentary





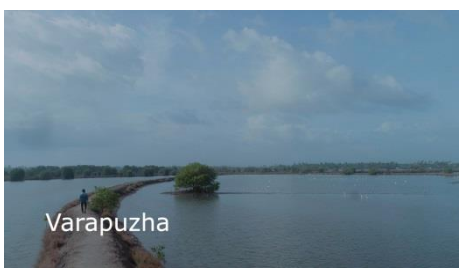


Fig. 2. A view of the various wetlands around Kochi taken during the preparation of documentary

- Resource Material

A part of the remaining portion of the fund was spent in preparing resource material on "Wetlands-Awareness and Conservation" which portrays images of wetlands and mangroves around Kochi along with their description and importance. The pamphlets were

distributed to college students who then circulated among their friends circle and also to residents staying nearby their homes, thus spreading the message. It was also distributed to the audience in various public gatherings where the documentary was being screened. The pamphlet provides a quick view of the wetlands around Kochi and the common mangrove species along with their vernacular names which can be used as a reference tool for the local as well as the scientific community.

- Awareness

Awareness activities were flagged off with an awareness campaign for the local people at Nettoor, which is included under Maradu Municipality. It was selected as a representative area of wetland adjacent to Sacred Heart College, Thevara. The meeting was held with the objective of creating awareness among the residents of Nettoor to conserve and preserve the wetland ecosystem and was attended by Fr. Dr. Prasant Palackappilllil, CMI, Principal, S.H, College, Thevara, Mr. Nithin Norbert, Station Director and Manager, IRTS, Chairperson, Smt. Nadira, Maradu Municipality, Shri. P.J.Johnson, Councillor, Maradu Municipality and Dr. T. J. James, Co-ordinator, Centre for Environmental Studies along with other faculty members and students. About 100 of them joined the meeting which included youth, children and elderly people. The official inauguration of the documentary was also done during this event by Smt. Nadira, Chairperson, Maradu Municipality. Pamphlets were distributed and lunch was provided to the audience after the meeting wound up in the afternoon.

Fig. 3- Awareness function at Nettoor, under Maradu Municipality

ബോധവത്കരണം സംഘടിപ്പിച്ചു

കൊച്ചി: തേവര സേക്രഡ് ഹാർട്ട് കോളജ് സെന്റർ ഫോർ എൻവയോൺമെന്റ് സ്റ്റഡീസിന്റെ നേതൃത്വത്തിൽ തണ്ണീർത്തടങ്ങൾ സംരക്ഷിക്കേണ്ടതിന്റെ ആവശ്യകതയെ സംബന്ധിച്ചു ബോധവത്കരണ പരിപാടി സംഘടിപ്പിച്ചു. സംസ്ഥാന തണ്ണീർത്തട അതോറിറ്റിയുടെ സഹകരണത്തോടെ നെട്ടൂരിൽ സംഘടിപ്പിച്ച പരിപാടി എറണാകുളം സൗത്ത് റെയിൽവേ സ്റ്റേഷൻ ഏരിയ മാനേജർ നിതിൻ നോർബെർട്ട് ഉദ്ഘാടനം ചെയ്തു. കോളജ് പ്രിൻസിപ്പൽ റവ. ഡോ. പ്രശാന്ത് പാലയ്ക്കാപ്പിള്ളിൽ അധ്യക്ഷത വഹിച്ചു. തണ്ണീർത്തടങ്ങളുള്ള വിവിധ പഞ്ചായത്തുകളിൽ ഒക്ടോബർ 30 വരെ ബോധവത്കരണ പരിപാടി സംഘടിപ്പിക്കും.

Fig.4- Newspaper clipping on the news of awareness class at Nettoor published in Deepika daily

A series of awareness activities were also held at other panchayats, schools and colleges as per the proposal. Accordingly, meetings and classes were conducted at Elamkunnapuzha and Kumbalam at panchayat level, where the respective Panchayat Presidents presided over the meeting. In both the panchayats, meeting was attended by about 100 local people who were really very keen to hear the speaker and promised to carry the message of documentary to their homes and neighbourhoods.

Fig. 5- Handing over of CD and documentary screening at Elamkunnapuzha Panchayat

Fig. 6- Awareness class, distribution of pamphlets and documentary screening at Kumbalam Grama Panchayat

At college level, awareness classes were held at Cochin College, St. Theresa's College and Sacred Heart College in Kochi district. The audience comprised of degree and post graduate students from Life Science Departments in all the three colleges. The students were very active and interacted well during the class and also had words of appreciation for the documentary. At Sacred Heart College, Thevara a seminar on "Wetland Conservation and Management with respect to Kerala" was also conducted as a part of creating awareness among the students. Dr. Harikumar, Senior Principal Scientist and Head, Water Quality Division, CWRDM, Kozhikode and Member, SWAK was the chief guest. A copy of the CD was handed over to the respective in-charges of Departments and pamphlets were distributed among the students. Refreshments were provided to the students after the meeting.

Fig. 7- Documentary screening and a section of audience at Cochin College

Fig. 8- Handing of CD to HOD, Zoology Department and screening of documentary at St. Theresa's College, Kochi.

Fig.9- Seminar and awareness class at Sacred Heart College, Thevara.

School level activities were conducted at Sacred Heart Public School Thevara. A group of students from high school and higher secondary section attended the meeting. An interactive session was held where the students shared their opinion regarding conservation of wetlands. They were ready to spread the message of conservation of wetlands to the outside world and were concerned about the way humans were destroying them. A copy of the CD was handed over to the Principal and documentary screening was done after the interactive session.

Fig. 10 Interactive Session on Wetland conservation and handing over of documentary CD to Principal, Sacred Heart Public School.

Activities done under Action component

Nettoor, a wetland ecosystem adjacent to Vembanad Lake and situated near to the college campus was selected as the area for conservation (9°55'37.2"N, 76°18'36"E). TiruNettur Railway Station on Kochi-Alappuzha railway line is situated on the northern end of Nettoor as well as both NH 66 and NH 966B passes through Nettoor. A number of creeks and canals are found to traverse the area fringed with mangrove plants. Eranakulam–Alapuzha railway line and National highway 47 are also passing the through this area. Extensive land filling has been made in this station through very thick mangrove forests. The study area is one of the adopted sites by Sacred Heart College authorities and has taken up some restoration works in association with Nature Club a few years back. But no follow up activities could be initiated after that, due to shortage of funds. At present, the conservation of the site has been taken up by the Centre for Environmental Studies along with other life science clubs existing in the college.

Fig. 11- Board displaying Nettoor Mangrove Forest placed along the highway

Under Action component; students voluntarily participated in a number of activities related to the conservation and restoration of the wetland. The activities can be listed under

- Observance of International Mangrove Day

  On July 26, 2019 as a part of International Mangrove Day, students and faculty visited Nettoor wetland ecosystem to study the various mangrove species present there. Mangrove saplings were obtained from KUFOS and were planted in areas where they were found to be ruined due to anthropogenic activities.




Fig. 11- Observance of International Mangrove Day

- Observance of World Wetland Day

On February 2, 2020 as a part of World Wetland Day students took initiative to remove plastic wastes from Vembanad Lake, thereby taking a small step towards conservation of Vembanad ecosystem.

Fig. 12- Observance of World Wetland Day

- Wetland restoration activities

  Restoration activities were done in Nettoor region with the help of students and other paid labourers. Even though part of the area is relatively less polluted, the other areas where there is human inhabitation was found to be polluted with solid wastes and other debris. The canals in the ecosystem were also found to be heavily silted and there was no flow of water. The accumulation of nutrients has paved the way for eutrophication leading to the growth of exotic invasive species like water hyacinth. Another observable feature was the presence of invasive species like Ipomoea invading the whole mangrove species, leading to its stunted growth.

  Therefore, students along with faculty visited Nettoor often and got themselves involved in activities to restore the ecosystem. The activities done included cleaning up of the ecosystem by removing wastes, pulling out invasive species which have invaded the mangroves, desilting the water ways etc. Regular follow up activities are also being done to monitor the ecosystem. Students meet the residents often and interact with them regarding the importance to conserve the ecosystem.

Fig. 13- Restoration activities around the ecosystem

- Physico-chemical analysis of soil and water

  To study the physico-chemical characteristics of the mangrove ecosystem, water and sediment samples were collected from three different spots in clean plastic bottles and zip lock plastic pouches respectively, and were brought to the laboratory for further analysis. The sampling was done based on random sampling method during the month of September and the distance between each spot was fixed as approximately 500m. Phytoplankton samples were also collected in clean plastic bottles from the respective water sampling spots, and plankton identification was carried out.. pH, Conductivity, Total dissolved solids, Alkalinity, Salinity, Hardness, Phosphate, Nitrate, Ammonia, Copper, Chromium, Dissolved Oxygen and Primary productivity of the water samples and pH, Moisture content, Phosphate, Chloride, Magnesium, Calcium and Organic carbon of the sediment samples were determined in the laboratory as per standard protocols.

- Biodiversity Assessment

  The biodiversity study was carried out in selected five different spots and species identification was carried out.

  The detailed methodology and the results obtained are presented in the report given below.

REPORT ON STUDY OF MANGROVE ECOSYSTEM AT NETTOOR

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Fig 4.21: Biodiversity Spot 1

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SUMMARY

As part of the MSc field study on mangrove ecosystem, we the students of second year MSc Environmental Science and faculty of Centre for Environmental Studies, Sacred Heart College, Thevara had visited Nettoor region in Kochi during September and October 2019 to study on mangrove ecosystem. We estimated the physico-chemical and biological parameters of the mangrove ecosystem. Physical parameters like temperature, humidity, and soil texture were calculated to understand the water and sediment profile of the Nettoor Mangrove ecosystem study area. Temperature and Humidity were in correlation with the standard values that occur during the time of study. Thesoil present was found to be fine sand. Chemical parameters like pH, Conductivity,TDS, Alkalinity, Salinity, Hardness, Phosphate, Nitrate, Ammonia, Copper,Chromium, DO and Primary Productivity were determined in order to assess thewater quality and to determine the extent of pollution in the mangrove ecosystem. pH,Conductivity, TDS, DO, Alkalinity, Salinity, Hardness, Phosphate and Ammonia readingswere also in correlation with the standard values taking in account both the geographical and seasonal variations. Polluting heavy metals like copper and chromium were estimated, in which the concentration of chromium in the study area was found to be on the higher side in the first spot when compared with the other spots. Phosphate, Chloride, Calcium, Magnesium, Organic carbon and pH were estimated from the sediment samples collected from various spots in the study area, where Phosphate concentration was found to be higher in Spot 3 . Spot 1 exhibited higher organic carbon content in the sediment sample which may be because of high vegetation and dumping of organic waste in and around the region. All the sediment samples collected were alkaline in nature.

From our biodiversity study six different true varieties of mangrove species viz. *Acanthus ilicifolius, Avicennia officinalis, Bruguiera cylindrica, Bruguiera gymnorrhiza*, *Kandelia candel* ,and *Rhizophora mucronata* which are commonly seen in India were observed. Biodiversity analysis was carried out using Quadrat method. Density, Relative density, Frequency, Relative frequency and Abundance along with biodiversity indices viz. Simpson's index of Diversity and Shannon index were estimated. Highest frequency and abundance was shown by *Avicennia officinalis*. *Eichhornia* species were the most abundant invasive species in the study area. Highest Simpson's Diversity Index and Shannon index values were seen in Spot 4. Eight phytoplankton species were identified. Crab is the keystone species of the ecosystem and was widely seen in various spots. Few other organisms viz. Spider, Snails, Water

striders and Crow were also observed.

1. Introduction

Mangroves are halophytes which grow in saline marshy places. The word mangrove is formed by two words – the Portuguese "Mangue" (meaning tree bush) and the English – "Grove". The term mangrove refers to an ecological group of evergreen plant species belonging to different families, but possessing marked similarity in their physiological characteristics and structural adaptations. These are salt tolerant forest ecosystems of the inter-tidal regions along the coastal lines. Mangroves consist of a complex of plant communities, fringing sheltered tropical shores and estuaries. Such communities usually comprise of trees, mostly species of the family *Rhizophoraceae* (Aksornkoae, 1993).

Mangroves occur worldwide in the tropics and subtropics, mainly between latitudes 25° N and 25° S. The total mangrove forest area of the world in 2000 was 137,800 square kilometres (53,200 sq mi), spanning 118 countries and territories. India has only 2.66% of the world's mangroves, covering an estimated area of 4,827 sq. km. Mangroves in Kerala represent 0.19% of the total mangroves of India, with total areas of just nine square kilometre but they represent 41% of the true mangrove species in India. Kerala was once blessed with this amazing ecosystem. About 700sq km mangroves were present till 1957 but it is now in a declined state. It has reduced to less than 17.0 sq.km. Kannur and Kasargod districts are having the maximum number of mangroves and Trivandrum, Kollam,Alappuzha, Kottayam, Ernakulam, Thrissur, Kozhikode and Malappuram are the other districts along with the three identified Ramsar sites namely Ashtamudi, Shasthamkotta, and Vembanad. More than 80% of the mangroves are under the custody of private owners; therefore they are under serious threat of destruction. *Rhizophoraceae ,Avicenniaceae, Sonneratiaceae* are the three families represented in Kerala. There are 59 species of mangroves are represented in India out of that 14 of them are represented in Kerala.

Fig :1.1 Mangrove Ecosystem, Nettoor

There are very few marine ecosystems dominated by plants, but mangroves are one of them. Mangroves provide important foraging grounds and habitats for both marine and terrestrial fauna. Two limiting factors in the distribution of plants generally is the salinity and waterlogged sediment. To cope with the high salinity, mangrove species have a number of mechanisms to remove or exclude salt from their tissues, and certain species have evolved the ability to actively secrete salt from their leaves. The waterlogged, anaerobic soil provides another challenge which has been overcome through the development of aerial roots to transport oxygen to roots which are underground or underwater. (Spalding *et.al.*,2010)

Mangroves have enormous ecological value. They protect and stabilize coastlines, enrich coastal waters, yield commercial forest products and support coastal fisheries. Mangrove forests are among the world's most productive ecosystems, producing organic carbon well in excess of the ecosystem requirements and contributing significantly to the global carbon cycle. Extracts from mangroves and mangrove-dependent species have proven activity against human, animal and plant pathogens. Mangroves may be further developed as sources of high-value commercial products and fishery resources and as sites for a burgeoning ecotourism industry. Their unique features also make them ideal sites for experimental studies of biodiversity and ecosystem function.

There are some true mangrove species present in the Kochi coast. Out of these, *Avicennia officinalis* and *Rhizophora mucronata* are the more dominant mangrove species found along with *Bruguirea gymnorhiza, B. cylindrica, Acrostichum aureum, Sonneratia alba and Sonneratia caseolaris.* About 40% mangrove area has been depleted in recent times. There is an urgent need for conservation of the remaining mangrove area. In Kochi the mangrove islands are increasingly threatened by population pressure, aquaculture operations and mangrove environment conversion to new shrimp pond. Industrial pollution, oil spills, storms, dredging for landfills and building ports, industrial estates and housing estates for human habitation have destroyed mangroves in Kochi. Formerly thriving shrimp production of Cochin backwaters has fallen almost too nil as the after effects of extensive mangrove. Conservation of these habitats is necessary for maintaining their rich biodiversity, sustainability of fishery, forestry and other products, and protection of coastal areas from natural calamity. Increased erosion due to deforestation can increase the amount of sediments in the river and this can adversely affect the mangroves. Due to immense biotic interference and multiple uses of mangrove vegetation, this resource is threatened with great destruction. So there is an urgent need to restore degraded mangrove ecosystems for economic, social and sustainability reasons. Social awareness would enable participation of public in conservation and management of mangroves.

2. Objectives

- To observe and analyse the Mangrove Ecosystem.
- To determine the physical and chemical characteristics of soil and water samples in Mangrove Ecosystem.
- To determine the presence or absence of trace metals (Cu and Cr) in the sediment and water samples.
- To study the biodiversity of mangrove ecosystem by estimating the species richness, animal interactions, frequency, abundance and biodiversity indices.
- To understand the diversity of plankton species around the ecosystem

3. Methodology

3.1 Field visit itinerary:

In partial fulfilment of the curriculum criteria, we the students and faculty of III Semester MSc Environmental Science, Centre for Environmental Studies, Sacred HeartCollege, Thevara carried out a field trip to Nettoor, in Kochi district, from September 28 to 29 to study the physico-chemical parameters of the ecosystem and from October 29 to 30 to study the biodiversity of the mangroves inhabiting the area.

3.2 Study area

Fig 3.1 : Study area –Nettoor,Kochi

Fig 3.2 : Study Area

Nettoor, Kochi

Nettoor is located on Panangad island and is a part of Maradu Municipality. TiruNettoor Railway Station on Kochi-Alappuzha railway line is situated on the northern end of Nettoor as well as both NH 66 and NH 966B passes through Nettoor. A number of creeks and canals are found to traverse the area fringed with mangrove plants. Eranakulam–Alapuzha railway line and National highway 47 are also passing the through this area. Extensive land filling has been made in this station through very thick mangrove forests. *Avicennia officianalis, Acanthus ilicifolius, Rhizophora mucronata, Kandelia candel, Sonneratia caseolaris*, *Bruguiera cylindrica* and *Bruguiera gymnorrhiza* are the mangrove species found in this region. *Acanthus ilicifolius* is the dominant species in Nettoor with 1560 in number per ha.

3.3 Sampling strategy

To study the physico-chemical characteristics of the mangrove ecosystem, water and sediment samples were collected from three different spots in clean plastic bottles and zip lock plastic pouches respectively, and were brought to the laboratory for further analysis. The sampling was done based on random sampling method during the month of September and the distance between each spot was fixed as approximately 500m. Phytoplankton samples were also collected in clean plastic bottles from the respective water sampling spots, and plankton identification was carried out. The biodiversity study was carried out in selected five different spots and species identification was carried out. pH,Conductivity,Total dissolved solids, Alkalinity, Salinity, Hardness, Phosphate, Nitrate, Ammonia, Copper, Chromium, Dissolved Oxygen and Primary productivity of the water samples and pH, Moisture content, Phosphate, Chloride, Magnesium, Calcium and Organic carbon of the sediment samples were determined in the laboratory as per standard protocols.

Co-ordinates of the study area

Table: 3.1 Co-ordinates of Water and Sediment sampling points

SL No	Zone	Co ordinates
1	Spot 1	$9^0$56’140”N $76^0$18’430”E
2	Spot 2	$9^0$56’234”N $76^0$18’383”E
3	Spot 3	$9^0$56’391”N $76^0$18’307”E

Table 3.2 : Co-ordinates of Biodiversity sampling points

SL No	Zone	Co ordinates
1	Spot 1	$9^0$56.0760’N $76^0$18.4750’E
2	Spot 2	$9^0$56.3940’N $76^0$18.3140’E
3	Spot 3	$9^0$56.2250’N $76^0$18.3570’E
4	Spot 4	$9^0$55.8200’N $76^0$18.3630’E
5	Spot 5	$9^0$56.1530’N $76^0$18.4310’E

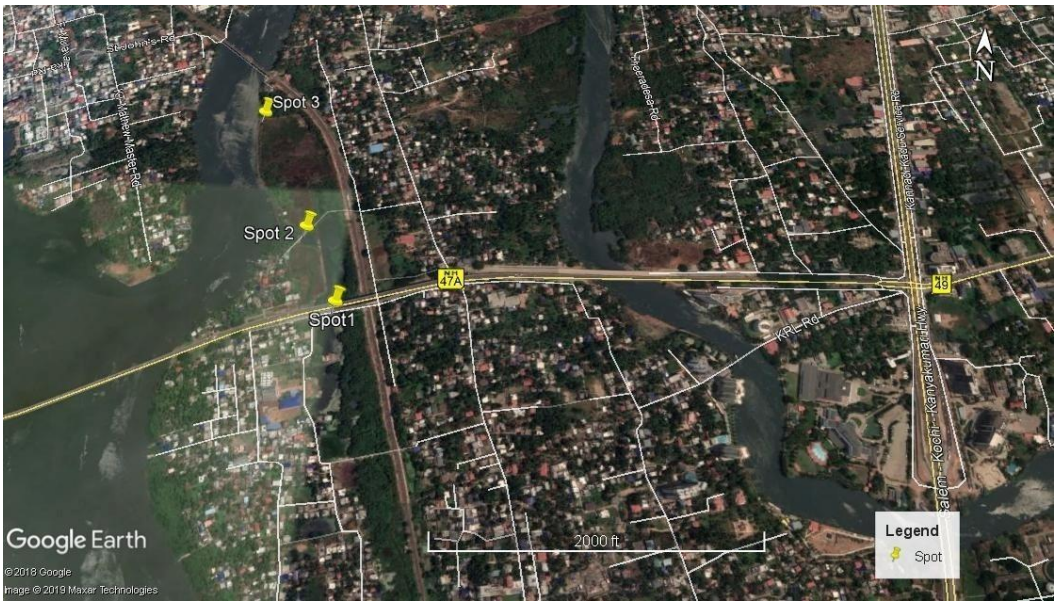

Fig : 3.3 Location map of water and sediment sampling spots

Fig:3.4 Location map of biodiversity sampling spots

Field Activities

Fig 3.5 :Soil sample collection

Fig 3.6: Water sample collection

Fig 3.7: Deployment of Secchi disc

Fig 3.8: Using GPS to find out location

3.3.1 Physical parameters

3.3.1.a Humidity :

There are many different ways to express humidity, for example humidity can define as the amount of water vapor content of air in the form of gas. In general the term humidity describes the quantity of water vapor in a gas like present in the air and also this invisible water vapor can be found in different type of Absolute humidity, Relative humidity, and Specific humidity. Usually expressed as grams of vapor per kilogram of air, or, in air conditioning, as grains per pound.

3.3.1.b Water temperature:

In the simplest term, water temperature is the hot or cold measure of water. Water temperature is probably the most important environmental variable. It affects metabolic activities, growth, feeding, reproduction, distribution and migratory behaviors of aquatic organisms. Generally, surface water temperature is influenced by the intensity of solar radiation, evaporation, freshwater influx and cooling and mix up with the ebb and flow from adjoining neritic waters. Water temperature also introduce the physical state of water, whether it is in the form of solid liquid or gas as the increase of water its form change from solid to liquid and gas.

In the present study, temperature of water in the sampling sites was measured using a thermometer.

3.3.1.c Soil texture

The soils in mangrove forests are complex systems resulting from various intricate interactions between abiotic (tides and physiography) and biotic (activities of plants and invertebrates) factors, that may alter within short distances. This acts as a reservoir of carbon that is in interaction with the atmosphere, storing about three times the biomass that makes up the vegetation and structure of mangroves .It is reported that tidal inundation seemed to affect soil salinity in mangrove forest. Mangroves are salt tolerant and relative tolerance varies among species.

Laboratory procedures normally estimate percentage of sand (0.05 - 2.0 mm), silt (0.002 - 0.05 mm), and clay (<0.002 mm) fractions in soils. Particle size distribution is an important parameter in soil classification and has implications on soil water, aeration, and nutrient availability to plants. In the present study, soil texture was estimated by micrometry.

3.3.2 Chemical parameters and trace metals:

3.3.2 a pH:

pH is defined as the concentration of hydrogen ion in a solution. It is an important factor in chemical and biological system of natural water. pH, quantitative measure of the acidity or basicity of aqueous or other liquid solutions. Solutions with a high concentration of hydrogen ions have a low pH and solutions with low concentrations of H+ ions have a high pH. The pH

scale ranges from 0 to 14. A pH of 7 is neutral. A pH less than 7 is acidic. A pH greater than 7 is basic.

pH of the sediment and water samples were determined by following the Electrometric Method; APHA 4500-H+ B, (1999) and Sarkar and Haldar, (2005) respectively.

3.3.2. b Conductivity

Electrical Conductivity is an important parameter that indicates the amount of salt dissolved in water, it is also described as capabilities of water to pass electrical flow. This capability is related to concentration of ions in water. It is useful indicator of salinity. Low ions indicate lower conductivity and high ions indicates higher conductivity.

In the present study, conductivity was measured using a Conductivity Meter.

3.3.2.c Total Dissolved Solids

Total Dissolved Solids is defined as organic and inorganic matters exist in water. In general TDS is sum of cation and anions in water. High TDS indicated hard water it also indicate the existence of toxic minerals. Some dissolved solids come from organic sources such as silt, plankton and industrial wastes. Ions and ionic compound making up TDS include carbon-ate, bicarbonate, chloride, fluoride, sulfate, phosphate, nitrate, calcium, sodium, magnesium and potassium.

The TDS of the water samples were estimated following APHA 2540 B, (1999)

3.3.2.d Alkalinity

Alkalinity refers to the buffering capacity of water samples and to their ability to neutralize acidic pollution from rainfall or wastewater. Alkalinity is primarily caused by the presence of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions, although hydroxide (OH^-) ions may also contribute, especially when there is industrial pollution. The values of alkalinity are reported in units of mg $CaCO_3$/L. The alkalinity of water is determined by the soil and bedrock which it passes. Alkalinity is important for fish and aquatic life because it protects or buffer against rapid pH changes. Living organisms function best in a pH range of 5.0 to 9.0 and levels of 20 to 200mg/L are typical alkalinity values for fresh water. Alkalinity is often related to hardness because the main source of alkalinity is usually from carbonate rocks which are

mostly $CaCO_3$. Standard Titration Method ;APHA 2320 B,1999 was followed for determining alkalinity.

3.3.2.e Salinity

The term "salinity" refers to the concentrations of salts in water or soils.Mangroves are small shrubs or trees that grow in the presence of salt water along coastlines. Salinity has long been recognized as an important factor that limits mangrove growth and productivity (Ball, 2002).Constant exposure to salt water can lead to an imbalance of ions within the plant's cells, which can have toxic effects on enzymes or interfere with water absorption. To address this, the cells control their internal environment by keeping sodium, potassium, and chloride ions at a stable concentration. Mangroves can survive in especially salty environmental conditions using various strategies that regulate how much salt ends up in their tissues. For example, certain species exclude salt by preventing salt from entering the roots, some excrete excess salt through glands in their leaves, while others accumulate ions in special compartments in their leaves (Noor *et al*., 2015).Consequently they can still grow and function well even up to a salinity of 90 ppt, but shown best growth when salinity fluctuates between 5 and 75 ppt (Krauss et al., 2008).

Determination of salinity was done by following Mohr's Method-Argentometric; APHA4500-Cl–B, (1999).

3.3.2.f Hardness

Hardness is the concentration of calcium and magnesium ions in water.Hardness is caused by compounds of calcium and magnesium, and by variety of other metals.Calcium and magnesium enter the water mainly through weathering of rocks.The degree of hardness is measured in Parts Per Million(ppm) or Grams Per Gallon(GPG). The total hardness of water varies greatly with locality and source.Water with total hardness less than 100 ppm of calcium carbonates is generally considered soft; water with total hardness above 300ppm is considered very hard.Generally, the harder the water, lower the toxicity of other metals to aquatic life.Large amounts of hardness are undesirable mostly for economic or aesthetic reasons.Hard water is formed when water percolates through deposits of limestone, chalk or gypsum which are largely made up of calcium and magnesium carbonates, bicarbonates and sulfates.The determination of total hardness of water can be made quickly and accurate by titration with Ethylene Diamine Tetra Acetic Acid (EDTA).

3.3.2.g Phosphate in water

Phosphorus is a key nutrient needed for the growth of plants and animals and is a common nonpoint source pollutant contributing to eutrophication of surface water bodies. Hence, routine analysis of P in surface water samples and soils constitutes a major workload in agricultural and environmental chemistry laboratories. Nutrients are considered as one of themost important parameters in the mangrove environment influencing growth, reproduction and metabolic activities of living being. Distribution of nutrients is mainly based on the season, tidal conditions and freshwater flow from land source (Gurmeet Singh et., al 2015)

3.3.2.h Phosphate in sediment

Phosphorus deficiency is widely considered the main biophysical constraint to food production in large areas of farmland in sub humid and semiarid. Phosphorus dynamics in soils are complex, because they involve both chemical and biological processes and the long-term effects of sorption (fixation) and desorption (release) processes. The low concentration and low solubility of P in soils frequently make P a limiting factor. The P content of plant residues and manures is normally insufficient to meet crop requirements. The phosphate content in sediment is determined by automated spectrophotometric method.

3.3.2.i Ammonia

Many mangrove soils have extremely low nutrient availability, although nutrient availability can vary greatly among and within mangrove forests. Nutrient-conserving processes in mangroves are well developed and include evergreens, resorption of nutrients prior to leaf fall, the immobilization of nutrients in leaf litter during decomposition, high root/shoot ratios and the repeated use of old root channels. Ammonium is the primary form of nitrogen in mangrove soils, in part as a result of anoxic soil conditions, and tree growth is supported mainly by ammonium uptake.

The water samples were tested for ammonia following the Phenate Method; APHA 4500 NH3-F (1999).

3.3.2.j Nitrate

Nitrogen is found in all living cells. A plant cannot grow and produce flowers and seeds without nitrate. This is primarily because nitrogen is an essential component of plant proteins and chlorophyll, which is an inevitable factor for the process of photosynthesis. Nitrogen is

found in the soil, but it is also a major ingredient in most fertilizers. Plants use nitrates as a supply of nitrogen, which is needed to make proteins for healthy growth. Plants absorb nitrates in water through their roots. Nitrogen is responsible for foliage development. Plants use nitrogen in the form of nitrates, which is nitrogen mixed with oxygen.

The nitrate content of water and soil samples have been estimated referring to the salicylic acid method with slight modifications; (Cataldo *et al*., 1975).

3.3.2.k Chloride

Chloride is the most recent addition to the list of essential elements.Chloride is important in the opening and closing of stomata. The role of the chloride anion (Cl^-) is essential to chemically balance the potassium ion (K^+) concentration that increases in the guard cells during the opening and closing of stomata.Chloride also functions in photosynthesis, specifically in the water splitting system.It occurs naturally in all types of waters.In natural fresh waters its concentration remains quite low.The most important source of chloride in natural waters is the discharge of sewage.In very high concentration, it gives a salty taste to the water (Neethu and Harilal, 2017).

In the present study, estimation of soil chloride was done following the method mentioned by Sarkar and Haldar (2005).

3.3.2.l Magnesium

Magnesium is an essential plant nutrient. It has a wide range of key roles in many plant functions. One of the magnesium's well-known roles is in the photosynthesis process, as it is a building block of the Chlorophyll, which makes leaves appear green. Magnesium deficiency might be a significant limiting factor in crop production. Plants take up magnesium in its ionic form Mg^{+2}, which is the form of dissolved magnesium in the soil solution. The uptake of magnesium by plants is dominated by two main processes: Passive uptake, driven by transpiration stream and Diffusion – magnesium ions move from zones of high concentration to zones of lower concentration. Therefore, the magnesium amounts that the plant can take up depend on its concentration in the soil solution and on the capacity of the soil to replenish the soil solution with magnesium.

The magnesium content of soil samples has been estimated by the Sarkar and Haldar method; (Sarkar *et al*., 2005)

3.3.2.m Calcium

Calcium uptake by the plant is passive and does not require energy input. Calcium mobility in the plant takes places mainly in the xylem, together with water. Therefore, calcium uptake is directly related to the plant transpiration rate. Calcium is an essential plant nutrient. It has many roles: Participates in metabolic processes of other nutrients uptake, promotes proper plant cell elongation, strengthen cell wall structure - calcium is an essential part of plant cell wall. It forms calcium pectate compounds which give stability to cell walls and bind cells together, participates in enzymatic and hormonal processes, helps in protecting the plant against heat stress - calcium improves stomata function and participates in induction of heat shock proteins, helps in protecting the plant against diseases - numerous fungi and bacteria secret enzymes which impair plant cell wall, stronger Cell walls, induced by calcium, can avoid the invasion, affects fruit quality, has a role in the regulation of the stomata.

The calcium content of soil samples have been estimated by the Rowell method; (Rowell., 1994)

3.3.2.n Copper

Absorption rate of Cu by plants is lowest among the essential elements and a linear relationship is seen between absorption rate and external Cu concentration.Total and available copper concentrations in soil are highest in the stations nearest to the waste discharge point and decreases towards the stations near to the sea. Excessive Cu can initiate a variety of responses in mangrove plants and cause damage at the cellular level or lead to wider phytotoxic responses in whole plants.

Copper determination was done by the Sodium diethyl dithiocarbamate spectrophotometric method (Callan and Henderson 1929; Haddock And Evers, 1932).

3.3.2.o Chromium

Chromium spreads widely on the nature. In the water bodies, Chromium can enter through two ways: naturally and non-naturally. The natural way of Chromium entering the waters is because some physical factors like erosion. The non natural way of Chromium entering the water is as side effect of human activity of industry like electroplating, tannery, textile industry, paint industry and domestic waste disposal. The presence of high Cr content in

sediment and water will cause high absorption of Cr by mangrove. Mangroves have the ability to accumulate metals in their bodies especially in parts of roots, leaves and stem.

Chromium was determined in water samples by Diphenylcarbazide photometric method; IS 3025 (Part 52), (2003).

3.3.2.p Dissolved Oxygen

Dissolved oxygen is an impotent characteristic of water and its concentration in water is an indicator of prevailing water quality, trophic status and the ability of water to support a well-balanced aquatic life (Prabu *et al*., 2008). The dissolved oxygen (DO) is oxygen that is dissolved in water. The oxygen dissolves by diffusion from the surrounding air, aeration of water, and as a waste product of photosynthesis. Fish and aquatic animal cannot split oxygen from water, only green plants and some bacteria can do that through photosynthesis. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress. Lower the concentration, greater the stress. Oxygen levels remaining below 1-2 mg/l for a few hours can result in large fish kills. Dissolved oxygen can range from less than 1mg/l to more than 20 mg/l depending on how the factors like temperature, salinity, pressure, diffusion, aeration, photosynthesis, respiration, decomposition etc interact.

3.3.2.q Primary Productivity

The flow of energy through any ecosystem starts with the fixation of sunlight by plants and other autotrophic organisms. In this way the plant accumulates energy and this energy is called primary production. The rate at which this energy accumulates is called primary productivity. The total energy accumulated is gross primary production. The difference between what is accumulated and what is available for the food web is called net primary production expressed in kilocalories. In general swamps and marshes have the highest primary production of all the world's ecosystems. Primary production of all wetland type varies from 600-2000 gC/m^2/y (Brinson *et al*.1981).

3.3.2.r Organic Carbon

Soil organic carbon is a measureable component of soil organic matter. A large number of studies have been conducted on organic carbon (OC) variation in mangrove ecosystems. Mangroves are some of the most bio-geochemically active regions on Earth and represent important carbon sinks in the biosphere. In addition to carbon accumulation in plants, processes of organic carbon in mangrove ecosystems include origins of sediment organic carbon, carbon fluxes between mangroves and their adjacent systems (coastal waters and atmosphere), and cycling processes. Sediment organic carbon originates from suspending solids in coastal waters, mangrove plants and benthic algae. The main origin of organic carbon in sediment is from tidal seawater, where the high sediment organic carbon contents is mainly originates from mangrove plants. Due to tidal flush, there is large material exchange between mangrove ecosystems and their adjacent coastal waters. The estimation of Organic Carbon in soil was done by Potassium Dichromate Titration, Walkley and Black Method (1934).

Table 3.3 :Methodology of the chemical parameters studied

Parameter	Method	
	Water	**Soil**
pH	Electrometric Method; APHA 4500-H+ B, 1999	Sarkar and Haldar, 2005
Conductivity	Conductivity meter- Laboratory Method; APHA 2510 B, 1999	-
Moisture Content	-	Sarkar and Haldar, 2005
Hardness	EDTA titrimetric method; APHA-2340 C, 1999	-
Calcium	-	Rowell, 1994
Magnesium	-	Sarkar and Haldar, 2005
Nitrate	Cataldo *et al.*, 1975	Modified cataldo method
Alkalinity	Titration Method; APHA 2320 B, 1999	-
Salinity	Mohr's Method- Argentometric; APHA 4500-Cl– B, 1999	-
Chloride	-	Sarkar and Haldar, 2005
Copper	Sodium diethyl dithiocarbamate spectrophotometric method; Callan and Henderson, 1929; Haddock and Evers, 1932	-
Chromium	Diphenyl carbazide photometric method; IS 3025 (Part 52), 2003	-
Phosphate	Stannous chloride method; APHA 4500-P D, 1999	-
Dissolved Oxygen and Primary Productivity	Winkler's Method, 1888; Trivedi *et al.*, 1987; Selvaraj, 2005	-
Organic Carbon	-	Walkley and Black Chromic acid Titration Method, 1934

3.4 Biodiversity Studies

3.4.1 Quadrat study of flora and fauna

In order to assess the plant biodiversity present in the mangrove ecosystem, a 30m X 30m quadrat was laid in each sampling site. At each station, half an hour timed study involving qualitative and quantitative analysis was undertaken. The different species were identified, counted and recorded for qualitative and quantitative studies. From the quadrat data obtained, density, relative density, frequency, relative frequency, abundance, along with biodiversity indices: Simpson's diversity index and Shannon index were calculated by using standard formulae.

Fig 3.9 : Quadrat Study

Primary Analysis

1. Density

Density is defined as the number of individuals of a species in a unit area and is an expression of the numerical strength of a species in a community. From the sampling data the density was calculated as follows

$$Density\ (D) = \frac{No.\ of\ individual\ encountered}{Total\ \ area\ \ sampled\ \ in\ \ sq.\ meters}$$

2. Relative density

Relative density is the study of the numerical strength of a species in relation to the total number of all species and is calculated as:

$$Relative\ density = \frac{Number\ of\ individual\ belonging\ to\ species\ i}{Total\ number\ of\ individuals} \times 100$$

3. Abundance

Abundance is described as the number of individuals per quadrant of occurrence

$$Abundance = \frac{Total\ number\ of\ individuals}{number\ of\ quadrant\ of\ occurence}$$

4. Frequency

It is expressed as the percentage of occurrence of a given species in the sample plot studied. It denotes the homogeneity of distribution of various species in the ecosystem. For comparison of different communities, frequency is expressed in terms of percentage values (Frequency percentage).

$$Frequency = \frac{Number\ of\ quadrant\ of\ a\ species}{Total\ number\ of\ quadrant\ studied} \times 100$$

Percentage frequency= (C*i*/c)x 100
Where C*i* is the number of quadrats where species present
C is the number of quadrats studied

5. Relative frequency

The species which is well distributed and have a chance of being recorded in any part of the ecosystem will have frequency 100%, while a species which is restricted to certain areas will been countered in low frequency values.

$$Relative\ frequency = \frac{Fi}{\sum Fi}$$

Where Fi is the frequency of the trees belonging to a species,
and Σ Fi is the sum of frequencies of all the trees in a plot

6. Biodiversity indices

A diversity index aims at obtaining a quantitative estimate of biological variability that can be used to compare biological entities, composed of distinct components, in space or in time. These entities may be gene pools, species communities or landscapes, composed of genes, species and habitats respectively. However, in practice, diversity indices have been applied mostly to collections or communities of species or other taxonomic units. Some of the diversity indices applied in this study include:

a. Simpson's diversity index

Diversity indices incorporate both species richness and evenness in to a single value as it takes in to account the number of species present as well as the relative abundance of each species. It represents the probability that two randomly selected individuals in the habitat belong to the same species .If the probability is high then the diversity of the community sampled is low. Simpson's index was the first diversity index used in ecology. The concentration of dominance was determined by Simpson's (1949) index as given below

$$Simpson\ diversity\ index,\ D = \frac{\sum (n-1)}{(N-1)}$$

Where, n=total number of organisms of a particular species
N=total number of organisms of all species

The value of this index ranges between 0 and 1, and greater the value, the greater the sample diversity. In this case, the index represents the probability that two individuals randomly selected from a sample will be long to different species.

b. Shannon index

The Shannon index, H (also called the Shannon-weaver index or the Shannon -Wiener index) is one of several diversity indices used to measure biodiversity. It has probably been the most widely used index in community ecology. The advantage of this index is that it takes into account the number of species and evenness of the species. The index is increased either by having more unique species or by having greater species evenness.

$$Shannon\ index,\ H = \sum_{i=0}^{s} Pi \ln Pi$$

Where,
P= n/N
ln= natural log
Σ= the sum
S= number of species

3.4.2 Plankton estimation

For plankton counting, the sample was collected from only three spots of the study area .The plankton concentrate was diluted by taking 1ml of the concentrate in a 10 mL graduated test tube and made up to 10ml with distilled water.1mL of the solution was transferred into the Sedgewick Rafter counting chamber and all individual organisms were counted. The counting was repeated using several subsamples and its average was taken. This value was used to find the number of plankton present per litre of the original concentrate sample.

$$\text{Dilution factor} = \frac{\text{Total volume of diluted sample}}{\text{Amount of concentrated sample}}$$

Number of plankton in 1mL diluted sample = X

Number of plankton in 10mL diluted sample = X × 10=A

Number of plankton in undiluted sample = A × dilution factor=B

Number of plankton in original concentrate sample = B/Amount of concentrated sample

4. RESULTS AND DISCUSSION

4.1 Physico-Chemical Parameters

The following quantitative analysis of water and soil quality tests were conducted on the samples collected from the three spots.

4.1.1 Water Analysis

4.1.1.a Physical parameters:

Fig 4.1 : Spot 1

Fig 4.2 : Spot 2

Fig 4.3 : Spot 3

1. **Temperature**

The atmospheric, surface water and deep water temperature were observed at three spots. The atmospheric temperature varied from 27^0C, 28^0C&34^0C(Table4.1) in respective spots. The air temperature varies with seasons. The observed high values of air temperature in spot 3 may be due to the intense solar radiation. Kumara and Kumar (2011) found the air temperature between 24^0C to 29^0C while working on Kundapur mangroves. Ramamurthy *et al.*,(2012) observed air temperature in the range of 27^0 C to 29^0 C in Vedaranyam mangrove forest. Srilatha *et al.,* (2013) noticed air temperature in the range of 25^0 C to 35^0 C in Muthupettai mangroves. Water temperature is of enormous significance as it regulates the biological activities and governs the solubility of gases in water. The surface and bottom water temperature in three spots ranged from 27^0C, 28^0C & 27^0C and 28^0C, 27^0C & 28^0C(Table 4.1) respectively. The results showed that there was no significant difference between the surface and bottom waters for all spots.Surface water temperature is influenced by the intensity of solar radiation, evaporation, fresh water influx and cooling and mix up with ebb and flow from adjoining coastal waters (Govindasamy *et al*., 2000, Saravanakumar *et al*., 2008). As observed by several workers like Desai (1992), Arthur (2000), Saravanakumar *et al*., (2008) in the west coast of India, the present work also showed summer peaks and monsoonal troughs in air and water temperature.

Table 4.1 : Temperature

Parameters	Spot 1	Spot 2	Spot 3
Atmospheric Temperature	27^0C	28^0C	34^0C
Surface water Temperature	27^0C	28^0C	27^0C
Deep water Temperature (1m)	28^0C	27^0C	28^0C
Humidity	96%	96%	75%

2. Humidity

Humidity recorded from three spots were 96%, 96% and 75% at a temperature between 27^0C to 34^0C. Humidity and temperature are inversely proportional as temperature goes up, relative humidity goes down and vice versa. According to Ribeiro *et al*. (2010), the structure and functionality of the mangrove depend on the stability of the physical environment. However, the physical environment is under pressure caused by anthropic action, including microclimatic changes. This has raised a concern about the possible irreversibility of the local environmental impact and its influence on the micrometeorological regime. Mangroves are important for coastal protection from the winds and tropical storm waves. The coverage provided by the canopy of mangroves controls the quantity, quality, and spatiotemporal distribution of solar radiation, which results in different levels of humidity, temperature, and soil moisture.

4.1.1.b Chemical parameters:

1. pH

In the study area, pH of the water samples was noted to be slightly alkaline in nature (table and figure) from 8.09 to 8.12. High pH values can be noted in some mangrove systems due to sea water penetration and high biological activity Rajasegar (2003). Studies done by Upadhyay (1998), Rajasegar (2003), and Paramasivam and Kannan (2005) states that the factors like removal of CO_2 in photosynthesis, through bicarbonate degradation, dilution of seawater by freshwater inflow, reduction of salinity, temperature and decomposition of organic matter fluctuate the values of pH in different seasons in a year.

Table 4.2: pH, Conductivity and TDS

Sample Station	***pH***	***Conductivity***	***TDS(1mg/l =1000000000 ppt)***
Spot 1	8.12	0.9mS/cm	0.6ppt (6e-10 mg/L)
Spot 2	8.09	0.7mS/cm	0.5ppt (5e-10 mg/L)
Spot 3	8.12	1.1mS/cm	0.7ppt (7e-10 mg/L)

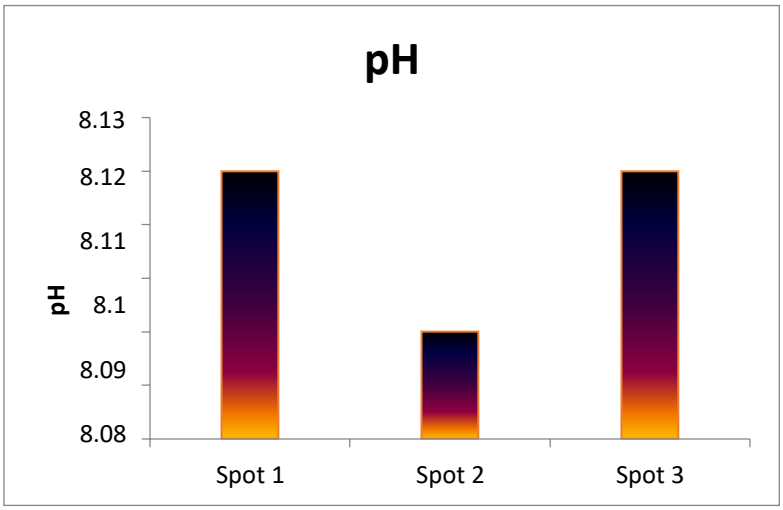

Fig 4.4 :pH

2. **Conductivity**

Electric conductivity (EC) is an indication of the amount of salt dissolved in water. It is also defined as the number of ions in water, and the ability to pass an electrical current. It is a useful indicator for salinity, total salt content of water. Samples were collected from three spots. The conductivity were found to be 0.9 mS/cm, 0.7 mS/cm and 1.1 mS/cm(Table 4.2).The electrical conductivity varies due to fresh water influx and mix up with ebb and flow (Vijay Kumar et.al.. 2013). High temperature favours degradation of organic pollutants which increase the conductivity value in water bodies (Sarwar (1998)).

3. **Total Dissolved Solids**

Dissolved solids are an important because it influence the ecology and quality of water. In the current study the TDS for spot 1 is 0.6ppt (6e-10 mg/L), for spot 2 is 0.5 ppt (5e-10 mg/L) and for spot 3 is 0.7 ppt (7e-10 mg/L) (Table 4.2).Water can be classified by the amount of TDS per litre: fresh water < 1500 mg/L TDS, brackish water 1500 to 5000 mg/L TDS and saline water > 5000 mg/L TDS. When TDS level is more than 1000mg/L it is unfit for human consumption. Increase in TDS level is due to the presence of potassium, chlorides and

sodium. High TDS indicates hard water and results in undesirable taste which could be salty, bitter, or metallic. TDS also indicate the presence of toxic minerals. The higher the suspended solids in water, the higher the total dissolved solids. Higher the salts content in the water; the higher is the value of the electric conductivity. Pure water contains no salts or minerals and has a very low electrical conductivity.

4. Dissolved Oxygen

Dissolved oxygen is an important indicator of water quality and it has the ability to support a well-balanced aquatic life. It is essential for the respiratory metabolism of the entire aerobic aquatic life in the mangrove ecosystem. Dissolved oxygen was estimated by Winkler's method. The values of dissolved oxygen for spot 1, 2 and 3 was 5.081 mg/L, 4.573 mg/L and 3.55 mg/L(Table 4.3 and Figure 4.5). Increased DO could lead to increased respiration (Boto, K. G., & Bunt, J. S. (1981)) and DO is increase with the cumulative effect of wind-generated turbulence and result of mixing coupled with rainfall and river runoff that will result in low saline conditions, which favours to increase the solubility of oxygen in the water (Dattatreya (2018). The spot 3 has the lowest value of dissolved oxygen compared to other spots Spot 3 was more polluted. High algal growth, mixing of rainfall and river runoff are few factors which reduce the amount of dissolved oxygen. (Prabu *et al*., 2008). DO ranging from 2.4 to 5.0 mg/L in case of Pichavaram mangroves was reported by Prabu *et al*., (2008). Srilatha *et al*., (2013) reported DO value of Point Calimere, and Muthupettai mangroves that ranged from 3.92 to 5.22 mg/L and 3.97 to 5.33 mg/L at respectively. Srinivasan *et al*., (2013) also reported DO in the range of 5.5 to 6.4 mg/L while working on Vedaranyam mangroves and our result also fall in this range.

Table 4.3 : Dissolved oxygen

Sample Station	***Dissolved Oxygen (mg/L)***
Spot 1	5.081
Spot 2	4.573
Spot 3	3.55

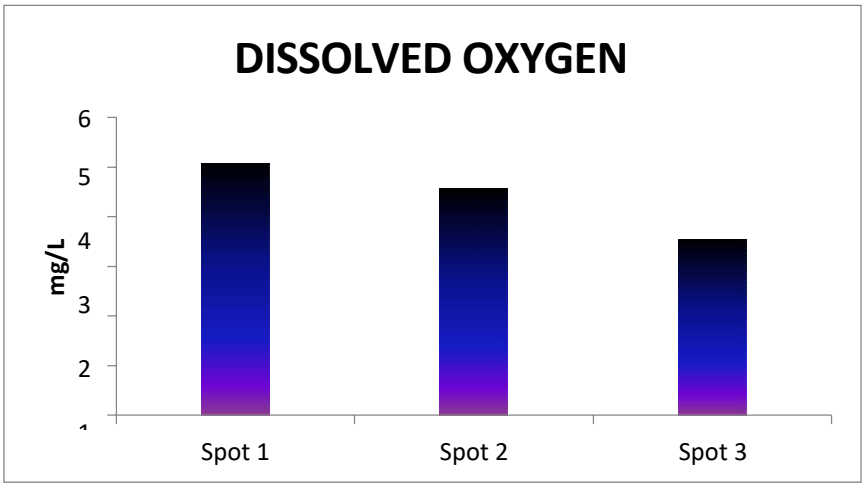

Fig 4.5 : Dissolved oxygen

5. Primary productivity

Samples were collected from the three spots and primary productivity was conducted. When results were compared, they all fall in the same range from 1.14 - 1.3 g/cal (Table 4.4 and Figure 4.6). Primary productivity is affected by high turbidity that imbed light penetration, tidal flushing, salinity and nutrients. (Victor. H et.al..(1998)) (Sheela et.al..(2014)). Drainage promotes enhanced productivity by increasing nutrient mineralization in spot 1. (Brinson *et al* 1981).

Table 4.4 : primary productivity

Sample Station	***Primary Productivity (g/cal)***
Spot 1	1.33
Spot 2	1.141
Spot 3	1.140

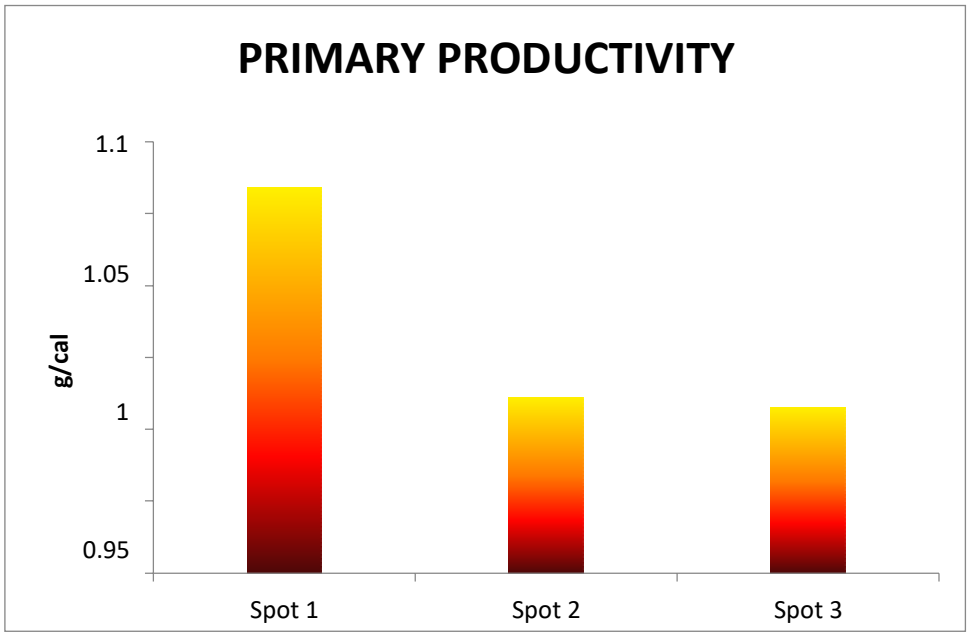

Fig 4.6 :Primary productivity

6. Alkalinity

Alkalinity of a water body is a measure of its capacity to neutralize acids to a designated pH. Alkalinity is an indirect measure of concentration of anions in water (E.O Lawson). Total alkalinity of Brackish water or seawater is 100 to 125 mg/L. The bicarbonates, carbonates, chlorides, nitrates, phosphates, sulphates are present in the form of Na^{+} , K^{+} , Mg^{2+}, Ca^{2+} and Fe $^{2+}$ are mainly responsible for the alkalinity and hardness of water . Alkalinity between 30 and 500 mg/l is generally acceptable to fish and shrimp production, between 20 and 50 mg/l according to Boyd (1972) will permit plankton production for fish culture. The alkalinity of water samples from 3 spots were 300 mg/L in spot 1, 130 mg/L in spot 2 and 220mg/L in spot 3 (Table 4.5 and Figure 4.7). Mohammad *et al* (2013) and Dattatreya (2018) reported that the variation of alkalinity values in irrespective of the season is influenced by the presence of domestic waste and the absence of normal tidal action, which would have had flushing and diluting effect on dissolved constituents as well as bicarbonates, which would increase alkalinity levels and also low rainfall, high evaporation, sea water intrusion. The alkalinity varies with the fluctuation of pollution load (Parashar et.al (2006)). Excess alkalinity gives bitter taste to water and reacts with cations forming precipitates. High alkalinity results in physiological stress on aquatic organisms and may lead to loss of biodiversity (E.O Lawson).

Table 4.5 : Alkalinity

Sample Station	***Alkalinity (mg/L)***
Spot 1	300
Spot 2	130
Spot 3	220

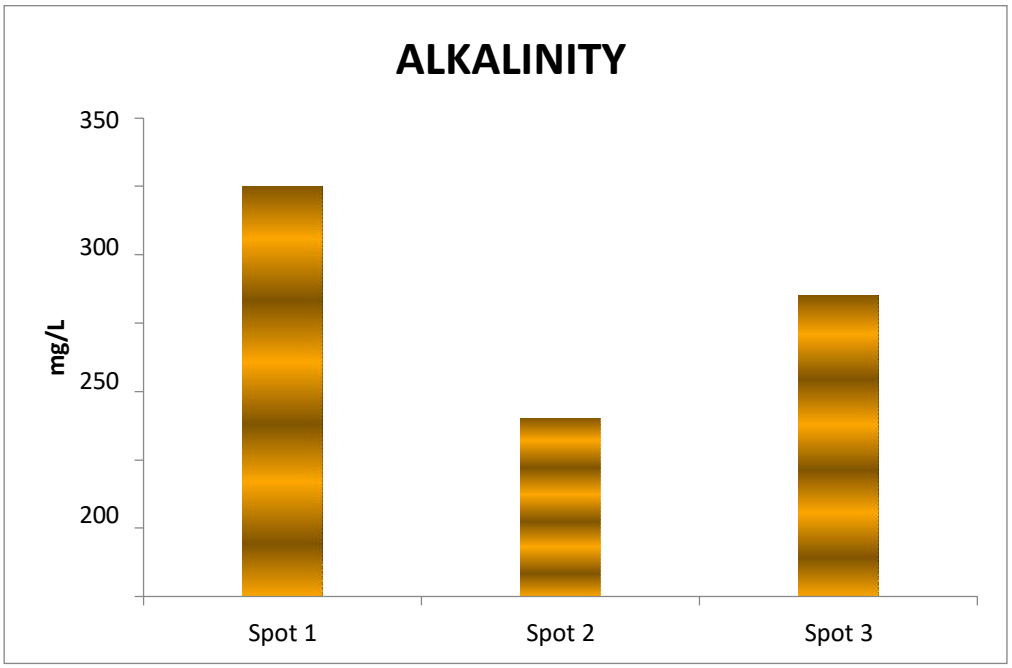

Fig 4.7 : Alkalinity

7. Hardness

Hardness is a very important parameter in decreasing the toxic effect of poisonous element. The major cations imparting hardness are calcium and magnesium. The anions responsible for hardness are bicarbonate, carbonate, sulphate and chlorides. In seawater magnesium is dominant and responsible for higher values of hardness. Typical seawater has a calcium hardness of 1000 mg/L, magnesium hardness of 5630 mg/L and total hardness of 6630 mg/L . Cations higher than divalent can contribute low level of hardness and mono-valent cations cannot produce any hardness (Muhammad et.al and Rahman et.al).Hardness of the water samples from 3 spots were found to be 60mg/L in spot1, 60mg/L in spot 2 and 70 mg/L in spot 3 (Table 4.6 and Figure 4.8) . Dattatreya (2018) reported that low values of hardness were observed during monsoon/ monsoon transition periods due to dilution with river water, as river water is rich in `Ca', the amount of hardness which is imparted to the coastal water during monsoon season is less compared to the amount of hardness of 'Mg' imparted during

the summer season. Total hardness of Sunderban mangrove ecosystem ranged from 1800-9200 mg/L which was observed by Vilas and Ashwina (2015). At Pichavaram mangrove forest hardness ranged from 680 to 6800 mg/L which was reported by Mariappan et. al.(2016).

Table 4.6 : Hardness

Sample Station	***Hardness (mg/L)***
Spot 1	60
Spot 2	60
Spot 3	70

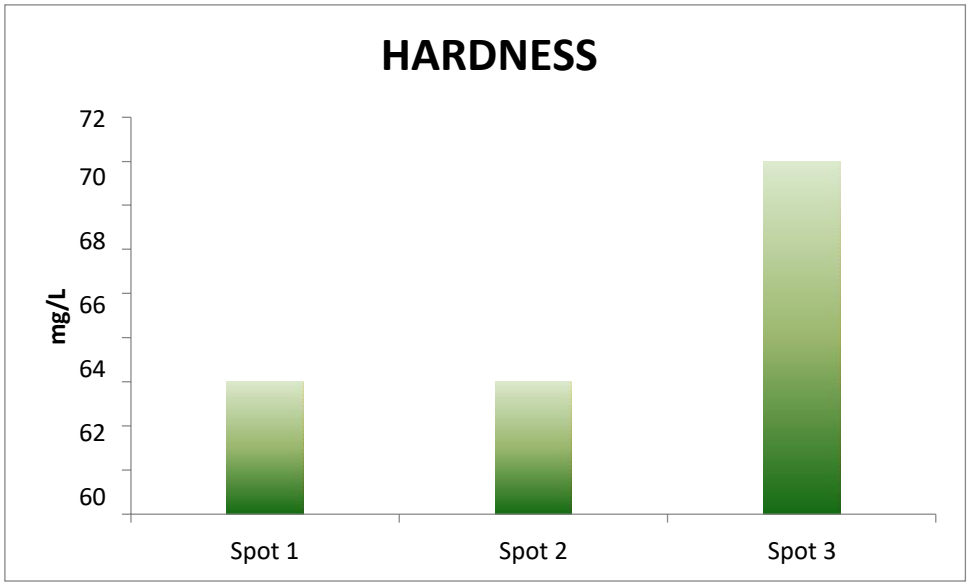

Fig 4.8 : Hardness

8. Salinity

Salinity is the important parameter which determines the composition of biological component and also affect the biological characteristics in the mangrove environment with the fluctuation in salinity for distributions of living organisms. Salinity for brackish water habitats such as estuaries, backwater and mangroves are influenced by fresh water influx from land run off, by monsoon or by tidal influence. Mangroves have unique adaptations to the intertidal zone, so they don't require salt water to survive but because of poor competition with freshwater vegetation they are generally found under the influence of salt water (Dattatreya *et al*.,(2018)). Salinity characteristic is determined by hydrology of the local

environment, where input of salt water comes from the periodic tides and fresh water comes from rivers, rainfall, groundwater, and runoff [Hogarth (1999)]. High evapo-transpiration (water loss through the soil and plant leaves) in the tropics and subtropics can increase salinity considerably, especially under environments with restricted water flow. Thus, salinity can fluctuate widely within mangrove forests, both over time and space. Most mangroves have developed the mechanisms to tolerate high salinities: salt exclusion, salt secretion, and tolerance to high salt concentrations within plant tissues [Duke(1992)]. The salinity values for Spot 1,Spot 2, and Spot 3 were found to be 14.109 g/Kg(1.41 e+10 ppt),13.026 g/Kg (1.302 e+10 ppt) and 26.383 g/Kg(2.638e+10 ppt) of water respectively(Table 4.7 and Figure 4.9). Manju et.al (2012) reported that there is a seasonal variation ($P<0.01$) for salinity ranging from 4.26 to 9.25 ppt (avg.6.73±2.32 ppt; post monsoon), 29.31 to 35.97 psu (avg.33.65±2.54 ppt; pre monsoon) and 0.24 to 26.64 psu (avg.7.89±11.44 ppt; monsoon) in the mangrove ecosystems along the Kerala coast. Salinity in the Pondicherry mangroves varied from 6.36 -36.77 ppt which was observed by Satheeshkumar and Anisa (2009). Salinity values ranged from 21 to 33 ppt in the mangrove region of Krishnapattanam coast (Dattatreyaet.,al (2018). Salinity from Vedaranyam mangrove ecosystem ranged from 28 to 23 ppt which was recorded by Ramamurthy *et al*.,(2012)

Table 4.7 : Salinity

Sample Station	***Salinity (g/Kg of water)***
Spot 1	14.109
Spot 2	13.026
Spot 3	26.383

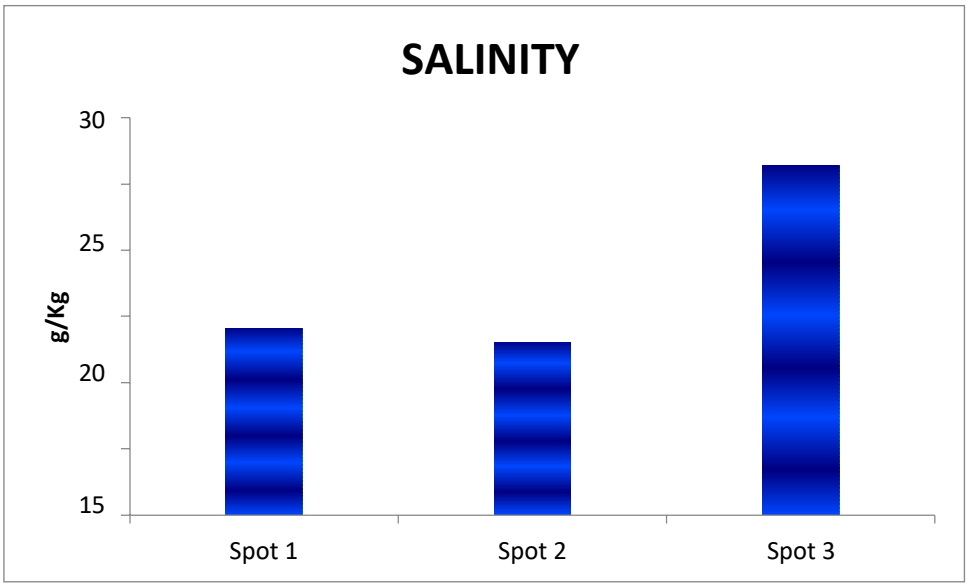

Fig 4.9 :Salinity

9. Water Chloride

Chloride occurs naturally in all types of waters. Chloride contents tend to vary inversely to the rate of flow of water Amita Sarkar and Bhavna Upadhyay (2013). The chloride content in Spot 1, Spot 2 and Spot 3 of the study area were found to be 193.611 mg/L, 178.66 mg/L and 362.299 mg/L respectively (Table 4.8 and Figure 4.10). . High chloride content is attributed to sources such as domestic effluent and fertilizers.The chlorides, in high concentration, indicate presence of organic matter (Dhanpakiam *et al*., (1999)).The studies conducted by Neethu and Harilal in the Thembukkad mangrove in Kannur district of Kerala, the water chloride ranged from 24566 to 25702 mg/L in pre monsoon, 293.47 mg/L to 899.33 mg/L in monsoon and in post monsoon was 16164.33 mg/L to 22057.33 mg/L respectively. Mariappan *et al*.,(2016) observed chloride values ranging from 891- 15345 mg/L while working on the Pichavaram mangrove ecosystem.

Table 4.8 :Water chloride

Sample Station	***Chloride (mg/L)***
Spot 1	193.611
Spot 2	178.66
Spot 3	392.077

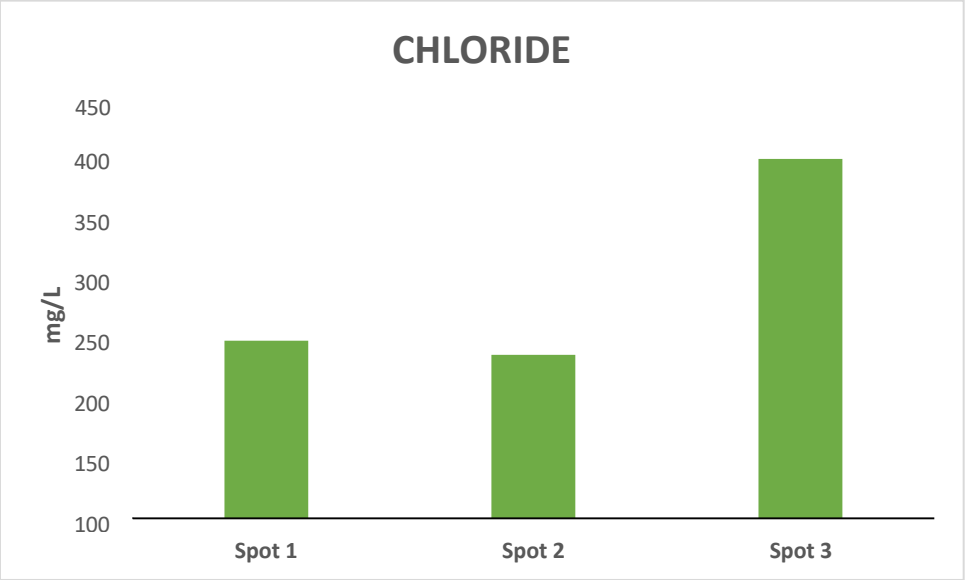

Fig 4.10 :Water chloride

10. Nitrate

Denitrifying bacteria are abundant in mangrove soils which deplete the nitrate and nitrate pools and produce ammonia, making ammonia the most common form of nitrogen observed in mangrove soils. The high productivity of mangroves is achieved through efficient nutrient cycling and conservation strategies. Samples were collected from three different spots ,the nitrate content in water was found to be highest in the spot 2 and spot 3, which was about 12.40 µg/mL and 7.633 µg/mL when compared to Spot 1 which had the lowest nitrate content of 2.385 µg/mL(Table 4.9 and Figure 4.11). The structure and functioning of both terrestrial and aquatic ecosystems is regulated by nitrogen availability (Elser *et al*. 2007; Lebauer and Treseder 2008; Chapin *et al*. 2011). Nitrogen enrichment is therefore one of the major threats to conservation of natural ecosystems and maintenance of human activities (Rockstrom *et al*. 2009; Erisman *et al*. 2013). N enters in the mangrove ecosystems through biological N fixation (Alongi 2002, 2009), the process whereby atmospheric N (N_2) is reduced to ammonia (NH_3^+) carried out by microorganisms that possess the nitrogenase enzyme complex (termed as diazotrophs).The lowest value of nitrate may be due to less nitrogen fixation and inhibition of nitrifying bacteria by the lack of oxygen (Melike balk *et al*.2015). The Krishnapatnam coastal area study observed the nitrate content varied from 1.84µg/L to 4.85 µg/L, highest values recorded during monsoon and immediate post-monsoon seasons, due to the influx of river and land runoff and decomposition of mangrove leaf litterfall in the adjacent mangrove environments by the seasonal influence (Dattatreya, P *et al* .2018).

Table 4.9 : Nitrate

Sample Station	*Nitrate (µg/mL)*
Spot 1	2.38
Spot 2	12.40
Spot 3	7.633

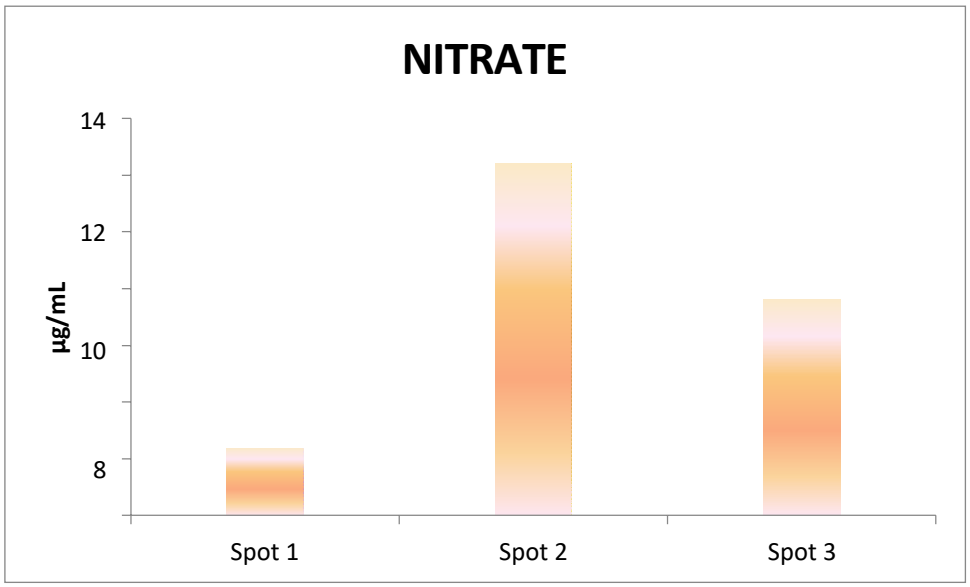

Fig 4.11 : Nitrate

11. Phosphate

With increasing human population growth in sub-tropical coastal regions, nutrient over enrichment in mangroves-dominant areas is increasing and leading to coastal eutrophication (Gruber and Galloway (2008)).Samples were collected from 3 different spots. Spot 2 exhibited the greater amount of phosphate content of 0.016mg/mL(16 ppm) whereas, Spot 1 and 3 was 0.0085mg/mL (8.5ppm) and 0.008mg/mL(8ppm)respectively(Table 4.10 and Figure 4.12). Nitrate and phosphate level in water increases during the monsoon time because of land drainage and anthropogenic input. Faecal contamination and excreta of birds also increase the level of phosphate in the mangrove ecosystems (Manju et.al.(2012)). Study done at Uppanar mangroves by Velsamy et.al (2013) explained that high level of phosphate may be due to the regeneration and release of total phosphorus from bottom into the water column by turbulence and mixing.

Table 4.10 : Phosphate

Sample Station	*Phosphate (mg/mL)*
Spot 1	0.0085
Spot 2	0.016
Spot 3	0.008

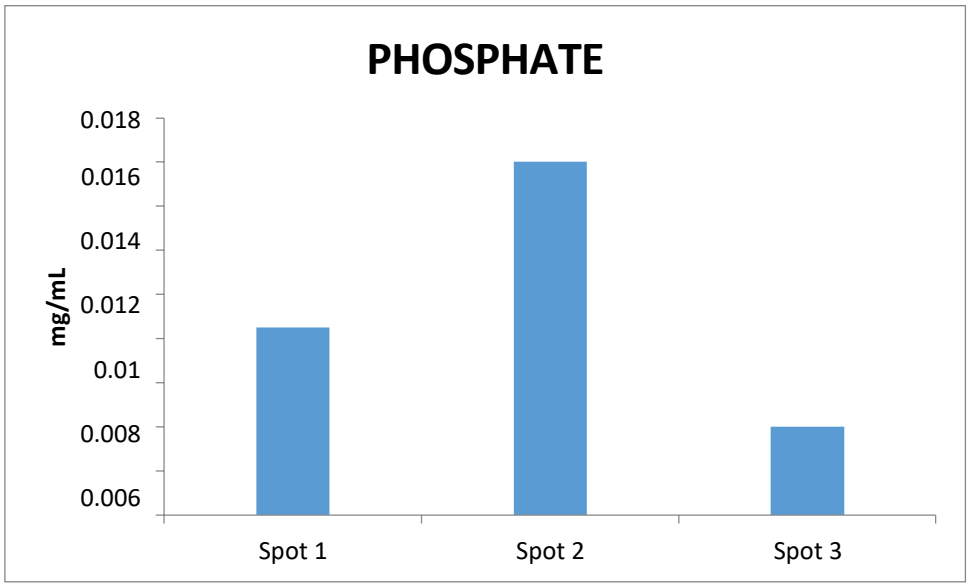

Fig 4.12 : Phosphate

12. Ammonia

Ammonia is the primary form of nitrogen in mangrove soils and nitrogenous end product of the bacterial decomposition of organic matter. Both ionized (NH_4^+) and un-ionized (NH_3) forms make up the total ammonia in water (Dattatreya, P., et.al (2018)). Concentration of ammonia in the study area ranged from 0.174 µg/mL in both 1st and 2nd spots to 0.522 µg/mL in the 3rd spot (Table 4.11and Figure 4.13). In organic rich mangrove sediments ammonia is released through degradation of organic compounds, which could easily get bound to clay particles, making it unavailable for biological uptake. The variation in the concentration of ammonia in the observed spots may be due to the decomposition of organic debris, land runoff water from VembanadKol to the mangroves area. In surface layers the low ammonia concentration is due to the utilization by plankton and other plants. Ammonia is the chief excretory product of the marine invertebrates, is also a nutrient, which is preferred over nitrate by the phytoplankton community in certain environmental conditions which significantly affect the concentration of ammonia (Prochazkova et.al..(1970)). At Point Calimere and Muthupettai mangrove regions, Srilatha *et al*., (2013) observed the

concentration of ammonia from 0.698 to 0.120 µmol/L and 0.030 to 0.744 µmol/L respectively.

Table 4.11: Ammonia

Sample Station	***Ammonia (µg/mL)***
Spot 1	0.174
Spot 2	0.174
Spot 3	0.522

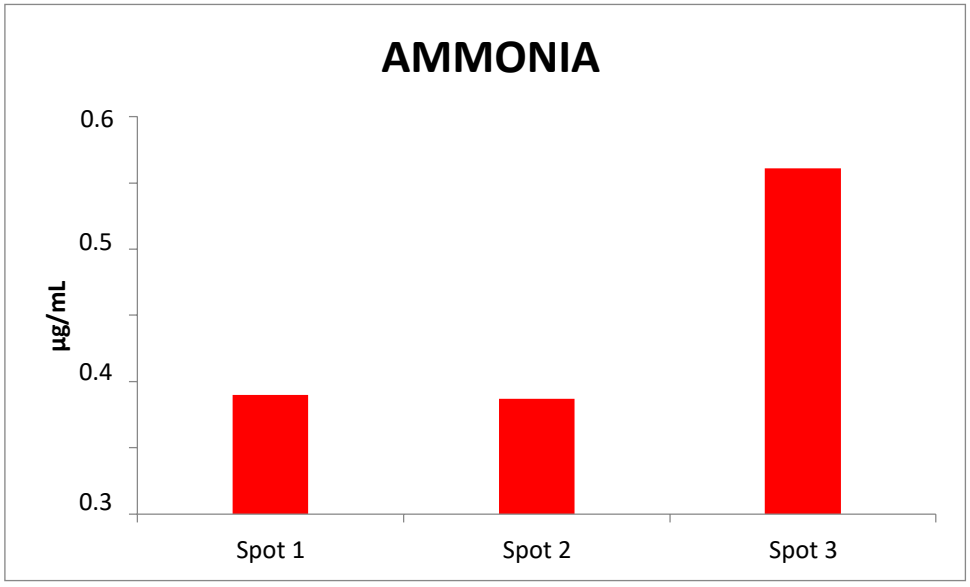

Fig 4.13 :Ammonia

13. Chromium

The concentration of chromium in the study area was found to be 2.083µg/mL in Spot 1, 0.245µg/mL in the Spot 2 and chromium content was nil in the Spot 3(Table 4.12 and Figure 4.14).High value of chromium may be due to the anthropogenic activities input from estuarine discharge to mangroves area. Mangroves have the ability to accumulate metals in their bodies specially in part of roots, leaves and stems (Kannan *et.al.* 2016). Depending on the concentration and exposure frequency it can be carcinogenic to humans via fishes through food chain (Zhuang *et.al*., 2009).

Table 4.12: Chromium

Sample Station	***Chromium (µg/mL)***
Spot 1	2.083
Spot 2	0.245
Spot 3	Nil

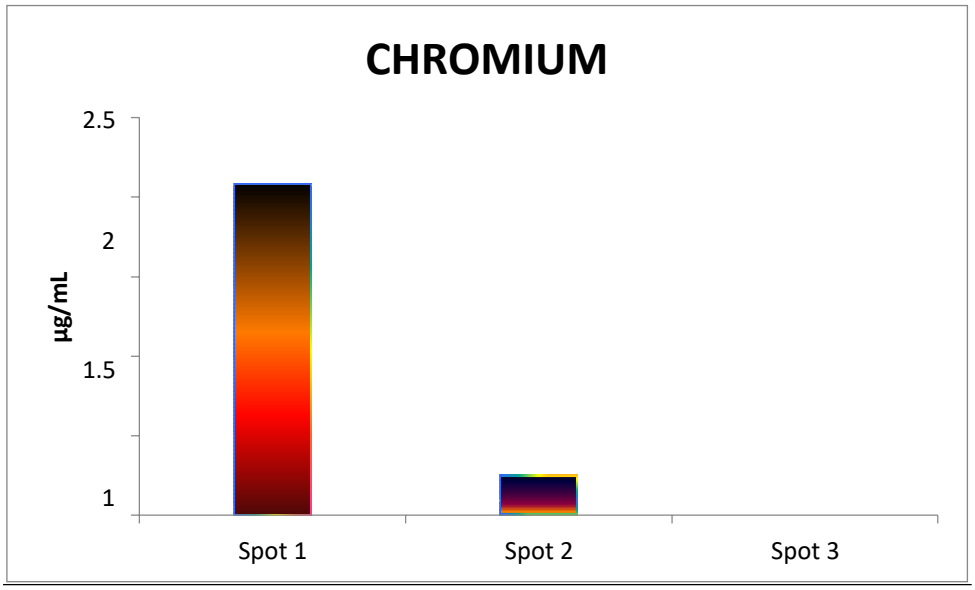

Fig 4.14 : Chromium

14. Copper

Heavy metal copper is one of the anthropogenic pollutants which enters into ecosystem through various sources such as contaminated rivers or from landfills area, waste debris etc. Here the samples were tested to check the presence of copper, which was found to be nil.

4.1.2 Soil Analysis

1. Soil Texture

The soil samples were not taken exactly from the mangrove water beds but from the banks of the mangrove area. The textural composition of mangrove soil was coarse, fine and silt sand. The sand particles occurred in high concentration in all the three spots. As the mangrove soil are in intertidal zone, fine sand particles are moved to these zone by tidal water (Dasgupta*et. al.*).According to Odum (1989) salt marshes soils typically contain more fine and sand clay from marine sources.

Table 4.13: Soil texture

Soil Texture	***Spot 1***	***Spot 2***	***Spot 3***
Coarse sand	0%	17.1%	2.8%
Fine sand	77.1%	77.1%	68.5%
Silt sand	22.8%	5.7%	28.57%

2. pH

Soil samples collected from three spots showed an alkaline nature (Table: 4.14 Fig: 4.15). Mangrove plants have adaptation to thrive at different pH values outside normal range. Similar work was reported by Sah *et al*. (1985) and Pal *et al*. (1996) of Sundarbans mangrove soils. Worldwide Studies conducted for the soil pH for tropical mangrove forests, observed that either the soil is acidic or alkaline in nature (Saravanakumaret.al, 2008).

Table 4.14 :pH

Sample Station	***pH***
Spot 1	8.30
Spot 2	8.38
Spot 3	8.39

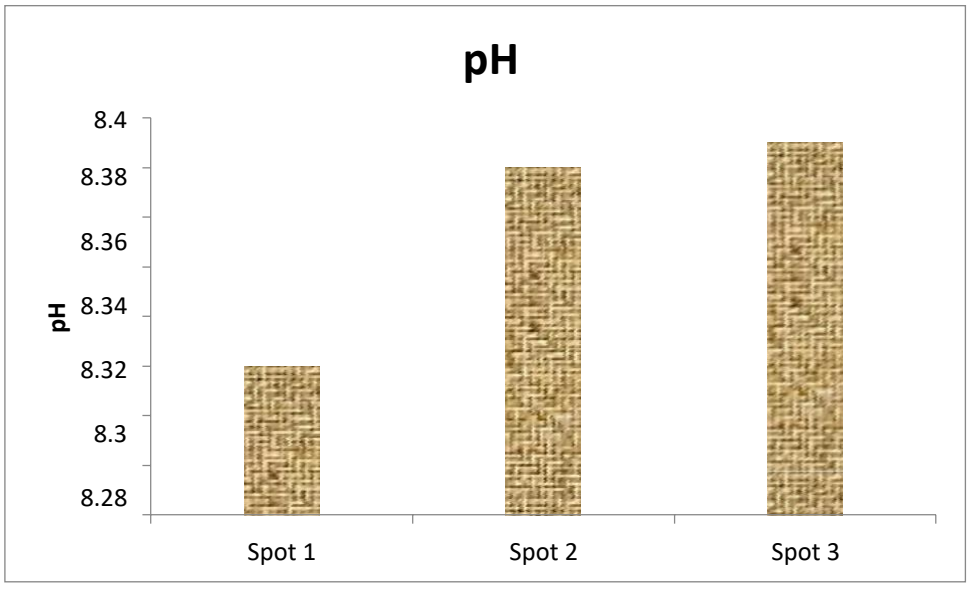

Fig 4.15 : pH

3. Soil Organic Carbon

Organic Carbon was estimated in all three spots for soil samples i.e, 15.21%, 11.7% and 7.8% for spot 1, 2 and 3 respectively (Table: 4.15 Fig: 4.16). Soil fertility depends on soil organic carbon content. Organic carbon releases nutrients for plant growth, promotes the structure, biological and physical health of soil, and is a buffer against harmful substances. The higher organic carbon content in spot 1 may be because of high vegetation and dumping of organic waste in and around the region. The concentration of organic matter in the mangrove forest varies with the plant species age. There exists interrelationship between mangrove vegetation and soil characteristics. As the age increases, the productivity and the production of litter and organic detritus that are deposited in the forest floor and within the soil profile increases. After the decomposition of the organic material the accumulation of organic matter increases. In some mangrove forests above 10% organic carbon was reported by Sukardjo (1994) reflecting the peaty nature of the soils. However less than one percent organic carbon reported by Sah *et al.,* (1989) and Hossain *et al.*, (2012) indicates the poor nutritional conditions of the soils of some mangrove forests. Reddy and Hariharan (1986) reported that as the clay content increased, the total organic carbon content also increased.

Table 4.15 : Organic carbon

Sample Station	***Organic Carbon (%)***
Spot 1	15.21
Spot 2	11.7
Spot 3	7.8

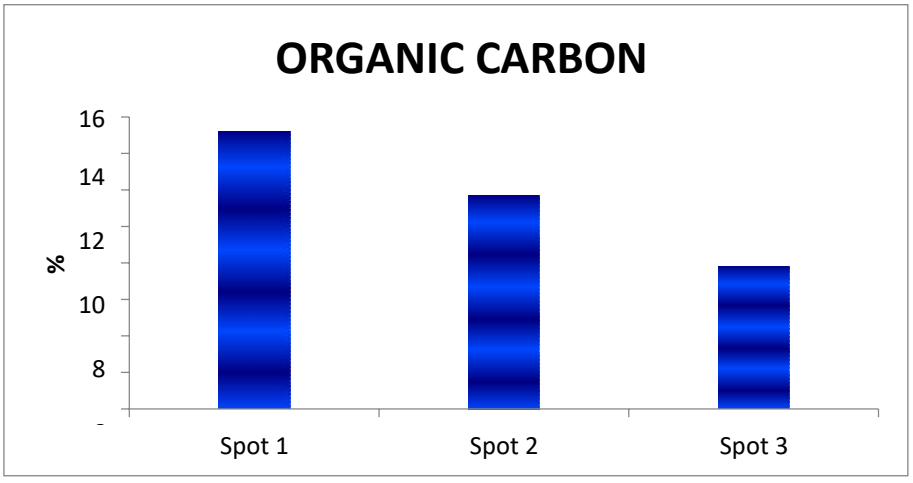

Fig 4.16 : Organic carbon

4. Soil chloride

Chlorides are present in fresh water with low concentrations. But in case of estuarines, water and soil chloride is a major constituent anion. Chlorides from mangrove soil are have been reported by several researchers like Joshi *et al*. (1972), Bhosale (1978), Kotmire and Bhosale (1985), Blasco *et al*. (1986), Mall *et al*.(1986), Joshi and Kumar (1986), Sah *et al*. (1986), Kadam and Bhosale (1986) and Bhosale (1990 a, 1990 b). In the present study chloride content in soil was estimated in three different spots i.e, 0.994mg/g for spot 1, 1.242mg/g for spot 2 and 4.224mg/g for Spot 3 respectively(Table: 4.16 Fig: 4.17). Salinity is always dependent on chlorinity. Salinity and chlorides show a definite relationship in the specific environment. Mangrove vegetation is more abundant in lower salinities and experimental evidence shows that at high salinity, mangrove spend more energy to maintain water balance and ion concentration rather than for primary production and growth. It is noticeable that under high salinity levels, mangrove biomass production and retention are adversely affected by the influence of vegetation in mangrove forest (Hossain M.D 2016).

Table 4.16 : Chloride

Sample Station	***Chloride (mg/g)***
Spot 1	0.994
Spot 2	1.242
Spot 3	4.22

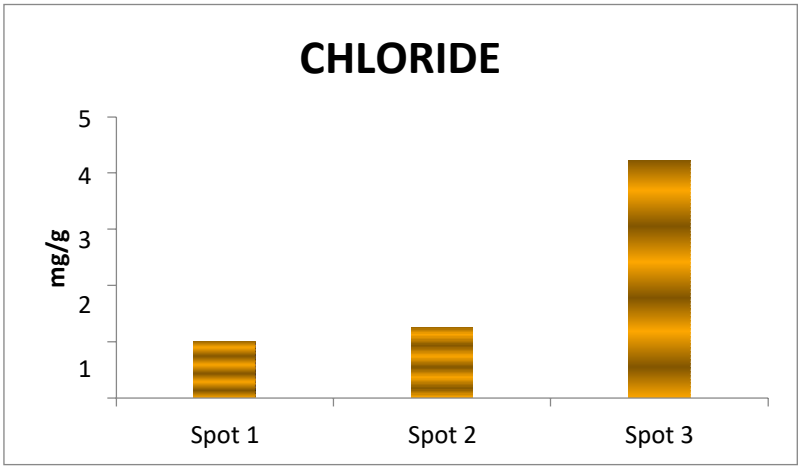

Fig 4.17 :Chloride

5. Soil phosphate

Phosphate, being one of the essential mineral nutrient that limits the plant growth and not readily available to plants due to its low solubility and high fixation in the soil (McVicker *et al*., 1963). Phosphate (P) in mangrove soils can be immobile and unavailable for plant use, thus organisms that solubilize P can have important implications for plant growth, especially in nutrient-limited environments. Due to the fact that obtains most of the phosphorus through fungal symbiosis, it is possible to assume that the plant phosphate transporters which partially regulate the phosphate intake have a great importance to productivity and plant growth (Smith *et al*. 2003). Symbiotic associations between roots and arbuscular mycorrhizal (AM) fungi are widespread in nearly all soils and are important for the uptake of immobile nutrients, especially for the solubilization of phosphorus (P) (Treseder *et.al*., 2006). In Nettoor mangroves, the phosphate concentration was found to be 0.32mg/g, 0.065mg/g and 0.47mg/g for spot 1, spot 2 and spot 3 respectively (Table: 4.17 Fig: 4.18).The observed high values could be attributed to the runoff from agricultural and aquaculture fields, household activities besides weathering of rocks. The lower values can be ascribed to the utilization of phosphates by phytoplankton during intense photosynthetic activity (Dattatreya *et al*. 2018).

Table 4.17 : Phosphate

Sample Station	***Phosphate (mg/g)***
Spot 1	0.32
Spot 2	0.065
Spot 3	0.47

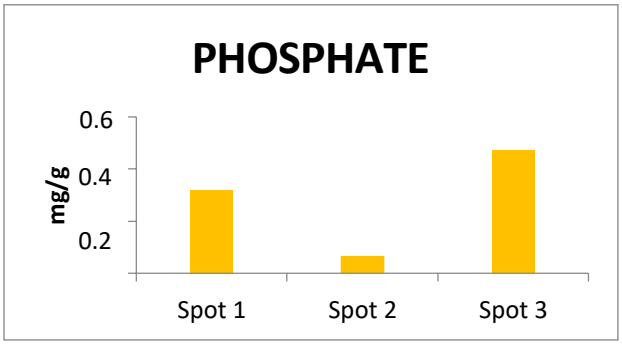

Fig 4.18 : Phosphate

6. Soil Calcium

Calcium in the present study was found to be 10%, 10% and 3.5% for spot 1, spot 2 and spot 3 respectively. The distribution of Ca among sediment components is important for assessing the potential of sediments to release Ca and to supply sufficient nutrient for plant growth. Muhibbullah *et al*. (2004) have observed the calcium content at Sunderban Mangrove Forest, Bangladesh that varied from 0.19% to 0.45% in soil and water. Calcium is one of the specific nutrients needed by plants to grow and remain healthy and also for cell wall deposition. Ramamurthy *et al*.,(2012) observed that micronutrients were maximum in monsoon and minimum in summer season in the Vedaranyam mangrove forest, Tamil Nadu.

Table 4.18 : Calcium

Sample Station	***Calcium (%)***
Spot 1	10
Spot 2	10
Spot 3	3.5

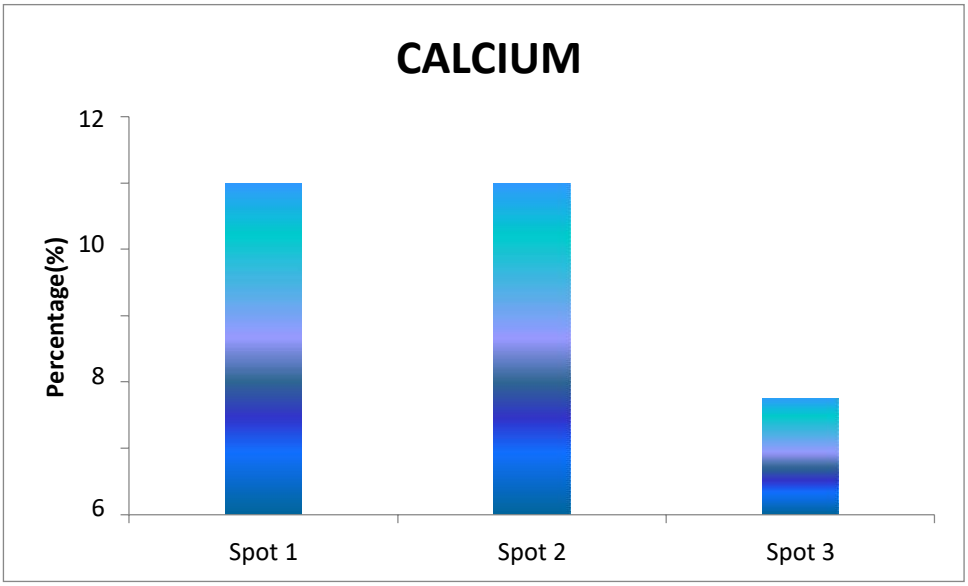

Fig 4.19 : Calcium

7. Soil Magnesium

Magnesium content was found to be 22.25%, 21.8% and 22.7% respectively for spot 1, spot 2 and spot 3. The increased magnesium content in the study area can be accounted to the microbial decomposition of organic matter which depends on the presence of electron acceptors, primarily oxygen in the surface sediment, but deeper down when oxygen is depleted these are replaced by nitrate, iron, magnesium or sulphate.(Thomsen *et al*, 2004). Magnesium is an indispensable mineral for plant growth, as it play a major role in the production of chlorophyll, on which photosynthesis depends. Without a ready source of magnesium plants cannot grow (Muhibbullah *et al*., 2004; Matsui *et al*., 2015).

Table 4.19 : Magnesium

Sample Station	***Magnesium (%)***
Spot 1	22.25
Spot 2	21.8
Spot 3	22.7

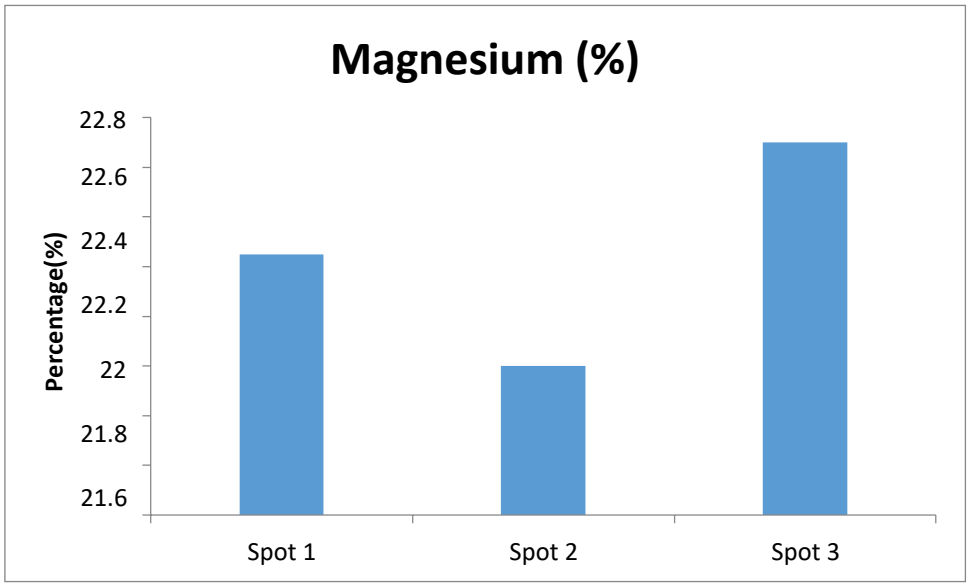

Fig 4.20 : Magnesium

4.2 Biodiversity Assessment

A preliminary observation on the general biodiversity of the studied quadrats revealed the presence of six true mangrove species, one semi mangrove, two mangrove associates and one invasive species. (Table 4.20). Regarding fauna, presence of crab, crow, spider, water strider and African snails were observed the description of which is given below.

Table 4.20 : List of Mangroves, Mangrove associates and Invasive species

Sl.No	**True Mangroves**
1.	*Acanthus ilicifolius*
2.	*Avicennia officinalis*
3.	*Bruguiera gymnorhiza*
4.	*Bruguiera cylindrica*
5.	*Rhizophora apiculata*
6.	*Kandelia candel*
	Semi Mangroves
7.	*Acrostichum aureum*
	Mangrove Associates
8.	*Scaevola sericea*
9	*Ipomoea*
	Invasive species
10	*Eichhornia*

Fig 4.21 : Biodiversity Spot 1

Fig 4.22 : Biodiversity Spot 2

Fig 4.23 :Biodiversity Spot 3

Fig 4.24 : Biodiversity Spot 4

Fig 4.25 : Biodiversity Spot 5

Description of various mangroves and other plant species seen in the different spots

Acanthus ilicifolius

Kingdom: Plantae

Family :Acanthaceae

Acanthus ilicifolius, is a spiny herb of the mangrove that is widely distributed in the coastal areas. They are commonly known as holly-leaved acanthus, sea holly, and holy mangrove. The plant grows up to 2 metres (6 ft 7 in) tall. It has typical spinose margins on its evergreen leaves and stipular spines at stem nodes .It has shallow tap roots and occasionally develops a stilt root. It is an evergreen non-viviparous mangrove associate. Flowers are sessile, very large, 35-40 mm long 35 mm across, bisexual and zygomorphic. Fruit is a loculicidal compressed capsule, nut-like, ellipsoid or ovoid-oblong, glabrous, 30 mm long and 10 mm wide and apiculate. It is initially green and light and dark brown when ripe and dry .It is used as medicine in asthma and rheumatism.

Fig4.26 : *Acanthus ilicifolius*

Avicennia officinalis

Kingdom: Plantae

Family: *Acanthaceae*

It is an evergreen tree, growing up to 25 m height and trunk to 1 m in diameter. It is also known as Indian Mangrove and White Mangrove. Numerous upright pneumatophores rise above soil from long shallow, horizontal roots. The bark is brownish-gray in colour and its leaves are simple, opposite with 4-12 cm long, 2-6 cm wide. The upper leaf surface is shiny green and hairless, underneath with fine gray-green hairs and resin dots. Flowers are bell-shaped, tubular and it is orange yellow to lemon yellow in colour. The fruits are densely hairy, about 3cm long with a short apical beak.

Fig 4.28: ***Avicennia officinalis***

Acrostichum aureum

Kingdom :Plantae

Family: Pteridaceae

These species are also known as golden leather fern. They grow in mangrove swamps and other wet locations and is one among the large species of fern. The plant is sometimes harvested from the wild for local use as a food and material for thatching. *Acrostichium aureum* has potential as an ornamental because of its handsome leathery leaves. Medicinally the pounded or grated leaves and rhizomes are applied as a paste to wounds, ulcers and boils. Like other mangrove plants they transpire freely and stomata occupy 30% of the lower surface. In mangrove reforestation programmes, *Acrostichum aureum* can be a noxious weed. Full sunlight and plenty of moisture are required throughout its year. The natural habitats of these ferns are under threatened due to accelerated exploitation of mangrove areas for timber and firewood or conversion of the land for other purposes.

Fig : 4.27: *Acrostichum aureum*

Bruguiera cylindrica

Kingdom: Plantae

Family: Rhizophoraceae

Common name: White Burma mangrove

*Bruguiera cylind*rica is a small tree growing up to 20 metres (66 ft) tall but often grows as a bush. The bark is smooth and grey, with corky raised patches containing lenticels which are used in gas exchange and the trunk is buttressed by roots. The aerial roots or pneumatophores project from the soil in knee-shaped loops and have many lenticels which allow air into the interconnecting roots while excluding water. The roots spread out widely to provide stability in the waterlogged soil. The glossy green leaves are opposite, simple and elliptical with pointed ends. The flowers are in small bunches of 2-5 in the axils of the leaves. They have 8 long green sepals and 8 smaller, greenish-white petals with several little bristles on the tip. The flowers are pollinated by insects and release a cloud of pollen when probed at the base by the insect's mouthparts. The seed does not detach itself from the flower stalk but germinates where it is and is known as a propagule. It grows into a slightly curved cylinder up to 15 centimetres (5.9 in) long, with the upturned calyx still attached, and looks rather like a slender, dangling cucumber.

Fig 4.29 :*Bruguiera cylindrical*

Bruguiera gymnorrhiza

Kingdom: Plantae

Family: Rhizophoraceae

Common name: Black mangrove

It is a small genus of six mangrove species of the Indian and west Pacific Ocean region, its range extending from East Africa and Madagascar through coastal India, Sri Lanka and Southeast Asia to northern Australia, Melanesia and Polynesia. Tree up to about 10 m tall, but often less; crown conical at first but later more irregular; bark black, rough; with knee-roots. New growth green becoming grey, glossy, hairless.Leaves opposite, crowded at the ends of branches, roughly elliptical, 60-120 x 20-60 mm, hairless, glossy apple green when young, becoming yellow with age; margins plain, not toothed or scalloped, slightly rolled under, tip pointed but without a spine, base narrowed, stalk up to 30 mm long; with interpetiolar stipules that fall early. (Interpetiolar stipules are small, triangular, leaflike outgrowths on the stem between and so at right angles to the opposite leaf stalks; they are usually a trademark of the coffee family, Rubiaceae, and mangroves are one of the very few other groups of plants to have this feature.)

Fig 4.30 : *Bruguiera gymnorrhiza*

Scaevola sericea

Kingdom :Plantae

Family*:* Goodeniaceae

Common Name*:* Half-flower.

Scaevola sericea is a dominant shrub species present in tropical and subtropical coastal environments, including sand dune, *mangrove* and seagrape habitats and ruderal land.*Scaevola sericea* is a dense, spreading shrub that forms rounded mounds from 1 to 3.5 meters tall. The multi-stemmed shrub produces medium green elliptic leaves which are alternate, waxy and fleshy or succulent, but not stiff or thick-skinned. They grow from 4 to 21 cm long and 1.8 to 9 cm wide and have a broader tip or apex than base.

Ipomoea

Kingdom :Plantae

Family: Convolvulaceae

Common Name: Morning glory

Ipomoea, herbaceous plants of the family *Convolvulaceae*. Several species are known as morning glories. Members of the genus *Ipomoea* usually have simple leaves, the margins of which may be entire, lobed, or divided, depending on the species. The trumpet- or funnel-shaped flowers are commonly borne in the axils of the leaves and are variable in size and colour. The fruit is a capsule and usually contains 4–6 seeds.

Fig4.31 : Ipomoea

Eichhornia crassipes

Kingdom :Plantae

Family: Pontederiaceae

Common Name: Water hyacinth

Eichhornia species are perennial aquatic plants native to tropical and sub tropical regions. It is a free floating aquatic plant growing generally up to 0.5 m in height but to nearly 1m height in Asian locations. Its leaf stalk is spongy and inflated and the upper lobes of purple flower have blue and yellow markings. It reproduces quickly and often clogs slow-flowing streams.

Fig 4.32 *: Eichhornia crassipes*

Description of various fauna seen in the different spots

ARTHROPODA

Crab

Kingdom: Animalia
Phylum: Arthropoda
Subphylum: Crustacea
Class: Malacostraca
Order: Decapoda

A number of crabs are amphibious, being capable of leaving the water to scavenge on land.. One of the mangrove crabs, *Aratus*, can climb trees. Some crabs spend so much time away from the water that they are known as land crabs; however, these crustaceans must return to the water when their larvae are ready to hatch.

Fig 4.33 : Crab

Spider

Kingdom: Animalia
Phylum: Arthropoda
Subphylum: Chelicerata
Class: Arachnida
Order: Araneae

Spiders (order Araneae) are air-breathing arthropods that have eight legs and chelicerae with fangs able to inject venom. They are the largest order of arachnids and rank seventh in total species diversity among all orders of organisms. Spiders are found worldwide on every continent except for Antarctica, and have become established in nearly every habitat with the exceptions of air and sea colonization. As of July 2019, at least 48,200 spider species, and 120 families have been recorded by taxonomists. However, there has been dissension within the scientific community as to how all these families should be classified, as evidenced by the over 20 different classifications that have been proposed since 1900.

Fig 4.34 : Spider

Water Strider

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Family: Gerridae

Water striders or are familiar insects on most bodies of fresh water. They live on thesurface of small streams to large rivers, ponds, and lakes, and even on the surface of the ocean. Theirlong legs distribute the body weight, enabling them to walk on the surface film. Gerridsare predators which use their front legs to grasp prey caught in the surface film. Water striders arevery conspicuous and may occur in large groups, but they are rarely eaten by other aquatic animalssuch as fish. Scent gland secretions are believed to be responsible for this apparent immunity. Theseinsects are common and widely distributed, but detailed biological studies of many North American species are lacking. Gerrids are small to moderate-sized insects with long, narrow legs.

Fig4.35 :Water Strider

African Giant Snail

Kingdom: Animalia
Phylum: Mollusca
Class: Gastropoda
Order: Stylommatophora
Family: Achatinidae

The shell of the giant African snail reaches up to 7.8 inches in length and 2.7-3.9 inches in height. Adult size is reached in about six months, after which growth slows, but does not cease until death. An adult weighs about 32 grams. The body has two short tentacles and two long ones that have the eyes. Life expectancy is commonly five to six years in captivity, but the snails can live for up to 10 years. They are active at night and spend the day buried underground

Fig 4.36: *African giant snail*

Crow

Kingdom: Animalia
Phylum: Chordata
Class: Aves
Order: Passeriformes

Crow, (genus Corvus), any of various glossy black birds found in most parts of the world, withthe exception of southern South America. Crows are generally smaller than and not as thick-billedas ravens, which belong to the same genus. A large majority of the 40 or so Corvus species are known as crows, and the name has been applied to other, unrelated birds.Crows feed chiefly on the ground, where they walk about purposefully. They are omnivores that enjoy meat and may even attack and kill young, weak animals. This habit makes them unpopular with farmers, as does the bird's propensity to raid graincrops. Berries, insects, the eggs of other birds, and carrion are also eaten. Sometimes they bury seeds or store them in crevices in bark

Fig 4.37 : Crow

4.2.1 Quadrat study

From the data obtained from quadrats made in five different spots in the studyarea the following parameters and indices were calculated using standard formulae:

- Density
- Relative density
- Frequency
- Relative frequency
- Abundance
- Simpson's index of diversity
- Shannon index

a) DENSITY

Table 4.21: Density of species in different quadrats studied

Spots	Species	Density (D)
1	*Avicennia officinalis*	0.011
	Acanthus illicifolius	0.006
	Acrostichum aureum	0.006
	Ipomoea	0.007
2	*Avicennia officinalis*	0.006
	Bruguiera gymnorhiza	0.041
	Acanthus illicifolius	0.011
	Acrostichum aureum	0.002
3	*Avicennia officinalis*	0.027
	Acanthus illicifolius	0.023
	Acrostichum aureum	0.006
	Ipomoea	0.006
	Eichhornia	0.07
4	*Avicennia officinalis*	0.05
	Bruguiera gymnorhiza	0.002
	Bruguiera cylindrica	0.001
	Rhizophora apiculata	0.03
	Kandelia candel	0.003
	Acanthus illicifolius	0.011
	Acrostichum aureum	0.03
	Scaevola sericea	0.001
	Eichhornia	0.011
5	*Avicennia officinalis*	0.062
	Ipomoea	0.003
	Eichhornia	0.024

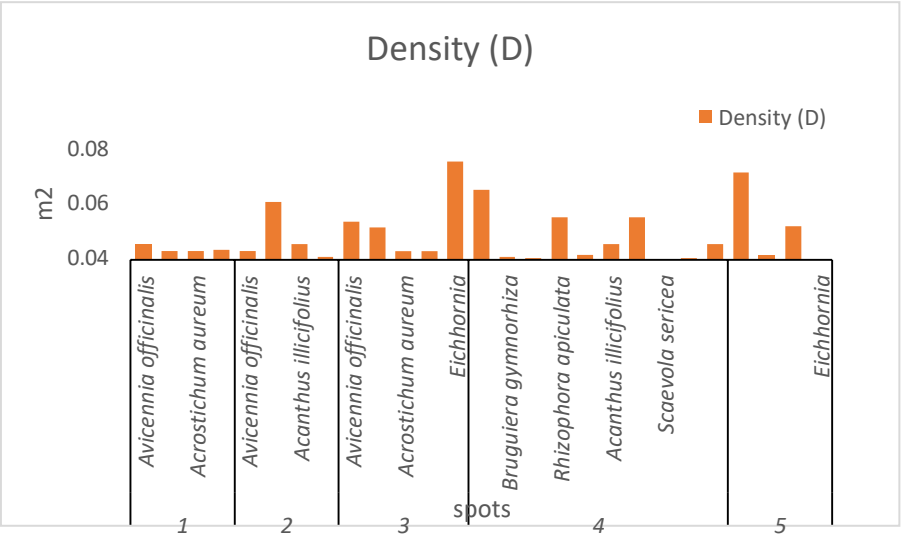

Fig 4.38 : Density

In spot 1, spot 2 and spot 4 minimum density was observed. *Eichhornia* showed maximum density of 0.07 in spot 3 and the other species like *Avicennia officinalis, Acanthus illicifolius, Acrostichum aureum, Ipomoea* showed minimum density. In spot 5 *Avicennia officinalis* species showed maximum density of 0.93 and minimum density of 0.003 was observed for *Ipomoea.*

RELATIVE DENSITY

Table 4.22 : Relative Density of species in different quadrats studied

Spots	Species	Relative density (RDi)(%)
1	*Avicennia officinalis*	34.4
	Acanthus illicifolius	20.6
	Acrostichum aureum	20.6
	Ipomoea	24.1
2	*Avicennia officinalis*	10.5
	Bruguiera gymnorhiza	64.9
	Acanthus illicifolius	17
	Acrostichum aureum	7
3	*Avicennia officinalis*	19.5
	Acanthus illicifolius	16
	Acrostichum aureum	4.6
	Ipomoea	4.6
	Eichhornia	54.6

4	*Avicennia officinalis* *Bruguiera gymnorhiza* *Bruguiera cylindrica* *Rhizophora apiculata* *Kandelia candel* *Acanthus illicifolius* *Acrostichumaureum* *Scaevolasericea* *Eichhornia*	34 1.5 0.7 22.7 2.2 7.5 22.7 0.7 7.5
5	*Avicennia officinalis* *Ipomoea* *Eichhornia*	69 3.7 27.16

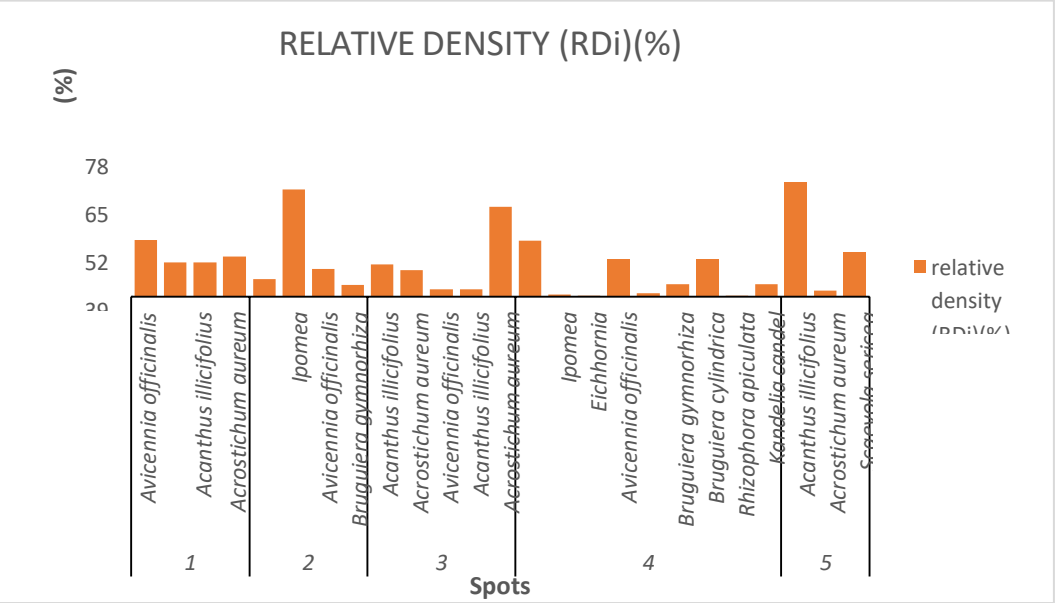

Fig 4.39 : Relative density

In spot 1 *Avicennia officinalis* showed maximum relative density of 34.4 and minimum relative density of 20.6 was observed for *Acanthus illicifolius* and *Acrostichum aureum.* Highest relative density value of 64.9 was noted for *Bruguiera gymnorrhiza* and *Acrostichum aureum* showed minimum relative density of 7 in spot 2.In Spot 3 maximum relative density value of 54.6 and minimum relative density value of 4.6 was observed for *Eichhornia*, *Acrostichum aureum* and *Ipomoea* species respectively. *Rhizophora apiculata* and *Acrostichum aureum* showed maximum relative density value of 22.7 and *Bruguiera cylindrical* and *Scaevola sericea* noted minimum relative density value of 0.7 in spot 4.

In spot 5 *Avicennia officinalis* species showed maximum relative density of 69 and minimum relative density of 27.16, 3.7 was observed for *Eichhornia and Ipomoea* respectively.

In the present study ,*Avicennia officinalis* had the highest density in spot5 whereas *Bruguiera gymnorhiza* was found to be highest in the spot 2(Table 4.22 , fig 4.35) .*Avicennia officinalis* species is abundant in Kumbalam village(Ernakulam). The most important invader species of environment is *Avicennia officinalis* and *Avicennia marina*, being of hardly nature and high range of adaptability. It possesses certain adaptive traits for reproduction and survival such as an efficient mechanism of persistence by arrival of widely dispersed propagules (Haig *et al*, 1986; Tomlinson, 1986). Another study was conducted by National Centre for Sustainable Coastal Management (NCSCM) and Central Marine Fisheries Research Institute (CMFRI) , 2013 .In this study , *Avicennia officinalis* was highest (41%) and the genus *Avicennia* alone constituted 56%. *Bruguiera gymnorrhiza* followed by *Avicennia officinalis* showed the highest relative density. (Table: 4.22 fig: 4.39). The results of the present study also goes well with the reports by Sreekanth (2015) where they have opined that a clear zonation exist in Puthuvypeen mangroves forest with *Bruguiera gymnorhiza* , followed by an assemblage of *Avicennia officinalis, Rhizophora mucronata, , Acanthus ilicifolius, Bruguiera gymnorrhiza*.

ABUNDANCE

Table 4.23: Abundance of species in different quadrats studied

Sl .NO	Species	Abundance (Ab)
1.	*Avicennia officinalis*	28.4
2.	*Bruguiera gymnorhiza*	7.8
3.	*Bruguiera cylindrica*	0.2
4.	*Rhizophora apiculata*	6
5.	*Kandelia candel*	0.6
6.	*Acanthus illicifolius*	11.75
7.	*Acrostichum aureum*	11.5
8.	*Ipomoea*	5.33
9.	*Scaevola sericea*	1
10.	*Eichhornia*	34

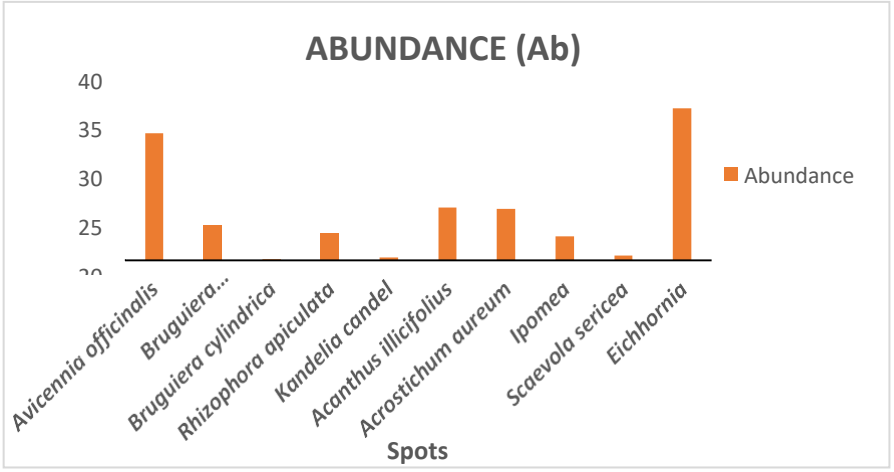

Fig 4.40: Abundance

Maximum abundance value of 34 was noted for *Eichhornia* species, while *Bruguiera cylindrica* and *Kandelia candel* species showed minimum abundance of 0.2 and 0.6 respectively. Abundance value of 28.4, 7.8, 6, 11.75, 11.5, 5.33, and 1 were observed for *Avicennia officinalis, Bruguiera gymnorhiza, Rhizophora apiculata, Acanthus illicifolius, Ipomoea,* and *Scaevola sericea* species respectively.

FREQUENCY

Table 4.24 : Frequency of species in different quadrats studied

Sl .NO	Species	Frequency (Fi)
1	*Avicennia officinalis*	100
2	*Bruguiera gymnorhiza*	40
3	*Bruguiera cylindrica*	20
4	*Rhizophora apiculata*	20
5	*Kandelia candel*	20
6	*Acanthus illicifolius*	80
7	*Acrostichum aureum*	80
8	*Ipomoea*	60
9	*Scaevola sericea*	20
10	*Eichhornia*	60

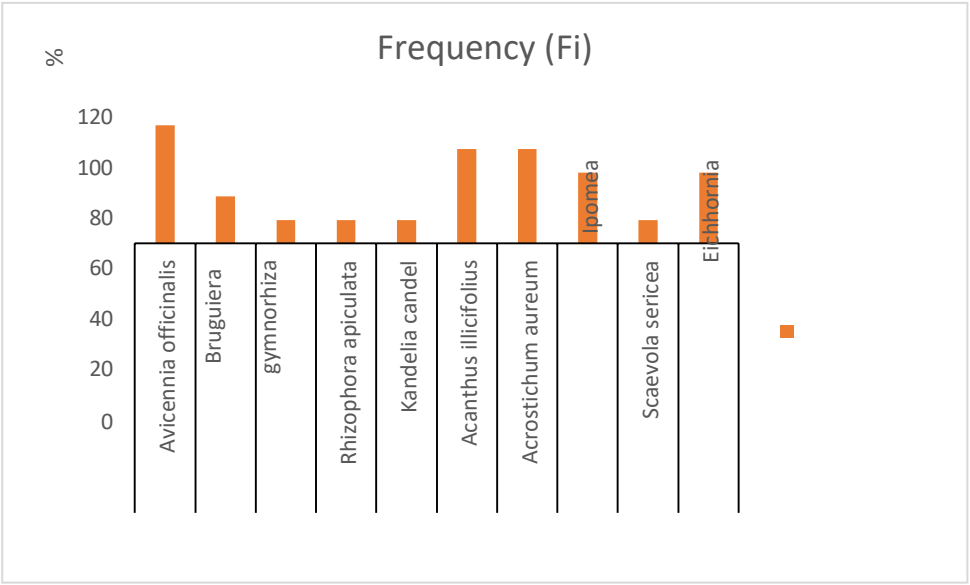

Fig 4.41 : Frequency

Maximum frequency value of 100 was observed for *Avicennia officinalis*. While minimum frequency of 20 was noted for four species,viz *Bruguiera cylindrica*, *Rhizophora apiculata*, *Kandelia candel, Scaevola sericea*. Frequency values of 80 was recorded for *Acanthus illicifolius* and *Acrostichum aureum*. Frequency of 60 was seen in for *Ipomoea* and *Bruguiera gymnorhiza* species showed a frequency of 40.

RELATIVE FREQUENCY

Table4.25 : Relative frequency of species in different quadrats studied

Spots	Species	Relative frequency
1	*Avicennia officinalis*	0.312
	Acanthus illicifolius	0.25
	Acrostichum aureum	0.25
	Ipomoea	0.187
2	*Avicenni aofficinalis*	0.33
	Bruguiera gymnorhiza	0.13
	Acanthus illicifolius	0.16
	Acrostichum aureum	0.16
3	*Avicennia officinalis*	0.263
	Acanthus illicifolius	0.21
	Acrostichum aureum	0.21
	Ipomoea	0.157
	Eichhornia	0.157
4	*Avicennia officinalis*	0.22
	Bruguiera gymnorhiza	0.09
	Bruguiera cylindrica	0.045
	Rhizophora apiculata	0.045
	Kandelia candel	0.045
	Acanthus illicifolius	0.181
	Acrostichum aureum	0.181
	Scaevola sericea	0.045
	Eichhornia	0.136
5	*Avicennia officinalis*	0.45

	Ipomoea	0.27
	Eichhornia	0.27

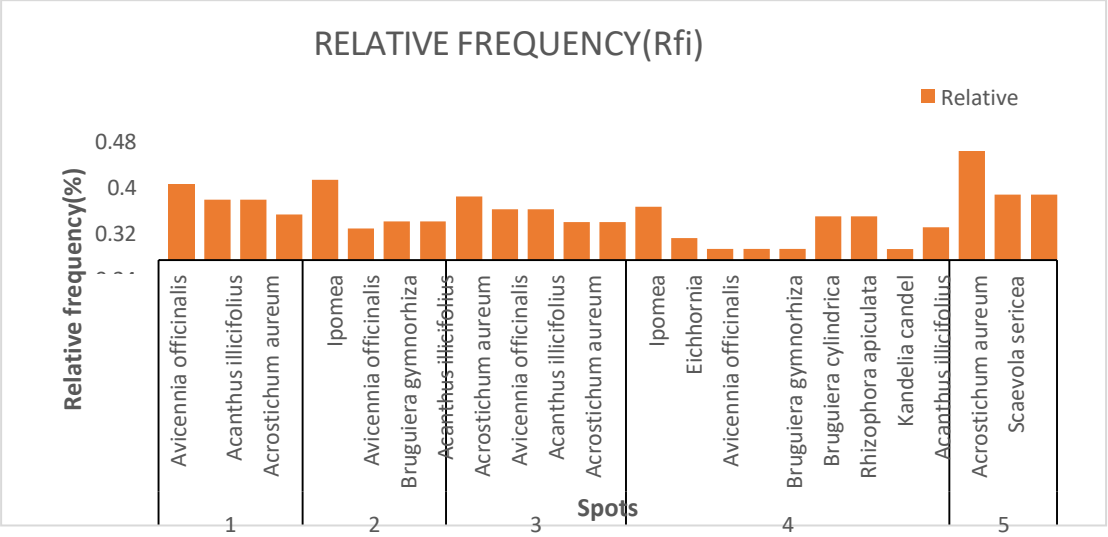

Fig 4.42 : Relative frequency

Maximum relative frequency value of 0.312 was observed for *Avicennia officinalis and* minimum relative frequency of 0.25was showed by *Acanthus illicifolius* and *Acrostichum aureum* in spot 1. In spot 2 *Avicennia officinalis* noted highest relative frequency of 0.33 and *Acrostichum aureum* and *Acanthus illicifolius* noted relative frequency of 0.16 and *Bruguiera gymnorhiza* showed minimum relative frequency of 0.13. In spot 3 *Avicennia officinalis* showed maximum relative frequency of 0.263 and in spot 4 *Eichhornia* noted more relative frequency of 0.136. *Avicennia officinalis* showed maximum relative frequency value of 0.45 and *Ipomoea* and *Eichhornia* noted minimum relative frequency value of 0.27 in spot 5.

Highest frequency and relative frequency was shown by *Avicennia officinalis* .(fig : 4.25) . According to Praveen (2014), *Avicennia officinalis* and *Excoecaria agallocha* were the most mangrove species at Kunhimangalam, Kannur. In the present study, *Avicennia officinalis* followed by *Bruguiera gymnorhiza* showed the highest abundance. These results goes well with the report by Ram 2013 , where he has reported *Avicennia officinalis* as the abundant species in Kumbalam followed by *Bruguiera gymnorrhiza, Rhizophora apiculata, Kandelia candel* and *Bruguiera* cylindrica. (Table 4.25).

SIMPSON'S INDEX OF DIVERSITY

Table 4 .26: Simpson's index of diversity of different spots

Spots	Simpson's index of diversity
1	0.77
2	0.55
3	0.637
4	0.226
5	0.453

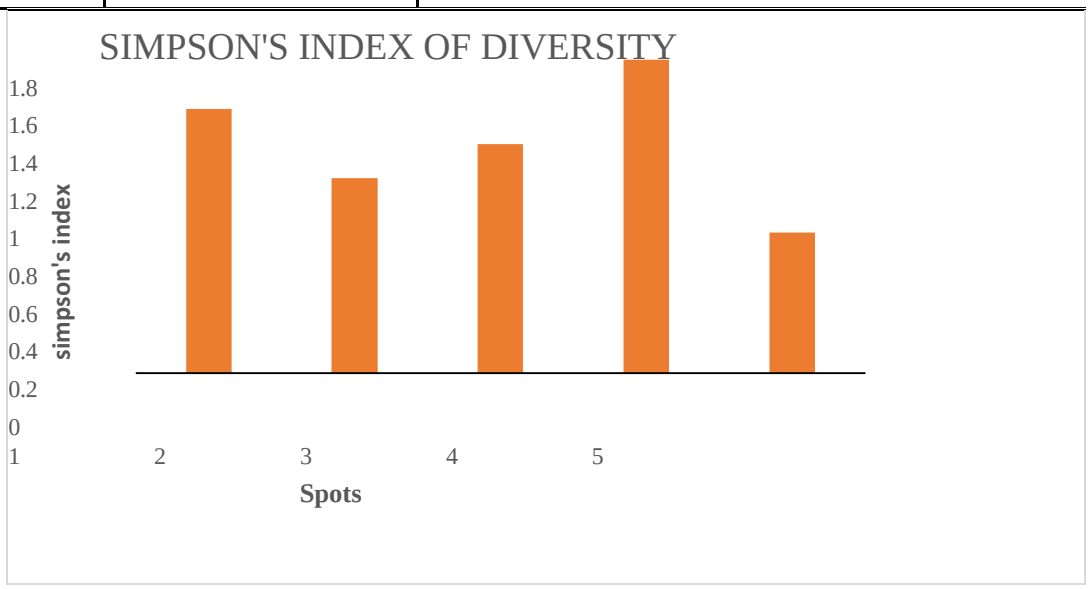

Fig 4.43 : Simpson's Index of Diversity

Maximum Simpson's Diversity Index of 0.77 was noted in Spot 1 while the minimum Simpson's Index of Diversity was seen in Spot 4, about 0.226. Simpson's Index of Diversities of 0.55, 0.637 and 0.453 was recorded in Spot 2 , Spot 3and Spot 5 respectively.

SHANNON INDEX

Table 4.27: Shannon index of diversity of different spots

Spots	Shannon index of diversity
1	1.34
2	0.99
3	1.16
4	1.589
5	0.711

Highest Shannon Index value of 1.589 and minimum Shannon Index value of 0.711 was noted in Spot 4 and Spot 5 respectively. Shannon Index values of 1.34, 0.99 and 1.16 were observed in Spot 1, Spot 2 and Spot 3 respectively.

In ecology, Simpson's Diversity index is often used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the abundance of each species. The value of Simpson's Index of Diversity ranges between 0 and 1, which means that, the greater the value, the greater the sample diversity. In this case, the index represents the probability that two individuals randomly selected from a sample will belong to different species. The Shannon diversity index (H) is another index that is commonly used to characterize species diversity in a community. Like Simpson's index, Shannon's index accounts for both abundance and evenness of the species present.

In the present study, Spot 1 and spot 4 showed maximum values of Simpson's Index of Diversity (0.77) . Spot 4 showed maximum values of Shannon Index (1.5), pointing to the high species richness as well as evenness in the region (Table: 4.26, Fig:4.39 ; Table: 4.27 Fig: 4.40). After Spot 1, Spot 2 and Spot 3 recorded the maximum values of Simpson's Index of Diversity and Shannon Index respectively. Studies from across the world have reported diverse range of values of Shannon Index for mangroves. In a comparative study of mangrove vegetation in Ernakulam district, Sofia and Teresa (2016) have reported value of 2.172 to 2.765; whereas in another study on the Botany of Mangroves by Tomlinson (1986), the value was found to range from 1.0 to 2.27. The study was conducted by National Centre for Sustainable Coastal Management (NCSCM) and Central Marine Fisheries Research Institute (CMFRI) has recorded that most diverse indices in Kannur, followed by Kasaragod, Malappuram, and Ernakulam.

4.4 Plankton Assessment

The following phytoplankton were observed from the water sample collected from the mangrove ecosystem study area**,** the description of which is given below**.**

SPIROGYRA

Phylum: Charophyta

Class: Zygnematophyceae

Order: Zygnematales

Family: Zygnemataceae

Spirogyra is very common in relatively clear eutrophic water, developing slimy filamentous green masses. In spring *Spirogyra* grows under water, but when there is enough sunlight and

warmth they produce large amounts of oxygen, adhering as bubbles between the tangled filaments. The filamentous masses come to the surface and become visible as slimy green mats. Spirogyra has a cell wall, nucleus, pyrenoid and spiral chloroplasts.

OSCILLATORIA

Phylum: Cynobacteria

Class: Cynophyceae

Order: Oscillatoriales

Family: Oscilatoriaceae

Genus: *Oscillatoria*

Oscillatoria is a genus of filamentous cyanobacterium which is named after the oscillation in its movement. It is commonly found in watering-troughs waters, and is mainly blue-green or brown-green. *Oscillatoria* is an organism that reproduces y fragmentation. *Oscillatoria* forms long filaments of cells which can break into fragments called hormogonia. The hormogonia can grow into a new, longer filament. Breaks in the filament usually occur where dead cells (necridia) are present. *Oscillatoria* uses photosynthesis to survive and reproduce.

ODONTELLA

Phylum Ochrophyta
Class Mediophyceae
Order Triceratiales
Family Triceratiaceae

In *Odontella* Cells are connected in straight or zigzag chains. Adjacent cells are united by mucous pads. The centres of valves are convex but slightly flattened at the top, with zero to several short and divergent spines. Chloroplasts are numerous, small, kidney-shaped or elliptical and are located near the valve walls, Cells are yellow-brown in colour which are harmful to local wildlife, as well as farm animals and pets. Production of these neurotoxins is assumed to be an input into its symbiotic relationships, protecting the plant from grazing pressure.

NAVICULA

Super-phylum: Heterokonta

Class: Bacillariophyceae

Order: Naviculales

Family: Naviculaceae

Navicula is a motile diatom which lives singly. It has the cell wall enclosing raphe which is located near the cell wall in the cytoplasm, two chloroplast located at the each sides of the raphe along with the pyrenoids and nucleus centrally located with two large vacuoles. It is boat shaped with yellow brownish colour.

OEDOGONIUM

Phylum: Chlorophyta

Class: Chlorophyceae

Order: Oedogoniales

Family: Oedogoniaceae

Oedogonium is a genus of filamentous, free-living green algae. The morphology of *Oedogonium* is unique, with an interior and exterior that function very differently from one another and change throughout the life cycle. These protists reside in freshwater systems above and below the equator and are both benthic and planktonic in nature. Forming algal patches on water's surface, they interact closely with a multitude of other algae. These filamentous cell's life cycles include both sexual and asexual reproduction depending on life cycle stage.

CHLAMYDOMONAS

Phylum: Chlorophyta

Class: Chlorophyceae

Order: Chlamydomonadales

Family: Chlamydomonadaceae

Chamydomonas is a genus of green algae consisting of 325 species all unicellular flagellates. *Chlamydomonas* is used as a model organism for molecular biology, especially studies of flagellar motility and chloroplast dynamics, biogenesis, and genetics. One of the many striking features of *Chlamydomonas* is that it contains ion channels (channel rhodopsins) that are directly activated by light. Some regulatory systems of *Chlamydomonas* are more complex than their homologs in Gymnosperms, with

evolutionarily related regulatory proteins being larger and containing additional domains.

CHLORELLA

Phylum: Chlorophyta

Class: Trebouxiophyceae

Order: Chlorellales

Family: Chlorellaceae

Chlorella is a genus of single-celled green algae belonging to the division Chlorophyta. It is spherical in shape, about 2 to 10 μm in diameter, and is without flagella. *Chlorella* contains the green photosynthetic pigments chlorophyll-a and -b in its chloroplast. Through photosynthesis, it multiplies rapidly, requiring only carbon dioxide, water, sunlight, and a small amount of minerals to reproduce.

Table 4.28 : Phytoplankton distribution in spot 1

SL.NO	CLASS	PLANKTON	PERCENTAGE OF PLANKTON IN THE ORGINAL CONCENTRATED SAMPLE (%)
1	Chlorophycea	*Chlamydomonas*	19.2
		Oedogonium	12.80
2	Cyanophyceae	*Oscillatoria*	14.07
3	Coscinodiscophyceae	*Odontella*	11.53
4	Trebouxiophyceae	*Chlorella*	19.23
5	Bacillariophyceae	*Navicula*	23.07

Six Phytoplankton species were identified from sample 1 of the study area. *Navicula* was found in highest concentration were as *Oedogoneum, Oscillatoria* and *Odontella* was found in least concentration (Table 4.28).

SPOT 2

Table 4.29 :Phytoplankton distribution in spot 2

SL.NO	CLASS	PLANKTON	PERCENTAGE OF PLANKTON IN THE ORGINAL CONCENTRATED SAMPLE (%)
1	Coscinodiscophyceae	*Skeletonema*	35.82
2	Cyanophyceae	*Oscillatoria*	23.86
3	Chlorophycea	*Oedogonium*	14.91
4	Bacillariophyceae	*Navicula*	25.34

Four Phytoplankton species were identified from spot 2 of the study area. *Skeletonema* was found in highest concentration whereas *Oedogonium* was found in least concentration (Table 4.29).

SPOT 3

Table 4.30 :Phytoplankton distribution in spot 3

SL.NO	CLASS	PLANKTON	PERCENTAGE OF PLANKTON IN THE ORGINAL CONCENTRATED SAMPLE (%)
1	Chlorophycea	*Oedogonium*	10.64
		Chlamydomonas	17.33
2	Cyanophyceae	*Oscillatoria*	22.65
		Anabaena	17.3
3	Coscinodiscophyceae	*Odontella*	20.08
4	Zygnematophyceae	*Spirogyra*	12.00

Six Phytoplankton species were identified from spot 3of the study area. *Oscillatoria and Odontella* were found in highest concentration where as *Oedogonium* was found in least concentration (Table 4.30).

4.5 Ecological Interactions

Lichen and Mangroves

In Nettoor mangrove ecosystem, commensalism was observed between lichen and mangroves. A commensalism is a relationship in which one species benefits and the other species is neither helped nor harmed. Lichens are the organisms formed from a combination of fungi and algae. The fungal filaments found into the algal cells, provide a proper shape. Based on the morphological appearance, lichens are categorized into three types, namely crustose (crusty), foliose (leafy) and fruticose (shrubby). In Nettoor, Foliose lichen species were abundant on the bark of mangroves.

Lichens mainly use trees as structural perches. They are not extracting nutrients or water

from tree tissue itself, as they are capable of photosynthesizing on their own. The trunk or branches of tree shelp lichens to avail better access to sunlight for making their own food. The decomposition of lichens, as with all organic matter, adds nutrients to the soil.

Crabs and Mangroves

In Nettoor ecosystem, crabs were found to closely dwell with mangroves, where the relationship observed was commensalism. The crab has a solid base to live and the mangrove is not harmed.

CONCLUSION

Mangroves are very important in protecting the shoreline from storm, hurricane and winds. It maintains water quality and also habitat of many organisms. Many problems are occurring in the environment and people are realizing the importance of mangroves. So studying more about the mangrove ecosystem has great significance in the present scenario. In this report we dealt with the study of mangrove ecosystem in Nettoor in Ernakulum district. Soil, water quality analysis and biodiversity study were conducted .This area is slightly polluted as it is left unattended or not protected by anyone in and around that area .Various studies and analysis is done in this area but it will remain the same unless and until we are ready to take the step to conserve this area. The results of this study strengthen the need to preserve mangrove ecosystem and restore those degraded to guarantee the provision of goods and services needed to support the biodiversity and functioning of wide portions of tropical ecosystems. Climate changes and human activities are the major threats of mangrove habitats. Lack of knowledge or high degree of ignorance can cause destruction of mangroves which will ultimately risk our lives. So it is important that we come up with thoughts and actions to conserve and protect mangroves.

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Acknowledgement

The Department of Environmental Science, Sacred Heart College, Thevara profusely thank State Wetland Authority Kerala for allocating fund for carrying out the activities under the project on Wetland Conservation and Management Awareness Campaign 2018-19. The Department was able to fulfil all its objectives outlined in the proposal with the allocated fund. The restoration and conservation activities were carried out voluntarily by students with the proactive participation of residents around Nettoor. The same will be continued by the Department by the help of students in future too.