TEMPORAL VARIATION IN THE HYDROGRAPHY AND BIODIVERSITY OF THE COCHIN BACKWATERS OF PUDUVEYPU REGION

by

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THESIS

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I DEDICATE THIS THESIS TO THE MEMORY OF MY MOTHER,

TO LET HER KNOW THAT FINALLY I DID IT,

WHO ALWAYS BELIEVED IN ME & KNEW THAT I COULD DO IT...

DECLARATION

I hereby declare that this thesis entitled **"TEMPORAL VARIATION IN THE HYDROGRAPHY AND BIODIVERSITY OF THE COCHIN BACKWATERS OF PUDUVEYPU REGION"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, or other similar title, of any other university or Society.

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CERTIFICATE

We the undersigned members of the Advisory Committee of **Sri Trinayan Deb Sarmah (2009-14-102),** a candidate for the degree of **Master of Fisheries Science** agree that this thesis entitled **"Temporal variation in the Hydrography and Biodiversity of the Cochin Backwaters of Puduveypu Region"** may be submitted by Sri **Trinayan Deb Sarmah (2009-14-102),** in partial fulfillment of the requirement for the degree.

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INTRODUCTION

1. INTRODUCTION

The state of Kerala has been blessed with an extensive water bodies like lakes, lagoons and estuaries. These brackish water lakes and lagoons are generally lying parallel to the Arabian sea coast of Kerala. The backwaters were formed by the action of waves (Anirudhan *et al.,* 1987).

The rich biodiversity and ecological value made Cochin estuary to be identified as a Ramsar site (1214).

The tropical estuarine environment shows multitudinal features which characterize fresh water and sea water mixing and provides breeding ground for marine organisms. Cochin backwater supports diverse species of flora and fauna according to their tolerance for saline environment (Marakala *et al.,* 2005).

Hydrography and biodiversity of Cochin backwater were studied by several workers (Ramamritham and Jayaraman, 1963; Cheriyan, 1967; Josanto, 1971; Sreedharan and Salih, 1974; Balakrishnan and Shynamma, 1976; Menon *et al.,* 2000; Verma *et al.,* 2002; Renjith *et al.,* 2004 and Anon 2004).

Large areas of brackish waters in Kerala are known by different names like backwaters, lakes, lagoons and estuaries including mangroves and swamps. The important water bodies of Kerala, from south to north are Veli, Kadinamkulam, Paravoor, Ashtamudi, Kayamkulam, Vembanad, Valiyangadi, Korapuzha and Valiyapatanam. The socio-economic and cultural development of Kerala is very much related to the network of these backwaters.

The studies on the Cochin backwater have shown that it has a high life carrying capacity and also that it has great potential for development of fisheries and recreation (Gopalon *et al.,* 1983).

The backwaters of Kerala support as much biological productivity and diversity as tropical rain forest (Menon *et al.*, 2004). These backwaters contribute a lot for rich fisheries potential in Kerala. Understanding the environmental parameters and productivity of a biotope is a prerequisite for effective utilization of fisheries resources.

Puduveypu is an area in the Kochi backwater system which is endowed with 3000 acres of newly formed wetlands. A number of water bodies exist here due to accretion of land and get inundated during highest of high tide and therefore many species of fishes enter and get trapped. The area is covered with heavy mangroves. Thousands of kg. of litter fall in per ha. of mangrove area every year and hence food is in plenty which results in a suitable condition for migratory fishes.

Brackish water environment in general and mangrove areas in particular have been the topic of interest for the biologists mainly because of their high productivity and rich biodiversity (Marakala *et al.*, 2005).

The seasonal changes in hydrography play an important role in regulating the fauna of backwaters (Menon *et al.*, 2000). Hydrographical parameters such as salinity, water temperature, turbidity, pH, total alkalinity, hardness, nutrients, dissolved oxygen, primary productions etc. are the main factors influencing the biological productivity of a region.

Study of the hydrobiological parameters and their seasonal change is essential for better utilization of a fisheries resource. Not much works have been done so far in this field in Puduveypu region. This study was carried out to understand the hydro-biological characteristics of backwaters of the Puduveypu region.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Cochin estuary is one of the intensively studied estuarine systems in India. The seasonal characteristics are well studied. The estuary exhibits partially mixed condition in postmonsoon season, a salt wedge in monsoon season and well mixed in pre-monsoon season (Anon, 2004).

The hydrographical conditions of the Cochin backwater is greatly influenced by sea water intrusion and influx of river water (Menon *et al.*, 2000).

2.1 HYDROGRAPHICAL PARAMETERS

2.1.1 Salinity

The major indicator of an estuarine mixing is the salinity of water (Kinne, 1971). The most dominant feature of the estuarine environment is the fluctuation in salinity. Fresh water discharge from some major rivers, the tidal flow from Arabian sea, the coastal upwelling and sinking etc., have considerable effect on the hydrographical condition of Cochin backwater and these factors bring about a well defined seasonal pattern in salinity variations (Ramamritham and Jayaraman, 1963; Qasim and Gopinanthan, 1969). Sankaranarayanan and Qasim (1967) reported that salinity values were maximum in the pre-monsoon months in Cochin backwater. Stratification was reported during monsoon at lower reaches of estuary because of salt water intrusion (Balakrishnan and Shynamma, 1976; Ramaraju *et al., 1979*; Udayavarma *et al.,* 1981; Sankaranarayanan *et al.,* 1986; Joseph and Kurup, 1990). About 70% of rainfall in Cochin occurs during monsoon and so during this season there is strong flow of fresh water and consequently the salinity of backwater reduces to much lower value. During monsoon (June-September) the range in salinity was much high 0.39-34.25‰ (Kurian, 1972). Varma *et al.*, (2002) analysed long term daily variation in salinity at a station near Panangad jetty and recorded a salinity range between 0 and 32‰. Salinity decreases during monsoon season to reach the value 0‰. The pre-monsoon is the season of peak salinity in the area. During monsoon period the salinity remains less due to the influx of large amount of fresh water (George, 1958). Gopinathan *et al.* (1984); Shakaranarayanan *et al.*, (1982); Singh (1987) and Venketasan *et al.*, (2001) observed an annual salinity range of 1‰-27‰ in seasonal and perennial prawn culture field of Cochin estuarine system. Sudheer (2003) observed that average salinity of an interior prawn filtration field in Cochin was around 15.2‰.

Salinity is one of the important water parameters that regulate the quality of water and determines the extent of dissolution of gases and pH of brackish water (Vijayakumar *et al.,* 2000). Changes in salinity are normally controlled by weather, hydrology, rainfall, topography and tidal flooding. The salinity of bottom sediment is a function of local precipitation, subterranean seepage, terrestrial runoff, evaporation and tidal flushing. High salinity controls the biological activities by reducing the availability of nutrient (Prasad and Ramanathan, 2008). Jayasree (2009) studied the seasonal characteristics in the salinity distribution in a prawn filtration pond near Panagad area and found a salinity range of 0.05‰ to 30.63‰.

2.1.2 Water temperature

The change in surface water temperature follows the change in air temperature. Kerala being a tropical state, temperature variations are not as high as salinity. Maximum evaporation takes place in the post monsoon season at Cochin (Balakrishnan, 1957). The influx of fresh water into the estuarine system is not the sole factor in bringing down the water temperature in water system but the cold water from the sea may also be a significant factor (Shankaranarayanan and Qasim, 1969).

According to Pillai *et al.,* (1975) the temperature value range between 25°C and 33°C. Nair and Tranter (1971) reported that the temperature does not vary much between pre and post monsoon. With the onset of monsoon, there was a decrease in surface temperature and a certain amount of uniformity maintained with persistently high temperature during pre-monsoon (Menon *et al.,* 1971, Pillai *et al.,* 1975, Balakrishnan and Shynamma, 1976, Singh, 1987, Jayachandran and Joseph, 1988, Kumary *et al.,* 2007).

Pillai *et al.,* (1975) reported a gradual increase in temperature from February to April, followed by a fall during July-August in Vembanad Lake (Alleppey and Azheekode) and adjacent waters. In general during post monsoon time (October-November), the surface temperature showed a slight increase in entire area. A bimodal variation was evident in the daily temperature data presented by Varma *et al.,* (2002) for Panangad jetty area.

The temperature values ranged between 25.1°C (August) and 33°C (November) in the area between Aleppey and Azheekod of Vembanad lake (Pillai *et al.,* 1975). Temperature range between 24°C and 33°C was observed at Mandavi-Zuari estuary by Padmavati and Goshwami (1996). The seasonal variation in water temperature showed high values in pre monsoon and low values during monsoon (Prabhadevi *et al.,* 1996). The range of temperature was between 27°C and 33°C at the surface and bottom water at Kayamkulam backwaters and Arattupuzha coast.

A sharp variation in temperature was noticed during the onset and withdrawal of monsoon in Cochin backwaters. The sharp variation is more pronounced in the northern part than in the southern part of the estuary (Lakshmanan *et al.,* 1982). The southern arm showed highest temperature values than the northern arm with a difference of about 2°C, causing horizontal gradient. Surface temperature ranged from 25.2°C (August) to 33.8°C (April) in the estuarine area between Vypeen and Thanneermukkam.

Harikrishnan and Kurup (2003), in their study of Vembanad Lake from Cochin to Kavalam (Kuttanad) reported that the water temperature was invariably low during June-July (25°C), which gradually increased from August onwards and reached highest value in March (32°C).

Anon (2004) reported a bimodal annual variation and the highest temperature values were observed during the months of March-April that is the pre monsoon season. Susheela *et al.,* (2006) observed a temperature range of 30°C-35°C after tsunami in an interior prawn filtration pond.

Kumar *et al.,* (2006) reported that the difference in temperature, in general was due to the factors such as solar radiation, cloud cover intensity and the direction of wind and thermal changes by tidal currents. During summer, the clear sky would have favoured intense radiation thus increasing the air and subsequently the surface water temperature. During monsoon season, mixing of cold fresh water through river runoff coupled with lower temperature has lead to reduction of surface water temperature.

Devi (2009) found that the water temperature of mangrove area fluctuated between 24°C and 30.5°C. She found the water temperature was low during the monsoon months with slight increase in early post-monsoon and the decreased due to winter effect. Higher temperature was found during pre-monsoon. Jayasree (2009) studied the backwaters of Panangad region and found a temperature range of 26°C to 32.5°C.

2.1.3 Hydrogen ion (H+) concentration or pH

pH is one of the most important parameters that controls fish life. This is important chemical factor that affects the metabolism and other physiological processes of aquatic organisms. pH range of 6.5-9 has been reported to be the most ideal for fish culture (Jhingran, 1982; Boyd,1990; Venkatesan *et al.*, 2001).

Sankaranarayanan and Qasim (1969) reported that pH exhibited considerable fluctuations at the surface of Cochin backwater. Snakaranarayanan *et al.* (1982) found that the pH value varied between 7.0 to 8.2 in some tidal ponds of Cochin. Higher values were recorded during the season of pre-monsoon, when the salinity values were high. Nagarajaih and Gupta (1983) recorded pH range between 7.0-8.4 in brackish water ponds along the Nethravati estuary. Banerjee and Roychoudhury (1966) and Sankaranarayanan and Qasim (1969) reported that the pH of Cochin backwater was low during monsoon months. The influx of fresh water during monsoon lower the pH and high values were observed during winter (December, January) and summer (May) months may be due to the abundance of algae.

Sheeba *et al.*, (1996) recorded a pH range of 6.46-8.64 in the mangrove areas of Cochin backwater. Dirunal peak values of pH were observed during the afternoon and declined gradually in the evening to reach low levels during the late night and lowest pH was observed in the morning hours. Das *et al.*, (2000) observed a positive relationship between pH and temperature of pond.

Marakala *et al.*, (2005) reported pH range of 7.08 and 7.63 in mangrove area in south west coast of India. A pH range of 7.19 to 7.58 was observed in Gautami-Godavari mangrove area of Andhra Pradesh (Tripathy *et al.*, 2005). Kumar *et al.*, (2006) studied Muthupettai mangroves in Tamil Nadu and found that pH value decrease due to fresh water inflow and were evidenced by significant positive correlation between salinity and pH.

Susheela *et al.*, (2006) found a pH range of 7.0-8.5 during pre tsunami (2003-04) and 6.0 to 10.5 during post tsunami (2005) periods in an interior prawn filtration field in Cochin.

The pH of Cochin backwater is slightly alkaline and it ranges between 7.01 and 8.8 (Joseph *et al., 2008*).

Devi (2009) found an alkaline pH through out the year in Cochin backwater. Jayasree (2009) studied the Panagad region of the Cochin backwater and found an increasing trend of pH from the post monsoon to pre-monsoon season.

2.1.4 Dissolved oxygen:

Dissolved oxygen is an essential factor in the aquatic ecosystem and is an important indicator of water quality. The air water interaction, respiration and photosynthetic processes influences dissolved oxygen status of aquatic ecosystems. Primary source of oxygen is through photosynthesis by phytoplankton (Hepher, 1963).

The solubility of oxygen in water is mainly influenced by temperature and salinity (Weiss, 1970) and it decreases with increase in salinity and temperature.

Higher values of dissolved oxygen were recorded during monsoon months (Qasim *et al.*, 1969; Haridas *et al.*, 1973; Pillai *et al.*, 1975). Kurian (1972) observed that dissolved oxygen was always supersaturated at the surface owing to the shallow nature of the estuary and mixing of water, it seldom goes below 2.5 ml/l even at the bottom.

Kumaran and Rao (1975) reported that the lowest dissolved oxygen in the Cochin backwater was found during the post monsoon months ie. October to December and the highest was in the monsoon months (July). It was shown that oxygen values which remain high during the monsoon months, suddenly decreased as soon as the peak rainy season was over. They found an annual range from 0.6 to 5.8ml/l in Cochin backwater.

Pillai et al. (1975) marked a distinct pattern of seasonal fluctuation in the Cochin backwater. He observed annual range between 1.10ml/l (April) to 5.9ml/l (June). He found the post monsoon period to be more stable with lesser variation. On an average, the dissolved oxygen values of Cochin backwater were always under saturated at all depths and in all seasons and this attributed the possible utilization of dissolved oxygen for decomposition of organic matter (Balakrishnan and Shynamma, 1976). The values were minimum during daybreak and gradually increased as the day advanced and was found a general decline in the values at night.

The biological process of an estuary is affected by dissolved oxygen content of water. Its utilization and release (Photosynthesis and respiration), indirectly affects the pH of estuarine water (Singbal, 1976). Suresh et al., (1978) found that dissolved oxygen values showed an inversed correlation with the values of salinity and temperature. Saraladevi *et al.,* (1979) remarked that dissolved oxygen was higher during the monsoon and was lower during the pre and post monsoon periods in the estuary near the industrial area. The annual range was 2-6 ml/l.

Trivedi and Goel (1984) remarked that dissolved oxygen value is an indicator of productive water body and an important factor for aquatic life that reflects the physical and biological processes prevailing in the water.

Balasubramanium *et al.,* (1995) found a typical pattern of diurnal change in dissolved oxygen values ranging from 0.5 to 8.9 ml/l and from 0.1 to 7.08 ml/l in two prawn filtration ponds.

Nasnolkar *et al.,* (1996) observed an inverse relationship between dissolved oxygen and salinity. Padmavati and Goshwami (1996) observed that the values range from 1.1 to 5.9 ml/l in Mandovi Zuari estuarine system. Sheeba et al. (1996) reported the dissolved oxygen range of 2 to 8.75 ml/l in the mangrove areas of Cochin backwater.

The higher dissolved oxygen values that were observed during monsoon might be due to intrusion of fresh water from rivers and resulting mixing and circulation of water (Lakshmi *et al.,* 2000).

Joseph et al., (2008) reported that dissolved oxygen content in mangrove are ranged between 1.4 and 6.4 mg O_2/l while in estuary it ranged between 4.9 and 8 mg O_2/l in Cochin backwater area. Prasad and Ramanathan (2008) observed that high temperature increases salinity of water by evaporation and reduces dissolved oxygen level due to increased rates in biological function of the ecosystem.

Devi (2009) studied the Cochin backwater of Panangad region and recorded maximum dissolved oxygen in the second half of July and minimum during the pre-monsoon season. She found a positive correlation of dissolved oxygen with the nutrients and negative correlation with salinity and alkalinity.

2.1.5 Total alkalinity:

The alkalinity of water refers to the total concentration of bases in water and it mainly depends on carbonates and bi-carbonates of Calcium and Magnesium (Chakrbarty *et al.,* 1959). It is defined as the quantity of hydrogen in milimole (mmol) to neutralize the weak bases in 1 kg of sea water. The capacity of a solution to neutralize a dilute acid is termed as total alkalinity in terms of $CaCO_3$ (Grasshoff *et al.,* 1983).

The alkalinity of water is a very important factor which influences the productivity of an ecosystem (Unnithan, 1985). The variation in alkalinity in Cochin backwater was less during the pre-monsoon months (Sankaranarayanan and Qasim, 1969). Generally it assumes higher values during summer months and starts decreasing with the advent of monsoon. The alkalinity of brackish water shrimp pond has been widely studied by Chakraborty *et al.,* (1986). Mathew (1987) reported high total alkalinity with wide fluctuations in some prawn culture fields in Cochin. He also reported that the values ranged between 10 ppm and 130 ppm in perennial fields, between 22.5 ppm and 111 ppm in seasonal fields and between 24 and 185 ppm in coconut groves. Susheela *et al.,* (2006) carried out a study in an interior prawn filtration field in Cochin and found that the total alkalinity was in the desirable range of (25-75) ppm during 2005 as against the minimum value of 15 ppm during 2003-04. Joseph *et al.*, (2008) found that the alkalinity of Cochin estuary ranged between 18 and 317 mg $CaCO_3$/l. Devi (2009) studied the Cochin backwater of Pnangad region and recorded minimum total alkalinity During monsoon and increased value in post monsoon and pre-monsoon. She estimated a maximum value of 200 mg $CaCO_3$/l.

2.1.6 Hardness:

Total hardness of water refers to the total concentration of divalent cations in water and is also expressed in milligrams per litre of equivalent Calcium carbonate.

Baticados *et al.*, (1986) reported a total hardness of 3350 ppm - 6567 ppm in brackish water ponds at Phillipines. Ecological and productivity study of ponds in Chellanam area was conducted by Ignatius (1995) found that hardness was above 5000 ppm in January and it decreased to 2618 ppm during March. Maya Ramachandran (2009) found that hardness ranged between 41.25 mg $CaCO_3$/l and 776.25 mg $CaCO_3$/l in a prawn filtration pond of Cochin area. She recorded the maximum hardness in February and the minimum in October. Jaysree P.S. (2009) found that pre-monsoon experience a gradual reduction in hardness where as drastic reduction was noticed during monsoon.

2.1.7 Nutrients:

Nutrients are functionally involved in living processes of organisms. Seasonal variations of nutrients in different part of

Cochin backwater were studied by various workers (Sankaranarayanan and Qasim, 1969 Reddy and Sankaranarayanan, 1972; Joseph, 1974; Anirudhan *et al.,* 1987; Lakshmanan *et al.,* 1987; Nair *et al.,* 1988; Anirudhan and Nambisan, 1990).

Studies have shown that seasonal variability of the nutrients in backwater demands an understanding of the fresh water discharge into the system, which is chiefly controlled by the spectacular regime of the rainfall during the monsoon months. Reddy and Sankaranarayanan (1972) suggested that the main reason for spatial variation in nutrients in Cochin estuary might be due to variation in the regenerative property of bottom sediments. Sreedharan and Salih (1974) found marked seasonal change influenced by local precipitation and run off. Temporal variation in the nutrients concentration was found between the pre monsoon period when the system was predominantly marine and nutrient concentration was low; andmonsoon period when the nutrient was high due to maximum influx of fresh water. Saraladevi *et al.,* (1983) studied the nutrient like phosphate, nitrite and nitrate in four estuaries in Kerala. She found that inorganic phosphate did not show any clear pattern or pronounced seasonal variation and showed an increase in nitrate content during monsoon in all the estuaries. Nitrate does not seem to be affected by the fresh water discharge in Cochin backwater and were mostly less than 1 microgram at/l (Sankaranarayan and Qasim, 1969).

Joseph and Pillai (1975) observed that nitrite ranged between 0 and 6 microgram at/l in the Cochin backwater.

Sankaranarayanan *et al.,* (1982) reported that inorganic phosphate values were high throughout year in Ramanthuruth Island.

Lakshmanan *et al.*, (1987) reported that the concentration of nitrite, nitrate and phosphate exhibit pronounced seasonal variation in distribution. Anon (2004) found a negative correlation between phosphate silicate and nitrite with salinity indicating their terrestrial origin. He studied the nutrient distribution at Panangad region of Vembanad Lake. The range of Phosphate-P, Nitrate-N and Silicate-Si were below detectable level to 4.85 µmole/l, 0.07 to 3.06 micromole/l, 0 to 4.18 µmol/l and 20.94 to 82.24 µmol/l respectively during pre-monsoon. During monsoon the range was from undetectable level to 17.3 µmol/l, 0.60 to 18.29 µmol/l l, 0 to 3.24 µmol/l and 8.17 to 197.08 µmol/l respectively. During post monsoon range was from undetectable to 8.30 µmol/l, 0.40 to 20.40 µmol/l, 0 to 1.80 µmol/l and 3.02 to 130.15 µmol/l respectively in the same area.

Sankaranayanan and Qasim, (1969) found that Silicon was associated with the heavy silt load of estuary. Sankaranarayanan and Qasim (1969); Nagarjaiah and Gupta (1983); Anirudhan et al. (1987); Anirudhan and Nambisan, (1990) reported negative correlation between silicate and salinity. Increased silicate concentration was found during monsoon and decreased during pre and post monsoon season (Anirudhan and Nambisan, 1990).

Selvam *et al.*, (1994) opined that the mangrove community may also remove large amount of inorganic materials from detritus.

Selvaraj *et al.*, (2003) reported higher phosphate and nitrate concentration in Cochin backwater. Tripathy *et al.*, (2005) reported a high concentration of nutrients in Gautami–Godavari estuarine ecosystem which revealed the importance of this zone as a source of nutrient to the adjacent coastal ecosystem.

Jayasree (2009) studied the seasonal changes of the macrobenthic community in relation to the hydrography of a prawn filtration pond at Panangad region. In her study, she reported that, higher values of nitrate was estimated during post monsoon and monsoon season and lower values were estimated during pre-monsoon. On the other hand the seasonal variation of nitrite was not pronounced. Higher values of phosphate were estimated during monsoon and lower values during pre-monsoon. Silicate showed large fluctuations during the study period and presented many fold increase during monsoon.

2.1.8 Turbidity:

Turbidity is the measure of clearity of water. As the amount of suspended sediments in the water increases, the turbidity value also increases. Anon (2004) found that turbidity values showed clear seasonal variation. During pre-monsoon, turbidity ranged between 0.9 NTU and 15.5 NTU at surface with an average of 5.8 NTU and at the bottom, the range was from 1.4 to 12.7 NTU with an average of 7.3 NTU. During monsoon period, it increased and ranged between 0.49 and 28.7 NTU (average 12.2NTU) at surface and ranged between 0.57 and 36.9 NTU(average 16 NTU) at the bottom. During post monsoon period the surface and bottom values ranged between 0.1 and 13.3 NTU(average 3.4NTU) and between 0.23 and 26.5 NTU (average 6.1NTU) respectively. Jayasree (2009) studied the Cochin backwater of Panangad region and found a turbidity range of 9.3 NTU to 38.95 NTU. She recorded maximum value during the second half of July and minimum was during the second half of November.

2.1.9 Primary productivity:

Cochin backwater is one of the estuarine areas in India, which has been subjected to extensive biological research work. The tropical estuary, with high primary productivity acts as a nursery ground for many species of marine finfishes, molluscs and crustaceans.

Primary productivity gives essential information in assessing the fertility of aquatic system (Anon, 2004) and predicting the potential of living resources.

Primary productivity of Cochin backwater and adjacent estuarine system were studied by several workers (Qasim, 1979; Qasim *et al.*, 1974; Nair *et al.*, 1975; Pillai *et al.*, 1975; Paulinose *et al.*, 1981; Gopinathan *et al.*, 1984; Sreekumar and Joseph, 1997; Renjith *et al.*, 2004 and Anon 2004).

Pillai *et al.*, (1975) observed comparatively lesser rates of production during the monsoon. Nair *et al.*, (1975) reported maximum rate of primary productivity of 3gC/m^2/day with an average of 1.2gC/m^2/day in Vembanad Lake.

The estimated gross production (GPP) ranged from 272-293 gC/m^2/yr and primary net production in Cochin backwater was 193gC/m^2/yr.

Primary production showed considerable seasonal variation with post monsoon season recording the peak value of 125 mgC/m^3/dayr (Pillai *et al.*, 1975) and lesser values were observed during monsoon in Vembanad Lake. The reason behind this may be due to optimum light intensity and effective utilization of nutrients (Menon *et al.*, 2000). Gross primary productivity ranged between 0.57 and 16.339 gC/m^2/day in a study conducted by Venketesan *et al.*, (2001) in Puduveypu and Valappu. He also observed that primary productivity was relatively more in Puduveypu than at Valappu. The reason for this high primary production in Puduveyppu was attributed to relatively higher tidal influence observed at Puduveypu than Valappu which brought more nutrients for the growth and multiplication of phytoplankton.

Anon (2004) found a trimodel pattern with maximum values during November, April and July. Renjith *et al.,* (2004) observed maximum primary production during post monsoon and minimum during monsoon season.

It is understood that salinity is the most important parameter that controls the phytoplankton diversity and succession (Menon *et al.*, 2000). Of the various categories, nanoplankton comprising diatoms is relatively high through out the year (Qasim *et al.*, 1974, Kumaran and Rao, 1975). They also found that around 70% of the total phytoplankton was contributed by skeletonema costatum. Gopinathan (1975) had inferred the proliferation of diatoms or biological spring fell during the monsoon months, when the diatoms peak coincides with the low salinity and temperature associated with high concentration of nutrients.

According to Menon *et al.,* (2000) the phytoplankton production in the Cochin estuary during Pre-monsoon was high and fairly stable with the dominant diatoms being Chaetoceros, Casinodiscus, Skeletonema. Pleurosigma and Nitzchia and dinoflagellates of the the genera Peridinium, Gymnodinium and Ceratium. During monsoon, flora was mostly fresh water species of the genera Pledorina, Volvox, Pediastrum mand Desmids. While during post monsoon gradually fresh water species disappear, coinciding with predominance of marine forms. Kumaran and Rao (1975) were of the opinion that most of the species recorded in the Cochin backwater were marine forms and the area near the bar mouth was the most productive area. Sreekumar and Joseph (1995) estimated that periphytic algae of Cochin backwater weer comprised of 66 species of Bacillariophycea, 8 species of Chlorophycea and 2 species of Cyanophycea.

Gopinathan (1972) found that the temperature had no direct effect on phytoplankton production. About no species of plankton were recorded by him. He also observed 2 peaks of abundance. One from May to July and the other from October to December.

Gopalkrishnan *et al.*, (1988) studied about phytoplankton present in paddy cum prawn culture fields at four locations in and around Cochin backwater. Total phytoplankton count in the seasonal and perennial fields in all the four areas showed maximum during monsoon period.

Balasubramanium *et al.*, (1995) carried a study in two adjoining culture ponds at Vallarpadom Island and found that phytoplankton was largely represented by diatoms, dinoflagellates and cyanophycea.

A pioneering attempt of making quantitative and qualitative study of zooplankton of the Cochin backwater was by George (1958). He attempted to correlate the seasonal fluctuations of the zooplankton population with change in the salinity of water.

There are several reports on the seasonal and spatial changes of zooplankton of Vembanad lake and connected backwaters (Nair and Tranter, 1971; Menon *et al.*, 1971; Haridas *et al.*, 1973; Wellershaus, 1974; Madhupratap, 1978).

Menon *et al.*, (1971) investigated the total faunal composition of zooplankton in Cochin backwater and found that three groups viz Copepod, decapods larvae and cladocerons dominated the total zooplankton. He also observed that no single group continued to dominate the community though copepod were the major component of the community for most part of the year and abundance of Cladocerons was noted only during the low salinity period.

Distribution pattern of zooplankton in the Cochin backwater suggested that salinity is the major limiting factor controlling abundance (Menon *et al.*, 2000). All groups of zooplankton exhibited seasonal changes according to the seasonal changes in salinity (Nair and Tranter, 1971; Haridas *et al.*, 1973; Wellershaus, 1974; Madhupratap and Haridas, 1975; Rao *et al.*, 1975; Madhupratap, 1978 and Silas and Pillai, 1975).

Jose *et al.*, (1988) studied the zooplankton of brackish water fish farm in the southwest coast of India and reported that the zooplankton mainly composed of copepods with an average annual mean of 170 nos./litre.

Joseph (1988) reported that in the culture fields the zooplanktons were constituted mainly by copepods, rotifers and crustacean larvae.

Nair et al., (1988) studied four areas in and around Cochin and came to the conclusion that in general, in all the areas the zooplankton community was represented by one or two groups durinng the low salinity regime and the the zooplankton increased as the salinity increased. The dominant groups of zooplankton are copepods, amphipods, fish larvae and decapod larvae. Primary production of Cochin backwater in the Panangad region was maximum during pre-monsoon when the light intensity was maximum and minimum During monsoon due to low light intensity (Devi, 2009). She recorded a maximum value of 3300.15 mg C/ m^3/ day.

2.1.10 Chlorophyll-a:

Chlorophyll is probably the most often used estimator of algal biomass and hence its measurement is an alternative approach to estimation of primary production. Nair *et al.*, (1975) reported an annual range of 2 to 21 mg/m^3 in entire Vembanad Lake. Selvaraj et al., (2003) reported values of 6.14 mg/m^3 4.93 mg/m^3 and 8.85 mg/m^3 for pre-monsoon, monsoon and post monsoon periods respectively near Thevara with an annual mean of 6.64 mg/m^3. Anon (2004) studied the circulation and mixing and their influence on productivity of Panangad region of Vembanad Lake. He found that chlorophyll-a ranged between 1 mg/m^3 and 34.61 mg/m^3 and the average was 9.83 mg/m^3. It was found that the chlorophyll distribution follows the trend of primary production, showing a primary peak during post monsoon season and others during monsoon and pre-monsoon.

2.1.11 Macro benthos:

Benthos plays a major role in the formulation of strategy for bioconservation. It is also useful for understanding the changes in biological diversity. The benthos serves as useful indicators of health of estuaries and near shore waters.

Kurian (1967) studied the benthos of south west coast of India and stated that apart from salinity, temperature and substratum 'food supply' or detritus plays an important role in benthic biomass. Desai and Krishnakutty (1969) compared the estuarine benthic fauna with marine benthic fauna and of the near shore region of Arabian Sea at Cochin and reported the difference between two ecologically different systems and the factors governing the abundance of benthos. Devassy and Gopinathan (1970) reported that there was an increase in benthic biomass from marine to freshwater region of

Cochin backwaters during monsoon. Damodaran (1973) studied the benthos of mud banks of Kerala and found that macrofauna consist mainly of polychetes, crustaceans and molluscs. Ansari (1974, 1977), Saraladevi and Venugopal (1989) and Sunil Kumar (1995) observed a progressive reduction in the faunal diversity and abundance with decreasing salinity from the lower reaches of Cochin backwater towards the upper reaches. Gopalan *et al.,* (1987) observed rich bottom fauna during the monsoonin the Vembanand Lake.

The meiobenthos of three different types of tradiotional prawn culture systems around Cochin were studied by Preetha and Pillai (2000) and they reported that nematodes were the most dominant group (79.6%) of the total meiofauna followed by harpacticoids and polychaetes. The perennial ponds had the highest abundance of meiobenthos (69.9%) followed by canals (17.9%) and seasonal cultural fields (12.2%).

The benthic fauna is mainly composed of polychaetes, molluscs and crustaceans in the order of abundance in the Cochin backwaters (Sunil Kumar, 2002). He studied the biomass distribution, horizontal zonation, relative dominance and vertical distribution of polychaetes in the littoral sediments of Cochin estuarine mangrove habitat and found that there was substantial amount of polychaete biomass existing in the region and it could be used for assessing the commercial demersal fishery potential.

Jayasree (2009) studied the structural and the seasonal changes of the macrobenthic community in relation to the hydrography of a prawn filtration pond in Panagad region of the Cochin backwater. She found that the macrobenthic groups obtained were polychaetes, tenaids, amphipods, bivalves and gastropods.

2.2 SEDIMENTARY CHARACTERISTICS:

In aquatic ecosystems, the sediment acts as the storage reservoir of nutrients materials in water. The replenishment of the nutrients in time and their consequent removal greatly helps in the biological cycle of the system. The geology and topography of the sediment determines the erosion and transport processes. Anthropogenic contaminants, including metals, organics and nutrient elements are associated with particulate and dissolved inputs to the natural inputs to the natural waters. Typically sediments are characterized as coarse material clay/silt and sand fractions. The exchange of nutrients depends upon the characteristics of sediments and the hydrographic features of the estuary (Gupta *et al.*, 2001).

In the Cochin backwater, there is wide range of substratrum types. There is coarse sand and clay near the bar mouth, sandy mud in the upper reaches , muddy sand at the junction of two channels and fine sand silt in the shallow regions. The nature of the deposits has a close relation to the current system in the estuary (Kurian, 1972).

The pH of mangrove sediment is governed by the concentration of reduced ions and manganese hydroxide and carbonates, carbonic acid and humic acid (Patric and Mikkelsen, 1971). Ignatius (1995) studied the soil pH of certain prawn filtration ponds at Chellanam and Poyya. Venkatesan *et al.*, (2001) reported that sediment pH ranged between 6.9 and 7.5 during pre monsoon in prawn filtration fields of Vypeen island of Cochin. Pre-monsoon recorded minimum pH values and was found that the values increase during monsoon indicating an enhanced microbial activity in summer months in Cochin backwater (Shaly, 2003).

Sediment composition of Cochin backwater varied from place to place and season to season (Josanto, 1971). Murty and Veerayya

(1972) studied the sediment composition of Vembanad Lake and four types of sediments like sands, silty sands, silty clays and clays silts having having higher organic matter when grain size is finer. Pillai (1977) based on his study, categorises sediments into clays silt with very little sand, sandy, (sand, silt, clay) in equal proportion and sandy mud. Kotmire and Bhosale (1979) analysed the sediments of Deogad and Mumbra and recorded 83.42% sand at Deogad while the sediments from Mumbra had 81.17% of sand.

Nagarjaiah and Gupta (1983) reported, in general, reduction the organic carbon content during the post monsoon and preb monsoon moths. The value ranged between 0.65 and 4.25%. The high carbon value was recorded during July and it might be due to the settled dead and decaying planktonic organisms as a result of sudden drop in salinity. Joseph (1988) found that soil particles were constituted by sand (89%), silt (3%) and clay (8%) in brackish water culture fields at Cochin. Alagarsamy (1991) reported high values of total organic carbon in Mandovy estuary. The texture of the sediment has a profound bearing on the physico chemical processes as well as the biological stock/diversity of depositional environment (Sunilkumar, 1997). In Cochin backwater, in general, the percentage of sand was high and relatively lower percentage of silt and clay may be due to constant tidal flushing (Sunilkumar, 1995). Ramanathan (1997) studied the sediment characteristics at Pitchavaram area and found that the sand and silt constituted 70-90% followed by clay. Sediment texture primarily designates the size, shape and mutual relationship particles constituting sedimentary deposits (Badarudeen *et al.,* 1998). Chinnadurai and Fernando (2003) found coarse and fine sand range from 80-98% at Pitchavaram mangrove area. Organic carbon represents the the organic matter in the sediment and this of potential significance for aquatic productivity. Estimation of organic carbon represent can serve as an important tool in determining the status of food availability to benthic fauna and indicates the extent to which the bottom is fertile for the sustenance of benthic fauna (Manjappa *et al.*, 2003).

Marakala *et al.*, (2005) analysed the sediment in the mangrove fringe along south west coast of India revealed the dominance of sand over clay and silt fraction. He observed an increased percentage of sand during pre monsoon and monsoon months. Similar observation was obtained by Untawale and Purulekar (1976). Renjith (2006) reported a combination of clay, sand and silt and the composition of the sediments showed distinct spatial variation, but the seasonal variations were minimum at Panangad area.

Ansel et al.(1972) studied the the sediment characteristics of south west coast of India and reported that organic carbon of sand was low during monsoon and reached peak values in sand and surf water during June/July due to heavy rain, resulting in erosion of organic materials in sand getting washed into the water. Boyd (1977) noticed that the organic matter content in bottom soils increases with increasing water depth. Sajan and Damodaran (1981) studied organic matter content in sediments of Ashtamudy Lake and found that it varied from 0.3% to 12.25% dry weight sediment.

Nasnolkar *et al.* (1996) studied the sediment of Mandovi estuary and reported that the organic carbon ranged between 1.04 and 32.77mg/g. Sunilkumar (1996) observed that total organic carbon at mangrove area of Cochin showed the values ranging between 0.17% and 4.05%. Badarudeen (1997) found the organic carbon range in between 0.64 and 7.94% in mangrove areas of Kerala. Chinnadrai and Fernando (2003) found that total organic carbon content ranged between 1.0 and 9.76 mg C/g. Shalay (2003) reported that total organic carbon ranged between 6.2% and 11.7% in Cochin mangrove area. Total organic carbon Cochin backwater areas ranged between 2.2 and 6.7% dry weight (Joseph *et al.*, 2008).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

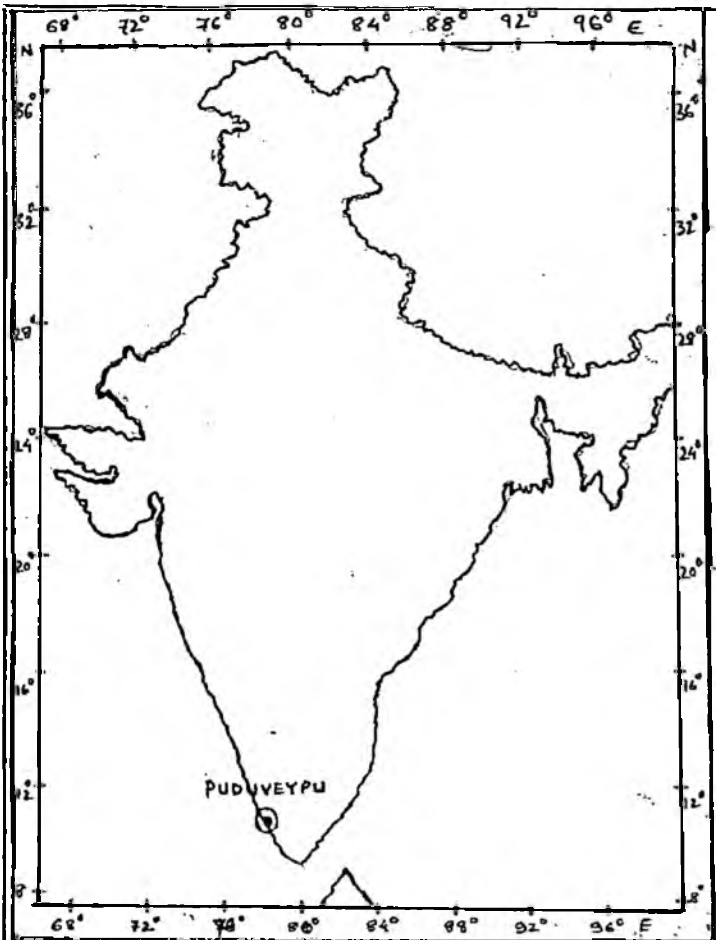
3.1 SELECTION OF THE STUDY FIELD

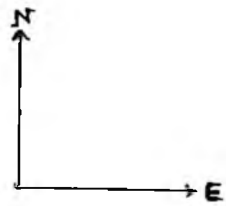
The Puduveypu is an area in the Kochi backwater system and is well known for its role as a biodiversity rich spot. The primary and secondary productions of Puduveypu region is to a great extent, influenced by the presence of mangroves in the area by its leaf litter fall. The hydrographical parameters of a region influence the diversity of species. Information on various physico-chemical and biological processes will help to know the ecological processes of the region which support the fishery resources. Detailed studies have not been carried out on the hydrography and biodiversity of Puduveypu region.This study was to understand the temporal variation of hydrographical parameters of the backwaters of the Puduveypu region and to understand the biodiversity.

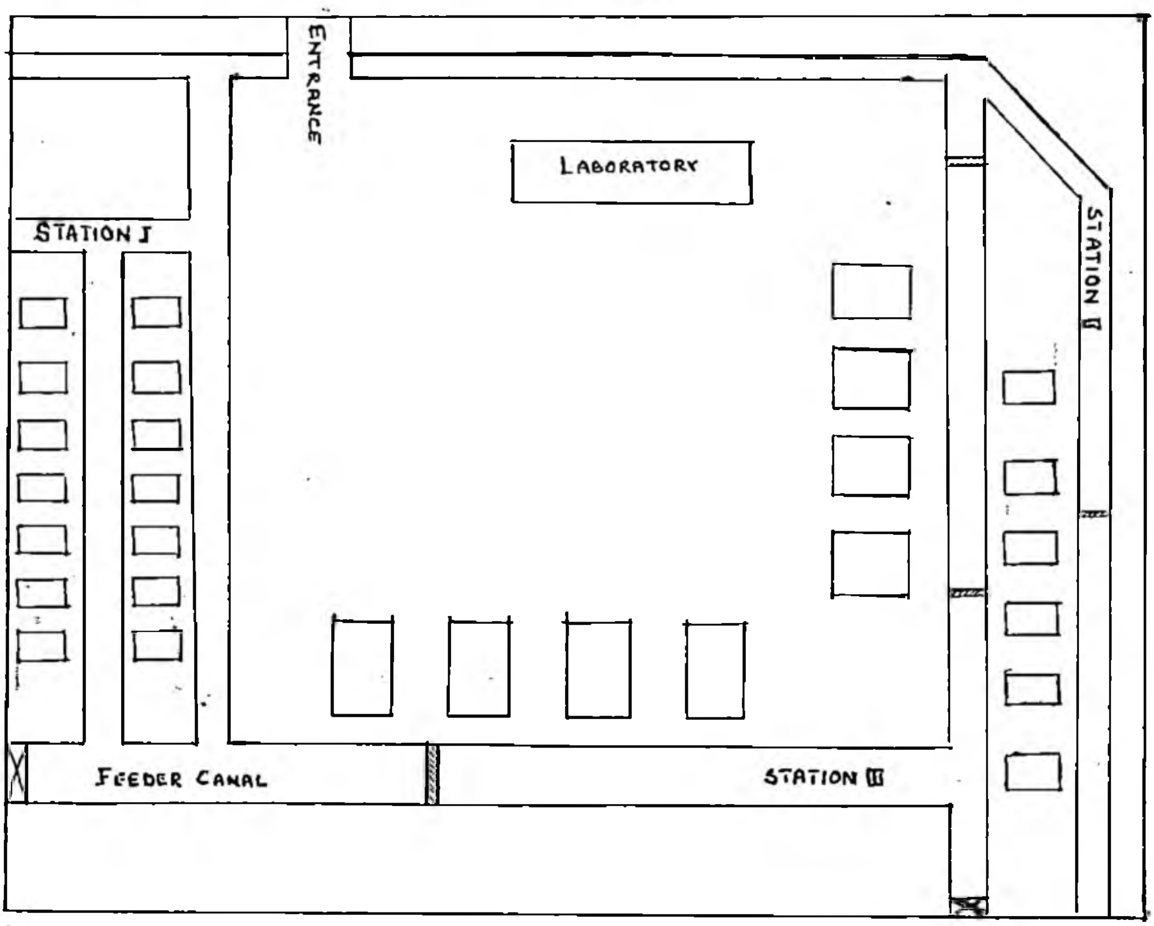
The study was carried at the Fisheries Research Station, Puduveypu. This station is located in the south western tip of Vypeen Island, adjacent to Cochin bar-mouth. Aquaculture activities are carried out in an area of 2.7 ha. Feeder canals, channels etc., covered an area of 1.3 ha. Areas of 10 ha of low lying marsh land are covered with different species of mangroves.

Three stations were selected in the area for the study. The first station was a small canal which was surrounded by mangroves. The second station was an interior location and third station was in a big canal system. All these three canals are interlinked to each other by feeder canal system. Since there was a mixing of water through these feeder canals among the three stations, so between stations comparision was not done.

POSITION AND LAYOUT OF PUDUVEYPU FISHERIES RESEARCH STATION







3.2 STUDY PERIOD

The study was conducted for the period from April, 2010 to April, 2011. Meteorologically the whole study period can be classified as pre-monsoon (April –May), S.W. monsoon or monsoon (June –September), post monsoon (October-November) and N.E. monsoon (December- February) and also the Pre monsoon of 2011 (March-April).

3.3 SAMPLING FREQUENCY

Water samples were collected fortnightly, in the morning hours (7.00-8.00 am). Collection of sediments was done on monthly basis. Monthly averages were computed from the fortnightly data of the three stations.

3.4 METHODS OF ANALYSIS

3.4.1 HYDROGRAPHICAL PARAMETERS

3.4.1.1 Salinity

Salinity determination was done by Knudsen-Mohr titration method (Grsshoff *et al.,* 1983). The standardization of silver nitrate was done by using standard sea water I.A.P.S.O. and Potassium chromate was used as the indicator.

3.4.1.2 Water temperature

The surface water temperature was measured immediately after the sample collection by using a mercury thermometer.

3.4.1.3 Hydrogen ion concentration (pH)

pH was determined using a pH pen. Each time prior to the analysis, the instrument was calibrated using buffer tablets of pH 4.

3.4.1.4 Dissolved oxygen

Standard Winkler's method (Strickland and Parson, 1972) was followed for the estimation of dissolved oxygen content of water samples. Surface water samples were collected *in situ* in 125 ml clean oxygen bottles without trapping of air bubbles. Immediately after collection of water sample D.O. was fixed by Winkler's reagents.

3.4.1.5 Total Alkalinity

Total alkalinity estimation was done by using acidimetric titration (Lenore *et al.,* 1998). The titration was carried out by using standard hydrochloric acid and methyl orange taken as the indicator.

3.4.1.6 Hardness

The hardness of the sample was determined by using complexometric titration (APHA, 1995). The indicator employed was eriochrome black T.

3.4.1.7 Nutrients

For determination of nutrients surface water samples were collected from all the three stations and were transferred into clean plastic bottles of 250 ml capacity. The bottles were stored in ice-box with ice and subsequently kept in a freezer till analysis to prevent the loss of nutrients during storage. Nutrients like Nitrate-N, Nitrite-N, Phosphate-P and Silicate-Si were analyzed in laboratory following standard photometric methods (Grasshoff *et al.,* 1983) using UV-VIS spectrophotometer (JASCO, V-530). Phosphate and reactive Silicon were estimated by standard Molybdenum blue method. Nitrate was first reduced in cadmium column and analysed as nitrite and reading was taken on spectrophotometer (Grasshoff *et al.,* 1983). Nitrite estimation was done by Photometric method, reaction of nitrite with an aromatic amine leading to the formation of diazonium compound which is then coupled with another aromatic compound to form an azodye (Grasshoff *et al.*, 1983).

3.4.1.8 Turbidity

Turbidity of sample was estimated by the use of digital nephelo-turbidity meter (Systronics, 132) immediately after collection. Calibration of the instrument was done with standard formazin suspension prepared by mixing hydrazine sulphate and hexamethylene tetramiine (APHA, 1998). The well mixed sample prepared by gentle agitation, was poured into the sample cell without air bubbles. The turbidity was read directly from the instrumentdisplay and was expressed in NTU (Nephelo Turbidimetric Unit).

3.4.2 BIOLOGICAL PARAMETERS

3.4.2.1 Primaty productivity

Gaarder and Graan's light and dark bottle method was used for primary productivity estimation. One dark and two lights bottles of 125 ml capacity, were filled with the water samples collected, without trapping of air bubbles. Oxygen in one of the light bottle was fixed immediately. The second light and dark bottles were incubated in water for four hours in identical condition in a tray filled with water in the same sampling site. After incubation bottles were taken out and the DO was fixed. The dissolved oxygen was determined titrimetrically using standard Winkler's method (Strickland and Parsons, 1972). From the difference in dissolved oxygen content of dark and light bottles, gross primary productivity was calculated.

3.4.2.2 Netting of fishes:

For collection of fishes, shellfishes and crabs: cast net was used as the main gear. From all the three stations cast netting was done to catch the species. Netting was done monthly. The species collected were identified to the genus level (Chhapgar, 1957: Francis Day *et al.,* 1978: Fisher and Bianchi, 1984: Munro, 1982).

3.4.2.3 Mangrove plants:

Mangrove plants available in that area were identified upto genus or species level based on literature (Anupama and Sivadasan, 2004; Singh and Odaki, 2004).

3.4.3 SEDIMENT ANALYSIS

For analysis of sediment, sediment samples were collected by using Van Veen grab which have a biting area of 0.042 m^2. Sediment analysis is done for estimation of sediment pH, total organic carbon and soil texture. The soil samples were sun dried and thereafter powdered using a motor and pestle and treated with hydrochloric acid and phosphoric acid. Then it is washed properly with distilled water and air dried. It was then stored in air tight shelf sealing polythene covers to determine soil texture.

3.4.3.1 Sediment pH:

Sediment pH was determined using a digital pH meter (Systronics, MK IV). The determination was done within 15 minutes of sample collection. The instrument was calibrated each time before taking reading with pH of 4.0 and 9.2.

3.4.3.2 Total organic carbon:

Back titration method (Gaudette and Flight, 1974) was used for determination of total organic carbon.

3.4.3.3 Sediment texture:

Texture analysis was carried out by sieving and pipette analysis. A known weight of wet sediment was dispersed in 0.025N Sodium Hexametaphosphate solution. The sand fraction was separated from the dispersed sediment by wet sieving using ASTM 230 mesh size (mesh size 63 micron) to separate the sand from silt and clay. The filtrate containing silt and clay in unknown proportions was subjected to pipette analysis (Krumbein and Pettijohn, 1938). Sediment nomenclature was taken from Folk (1974).

3.5 STATISTICAL ANALYSIS

To study the relationship among different hydrographical parameters, linear coorelation coefficients (r) were worked out (Snedecor and Cochran, 1968). The computed values of correlation coefficients (r) were tested for statistical significance at 1% and 5% level. The data on water quality parameters were subjected to statistical analysis employing ANOVA technique to assess significant among the seasons.

RESULTS

4. RESULTS

4.1 HYDROGRAPHICAL PARAMETERS:

The temporal variation in the hydrography and biodiversity of the brackishwater of Puduveypu was studied. The average fortnightly data on hydrographical parameters are presented in Table 1(a&b) and the corresponding graphs are presented in Fig (1-10). The summary statistics for fortnightly data are presented in table 2 and for different seasons are presented in Table 3. The Figures from 11-20 shows the graph for seasonal variation of hydrographical parameters. The results of statistical analysis are presented in Table 4 and 5.

4.1.1 Salinity:

The salinity in the backwaters of Puduveypu showed wide fluctuation and ranged between 0.06‰ and 27‰ during the study period [Table1 (a), Fig 1].The average salinity during the study period was found to be 10.15‰ (Table 2). The maximum value was recorded in the second half of January (27‰). The average salinity during the N.E. monsoon period was found to be 21.47‰. The salinity was very low (12.12‰) during the period from April to May due to pre-monsoon showers. As the monsoon progressed the salinity further decreased (3.07‰) due to heavy rainfall and land runoff. The values showed an increasing trend in the post monsoon period (Oct-Nov) and the trend continued in the N.E. monsoon season (Dec-Feb) [Table 3(a), Fig 11]. The range and mean of salinity in the four seasons are given below

Seasons	Range	Mean
Pre-monsoon	: 10.98‰-14.45‰	12.12‰
Monsoon	: 0.06‰-9.98‰	3.07‰

Post monsoon	: 1.56‰-10.81‰	5.34‰
N.E. monsoon	: 16.90‰-27‰	21.47‰

The seasonal means were compared using one way ANOVA (Table 4). It showed overall significance among the mean salinity value of the four seasons ($P<0.01$) (Table 4). Multiple comparision test showed significant difference in all pairs except between monsoon and post monsoon seasons (Table 5)

Salinity showed significant positive correlation with temperature ($r=0.44$) and hardness ($r=0.55$) and significant negative correlation with pH ($r= -0.52$), dissolved oxygen ($r= -0.865$), nitrate-N ($r= -0.682$) and silicate-Si ($r= - 0.61$) [Table 14].

.1.2 Water temperature:

The average temperature during the study period was 26.5°C (Table 2). The highest temperature (30°C) was observed during the second half of April and the lowest temperature (22°C) was observed during the first half of October [Table 1(a), Fig 2]. The average temperature was 28.9°C during pre-monsoon. But it decreased (26.43°C) during the monsoon period. The temperature further decreased (23.65°C) during post monsoon period; and then increased to 24.72°C during N.E.monsoon [Table 3(b), Fig 12]. The range and mean of temperature in four different seasons are

Seasons	Range	Mean
Pre-monsoon	: 28 °C-30°C	28.9°C
Monsoon	: 23.7°C-28.8°C	26.43°C
Post monsoon	: 22°C-25.4°C	23.65°C
N.E. monsoon	: 22°C-27°C	24.72°C

Statistical analysis using one way ANOVA showed overall significance among the mean temperature values of the four seasons (P<0.01) (Table 4). Multiple comparision tests showed significant difference in all pairs except between N.E. monsoon and monsoon season (Table 5).

Water temperature showed significant positive correlation with salinity (r=0.440), alkalinity (r=0.6), hardness (r=0.729), nitrite-N (r=0.622) and phosphate-P (r=0.528). It showed significant negative correlation with dissolved oxygen (r= -0.62), nitrate-N (r= -0.760), silicate-Si (r= -0.712) and transperancy (r= -0.484) [Table 14].

4.1.3 HYDROGEN ION (H+) CONCENTRATION or pH:

pH of the study region varied between 7.58 and 9.35. The average pH, estimated during the study period was 8.42 (Table 2).

In the pre-monsoon period of 2010, the pH value ranged between 8.65 and 8.86 with an average of 8.75. But in the next pre monsoon period the range was between 7.28 and 7.67. The average value during monsoon was 8.90 [Table3 (c), Fig 13] with a maximum of 9.35 by the second half of August [Table 1 (a), Fig 3]. pH showed a variation between 7.79 and 8.25 in the post monsoon season with an average of 8.02 (Table 2). During the N.E. monsoon the value decreased slightly (7.82). The range and mean of pH for the four seasons are given below:

Seasons	Range	Mean
Pre-monsoon	: 8.65-8.86	8.75
Monsoon	: 8.03-9.35	8.91
Post monsoon	: 7.79-8.25	8.02
N.E. monsoon	: 7.58-8.03	7.83

Statistical analysis to find out the seasonal variation in pH, by one way ANOVA showed overall significance in pH ($P<0.01$) (Table 4); but no significant difference were observed between premonsoon and monsoon, monsoon and postmonsoon and also between post monsoon and N.E. monsoon (Table 5).

pH showed significant positive correlation with alkalinity ($r=0.595$), nitrite-N ($r=0.588$) turbidity ($r=0.515$), primary production($r=0.61$) and chlorophyll ($r=0.66$). It showed a significant negative correlation with salinity ($r= -0.52$) and transparency ($r= -0.429$) [Table 14].

4.1.4 Total alkalinity:

Generally alkalinity showed an increasing trend during the pre-monsoon, post monsoon and N.E. monsoon seasons but a decreasing trend was observed during monsoon season. But during the 2011 pre-monsoon alkalinity showed a decreasing pattern. The value of alkalinity in the study region varied between 75.50 mg $CaCO_3$/l and 240 mg $CaCO_3$/l with an average of 162.50 mg $CaCO_3$/l (Table 2). The highest value was recorded in the first half of June and minimum was estimated in the first half of October [Table 1(a), Fig 4]. The average alkalinity during pre monsson was 182.75 mg $CaCO_3$/l. The trend of variation was in increasing pattern [Table 1, Fig 14]. The average alkalinity during the monsoon season was 190.63 mg $CaCO_3$/l. During the post monsoon period the average value was 91.25 mg $CaCO_3$/l which increased to 159.03 mg $CaCO_3$/l during N.E. monsoon. The range and mean of alkalinity in different seasons is given below:

Season	Range	Mean
Pre-monsoon:	142 mg $CaCO_3$/l-216 mg $CaCO_3$/l	182.75 mg $CaCO_3$/l
Monsoon:	150mg $CaCO_3$/l-240 mg $CaCO_3$/l	190.63mg$CaCO_3$/l
Post monsoon:	75.5 mg $CaCO_3$/l-117.5mg$CaCO_3$/l	91.25 mg $CaCO_3$/l
N.E.monsoo:	110.7 mg $CaCO_3$/l-200 mg $CaCO_3$/l	159.03 mg $CaCO_3$/l

The one way ANOVA on alkalinity showed significant difference among the among the mean alkalinity values of the four seasons ($P<0.01$) (Table 4). Multiple comparision tests showed significant difference in all pairs except between N.E. monsoon and pre-monsoon, between pre-monsoon and monsoon and also between postmonsoon and N.E. monsoon seasons. (Table 5).

Total alkalinity showed significant positive correlation with temperature ($r=0.6$), pH ($r=0.595$), hardness ($r=0.683$), turbidity ($r=0.452$), primary production ($r=0.45$) and chlorophyll ($r=0.68$). It showed significant negative correlation with nitrate-N ($r= -0.593$), silicate-Si ($r= -0.63$) and transparency ($r= -0.506$) [Table 14].

4.1.5 Hardness:

Total hardness varied between 22.22 mg $CaCO_3$/l and 710.01 mg $CaCO_3$/l with an average of 349.75 mg $CaCO_3$/l (Table 2). The average value during the pre-monsoon was estimated as 512.94 mg $CaCO_3$/l. Hardness showed a decreasing trend during monsoon (Fig. 15). The minimum value was found in the post monsoon in the first half of November. The hardness showed an increasing trend in the N.E. monsoon season. The average value during the N.E. monsoon was 432.88 mg $CaCO_3$/l. In the next pre-monsoon season of 2011, the value started decreasing from a maximum of 710.01 mg $CaCO_3$/l, that was observed in the second half of February [Table 1(a) , Fig 5]. The range and mean of hardness for the four different seasons are given below:

Seasons	Range	Mean
Premonsoom:	437mg $CaCO_3$/l-598.3 mg $CaCO_3$/l	512.94 mg $CaCO_3$/l
Monsoon:	77mg $CaCO_3$/l-488 mg $CaCO_3$/l	285.46 mg $CaCO_3$/l
Post monsoon:	22.22 mg $CaCO_3$/l-48 mg $CaCO_3$/l	36.60 mg $CaCO_3$/l
N.E.monsoon:	87.9mg$CaCO_3$/l-710.01mg$CaCO_3$/l	432.88mg$CaCO_3$/l

The seasonal means were compared using one way ANOVA (Table 4). It showed overall significant difference among the among the mean hardness value of the four seasons ($P<0.01$). Multiple comparision tests showed significant difference in all pairs except between pre-monsoon with N.E monsoon and monsoon and also between N.E monsoon and monsoon seasons (Table 5).

Hardness showed significant positive correlation with salinity ($r= 0.55$), temperature ($r= 0.729$), alkalinity ($r=0.683$) and phosphate ($r=0.570$). It showed negative correlation with D.O. ($r= - 0.8$), Nitrate-N ($r=- 0.82$), silicate ($r=- 0.873$) and transparency ($r= - 0.437$).

4.1.6 Dissolved Oxygen:

The average dissolved oxygen value estimated for the study period in the study region was 5.62 mg /l (Table 2). During pre-monsoon period dissolved oxygen value remained less and the average value during the period was estimated to be 4.61 mg/l. With the onset of monsoon the dissolved oxygen value increased to 6.79 mg/l [Table 3(f), Fig 16]. During the N.E. monsoon period the dissolved oxygen showed a decreasing pattern. The minimum dissolved oxygen was in the last part of N.E. monsoon ie in the second half of February and it was 2.1mg /l. The maximum dissolved oxygen (8.95 mg/l) was ovserved during the first half of August [Table 1(a), Fig 6]. The dissolved oxygen value during the pre-monsoon 2011 was slightly lesser than the previous pre-monsoon value. The range and mean of dissolved oxygen content for the four seasons are given below:

Seasons	Range	Mean
Pre-monsoon	: 4.17 mg/l - 5.2 mg/l	4.61 mg/l
Monsoon	: 4.66mg/l - 8.95 mg/l	6.79 mg/l
Post monsoon	: 6.0 mg/l – 8 mg/l	7.32 mg/l
N.E. monsoon	: 2.1 mg/l - 5.5 mg/l	3.58 mg/l

Statistical analysis to find out the significance of variations among different seasons with one way ANOVA showed overall significant variation among the seasons (Table 4). Multiple comparison tests showed no significant difference between Post monsoon and monsoon and also between N.E. monsoon and pre monsoon (Table 5).

Dissolved oxygen showed significant positive correlation with nitrate-N ($r=0.827$) and silicate-Si ($r=0.780$). It showed significant negative correlation with salinity ($r= -0.865$), temperature ($r= -0.62$) and hardness ($r= -0.800$) [Table 14].

4.1.7 Nutrients:

Nitrate-N:

The value of nitrate-N in the study region was found in the range of 1.30μg at/l and 18.14μg at/l (Table 2). The higher values were observed during post monsoon and monsoon seasons [Table 3(g), Fig 17]. The estimated nitrate values during these two seasons were 12.51 μg at/l and 8.52 μg at/l respectively. The lower values were observed during N.E monsoon and pre-monsoon periods as 3.48 μg at/l and 3.77 μg at/l respectively. The highest value (18.14 μg at/l) of nitrate-N was observed in the second half of September

[Table1 (b), Fig 7]. The ranges and mean of Nitrate-N values for the four seasons are given below:

Seasons	Range	Mean
Pre-monsoon	: 3.68 μg at/l - 3.96 μg at/l	3.77 μg at/l
Monsoon	: 3.82 μg at/l - 18.14 μg at/l	8.53 μg at/l
Post monsoon	: 8.76 μg at/l - 18.10 μg at/l	12.51 μg at/l
N.E. monsoon	: 1.3 μg at/l - 7.76 μg at/l	3.48 μg at/l

Statistical analysis of the seasonal variation with one way ANOVA showed significant difference in Nitrate-N among different seasons ($P<0.01$) (Table 4). Multiple comparision tests showed significant difference in all pairs except between the values of post monsoon and monsoon and between pre-monsoon with postmonsoon and N.E. monsoon. (Table 5).

Nitrate–N showed significant positive correlation between dissolved oxygen (r=0.827), silicate-Si (r= 0.882) and transparency (r= 0.481). It showed significant negative correlation with salinity (r= -0.682), temperature (r= -0.760), alkalinity (r= -0.593) and hardness (r= -0.820) [Table 14].

Nitrite-N:

Nitrite value ranged between 0.20 μg at/l and 3.87 μg at/l, during the study period (Table 2). The maximum value (3.87 μg at/l) was recorded in the month of April, 2010, the beginning of the study period but in April, 2011 the value was found little lesser (2.79 μg at/l). The minimum value (0.20 μg at/l) was recorded in the first half of October [Table 1(b), Fig 8]. During the pre-monsoon and monsoon period the estimated values were 2.85 μg at/l and 1.64 μg at/l respectively. During post monsoon season the estimated nitrite content was 0.72 μg at/l which is then slightly decreased to

0.56mgat/l in the N.E. monsoon [Table 3(h), Fig 18]. The range and mean for the four seasons are given below:

Seasons	Ranges	Means
Pre-monsoon	: 1.87µg at/l – 3.87µg at/l	2.85 µg at/l
Monsoon	: 0.87µg at/l – 2.77µg at/l	1.643 µg at/l
Post monsoon	: 0.20µg at/l – 1.35µg at/l	0.72 µg at/l
N.E. monsoon	: 0.37µg at/l – 1.10µg at/l	0.558 µg at/l

Statistical analysis of nitrite-N data with one way ANOVA showed overall significant difference among the seasons (P<0.01) (Table 4). Multiple comparison tests showed no seasonal variation between postmonsoon and N.E.monsoon (Table 5).

Nitrite showed positive significant correlation with temperature (r= 0.622), pH (r=0.588), phosphate-P (r=0.455) and primary production (r=0.66). It showed a negative significant correlation with silicate (r= -0.440) [Table 14].

Phosphate –Phosphorous:

The phosphate value ranged between 2.2 µg at/l and 5.8 µg at/l during the study period (Table 2). Highest value was recorded in the second half of March and the lowest value was recorded in the first half of November [Table 1(b), Fig 9]. The mean of phosphate during monsoon period was 3.58 µg at/l. the value then suddenly decreased during postmonsoon. The phosphate concentration during during post-monsoon, N.E.monsoon and pre-monsoon periods were 3 µg at/l, 3.75 µg at/l and 5.05 µg at/l respectively which showed an increasing trend [Table 3(i), Fig 19]. The range and mean for the four seasons are given below:

Season	Range	Mean
Pre-monsoon	: 3.96 μg at/l – 5.8 μg at/l	5.05 μg at/
Monsoon	: 2.99 μg at/l – 4.72 μg at/l	3.58 μg at/l
Post monsoon	: 2.2 μg at/l – 3.9 μg at/l	3 μg at/l
N.E. monsoon	: 2.77 μg at/l – 4.72 μg at/l	3.75 μg at/l

Statistical analysis by one way ANOVA showed overall significance among the mean phosphate value of the four seasons ($P<0.01$) (Table 4). Multiple comparison tests showed no significant difference in the values of phosphate-P among post monsoon, N.E.monsoon and monsoon season (Table 5).

Phosphate value showed significant positive correlation with temperature ($r=0.528$), hardness ($r=0.570$), nitrite-N ($r=0.455$) and primary production (0.660) [Table 14].

Silicate- Silicon :

The maximum value was recorded during the last phase of the monsoon ie in the first half of September [Table 1(b), Fig 10]. Silicate varied from 7.02 μg at/l and 188.52 μg at/l with an average of 81.89 μg at/l (Table 2). The average estimated value of silicate-silicon during pre-monsoon, monsoon, post monsoon and N.E.monsoon were 31.72 μg at/l, 93.01 μg at/l, 159.03 μg at/l and 49.09 μg at/l respectively [Table 3(j), Fig 20]. Silicate-Si values remain almost same in both the pre-monsoon seasons. The range and means of silicate-silicon for the four seasons are given below

Season	Range	Mean
Pre-monsoon	: 23.33 μg at/l – 39.72 μg at/l	31.72 μg at/l
monsoon	: 36.77 μg at/l – 188.52 μg at/l	93.01 μg at/l
Post monsoon	: 99 μg at/l – 187.07 μg at/l	159.04 μg at/l
N.E. monsoon	: 7.02 μg at/l – 92.02 μg at/l	49.09 μg at/l

Statistical analysis by one way ANOVA showed overall significance among the seasons (P<0.01) (Table 4). Multiple comparision test showed significant difference in all pairs except between the values of N.E. monsoon and pre-monsoon and also between N.E.monsoon and monsoon (Table 5).

Silicate showed significant positive correlation with dissolved oxygen (r=0.780), nitrate-N (r=0.882) and transparency (r=0.565). It showed negative correlation with salinity (r=-0.61), temperature (r=-0.712), alkalinity (r=-0.63), hardness (r=-0.873) and nitrite (r=-0.440) [Table 14].

Table 1(a): Average fortnightly data on Hydrographical parameters

Months	Salinity (‰)	Temp. (°C)	pH	Alkalinity mgCaCO3/l	Hardness mgCaCO3/l	DO mg/l
April I	11.18	29	8.65	142	560.42	4.34
AprilII	14.45	30	8.70	167	598.29	4.17
May I	11.88	28	8.8	216	456.08	5.2
May II	10.98	28.6	8.86	206	437	4.76
June I	9.98	28.8	9.1	240	488	4.66
June II	9.06	28.1	8.8	210	444.48	4.90
July I	1.78	25.8	9.2	220	460	5.70
July II	1.11	26	9.3	207	458	6.21
Aug I	1.08	26.1	9.25	163	168	8.95
Aug II	0.97	26.3	9.35	185	88	7.95
Sept I	0.57	26.7	8.03	150	100.20	7.5
Sept II	0.06	23.7	8.23	150	77	8.5

Continuation of Table 1(a)

Months	Salinity (‰)	Temp. (°C)	pH	Alkalinity mgCaCO3/l	Hardness mgCaCO3/l	DO mg/l
oct I	1.77	22	8.03	75.5	48	8.0
Oct II	1.56	24.2	8.01	87	29.05	7.4
Nov I	7.23	25.4	8.25	117.5	22.22	7.9
Nov II	10.81	23	7.79	85	43.16	6.0
Dec I	17.70	25.2	8.03	110.7	87.88	5.5
Dec II	16.90	27	7.6	126	180	3.8
Jan I	25.93	27.9	7.95	162.5	420.5	3.02
Jan II	27.00	27.5	7.90	200	569.9	3.3
Feb I	20.16	26.7	7.58	188	629	3.8
Feb II	21.16	27	7.88	167	710.01	2.1
MarcI	20.33	29	7.67	176	699	2.6
MarcII	19.43	28.7	7.29	168	620	3.4
April 2011	12.39	28.9	7.28	156	587	4.02

Table 1(b): Average fortnightly data on hydrographical parameters (nutrients)

Months	NO3-N (µg at/l)	NO2-N (µg at/l)	PO4-P (µg at/l)	SiO4-Si (µg at/l)
April I	3.96	3.87	5.76	23.33
April II	3.76	3.40	5.80	27.66
MayI	3.68	1.87	3.96	39.72
May II	3.68	2.16	4.68	36.19
June I	3.88	2.67	3.26	36.77
JuneII	3.82	2.77	3.80	57.45
July I	4.87	1.8	3.18	66.25
July II	4.93	1.6	3.01	67.83
Aug I	7.60	1.24	2.99	83.83
Aug II	11.78	1.1	3.83	113.49
Sept I	13.18	1.1	4.72	188.52
Sept II	18.14	0.87	3.9	129.97

Continuation of Table 1(b)

Month	Nitrate (µg at/l)	Nitrite (µg at/l)	Phosphate (µg at/l)	Silicate (µg at/l)
Oct I	18.10	0.20	3.9	187.07
Oct II	13.92	0.23	2.8	180.00
Nov I	8.76	1.10	2.2	170.07
Nov II	9.26	1.35	3.1	99
Dec I	7.76	1.10	2.82	92.02
Dec II	3.96	0.43	2.77	67
Jan I	3.26	0.46	3.76	66
Jan II	2.89	.56	3.98	42
Feb I	1.7	.37	4.72	7.02
Feb II	1.3	.43	4.5	20.5
Mar I	0.76	1.01	5.20	1.7
Mar II	1.89	2.59	6.6	8.76
April 2011	2.88	2.79	5.96	16.66

Table 2: Summary Statistics for fortnightly data of Hydrographical parameter

	N	Minimum	Maximum	Mean	Std. Deviation
Salinity	22	.06	27	10.15	8.58
Temperature	22	22.0	30	26.50	2.02
Alkalinity	22	75.50	240	162.50	47.28
pH	22	7.58	9.35	8.42	.58
Hardness	22	22.22	710	321.59	234.17
DO	22	2.10	8.95	5.62	1.95
Nitrate	22	1.30	18.14	7.00	5.05
Nitrite	22	.20	3.87	1.39	1.03
Phosphate	22	2.20	5.80	3.79	.95
Silicate	22	7.02	188.52	81.89	57.02

FORTNIGHTLY VARIATION IN HYDROGRAPHICAL PARAMETERS

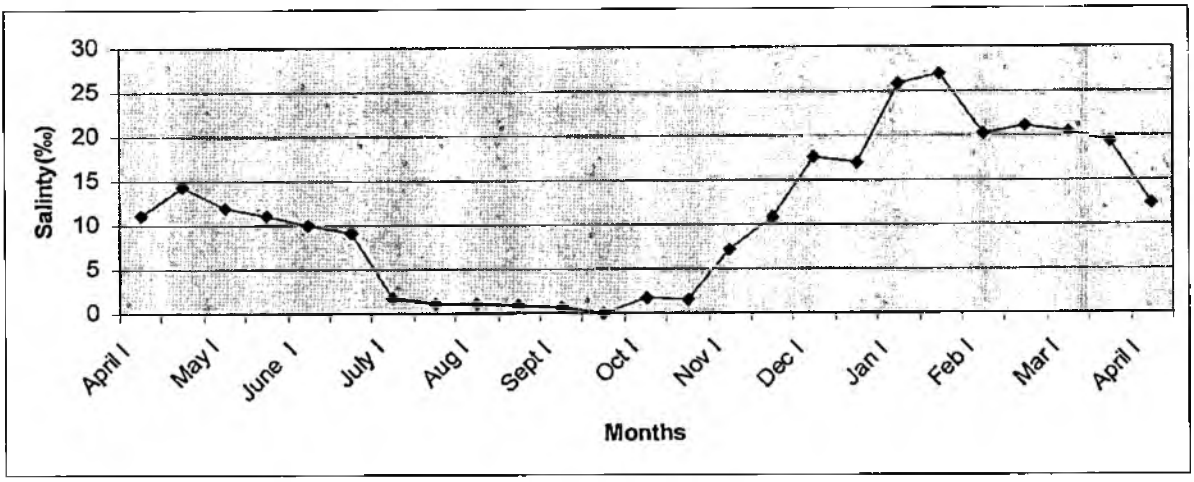


Fig1: Fortnightly variation in Salinity

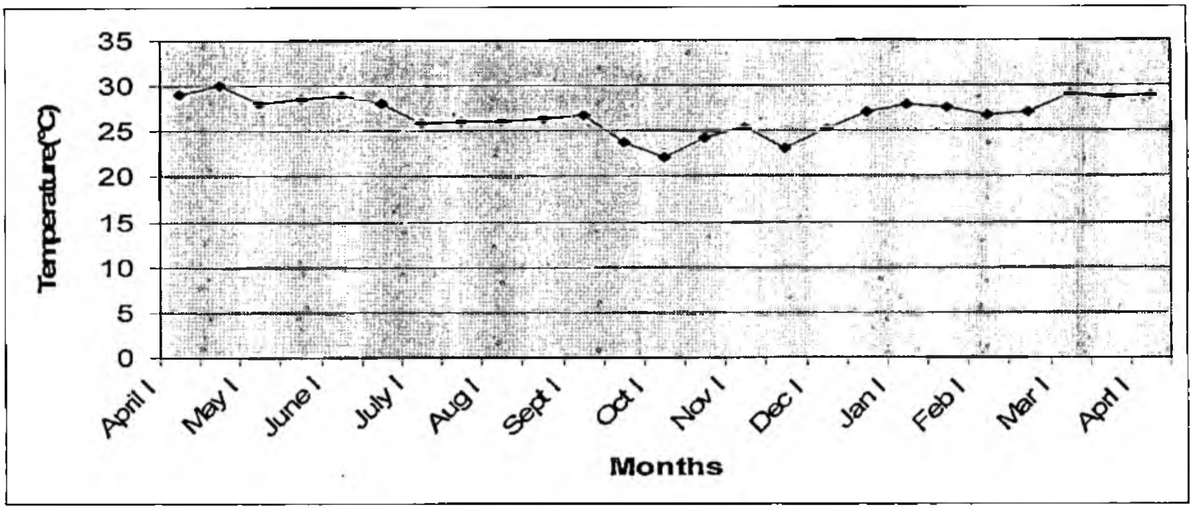


Fig2: Fortnightly variation in Temperature

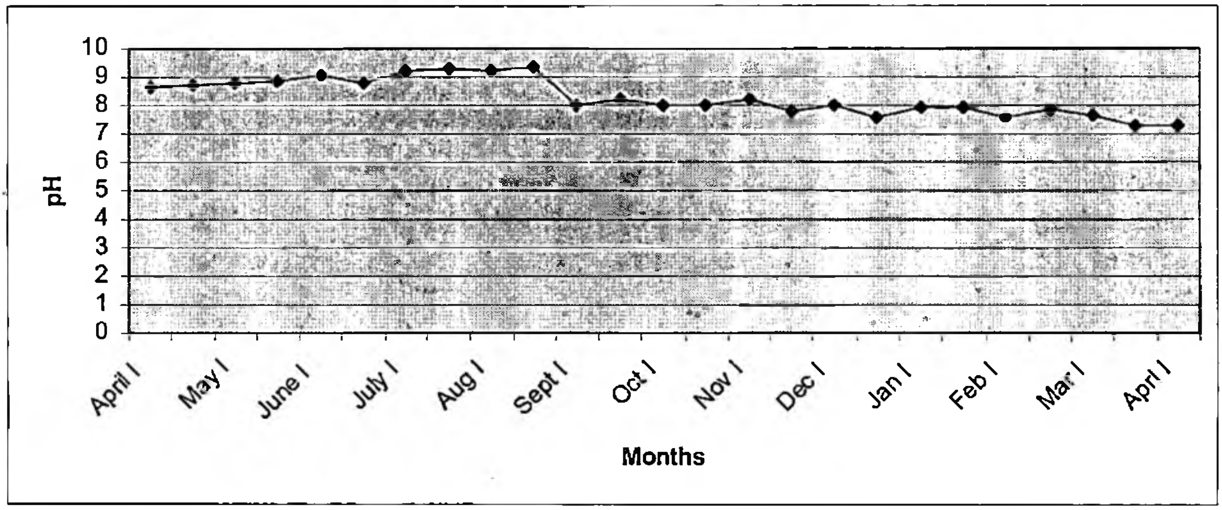


Fig3: Fortnightly variation in pH

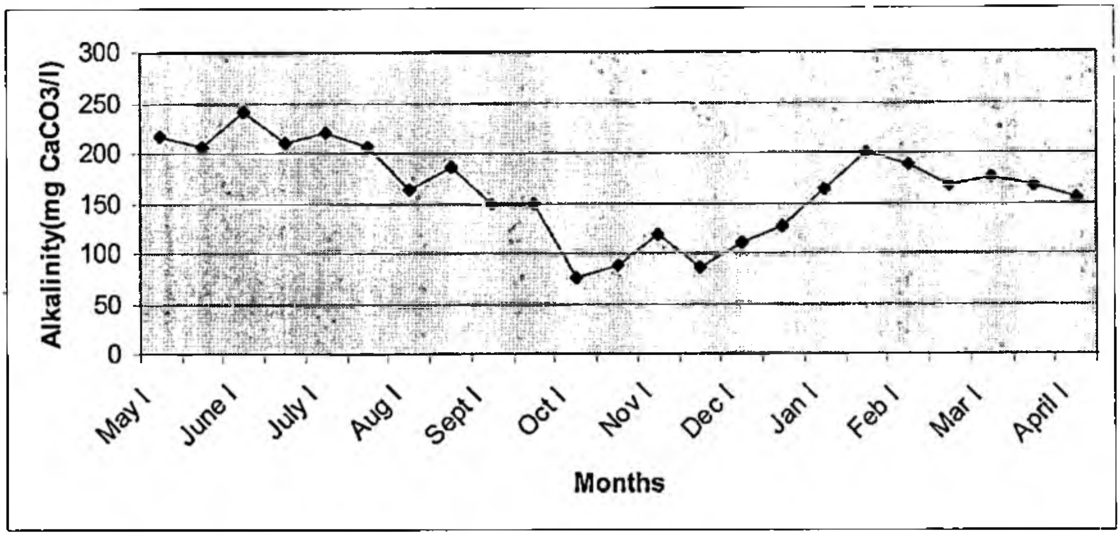


Fig 4: Fortnightly variation in Alkalinity

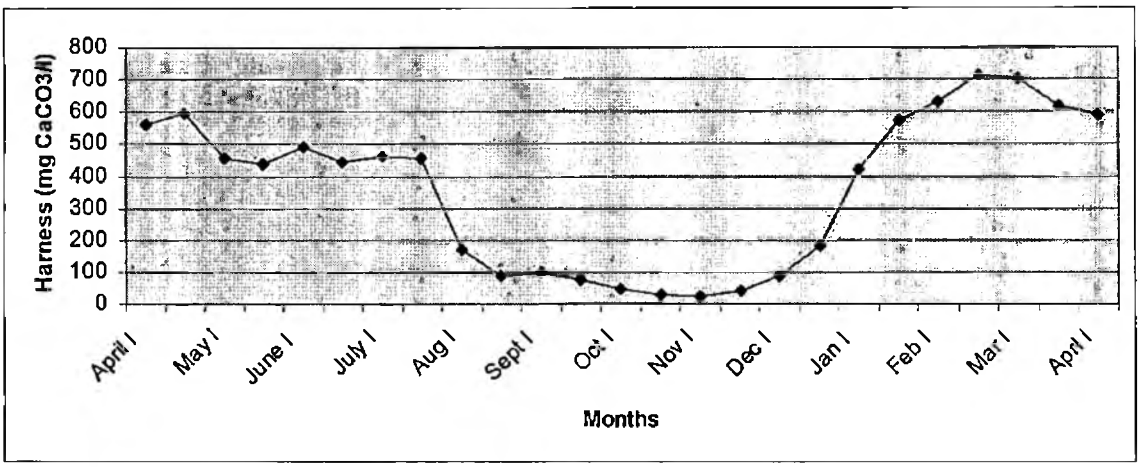


Fig 5: Fortnightly variation in Hardness

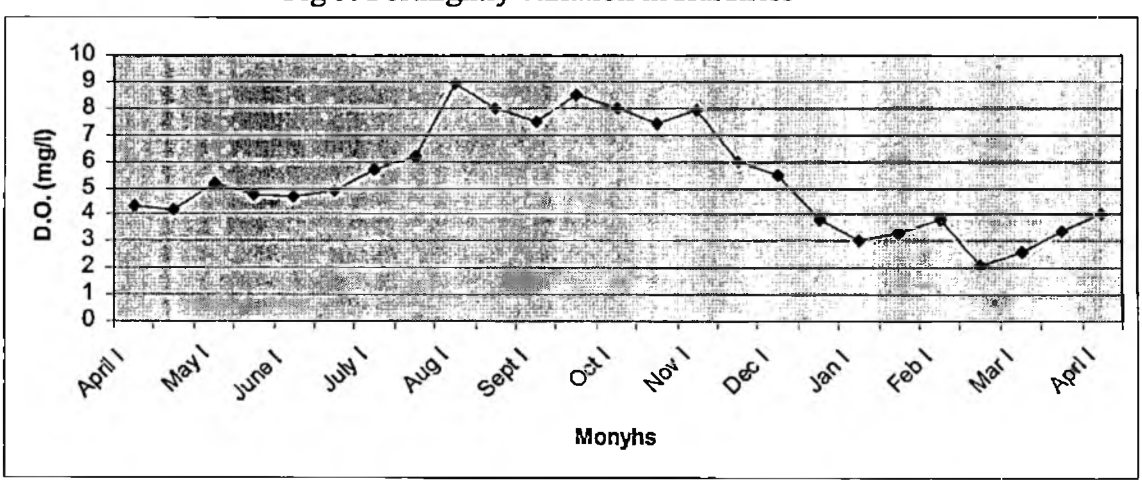


Fig 6: Fortnightly variation in dissolved oxygen

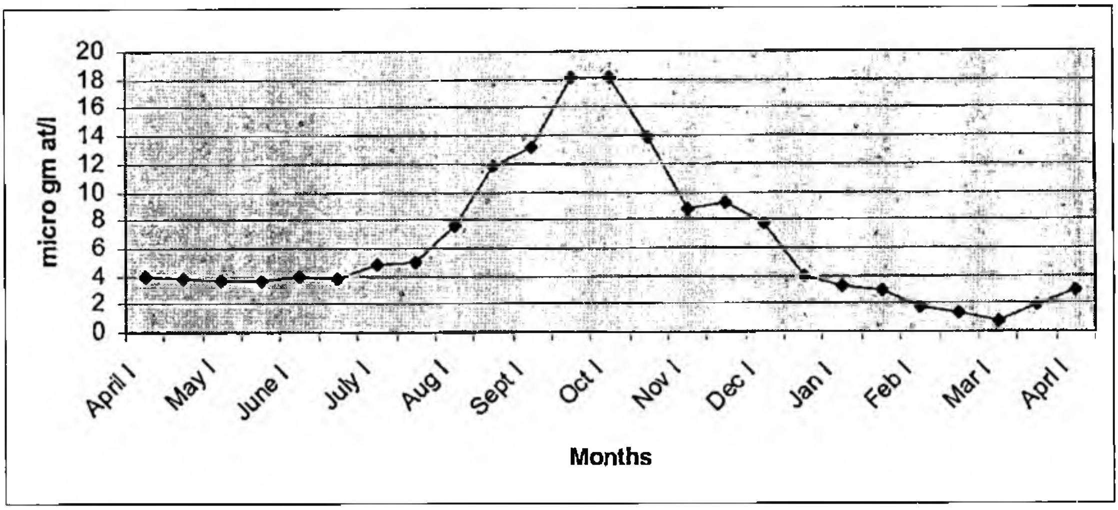


Fig 7: Fortnightly variation in Nitrate-N

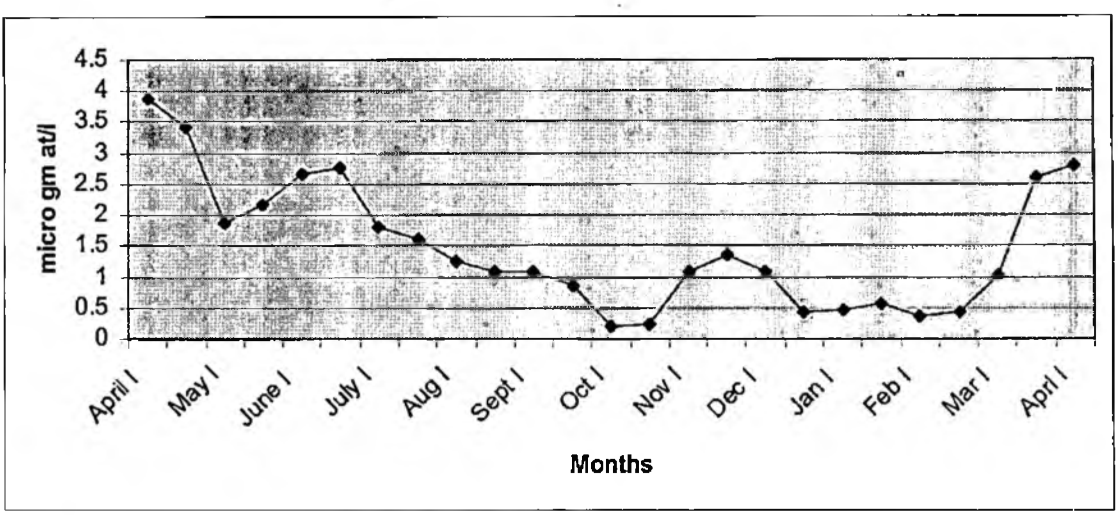


Fig 8: Fortnightly variation in Nitrite-N

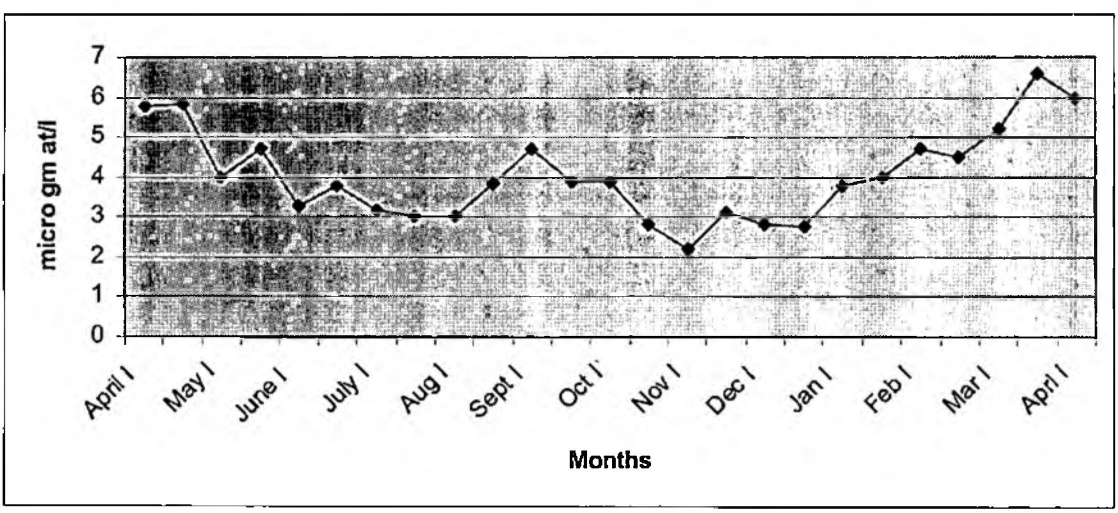


Fig 9: Fortnightly variation in Phosphate

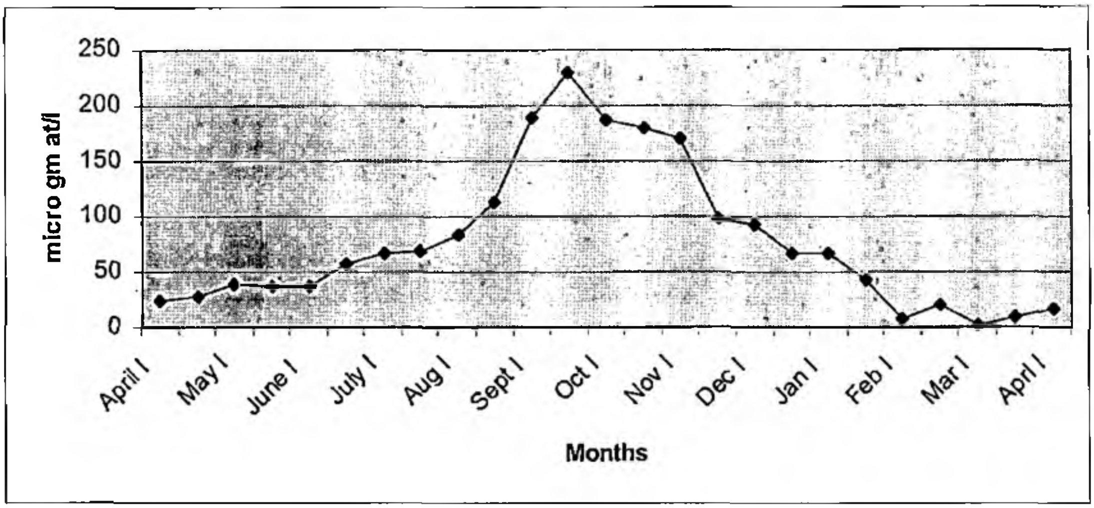


Fig 10: Fortnightly variation in Silicate-Si

Table 3: Summary statistics for seasonal data on Hydrographical parameters

Table 3(a): Salinity (‰)

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	14.45	9.98	10.81	27	20.33
Minimum	10.98	0.06	1.56	16.9	12.39
Mean	12.12	3.08	5.34	21.47	17.38
S.D.	7	4.01	4.49	4.18	4
S.E.	9	1.42	2.25	1.70	8

Table 3(b): Temperature (° C)

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	30	28.8	25.4	27	29
Minimum	28	23.7	22	22	28.7
Mean	28.9	26.43	23.65	24.72	28.8
S.D.	0.84	1.54	1.47	2.01	0.15
S.E.	0.42	0.54	0.73	0.82	0.08

Table 3(c): pH

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	8.86	9.35	8.25	8.03	7.67
Minimum	8.65	8.03	7.79	7.58	7.28
Mean	8.75	8.90	8.02	7.82	7.41
S.D.	0.09	0.51	0.18	0.18	0.22
S.E.	0.04	0.18	0.09	0.07	0.12

Table 3(d): Alkalinity (mg CaCO3/l)

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	216	240	117.5	200	176
Minimum	142	150	75.5	110.7	156
Mean	182.75	190.63	91.25	159.03	166.66
S.D.	34.42	33.89	18.20	34.69	10.06
S.E.	17.21	11.98	9.10	14.18	5.81

Table 3(e): Hardness (mg CaCO3/l)

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	598.29	488	48	710.01	699
Minimum	437	77	22.22	87.88	587
Mean	512.94	285.46	36.60	432.88	635.33
S.D.	78.61	191.65	12.01	251.85	57.55
S.E.	39.30	67.75	6.00	102.82	33.22

Table 3(f): Dissolved Oxygen (mg /l)

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	5.2	8.95	8	5.5	4.02
Minimum	4.17	4.66	6	2.1	2.6
Mean	4.61	6.79	7.32	3.58	3.34
S.D.	8	1.65	0.92	1.12	9
S.E.	9	0.58	0.46	0.46	5

Table 3(g): Nitrate (μg at/l)

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	3.96	18.14	18.1	7.76	2.88
Minimum	3.68	3.82	8.76	1.3	0.76
Mean	3.77	8.53	12.51	3.48	1.84
S.D.	0.13	5.28	4.39	2.31	1.06
S.E.	0.06	1.86	2.19	0.94	0.61

Table 3(h): Nitrite (μg at/l)

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	3.87	2.77	1.35	1.1	2.79
Minimum	1.87	0.87	0.2	0.37	1.01
Mean	2.85	1.64	0.72	0.55	2.13
S.D.	0.96	0.72	0.59	0.27	0.97
S.E.	2.82	0.25	0.29	0.11	2.13

Table 3(i): Phosphate (μg at/l)

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	5.8	4.72	3.9	4.72	6.6
Minimum	3.96	2.99	2.2	2.77	5.2
Mean	5.05	3.58	3	3.75	5.92
S.D.	1	0.59	0.70	0.82	7
S.E.	6	0.20	0.35	0.33	0.40

Table 3(j): Silicate (μg at/l)

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	39.72	188.52	187.07	92.02	76.66
Minimum	23.33	36.77	99	7.02	1.7
Mean	31.72	93.01	159.03	49.09	29.04
S.D.	1	48.94	40.62	31.89	3
S.E.	5	17.30	20.31	13.02	7

SEASONAL VARIATION OF HYDROGRAPHICAL PARAMETERS

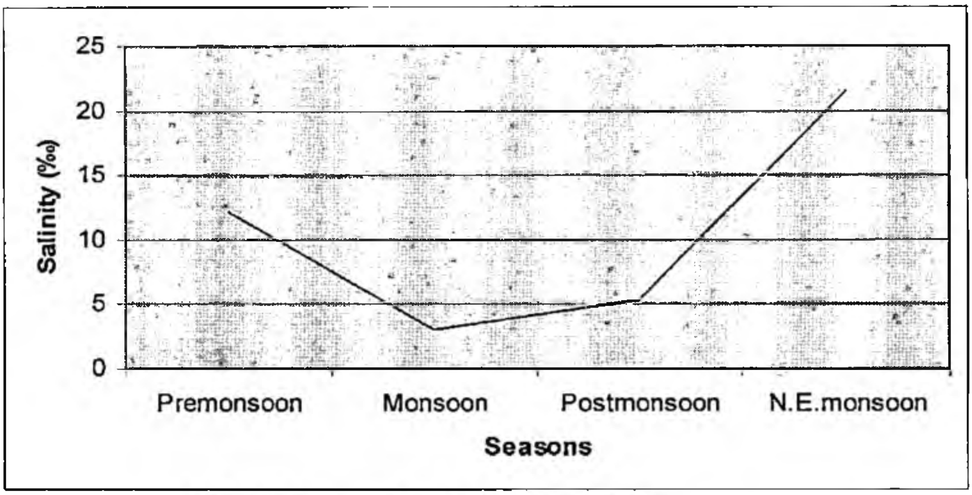


Fig 11: Seasonal variation in Salinity

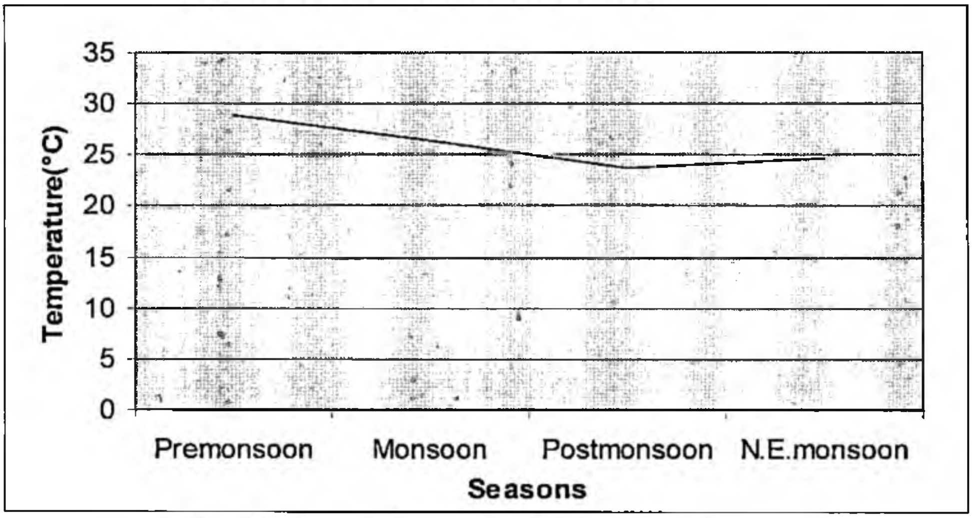


Fig 12: Seasonal variation in Temperature

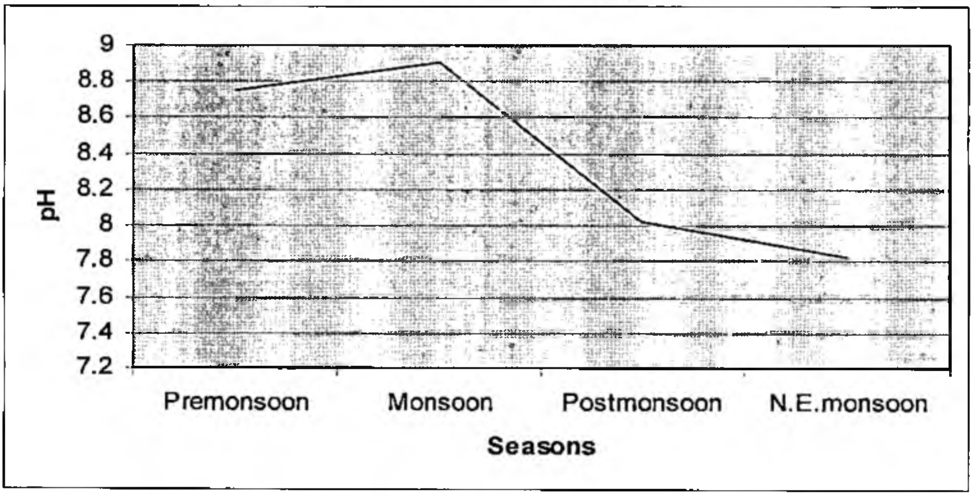


Fig 13: Seasonal variation in pH

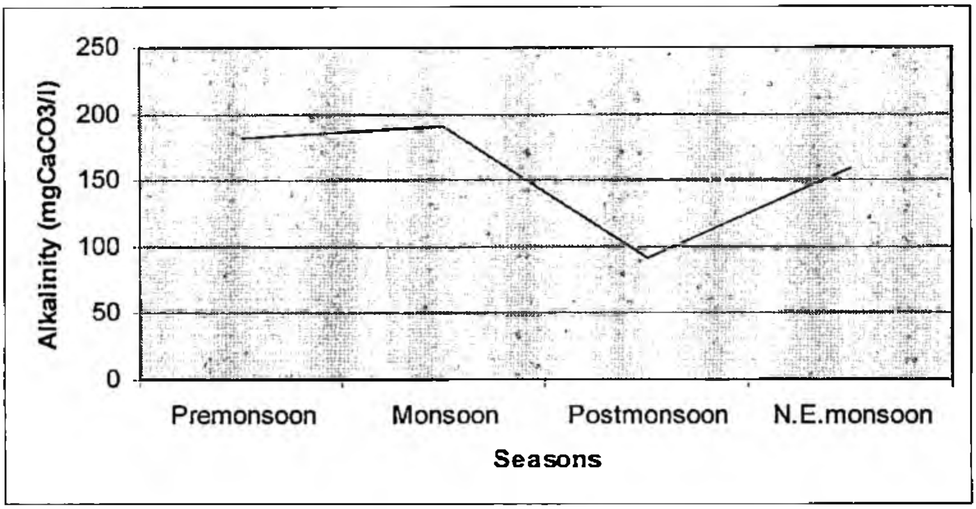


Fig 14: Seasonal variation in Alkalinity

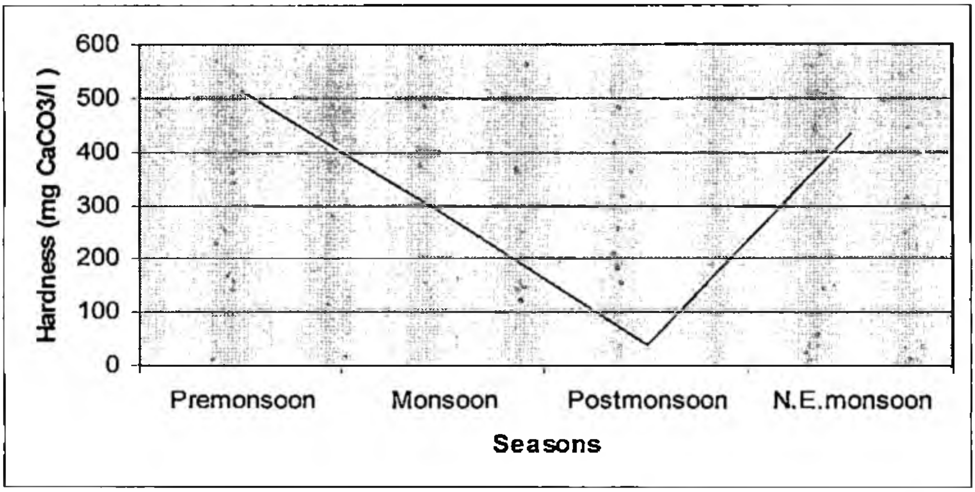


Fig 15: Seasonal variation in Hardness

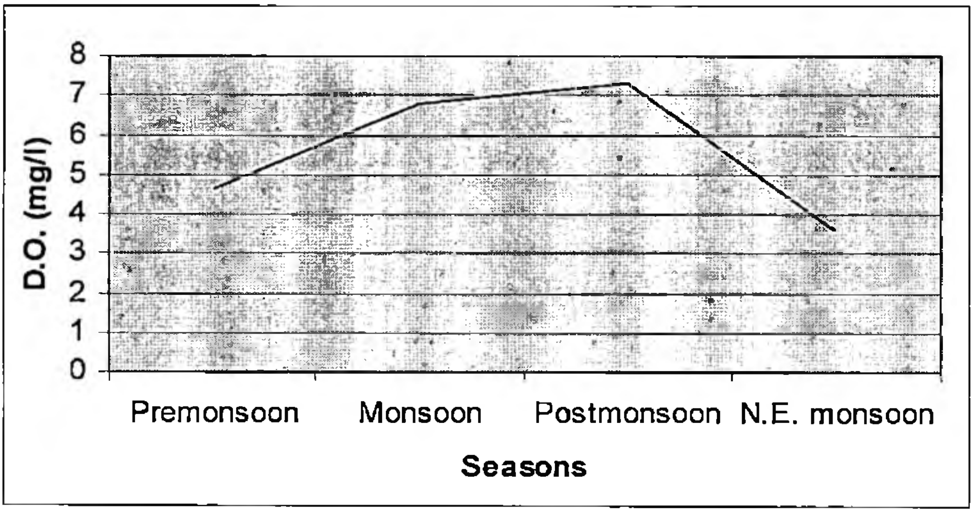


Fig 16: Seasonal variation in dissolved oxygen

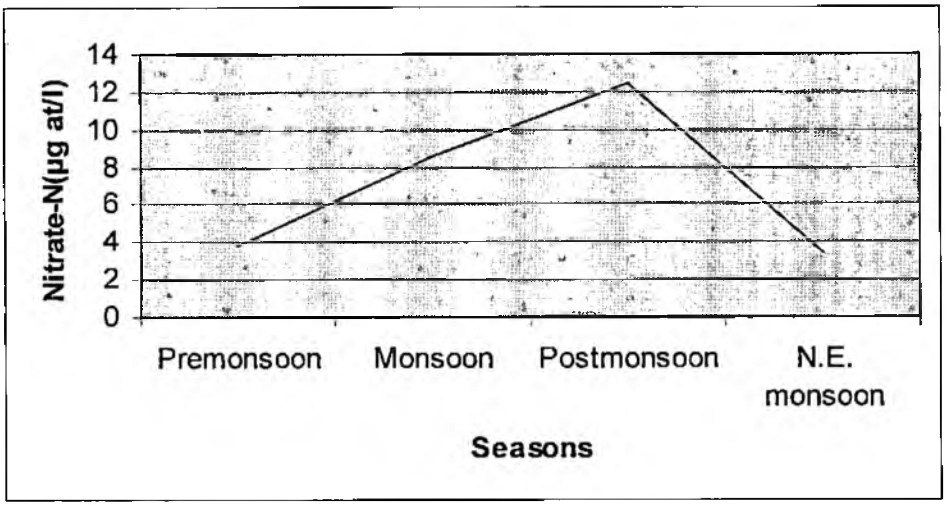


Fig 17: Seasonal variation in Nitrate-N

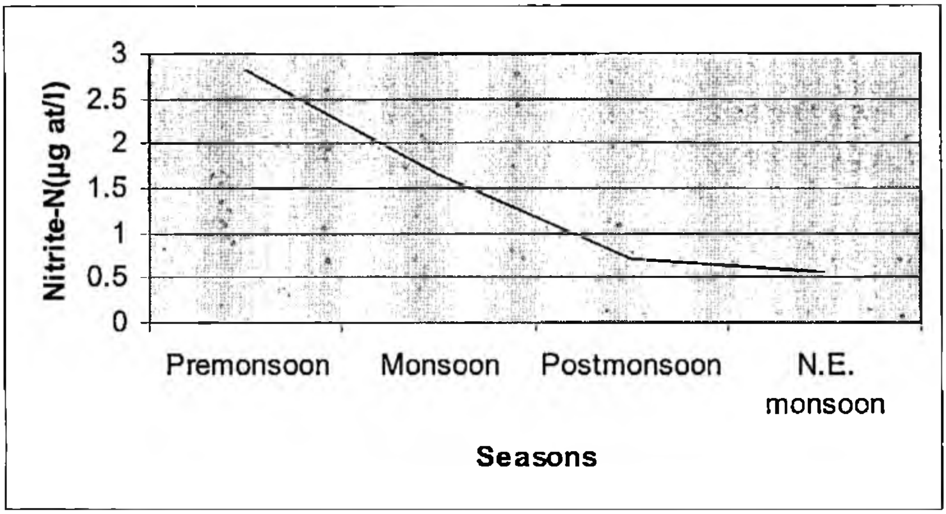


Fig 18: Seasonal variation in Nitrite-N

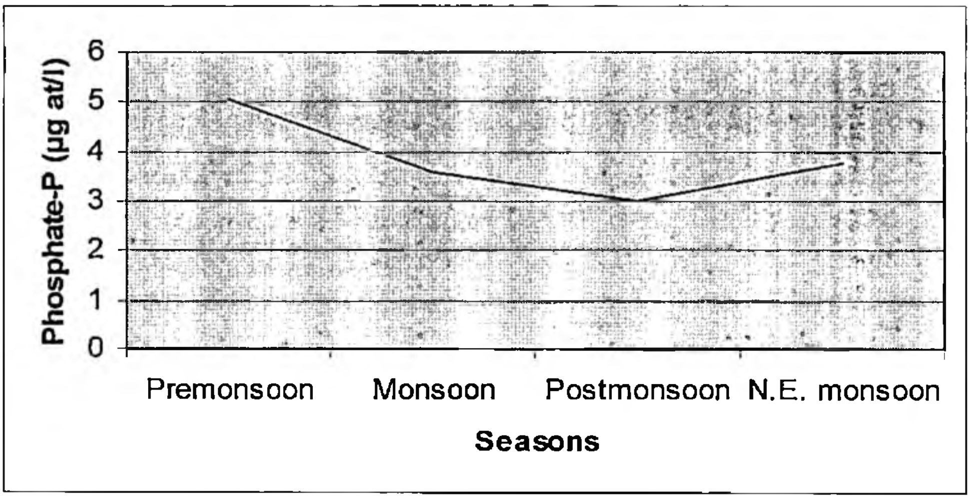


Fig 19: Seasonal variation in Phosphate

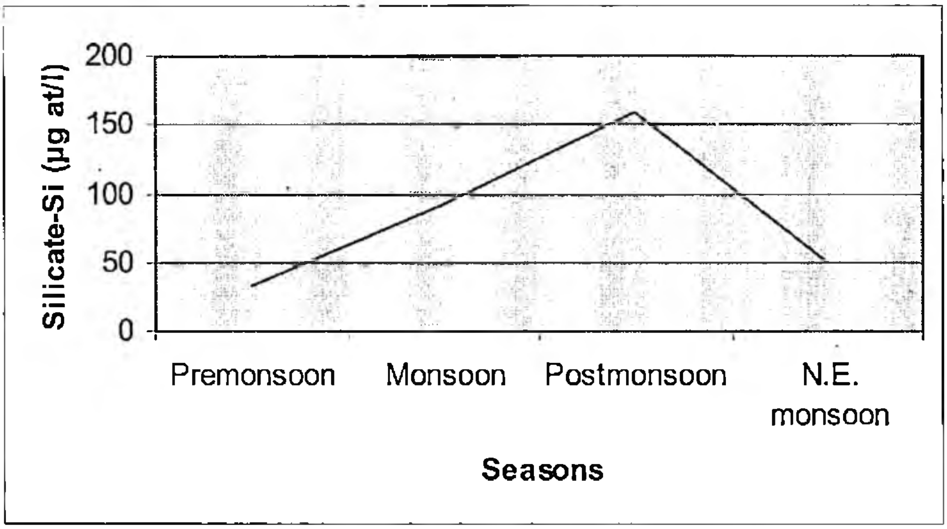


Fig 20: Seasonal variation in Silicate-Si

Table 4: ANOVA for Hydrographical parameters

		Sum of Squares	df	Mean Square	F	Sig.
Salinity	Between Seasons	1277.848	3	425.949	28.567	.000
	Within Seasons	268.392	18	14.911		
	Total	1546.241	21			
Temperature	Between Seasons	56.443	3	18.814	11.450	.000
	Within Seasons	29.577	18	1.643		
	Total	86.020	21			
pH	Between Seasons	5.12	3	1.70	14.35	0
	Within Seasons	2.14	18	0.12		
	Total	7.26	21			
Alkalinity	Between Seasons	28346.730	3	9448.910	9.140	.001
	Within Seasons	18609.008	18	1033.834		
	Total	46955.738	21			
Hardness	Between Seasons	558372.756	3	186124.252	5.647	.007
	Within Seasons	593245.104	18	32958.061		
	Total	1151617.860	21			
DO	Between Seasons	51.523	3	17.174	10.801	.000
	Within Seasons	28.622	18	1.590		
	Total	80.146	21			
Nitrate	Between Seasons	256.188	3	85.396	5.483	.007
	Within Seasons	280.344	18	15.575		
	Total	536.532	21			
Nitrite	Between Seasons	14.697	3	4.899	11.161	.000
	Within Seasons	7.901	18	.439		
	Total	22.598	21			
Phosphate	Between Seasons	9.185	3	3.062	5.669	.006
	Within Seasons	9.721	18	.540		
	Total	18.906	21			
Silicate	Between Seasons	41316.455	3	13772.152	9.189	.001
	Within Seasons	26979.049	18	1498.836		
	Total	68295.504	21			

Table 5: Multiple Comparisons for Hydrographical parameters (POST HOC test using LSD)

Parameter	Seasons	Seasons	Mean Difference	Std. Error	Sig.
Salinity	1	2	9.046250(*)	2.364636	.001
		3	6.780000(*)	2.730446	.023
		4	-9.352500(*)	2.492545	.001
	2	3	-2.266250	2.364636	.351
		4	-18.398750(*)	2.085413	.000
	3	4	-16.132500(*)	2.492545	.000
Tempera-ture	1	2	2.4625(*)	.7850	.006
		3	5.2500(*)	.9064	.000
		4	2.0167(*)	.8274	.025
	2	3	2.7875(*)	.7850	.002
		4	-.4458	.6923	.528
	3	4	-3.2333(*)	.8274	.001
pH	1	2	-.15500	.21117	.472
		3	.73250(*)	.24383	.008
		4	.92917(*)	.22259	.001
	2	3	.88750(*)	.21117	.001
		4	1.08417(*)	.18623	.000
	3	4	.19667	.22259	.389
Alkalinity	1	2	-7.85	19.68	0.694
		3	91.5(*)	22.73	0.001
		4	23.71	20.75	0.268
	2	3	99.37(*)	19.68	0
		4	31.59	17.36	0.086
	3	4	67.78	20.75	0.004
Hardness	1	2	227.487500	111.172267	.056
		3	477.340000(*)	128.370677	.002
		4	80.065833	117.185859	.503
	2	3	249.852500(*)	111.172267	.037
		4	-147.421667	98.044724	.150
	3	4	-397.274167(*)	117.185859	.003
DO	1	2	-2.178750(*)	.772203	.011
		3	-2.707500(*)	.891663	.007
		4	1.030833	.813974	.222
	2	3	-.528750	.772203	.502
		4	3.209583(*)	.681019	.000
	3	4	9.031667(*)	2.547437	.002

Continuation of Table 5

Parameter	Seasons	Seasons	Mean Difference	Std. Error	Sig.
Nitrate	1	2	-4.755000	2.416711	.065
		3	-8.740000(*)	2.790578	.006
		4	.291667	2.547437	.910
	2	3	-3.985000	2.416711	.117
		4	5.046667(*)	2.131339	.029
	3	4	9.031667(*)	2.547437	.002
Nitrite	1	2	1.181250(*)	.405719	.009
		3	2.105000(*)	.468484	.000
		4	2.266667(*)	.427665	.000
	2	3	.923750(*)	.405719	.035
		4	1.085417(*)	.357810	.007
	3	4	.161667	.427665	.710
Phosphate	1	2	1.463750(*)	.450020	.004
		3	2.050000(*)	.519639	.001
		4	1.291667(*)	.474363	.014
	2	3	.586250	.450020	.209
		4	-.172083	.396880	.670
	3	4	-.758333	.474363	.127
Silicate	1	2	-61.288750(*)	23.707879	.019
		3	-127.310000(*)	27.375501	.000
		4	-17.365000	24.990299	.496
	2	3	-66.021250(*)	23.707879	.012
		4	43.923750	20.908384	.050
	3	4	109.945000(*)	24.990299	.000

1: pre-monsoon
2: monsoon
3: post monsoon
4: N.E. monsoon

4.2 PHYSICAL AND BIOLOGICAL PARAMETERS

The average fortnightly data on physical and biological parameters are presented in Table 6 and the corresponding graphs are presented in Fig 21 to 24. The summary statistics for fortnightly data are presented in table 7 and for different seasons are presented in Table 8. The Figures from 25 to 28 shows the graph for seasonal variation of hydrographical parameters. The results of statistical analysis are presented in Table 9 and 10.

4.2.1 Turbidity:

Turbidity ranged between 11.11 NTU and 40.4 NTU with an average of 22.36 NTU (Table 7). The maximum was recorded in the second half of July, while the minimum was recorded in first half of November [Table 6, Fig21]. The average value of turbidity during pre-monsoon, monsoon, post monsoon and N.E.monsoon was estimated as 22.78 NTU, 25.60 NTU, 18.53 NTU and 20.32 NTU respectively [Table 8, Fig25]. Turbidity showed lesser value (16.68 NTU) in the next pre-monsoon season. The range and mean of values for the four seasons are given below:

Seasons	Range	Mean
Pre-monsoon	: 21.43 NTU – 24.2 NTU	22.78NTU
Monsoon	: 14.49 NTU - 40.40 NTU	25.60NTU
Post monsoon	: 11.11 NTU - 25.2 NTU	18.53NTU
N.E. monsoon	: 13.33 NTU - 30.19 NTU	20.32NTU

The seasonal means were compared using one way ANOVA (Table 9). It showed no significant difference among the seasons ($P>0.05$).

Turbidity showed significant positive correlation with alkalinity (r=0.452), pH (r=0.515) and chlorophyll (r=0.500). It showed significant negative correlation with transparency (r= - 0.584) [Table 14].

4.2.2 Transparency:

Transparency value of the study region falls within a range of 30 cm. to 47 cm. with an average of 36.86 cm. (Table 7). In most of the times during the study period, the value did not show much variation (Table 6, Fig 22). The average value of transparency during pre-monsoon, monsoon, post monsoon and N.E. monsoon season were 34.5 cm. 35.88 cm. 42.75 cm. and 35.83 cm. respectively (Table 8, Fig 26). The maximum value of 47cm. was estimated in the first half of November and the minimum value of 30cm. was estimated in in the second half July. Transparency value during the 2011 premonsoon (34.6 cm.) was almost same as the previous premonsoon season. The range and mean of transperancy for the four seasons are given below:

Season	Range	Mean
Pre-monsoon	: 30cm.-37cm.	34.5cm.
Monsoon	: 30cm.-42cm.	35.87cm.
Post monsoon	: 40 cm.-47 cm.	42.75cm.
N.E. monsoon	: 32cm.-38cm.	35.83cm.

Statistical analysis with one way ANOVA showed overall significant difference among the seasons (Table 9). Multiple comparison tests revealed significant difference between pre monsoon and post monsoon, monsoon and post monsoon and also between post monsoon and N.E. monsoon seasons (Table 10).

Transparency showed significant positive correlation with nitrate (r=0.481), silicate-Si (r=0.565) and significant negative correlation with temperature (r= - 0.484), alkalinity (r= - 0.506), pH (r= - 0.429), hardness(r= - 0.437), turbidity (r= - 0.584) and chlorophyll (r= - 0.48) [Table 14].

4.2.3 Primary production:

Primary production showed a wide range from 32 $mgC/m^3/day$ to 3707 mgC/m3/day with an average of 1275 $mgC/m^3/day$ (Table 7). The maximum was recorded during the second half of June that was in the beginning of monsoon and the minimum value was recorded in the first half of February that was by the end of the N.E. monsoon (Table 6, Fig 23). Primary production showed the highest value of 2332 $mgC/m^3/day$ during pre-monsoon period. The value was 1559.25 $mgC/m^3/day$ during the monsoon which was then decreased (1110 $mgC/m^3/day$) during the period of post monsoon, and further decreased to a very low value of 302.66 $mg/m^3/h$ during N.E. monsoon. (Table 8, Fig 27). The ranges and means estimated for the four seasons are given below

Seasons	Range	Mean
Pre-monsoon:	1432 $mgC/m^3/day$-3340 $mgC/m^3/day$	2332 $mgC/m^3/day$
Monsoon:	413 $mgC/m^3/day$-3707 $mgC/m^3/day$	1559.13 $mgC/m^3/day$
Post monsoon:	900 $mgC/m^3/day$-1230mgC/m3/day	1110 $mgC/m^3/day$
N.E. monsoon:	32 $mgC/m^3/day$-650 $mgC/m^3/day$	302.66 $mgC/m^3/day$

Statistical analysis with one way ANOVA showed significant difference in the primary production between the seasons ($P<0.01$). Multiple comparison tests showed no significant difference between pre monsoon with the other seasons and also between post monsoon and N.E. monsoon season.

Primary production showed a positive correlation with alkalinity (r=0.45), pH (r=0.61), nitrite-N (r=0.66) and chlorophyll (r=0.63) [Table 14].

4.2.4 Chlorophyll-a:

Chlorophyll values ranged between 4.8mg/m^3 and 62.8 mg/m^3. The highest value was observed during the second half of July and the minimum value was observed during the second half of October (Table 7, Fig 24). The average value of chlorophyll for pre-monsoon, monsoon, post monsoon and N.E. monsoon season were estimated as 22.37mg/m^3, 29.74 mg/m^3, 9.83 mg /m^3 and 14.38mg/m^3 respectively and it showed a decreasing trend from monsoon to postmonsoon [Table 8(d), Fig 28]. The range and mean of Chlorophyll content-in the four seasons are given below:

Seasons	Range	Mean
Pre-monsoon	: 9.4 mg/m^3- 35.7 mg/m^3	22.37 mg/m^3
Monsoon	: 7.7 mg/m^3-62.8 mg/m^3	29.74 mg/m^3
Post monsoon	: 4.8 mg/m^3-14.54 mg/m^3	9.83 mg/m^3
N.E. monsoon	: 11 mg/m^3- 17.6 mg/m^3	14.38 mg/m^3

Statistical analysis with one way ANOVA showed no significant variation among the seasons ($P>0.01$).

Chlorophyll showed significant positive correlation with alkalinity ($r=0.68$), pH ($r=0.66$), turbidity ($r=0.50$) and primary production ($r=0.63$). It showed significant negative correlation with transparency ($r= - 0.48$) [Table 14].

Table 6: Fortnightly data on Physical and Biological parameters

Period	Turbidity(NTU)	Transperancy(cm.)	Prmary productivity (mgC/m3/day)	Chlorophyll (mg/m^3)
April I	22.8	34	1432	17.5
April II	21.43	37	1787	9.4
May I	24.2	35	2770	26.9
May II	22.7	32	3340	35.7
June I	17.6	39	2197	40.5
June II	19.7	36	3707	47.7
July I	39.4	37	2010	29.8
July II	40.4	30	1507	62.8
Aug I	29.07	32	907	15.4
Aug II	27.67	32	1017	22.8
Sept I	16.53	39	715	7.7
Sept II	14.49	42	413	11.18
Oct I	20.55	40	1230	14.54
Oct II	17.27	42	1110	4.8
Nov I	11.11	47	1200	9.87
Nov II	25.2	42	900	10.14
Dec I	13.33	38	650	14.95
Dec II	20.00	32	325	11
Jan I	17.17	36	117	13.63
Jan II	30.19	36	85	17.10
Feb I	24.29	36	32	12

Continuation of Table 6:

Period	Turbidity(NTU)	Transperancy(cm.)	Prmary productivity (mgC/m3/day)	Chlorophyll (mg/m^3)
Feb II	16.98	37	607	17.6
Mar I	15.16	35	400	10.12
Mar II	15.9	35	732	15.2
April I	18.98	34	1090	16.2

Table 7: Summary statistics for Physical and Biological parameters

	N	Minimum	Maximum	Mean	Std. Deviation
Turbidity	22	11.11	40.4	22.36	7.53
Transperancy	22	30.00	47	36.86	4.132
Pri.production	22	32	3707	1275.36	1014.66
Chlorophyll	22	4.80	62.8	20.59	14.58

FORTNIGHTLY VARIATION IN PHYSICAL AND BIOLOGICAL PARAMETER

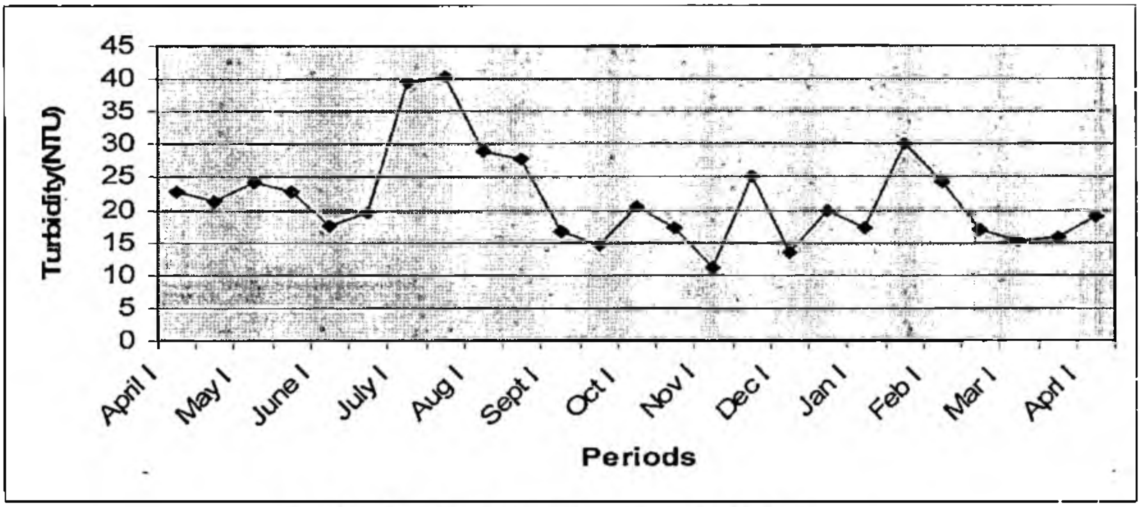


Fig 21: Fortnightly variation in Turbidity

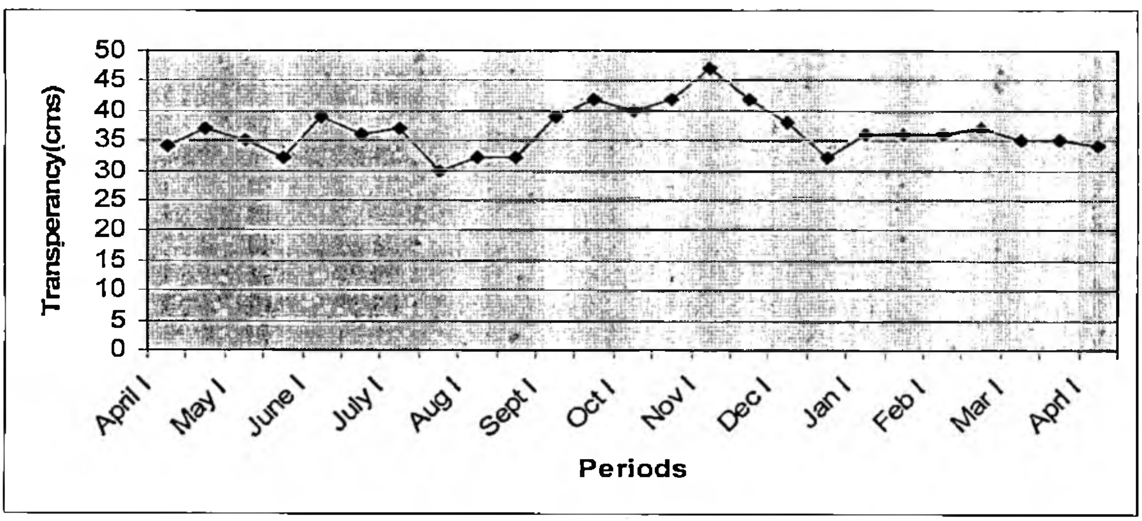


Fig 22: Fortnightly variation in Transperancy

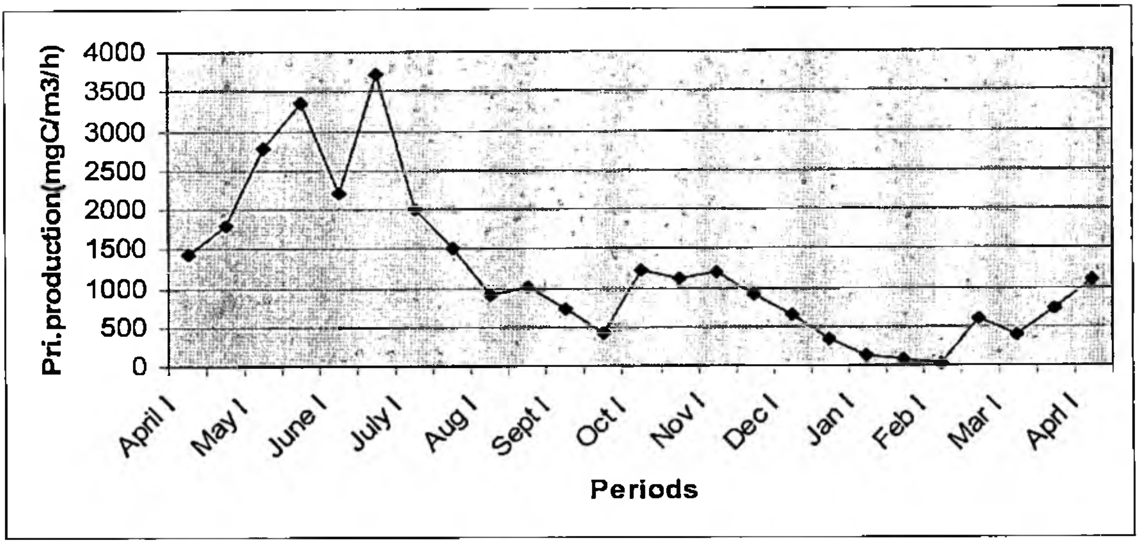


Fig 23: Fortnightly variation in Primary production

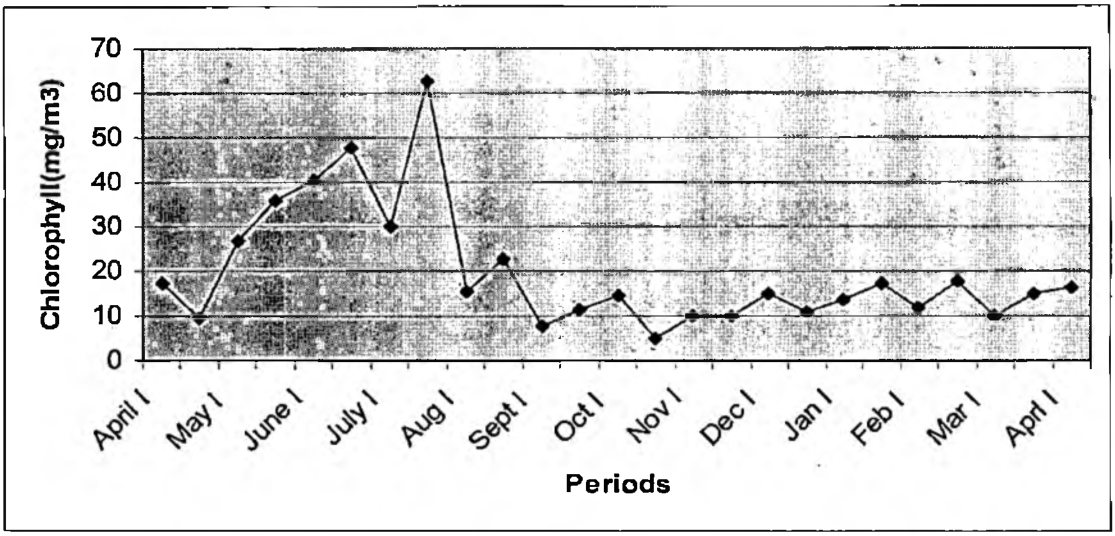


Fig 24: Fortnightly variation in Chlorophyll

Table 8: Summary statistics for seasonal data on Physical and Biological parameter

Table 8(a): Turbidity

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	24.2	40.4	25.2	30.19	18.98
Minimum	21.43	14.49	11.11	13.33	15.16
Mean	22.78	25.60	18.53	20.32	16.68
S.D.	1.13	10.21	5.92	6.05	2.02
S.E.	0.56	3.61	2.96	2.47	1.16

Table 8(b): Transparancy

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	37	42	47	38	35
Minimum	30	30	40	32	34
Mean	34.5	35.88	42.75	35.83	34.6
S.D.	2.08	4.18	2.98	2.04	0.57
S.E.	1.04	1.48	1.49	0.83	0.33

Table 8(c): Primary productivity

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	3340	3707	1230	650	1090
Minimum	1432	413	900	32	400
Mean	2332	1559.125	1110	302.66	740
S.D.	878	1067.144	148.99	271.61	345
S.E.	939.2	377.29	74.49	110.88	199

Table 8(d): Chlorophyll

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	4	8	4	6	3
Maximum	35.7	62.8	14.54	17.6	16.2
Minimum	9.4	7.7	4.8	11	10.12
Mean	22.37	29.74	9.83	14.38	13.84
S.D.	11.4	19.32	3.98	2.67	3.2
S.E.	5.7	6.83	1.99	1.09	1.8

Seasonal variation in Physical and Biological parameter

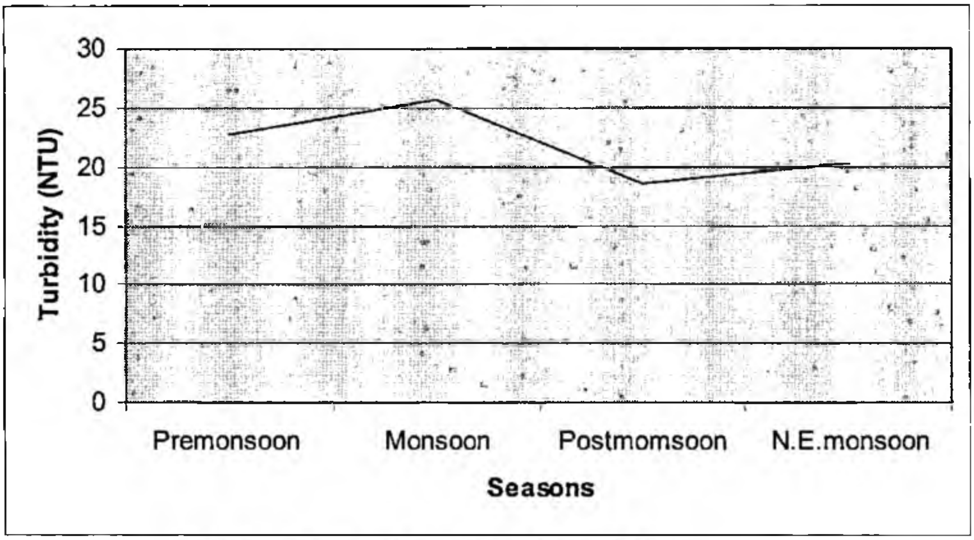


Fig 25: Seasonal variation in Turbidity

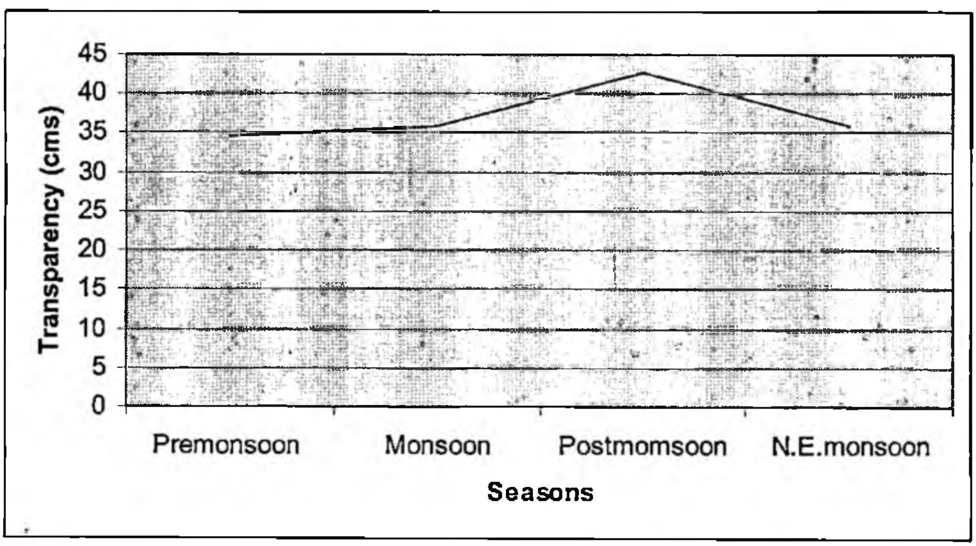


Fig 26: Seasonal variation in Transperancy

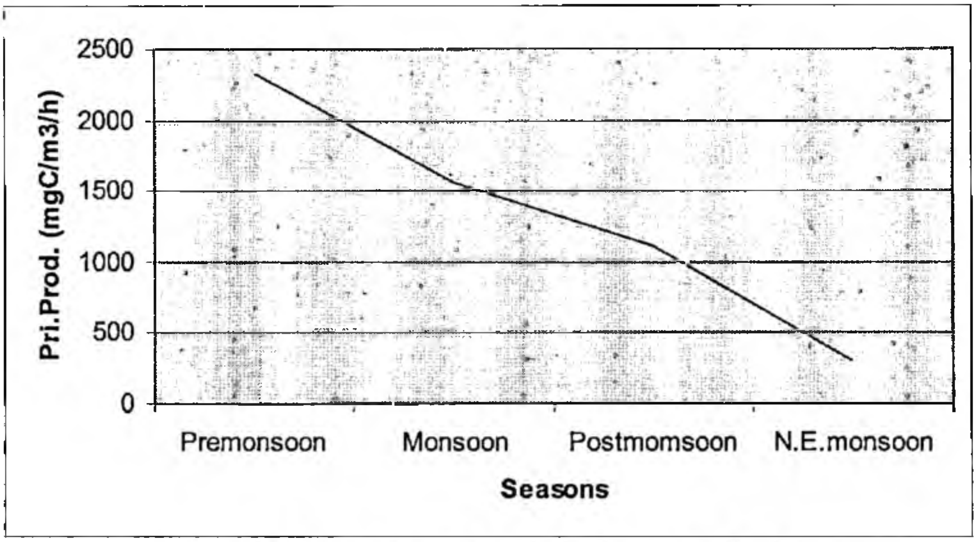


Fig 27: Seasonal variation in Primary production

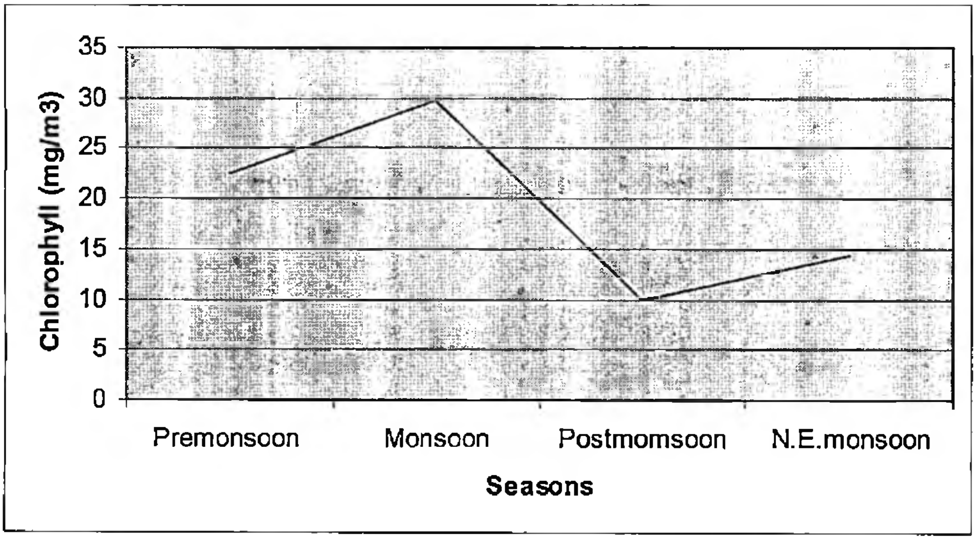


Fig 28: Seasonal variation in Chlorophyll

Table 9: ANOVA TABLE FOR PHYSICAL AND BIOLOGICAL PARAMETERS

		Sum of Square	df	Mean Square	F	Sig.
Turbidity	Between Seasons	168.489	3	56.163	.989	.420
	Within Seasons	1022.589	18	56.811		
	Total	1191.078	21			
Transperancy	Between Seasons	175.133	3	58.378	5.728	.006
	Within Seasons	183.458	18	10.192		
	Total	358.591	21			
Pri.production	Between Seasons	10898416.133	3	3632805.378	6.099	.005
	Within Seasons	10721974.958	18	595665.275		
	Total	21620391.091	21			
Chlorophyll	Between Seasons	1375.643	3	458.548	2.672	.078
	Within Seasons	3088.814	18	171.601		
	Total	4464.456	21			

Table 10: Multiple Comparisons forPhysical and Biological parameters(POST HOC test using LSD)

Dependent Variable	Seasons	Seasons	Mean Difference	Std. Error	Sig.
Transperancy	1	2	-1.37500	1.95501	.491
		3	-8.25000(*)	2.25745	.002
		4	-1.33333	2.06076	.526
	2	3	-6.87500(*)	1.95501	.002
		4	.04167	1.72415	.981
	3	4	6.91667(*)	2.06076	.004
Pri.production	1	2	773.12500	472.62509	.119
		3	1222.25000(*)	545.74045	.038
		4	2029.58333(*)	498.19059	.001
	2	3	449.12500	472.62509	.355
		4	1256.45833(*)	416.81615	.007
	3	4	807.33333	498.19059	.123

* The mean difference is significant at the .05 level

1: pre-monsoon
2: monsoon
3: post monsoon
4: N.E. monsoon

4.3 SEDIMENTARY CHARACTERISTICS

The Puduveypu area is marshy; being daily inundated by saline and brackish water intrusions. The sediment is of loose mud, clay and sand with calcareous deposits. The unique geographical position of the area affects the sediment characteristics of the region. The summary statistics of sedimentary chararacteristics for different seasons is presented in table 13(c), 13(d) and 13(e) and graphically shown in Fig 31 to 33. Monthly variation in sedimentary characteristics is graphically shown in Fig 34.

4.3.1 Sediment pH

The sediment pH value ranged between 7.02 and 8.3 (Table11) with an average of 7.78 (Table 12). The average sediment pH decreased from pre-monsoon (8.17) to monsoon season (7.53), but showed an increase during postmonsoon (7.8) and N.E. monsoon (7.9) [Table 13(a), Fig 29]. The highest value was observed during October (8.3) and the lowest value was estimated during July (7.02). The ranges and means for the four seasons are:

Seasons	Range	Mean
Pre-monsoon	: 8.15.-8.2	8.17
Monsoon	: 7.02-7.78	7.53
Post monsoon	: 7.3-8.3	7.8
N.E. monsoon	: 7.6-8.2	7.9

4.3.2 Total Organic Carbon (TOC)

Total organic carbon ranged between 4.56% (September) and 8.80% (November) with an average of 6.8% (Table 12).The average value of total organic carbon for the pre-monsoon, S.W,monsoon, post monsoon and N.E. monsoon, are 7.73%, 6.25%, 7.33% and 7.34% respectively. [Table 13(b), Fig 30]. The range and mean estimated for the four seasons are given below:

Seasons	Range	Mean
Pre-monsoon	: 4.56% - 7.77%	6.67%
Monsoon	: 4.8% - 7.7%	6.25%
Post monsoon	: 5.85% - 8.8%	7.33%
N.E. monsoon	: 5.62% - 8.77%	7.34%

Sediment texture

The analysis revealed that sediment of the Puduveypu region contained maximum sand followed by silt and clay. During post monsoon, the average value of textural pattern of the sediment were estimated as sand 71.09%, silt 21.96% and clay as 6.95% .During N.E.monsoon the values were 72.15%, 20.29% and 7.55% for sand , silt and clay respectively. While in pre-monsoon the average values for sand, silt and clay were 68.79%, 11.12% and 20.09%. The values during monsoon are 69.99%, 19.97% and 10.03% for sand silt and clay respectively (Fig 34).

Table 11: Monthly data on sedimentary characterstics

Period	Soil pH	TOC%	Sand%	Silt%	Clay%
April 2010	8.15	7.77	71.05	20.43	8.52
May	8.2	7.7	66.53	19.75	13.72
June	7.78	6.6	69.55	19.6	10.85
July	7.02	7	69.41	19.85	10.74
Aug	7.56	6.6	70.33	19.88	9.79
Sept	7.78	4.8	70.7	20.56	8.74
Oct	8.3	5.85	70.22	22.57	7.21
Nov	7.3	8.8	71.95	21.35	6.7
Dec	7.6	8.77	69.4	21.63	8.97
Jan	8.2	7.64	74.95	20.49	4.56
Feb	7.9	5.62	72.1	18.76	9.14
Mar	7.6	4.56	68.6	19.31	12.09
April 2011	7.95	6.36	70.15	20.06	9.79

Table 12: Summary statistics for fortnightly data on Sediment characteristics

Parameter	Sample size	Minimum	Maximum	Mean	S.D.
Sediment pH	12	7.02	8.30	7.78	0.3926
TOC	12	4.56	8.80	6.8	1.406
Sand	12	66.53	74.95	70.39	2.077
Silt	12	18.76	22.57	20.34	1.072
Clay	12	4.56	13.72	9.25	2.461

Table 13: Summary statistics for seasonal data on Sediment characteristics

Table 13(a): Sediment pH

	Pre-monsoon 2010	Monsoon	Post monsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	2	4	2	3	2
Maximum	8.2	7.78	8.3	8.2	7.95
Minimum	8.15	7.02	7.3	7.6	7.6
Mean	8.17	7.53	7.8	7.9	7.7
S.D.	0.001	0.35	0.707	0.3	0.24
S.E.	0.02	0.17	0.5	0.17	0.17

Table 13(b): Total Organic Carbom (%)

	Pre-monsoon 2010	Monsoon	Post monsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	2	4	2	3	2
Maximum	7.77	7	8.8	8.77	6.36
Minimum	7.7	4.8	5.85	5.82	4.56
Mean	7.73	6.25	7.325	7.343	5.46
S.D.	0.04	0.984	2.085	1.595	1.27
S.E.	0.03	0.492	1.475	0.921	0.9

Table 13(c): Sand (%)

	Pre-monsoon 2010	Monsoon	Post monsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	2	4	2	3	2
Maximum	71.05	70.7	71.95	74.95	70.15
Minimum	66.53	69.41	70.22	69.4	68.6
Mean	68.79	69.997	71.085	72.15	69.37
S.D.	3.19	0.618	1.223	2.775	1.09
S.E.	2.26	0.309	0.865	1.602	0.7

Table 13(d): Silt (%)

	Pre-monsoon 2010	Monsoon	Post monsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	2	4	2	3	2
Maximum	13.72	20.58	22.57	21.63	12.09
Minimum	8.52	19.6	21.35	18.76	9.79
Mean	11.12	19.97	21.96	20.29	10.94
S.D.	3.67	0.411	0.863	1.445	1.62
S.E.	2.6	0.205	0.61	0.83	1.15

Table 13(e): Clay (%)

	Pre-monsoon 2010	Monsoon	Postmonsoon	N.E.monsoon	Pre-monsoon 2011
No. of Obs.	2	4	2	3	2
Maximum	20.43	10.85	7.21	9.14	20.06
Minimum	19.75	8.74	6.7	4.56	19.31
Mean	20.09	10.03	6.955	7.556	19.68
S.D.	0.48	0.983	0.360	2.596	0.53
S.E.	0.34	0.491	0.255	1.499	0.37

SEASONAL VARIATION OF SEDIMENTARY CHARACTERISTICS

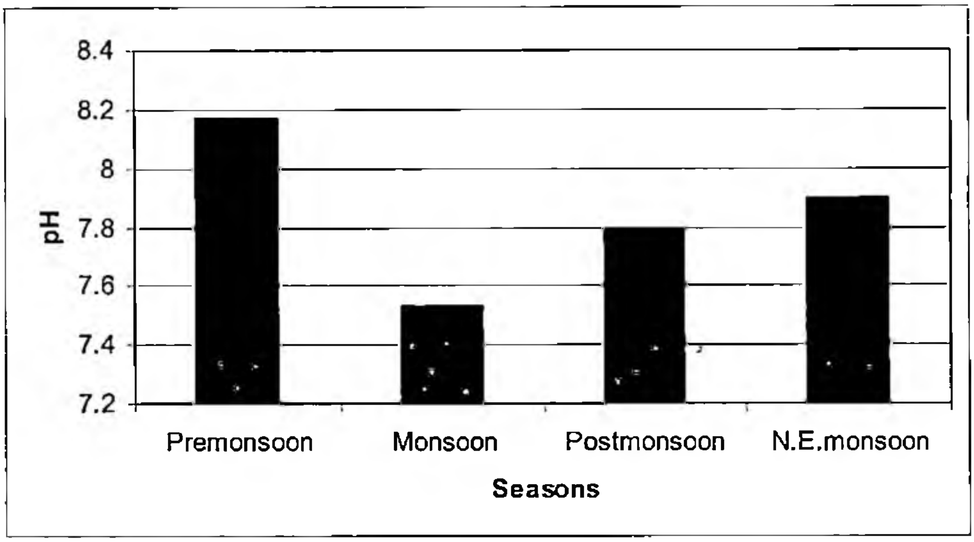


Fig 29: Seasonal variation in Sediment pH

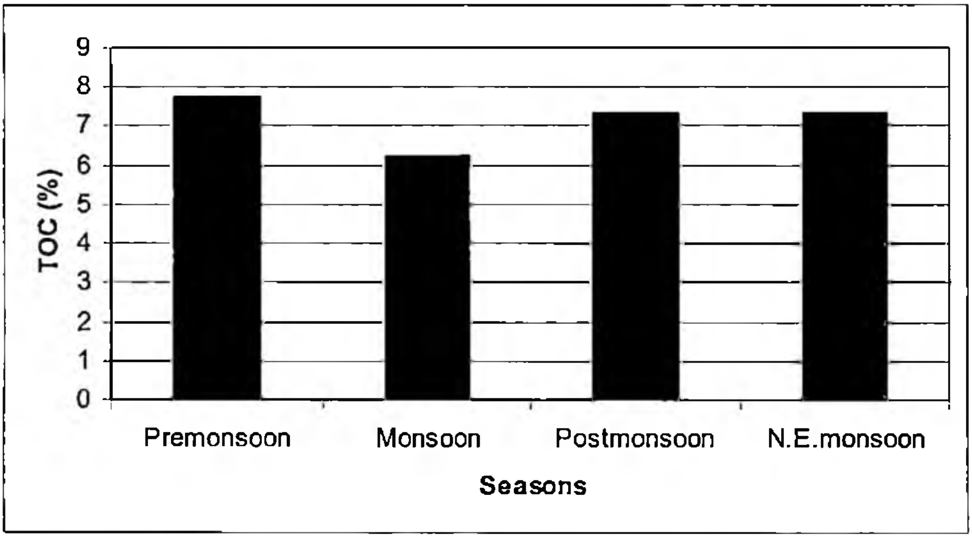


Fig 30: Seasonal variation in Total Organic Carbon

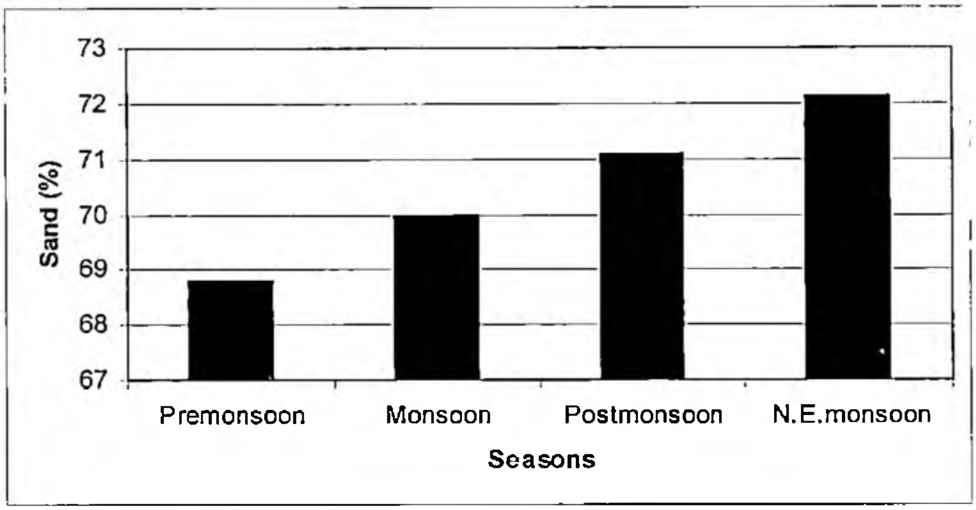


Fig 31: Seasonal variation in Sand

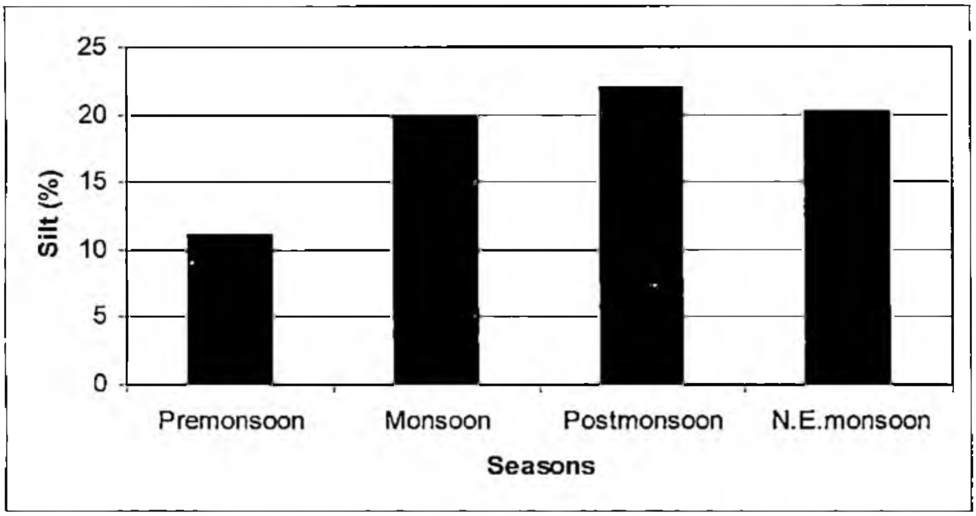


Fig 32: Seasonal variation in Silt

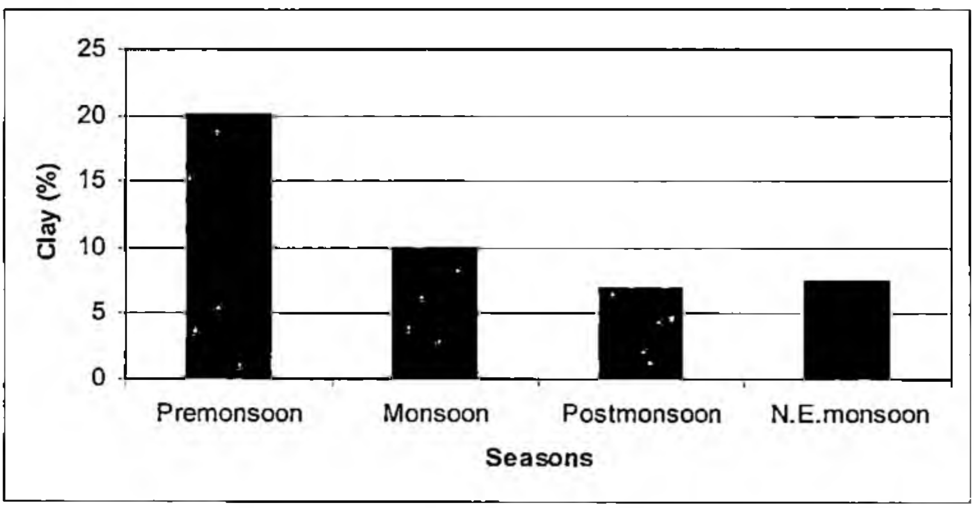
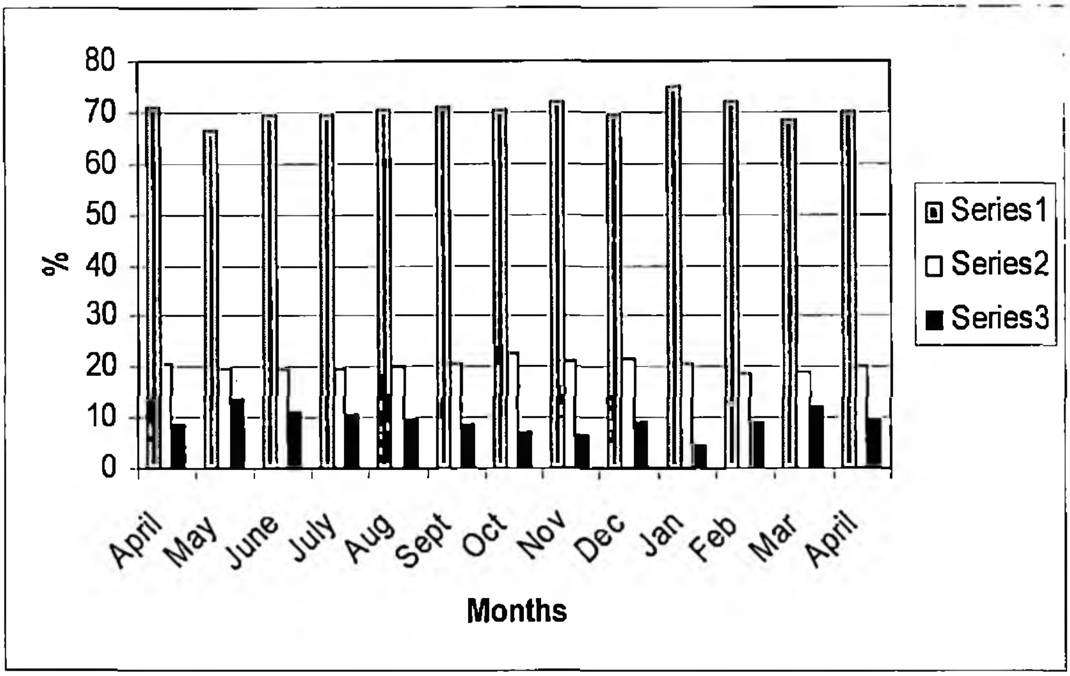


Fig 33: Seasonal variation in Clay



Series 1: Sand Series 2: Silt Series 3: Clay
Fig 34: Monthly variation of Sediment Texture

Table 14: Correlation between hydrographical and biological parameters

	Salin- ity	Temp e- rature	pH	Alkali- nity	Hard- ness	DO	Nitrate	Nitrite	Phosphate	Silicate	Turbi- dity	Transpa rancy	Pri. Product -ion	Chloro- phyll
Salinity	1	.44(*)	-.52(*)	.114	.550(**)	-.865(**)	-.682(**)	-.105	.224	-.61(**)	-.189	-.118	-.28	-.17
Tempera- ture		1	.310	.6(**)	.729(**)	-.62(**)	-.760(**)	.622(**)	.528(*)	-.712(**)	.042	-.484(*)	.36	.2
pH			1	.595(**)	.148	.298	-.096	.588(**)	-.002	-.175	.515(*)	-.429(*)	.61(**)	.66(**)
Alkalinity				1	.683(**)	-.347	-.593(**)	.402	.218	-.63(**)	.452(*)	-.506(*)	.45(*)	.68(**)
Hardness					1	-.8(**)	-.82(**)	.399	.570(**)	-.873(**)	.316	-.437(*)	.21	.385
D.O.						1	.827(**)	-.152	-.379	.780(**)	-.008	.295	.008	-.121
Nitrate							1	-.348	-.219	.882(**)	-.264	.481(*)	-.20	-.35
Nitrite								1	.455(*)	-.440(*)	.135	-.208	.66(**)	.40
Phos- phate									1	-.419	-.015	-.255	.114	-.09
Silicate										1	-.317	.565(**)	-.203	-.36
Turbidity											1	-.584(**)	.134	.50(*)
Transpa- rency												1	-.161	-.48(*)
Pri.- productio n													1	.63(**)
Chloro- phyll														1

** significant at 1% level * significant at 5%level

4.4 MANGROVE PLANTS

The mangrove plants that have been identified from the study area are

Rhizophora mucronata,

Rhizophora apiculata,

Rhizophora conjugate,

Brugiuera cylindrica,

Brugiuera gymnorhiza,

Sonerasia caseolaris,

Sonerasia alba,

Avicennia officianalis,

Exocearia agallocha,

Acanthus ilicifolius,

Clerodenterum innerme,

Premma latifolia,

Acrostichum aureum.

Among these species *Avicennia officianalis* formed 70% of total mangrove population.

Rhizophora mucronata and *Avicennia officianalis* were found in the proximal zones. These were mostly abundant in the areas towards the water front, where intensity of soil accumulation and inundation is a continuous process due to regular tidal effect. These two species are specially adapted with silt root and prop roots for stability and anchorage.

Exocearia agallocha, Acanthus ilicifolius and *Acrostichum aureum* were found in the distal zone.

4.5 SHELLFISHES

Prawns, which were found in the study region include *Penaeus monodon, P. indicus, Metapenaeus dobsonii, M. monoceros, Feneropenaeus indicus, Penaeus semisulcatus, Macrobrachium equidens, M. idella.*

Crabs include *Scylla serrata, Scylla tranquebarica, Thalamita creneta, Charybdis annulata, Sesarma quadratum, Uca vocans.*

Bivalves includes *Lamellidens sp., Villorita Sp.* and Cirriped in the study region include Balanus.

4.6 FISHES

Due to limited facilities available and time constraints, collection of fishes could not be carried out regularly. From the record available at Fisheries Station, Puduveypu; the information about the availabity of fish species in the study area could be gathered. The various species of fishes found in the study region were Milk fish *Chanos chanos,* Mullets like *Mugil cephalus, Liza parsia, L. macrolepis,* Pearl spot *Etroplus suratensis,* Spotted Etroplus *E. maculates, Tilapia Oreochromis mossambicus,* Sea bass *Lates calcarifer,,* Snapper *Lutjanus argentimaculatus, L.johni,* Grouper *Epinephalus sp.,*Indian salmon *Eleutheronema tetradactylum,* Ten pounder *Elops saurus,* Scat *Scatophagus argus,* Cresunt perch *Therapon jarbua,* Glassy perchlet *Ambasis commersoni,*Climbing perch *Anabas testudineus,* ,Goby *Glossogobius giuris,* Panchax *Aplocheilus sp.,*Indo-Pacific tarpon *Megalops cyprinoids,* Tongue sole *Cynoglossus sp.,* Sand whiting *Sillago sihama,* Full beak *Belone cancila,* Halibut *Psettodes erumei,*Cat fish *Mystus singhala, Mystus gulio, Anguila bengalensis,* Puffers like *Tetraodon nigropunctatus, T. viridipunctatus,* Gizzard shad *Anodontostoma chacunda,* White bait *Stolephorus commersoni,* Anchovy *Thryssa mystax,* Silver bellies *Leiognathus brevirostris, Secutor ruconius, S. insidiator,* and Queen fish *Scomberoides sp.*The classification of the fishes are given in the Table 15.

Table 15: Fishes caught during the study period

I.Order: Elopiformes

i)Family: Megalopidae

1. *Megalops cyprinoids*

ii) Family: Elopidae

2. *Elops saurus*

II. Order: Clupeiformes

iii) Family Clupeidae

3. *Anodontostoma chacunda*

iv) Family: Engraulididae

4. *Stolephorus commersoni*

5. *Thryssa mystax*

III. Order: Siluriformes

v) Family: Bagridae

6. *Mystus singhala*

7. *M. gulio*

IV. Order: Perciformes

vi) Family: Ambassidae

8. *Ambasis commersoni*

vii) Family: Leiognathidae

9. *Leiognathus brevirostris*

10. *Secutor ruconius*

11. *S. insidiator*

viii) Family: Carangidae

12. *Scomberoides sp*

ix) Family: Lutjanidae

13. *Lutjanus argentimaculatus*

14.. *L. johni*

x) Family: Cichilidae

15. *Etroplus suratensis*

16. *E. maculates*

17. *Oreochromis mossambicus*

xi) Family: Scatophagidae

18. *Scatophagus argus*

xii) Family: Mugilidae

19. *Mugil cephalus*

20. *Liza parsia*

21. *Liza macrolepis*

xiii) Family: Gobidae

22. *Glossogobius giuris*

xiv) Family: Centropomidae

23. *Lates calcarifer*

xv) Family: Serranidae

24. *Epinephalus sp.*

xvi) Family: Polynemidae

25. *Eleutheronema tetradactylum*

xvii) Family: Terapontidae

26. *Therapon jarbua*

xviii) Family: Anabantidae

27. *Anabas testudineus*

xix) Family: Sillaginidae

28. *Sillago sihama*

V. Order: Pleuronectiformes

xx) Family Cynoglossidae

29. *Cynoglossus sp.*

xxi) Family: Psettodidae

30. *Psettodes erumei*

VI. Order: Tetraodontiformes

xxii) Family: Tetraodontidae

31. *Tetraodon nigropunctatus*

32. *T. viridipunctatus*

VII. Order: Gonorhynchiformes

xxiii) Family: Chanidae

33. *Chanos chanos*

VIII. Order: Cyprinodontiformes

xxiv) Family: Aplocheilidae

34. *Aplocheilus sp*

IX. Order: Beloniformes

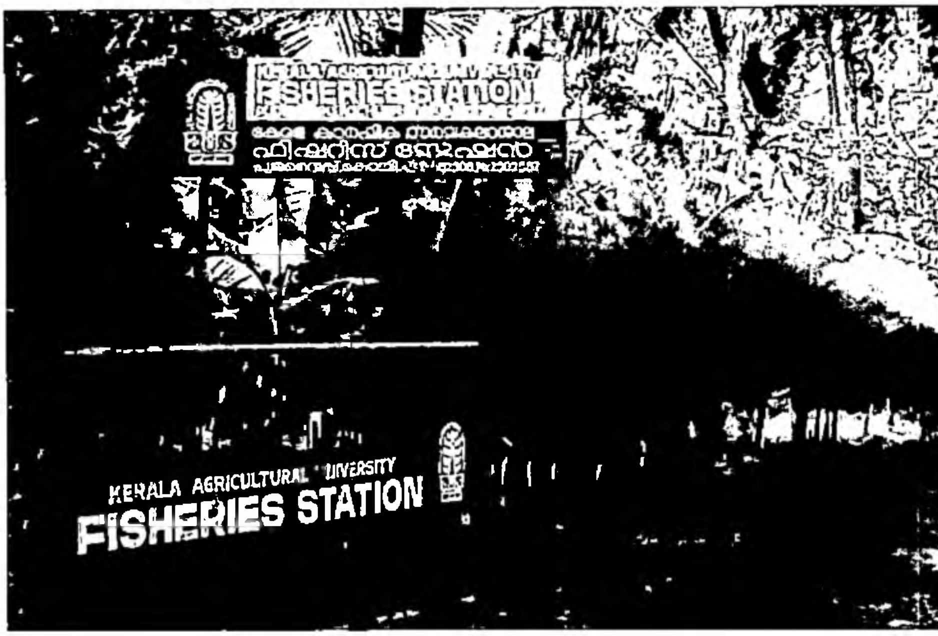
xxv)Family: Belonidae

35. *Belone cancila*

X. Order: Anguilliformes

xxvi) Family: Anguillidae

36. *Anguila bengkensis*



The Puduveypu Fisheries Research Station

View of Station I

The Puduveypu Fisheries Research Station

View of Station I

View of Station II

View of station III

DISCUSSION

5. DISCUSSION

5.1 HYDROGRAPHICAL PARAMETER

5.1.1 Salinity

The salinity of the backwaters of Puduveypu ranged between 0.06‰ and 27‰. Gopinathan *et al.* (1984); Sakaranarayanan *et al.,* (1982); Singh (1987) and Venketasan *et al.,* (2001) observed an annual salinity range of 1‰-27‰ in seasonal and perennial prawn culture field of Cochin estuarine system. Varma *et al.,* (2002) also analysed long term daily variation in salinity at a station near Panangad jetty and recorded a salinity range between 0 and 32‰. Similar observation was made by Jayasree (2009). She studied the seasonal characteristics in the salinity distribution in a prawn filtration pond near Panagad area and found a salinity range of 0.05‰ to 30.63‰. The average salinity during the study period was 10.15‰.

During the study period, the values showed an increasing trend in the post monsoon period (Oct-Nov) and the trend continued in the N.E. monsoon season (Dec-Feb). Similar was the finding made by Varma *et al.,* (2002). The maximum value was recorded in the second half of January. The average salinity during this N.E monsoon period was 21.47‰. But the average value experienced considerable reduction to 17.38‰ during the period of March to April, 2011; and it might be due to pre-monsoon showers.Convective thunder showers increase over Kerala progressively as the hot season (pre-monsoon season) advances (Menon, 1989). Nearly 75% of the annual rainfall occurs in almost all places except Tamil Nadu and sub Himalayan belt during monsoon. During this season there is strong flow of rain to the backwater and as a result, salinity of backwater reduces to much lower value (Balakrishnan and Shynamma, 1976; Ramaraju *et al.,* 1979; Udayavarma *et al.,* 1981; Sankaranarayanan *et al.,* 1986; Joseph and Kurup, 1990). During the present study also, it was observed that as the monsoon started the salinity further decreased (average 3.07‰) due to heavy rainfall.

5.1.2 Water temperature

The average temperature during the study period was 26.5°C. The highest temperature (30°C) was observed during the second half of April and the lowest temperature (22°C) was observed during the first half of October. Cheriyan (1967) also reported the maximum temperature during summer (32°C). Pillai *et al.,* (1975) reported that the temperature value ranged between 25°C and 33°C in Cochin backwater. The seasonal variation in water temperature showed high values in pre monsoon and low values during monsoon (Prabhadevi *et al.,* 1996).

The average temperature was 28.9°C during pre-monsoon. But it decreased (26.43°C) during the monsoon period. There was a slight increase of temperature (23.65°C) during post monsoon period; whch was then further increased to 24.72°C during N.E.monsoon. Similar observation was made by Pillai *et al.,* (1975). He reported a gradual increase in temperature from February to April, followed by a fall during July-August in Vembanad Lake (Alleppey and Azheekode) and adjacent waters. Gopinathan *et al.,* (1982), Sankaranayanan *et al.,* (1982), Nair et al., (1988), Prabhadevi et al., (1996), Varma *et al.,* (2002) and Haridevi *et al.,* (2003) also reported similar trends in temperature. Harikrishnan and Kurup (2003), in their study of Vembanad Lake from Cochin to Kavalam (Kuttanad) reported that the water temperature was invariably low during June-July (25°C), which gradually increased from August onwards and reached highest value in March (32°C). Devi (2009) found that the water temperature of mangrove area of Cochin backwater near Panangad region, fluctuate between 24°C and 30.5°C which is much matching with the range of the present study.

5.1.3 Hydrogen ion concentration or pH:

pH value of the study region varied between 7.58 and 9.35. Devi (2009) also found an alkaline pH through out the year in Cochin backwater. The average pH estimated during the study period was 8.42.

In the pre-monsoon period of 2010, the pH value increased from 8.65 to 8.86. The increasing trend continued during monsoon and reached a maximum of 9.35 by the second half of August. pH value showed a variation between 7.79 and 8.25 in the post monsoon season with an average of 8.03. During the N.E. monsoon the value decreased slightly (7.82) .The average value during monsoon was 8.90. Sakaranarayanan *et al.* (1982) also observed the higher values during the season of pre-monsoon, when the salinity values were high. Higher values were observed during winter (December, January) and summer (May) months may be due to the abundance of algae. Jayasree (2009) studied the structure and the seasonal changes of the macrobenthic community in relation to the hydrography of a prawn filtration pond, near Panagad region of the Cochin backwater and found an increasing trend of pH from the post monsoon to pre-monsoon season as in the case of present study.

5.1.4 Total alkalinity:

Generally alkalinity showed an increasing trend during the pre-monsoon, post monsoon and N.E. monsoon seasons but a decreasing trend was observed during monsoon season. But during the 2011 pre-monsoon alkalinity showed a decreasing pattern. Sankaranarayanan and Qasim, (1969) also found that alkalinity showed higher values during summer months and started decreasing with the advent of monsoon.

The value of alkalinity in the study region ranged between 75.50 mg $CaCO_3$/l to 240 mg $CaCO_3$/l. Devi (2009) studied the Cochin backwater of Panangad region and recorded minimum total alkalinity during monsoon which increased in post monsoon and pre-monsoon seasons. She also found an alkalinity range of 75 and 200 mg $CaCo_3$/l in mangrove area.

During the study period the highest value was recorded in the first half of June and minimum was estimated in the first half of October. The average alkalinity during pre monsson was 182.75 mg $CaCO_3$/l. The trend of variation was having an increasing pattern. The average alkalinity during the monsoon season was 190.63 mg $CaCO_3$/l. During the post monsoon period the average alkalinity value was 91.25 mg $CaCO_3$/l due to late monsoon showers, which increased to 159.03 mg $CaCO_3$/l during N.E. monsoon. Silas and Pillai (1975); Banerjee and Choudhury (1996) also observed a fall in alkalinity with the advent of monsoon.

5.1.5 Hardness:

Total hardness varied between 22.22 mg $CaCO_3$/l and 710.01 mg $CaCO_3$/l with an average of 321.59 mg $CaCO_3$/l. The average value during the pre-monsoon was estimated as 512.94 mg $CaCO_3$/l. Hardness showed a decreasing trend during monsoon. The minimum value was found in the post monsoon season and reached in the first half of November. The hardness showed an increasing trend in the N.E. monsoon season. During the 2011 pre-monsoon season the value started decreasing from a maximum of 710.01 mg $CaCO_3$/l, which was observed in the second half of February. Ramachandran (2009) found that hardness ranged between 41.25 mg $CaCO_3$/l and 776.25 mg $CaCO_3$/l in a prawn filtration pond of Cochin area. She recorded the maximum hardness in February and the minimum in October which is very much similar with the present study. Jaysree (2009) found that the hardness during pre-monsoon showed a gradual reduction while a drastic reduction was noticed during monsoon.

5.1.6 Dissolved oxygen:

Dissolved oxygen is an essential factor in the aquatic ecosystem and is an important indicator of water quality. The air-water interaction, respiration and photosynthetic processes influenced dissolved oxygen status of aquatic ecosystems. The average dissolved oxygen value estimated for the study period in the study region was 5.62 mg /l. During Pre-monsoon period dissolved oxygen value remained less and the average value during the period was estimated as 4.61 mg/l. With the onset of monsoon the dissolved oxygen value increased to 6.79 mg/l. During the N.E. monsoon period the dissolved oxygen showed a decreasing pattern. The minimum dissolved oxygen was in the last part of N.E. monsoon ie in the second part of February and it was 2.1mg /l. The maximum dissolved oxygen (8.95 mg/l) was estimated during the first half of August. In the earlier studies also higher values of dissolved oxygen were recorded during monsoon months (Qasim *et al.*, 1969; Haridas *et al.*, 1973; Pillai *et al.*, 1975). Similarly Kumar and Rao (1975) reported that the lowest dissolved oxygen in the Cochin backwater was found during the post monsoon months ie. October to December and the highest was in the monsoon months (July). Saraladevi *et al.*, (1979) remarked that dissolved oxygen was higher during the monsoon and was lower during the pre and post monsoon periods in the Cochin estuarine system near the industrial area. The annual range was 2-6 ml/l in the study area.

Dissolved oxygen showed a negative correlation with salinity and temperature. Similar observation was made by Suresh *et al.*, (1978), where as it showed a positive correlation with nutrients. Devi (2009) studied the Cochin backwater of Panangad region and found a positive correlation of dissolved oxygen with the nutrients.

5.1.7 Nutrients:

Nutrients are functionally involved in living processes of organisms. Nutrients are usually not a limiting factor to productivity in mangrove waters (Devi, 2009). The water present in the mangrove areas has peculiar characteristics acquired during their long residence in swamps and they contain a large amount of dissolved organic matter in the form of nutrients (Shaly, 2003). The nutrient content was high in the study area because of the high abundance of mangroves. Tripathy et al. (2005) also observed high concentration of nutrients in a mangrove estuarine ecosystem. The availability of high concentration of nutrients might be the reason for abundance of diverse fishes, prawns and molluscs.

Nitrate-N

The value of nitrate-N in the study region was found in the range of 1.30µg at/l and 18.14µg at/l. The higher values were observed during post monsoon and monsoon season. The estimated nitrate values during these two seasons were 12.51 µg at/l and 8.53 µg at/l respectively. The lower values were observed during N.E monsoon and pre-monsoon periods as 3.48 µg at/l and 3.77 µg at/l respectively. The highest value (18.14 µg at/l) of nitrate-N was observed in the second half of September. Saraladevi *et al.*, (1983) studied the nutrients like phosphate, nitrite and nitrate in four estuaries in Kerala. They found an increase in nitrate content during monsoon in all the estuaries. Lakshmanan et al. (1987) observed that nitrate-N concentration varying between 0 µg/l to 20.3 µg/l in Cochin backwater, which is much matching with the present study.

Krishnakumari et al. (2002) reported negative correlation between nitrate and salinity as in the case of present study.

Shaly(2003) reported nitrate-N concentration of surface water showed seasonal variation. In the present study also ANOVA showed significant difference in the value of Nitrate-N with seasons. Kumary et al. (2007) also reported significant seasonal variation of nitrate-N in Adimalathura estuary. Similar finding was made by Devi (2009) in the Cochin backwater of Panangad region.

Nitrite-N

Nitrite value ranged between 0.20 µg at/l and 3.87 µg at/l, during the study period. Joseph and Pillai (1975) observed that nitrite ranged between 0 and 6 microgram at/l in the Cochin backwater. Seasonal variation of nitrite was not that much pronounced. Nitrite-N concentration was maximum during pre-monsoon and monsoon period; it was then decreased during post monsoon season. During post monsoon season the estimated nitrite content was 0.72 µg at/l which was then decreases by a liitle in the N.E. monsoon and the value reached 0.56 µg at/l. During the pre-monsoon and monsoon period the estimated value were 2.85 µg at/l and 1.64 µg at/l respectively. Jaysree (2009) found that the seasonal variation of nitrite was not pronounced as found in the present study.

The concentration of nitrite-N was much lower than that of nitrate-N. Kumary et al. (2007) found nitrite-N ranged between 0.17µmol/l and 5.66 µmol/l in Adimalathura estuary. The present observation is well within the range.

Phosphate-P

The phosphate value ranged between 2.2 µg at/l and 5.8 µg at/l during the study period. The highest value was recorded in the second half of March and the lowest value was recorded in the first half of November. The value of phosphate during monsoon period was 3.58 µg at/l. The value then suddenly decreased during postmonsoon. The phosphate concentration during post-monsoon, N.E.monsoon and pre-monsoon periods were 3 µg at/l, 3.75 µg at/l and 5.05 µg at/l respectively which showed an increasing trend. Renjith *et al.* (2004) also reported a decrease in nutrient content during the post monsoon season and this was attributed to the increased utilization of phosphate by phytoplankton.

Phosphate-P showed a seasonal variation among the seasons. Phosphate value showed a positive correlation with temperature, hardness and nitrite-N. Similar findings were made by Devi (2009). It showed a negative correlation with D.O. and silicate-Si. Phosphate-P showed positive correlation with nitrite-N and nitrate-N as observed by Vijayakumar et al. (2000). The present findings agree with the observations made by Vijaykumar *et al.* (2000).

Silicate-Si

Silicate varied from 7.02 µg at/l and 188.52 µg at/l. The maximum value was recorded during the last part of the monsoon *i.e.* in the second half of September. Comparatively low levels of nutrients during pre-monsoon indicate the absorption of these nutrients for high primary productivity. Mixing of bottom sediments and land leaching might have resulted in observed high values of silicate-Si during the last part of the monsoon. The average values of silicate-silicon during pre-monsoon, monsoon, post monsoon and N.E.monsoon were 31.72 µg at/l, 93.01 µg at/l, 159.03 µg at/l and 49.09 µg at/l respectively. Sankaranayanan and Qasim, (1969) found that Silicon was associated with the heavy silt load of estuary. Silicate-Si showed a seasonal variation among the seasons. Silicate showed positive correlation with D.O., nitrate-N and transparency. It showed negative correlation with salinity, temperature, alkalinity and hardness. Similar finding were made by Devi (2009) in the backwaters of Panangad area. Sankaranarayanan and Qasim (1969) reported inverse relationship between silicate-Si and salinity in Cochin backwater. Same was the findings made by Anirudhan and Nambisian (1990) in Cochin estuary. Vijayakumar *et al.,* (2000) reported that high silicate-Si values were associated with low salinity of water and vice versa, indicating an inverse relationship between the two. Sankaranarayanan and Qasim (1969); Nagarjaiah and Gupta (1983); Anirudhan *et al.* (1987); Anirudhan and Nambisan, (1990) reported negative correlation between silicate and salinity. Increased silicate concentration was found during monsoon and decreased during pre monsoon season (Anirudhan and Nambisan, 1990).

5.1.8 Turbidity:

Turbidity ranged between 11.11 NTU and 40.40 NTU. The maximum was recorded in the second half of July, while the minimum was recorded in first half of November. Jayasree (2009) found a turbidity range between 9.3 NTU and 38.95 NTU in the Cochin backwater of Panangad region, which is much matching with the present findings. She recorded maximum value during the second half of July and minimum was during the second half of November.

The average value of turbidity during pre-monsoon, monsoon, post monsoon and N.E.monsoon was estimated as 22.78 NTU, 25.61 NTU, 18.53 NTU and 20.33 NTU respectively. Turbidity showed a positive correlation with alkalinity, pH and chlorophyll. It showed a negative correlation with transparency.

5.1.9 Transperancy:

Transparency value of the study region was between the range of 30 cm. and 47 cm. In most of the times during the study period, the value does not show much variation. The average value of transparency during pre-monsoon, monsoon, post monsoon and N.E. monsoon season were 34.5 cm. 35.88 cm. 42.75 cm. and 35.83 cm. respectively. The maximum value of 47cm. was estimated in the first half of November and the minimum value of 30cm. was estimated in in the second half July.

5.2 BIOLOGICAL PARAMETERS

5.2.1 Primary productivity:

Primary production showed a wide range from 32 mgC/m3/day to 3707 mgC/m3/day. The maximum was recorded during the second half of June that was in the beginning ofmonsoon and the minimum value was recorded in the first half of February that was by the end of the N.E. monsoon. The average value of primary production decreased from 2332 $mg/m^3/h$ during pre-monsoon to 1559.12 mgC/m3/day during monsoon. During the period of post monsoon the value further decreased to 1110 mgC/m3/day. Pillai *et al.,* 1975 stated that primary production showed considerable seasonal variation with Post monsoon season recording the peak value of 125 mgC/m3/day. Comparatively lesser values were observed During monsoon in Vembanad Lake. The reason behind this may be due to optimum light intensity and effective utilization of nutrients (Menon *et al.,* 2000). The primary productivity was found very high in the Puduveypu area. Gross primary productivity ranged between 0.57 and 16.339 gC/m2/h in a study conducted by Venketesan *et al.,* (2001) in Puduveypu and Valappu. He also observed that primary productivity was relatively more in Puduveypu than at Valappu. The reason for this high primary production in Puduveyppu was attributed to relatively higher tidal influence observed at Puduveypu than Valappu which brought more nutrients for the growth and multiplication of phytoplankton. According to Menon *et al.*, (2000) the phytoplankton production in the Cochin estuary during Pre-monsoon was high. The similar result was found during the present study. The maximum value of primary productivity found during the study period was 3707 mgC/m3/day. Devi (2009) recorded a maximum value of 3300.15 mg C/ m^3/h in the Cochin backwater of Panangad region.

Statistical analysis with one way ANOVA showed significant difference between the seasons. Multiple comparison tests showed not significant difference between post monsoon with other three seasons and also between pre-monsoon and monsoon. Primary production showed a positive correlation between alkalinity pH, nitrite-N and chlorophyll.

5.2.2 Chlorophyll-a:

Chlorophyll value ranged between 4.8mg/m^3 and 62.8 mg/m^3. The highest value was observed during the second half of July and the minimum value was observed during the second half of October. The average value of chlorophyll-a for pre-monsoon, monsoon, post monsoon and N.E. monsoon season were estimated as 22.37mg/m^3, 29.74 mg/m^3 , 9.83 mg /m^3 and 14.38mg/m^3 respectively and it showed an decreasing trend from monsoon to postmonsoon. Anon (2004) studied the circulation and mixing and their influence on productivity of Panangad region of Vembanad Lake and found that chlorophyll-a ranged between 1 mg/m^3 and 34.61 mg/m^3 and the average was 9.83 mg/m^3.

5.3 SEDIMENT CHARACTERISTICS:

The sediment pH value ranged between 7.02 and 8.3 with an average of 7.78. The average value of sediment pH decreased from pre-monsoon (8.17) to monsoon season (7.53), but showed an increase during postmonsoon (7.8) and N.E. monsoon (7.9). Venkatesan *et al.,* (2001) reported that sediment pH ranged between 6.9 and 7.5 during pre monsoon in prawn filtration fields of Vypeen island of Cochin.

Total organic carbon ranged between 4.8% (September) and 8.88% (November) with an average of 6.81%.The average value of total organic carbon for the for the pre-monsoon, monsoon, post monsoon and N.E. monsoon, are 6.67%, 6.25%, 7.33% and 7.34% respectively. Nagarjaiah and Gupta (1983) reported, in general, reduction the organic carbon content during the post monsoon and pre monsoon moths in Cochin backwater. The presnt study showed a reverse pattern and it might be due to the settled dead and decaying planktonic organisms and mangrove leaf litter fall during winter.

The result of analysis revealed that sediment of the Puduveypu region contains maximum sand followed by silt and clay. No seasonal variation is observed in the composition of soil. During post monsoon, the average value of textural pattern of the sediment were estimated as sand 71.09%, silt 21.96% and clay as 6.95% .During N.E.monsoon the values were 72.15%, 20.29% and 7.55% for sand , silt and clay respectively. While in pre-monsoon the average values for sand silt and clay were 68.72%, 19.83% and 11.44%. The values during monsoon are 69.99%, 19.97% and 10.03% for sand silt and clay respectively. The present study showed that sand was the dominant component of the substratum.

5.4 MANGROVE PLANTS:

Rhizophora mucronata, Rhizophora apiculata, Rhizophora conjugate, Brugiuera cylindrica, Brugiuera gymnorhiza, Sonerasia caseolaris, Sonerasia alba, Avicennia officianalis, Exocearia agallocha, Acanthus ilicifolius, Clerodenterum innerme, Premna latifolia, and Acrostichum aureum have been identified from the study region.Kotmire and Bhosale (1979) reported presence of *Avicennia officianalis, Sonerasia alba, Exocearia agallocha* at Deogad-Mumbra creeks. Bopaiah and Neelakanthan (1982) reported the presence of *Avicennia officianalis, Acanthus ilicifolius* mangrove plants near tidal pond in Karwar. Lakshmi et al. (2000) collected *Rhizophora mucronata, Avicennia officianalis, Brugiuera gymnorhiza, Exocearia agallocha, Kandelia candel, Acrostichum aureum, Acanthus ilicifolius, Derris trifoliate, Ipomoea biloba* from mangrove ecosystem in Valapattanam river basin, Kerala.

Rhizophora mucronata, commonly known as red mangrove, is the species which established itself first on the banks. Usually the mangrove swamps are protected by Rhizophora mucronata with the supporting root system, which form row towards water-front. Red mangrove creates an essential environment for the black mangrove *Avicennia officianalis*. *Avicennia*, soon after the seedling stage, develops a horizontal root system, which gives rise to another special type of aerial roots-pneumatophores. Decayed leaves of the plant also play an important role in the enrichment of the substratum. *Brugiuera gymnorhiza* produces knee roots which come out of the substratum as a support for the mangrove plant (Untawale *et al.*, 1973). *Exocearia agallocha* do not show vegetative propagation. *Acanthus ilicifolius* are runners which flowers during November/December (Singh and Odaki, 2004).

5.5 SHELLFISHES:

Penaeus monodon, P. indicus, Metapenaeus dobsonii, M. monoceros, Feneropenaeus indicus, Penaeus semisulcatus, Macrobrachium equidens, M. idella have been identified from the study area. The penaeid prawn constitute an important fishery in the backwaters of Cochin of which *Metapenaeus dobsonii, M. monocero* and *Feneropenaeus indicus* are the most important ones. These prawns enter the backwater quite early in life in the larval and post-larval phases, and after a few months growth there, return to the sea for breeding (Menon, 1951; Panikar and Menon, 1956 and George, 1959).

5.6 FISHES:

36 species of finfishes were collected during the study period. The fishes can be categorized into 10 order and 26 families. Nammalwar (2008) reported similar findings from his review of mangrove associated fishes diversity from Gulf of Mannar, Tamil Nadu *Mugil cephalus, Liza parsia, Etroplus maculates, Etroplus canarensis, Ambasis commersoni, A. gymnocephalus, Siganus javus, Lutjanus fluviflammus, Epinephelus tauvina, Lates calcarifer, Arius subrostrarus, Chanos chanos* and *Therapon jarbua*. Devi (2009) also repoted species like *Megalops cyprinoids, Anodontostoma*

chacunda, Stolephorus commersoni, Thryssa mystax, Mstus gulio, Zenarchopterus dispar, Ambasis commersoni, Mugil cephalus, Liza parsia, Etroplus suratensis, Oreochromis mossambicus, Lutjanus argentimaculatus, Scatophagus argus, Etroplus maculates, Leiognathus equulus, L. splendens, L. brevirostris, Secutor ruconius, S. insidiator, Carnx ignobilis, Carangoides chrysophrys, L.johni, Glossogobius giuris, Cynoglossus sp. from the Cochin backwater of Panangad region.

6. SUMMARY

1. The present study was carried out to find out the temporal variation in the hydrography of the Cochin backwater of Puduveypu region and to find out the richness of the biodiversity of the area.

2. The study was conducted from April, 2010 to Apil, 2011 for all the four prevailing seasons viz, pre-monsoon (March –May), monsoon (June – September), post monsoon (October-November) and N.E. monsoon (December- February).

3. Water samples were collected fortnightly, in the morning hours 7.00-8.00 am. Collection of sediments was done on monthly basis Hydrographical factors like temperature, salinity, turbidity, pH, transperancy, total alkalinity, hardness, dissolved oxygen, primary production, chlorophyll-a and transperancy. Sediment characteristics like sediment pH, TOC and sediment texture were studied.

4. Fishes, shellfishes, crabs and mangrove plants found in the study region were identified.

5. To study the relationship between different hydrographical and biological parameters, linear correlation coefficients (r) were worked out.

6. The value of salinity in the backwaters of Puduveypu showed wide fluctuation and ranged between 0.06‰ and 27‰. The maximum value was recorded in the second half of January (27‰). The salinity showed considerable reduction to 17.38‰ during the period of March-April, 2011 due to Pre-monsoon showers.

7. The average temperature during the study period was 26.5°C. Water temperature showed peak values during pre-monsoon period and with the onset of monsoon the value decreased. The highest temperature

(30°C) was observed during the second half of April and the lowest temperature (22°C) was observed during the first half of October.

8. High pH was observed during the monsoon season while low values were observed during N.E. monsoon and pre-monsoon period.

9. Alkalinity showed an increasing trend during the pre-monsoon, post monsoon and N.E. monsoon seasons but a decreasing trend was observed during monsoon season. But during the 2011 pre-monsoon alkalinity showed a decreasing pattern. The value of alkalinity in the study region ranged between 75.50 mg $CaCO_3$/l and 240 mg $CaCO_3$/l. The highest value was recorded in the first half of June and minimum was estimated in the first half of October.

10. Total hardness ranged between 22.22 mg $CaCO_3$/l and 710.01 mg $CaCO_3$/l. The minimum value was found in the post monsoon season and reached in the first half of November while the maximum value was observed in the N.E.monsson and reached in the second half of February.

11. The average dissolved oxygen value of the area found as 5.62 mg /l. Dissolved oxygen showed high values during monsoon and post monsoon period. During the N.E. monsoon period the dissolved oxygen showed a decreasing pattern and reached a minimum of 2.1mg/l in the second half of February. The maximum dissolved oxygen (8.95 mg/l) was estimated during the first half of August. It showed a negative correlation with temperature.

12. The value of nitrate-N in the study region was found in the range between 1.3 µg at/l and 18.14µg at/l. The higher values were observed during post monsoon and monsoon season.

13. Nitrite value ranged between 0.20 µg at/l and 3.87 µg at/l, during the study period. Seasonal variation of nitrite was not that much

pronounced. The maximum value (3.87 μg at/l) was recorded in the month of April, 2010. Nitrite showed positive correlation with phosphate-P and primary production.

14. The phosphate value ranged between 2.2 μg at/l and 5.8 μg at/l during the study period. Highest value was recorded in the second half of March and the lowest value was recorded in the first half of November.

15. Silicate varied from 7.02 μg at/l and 188.52 μg at/l. The maximum value was recorded during the last phase of the monsoon ie in the second half of September.

16. Turbidity ranged between 11.11 NTU and 40.4 NTU. The maximum was recorded in the second half of July, while the minimum was recorded in first half of November. It showed a negative correlation with transparency.

17. Transparency value of the study region falls within a range of 30 cm. to 47 cm.

18. Primary production showed a wide range from 32 mgC/m3/day to 3707 mgC/m3/day. The maximum was recorded during the second half of June that is in the beginning of monsoon and the minimum value was recorded in the first half of February that is by the end of the N.E. monsoon.

19. Chlorophyll value ranged between 4.8mg/m^3 and 62.8 mg/m^3. The highest value was observed during the second half of July and the minimum value was observed during the second half of October.

20. The sediment pH value ranged between 7.02 and 8.3 with an average of 7.78.

21. Total organic carbon ranged between 4.8% (September) and 8.88% (November) with an average of 6.81%.

22. The analysis revealed that sediment of the Puduveypu region contains maximum sand followed by silt and clay..

23. Mangrove species like *Rhizophora mucronata, Rhizophora apiculata, Rhizophora conjugate, Brugiuera cylindrica, Brugiuera gymnorhiza, Sonerasia caseolaris, Sonerasia alba, Avicennia officianalis, Exocearia agallocha, Acanthus ilicifolius, Clerodenterum innerme, Premna latifolia,* and *Acrostichum aureum* were found in the study area. , *Avicennia officianalis* contribute 70% of the total population of mangrove.

24. *Penaeus monodon, P. indicus, Metapenaeus dobsonii, M. monoceros, Feneropenaeus indicus, Penaeus semisulcatus, Macrobrachium equidens, M. idella* have been identified from the study area.

25. Crabs in the study area include Scylla serrata, Scylla tranquebarica, Thalamita creneta, Charybdis annulata, Sesarma quadratum, Uca vocans.

26. Bivalves includes *Lamellidens sp., Villorita Sp.* and Cirriped in the study region include Balanus.

27. 36 species of finfishes were collected during the study period. The fishes can be categorized into 10 order and 26 families.

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ABSTRACT

The study was carried out to find out the temporal variation in the hydrography of the Cochin backwaterS of Puduveypu region and to find out the richness of the biodiversity of the area. The study was conducted from April, 2010 to Apil, 2011. The present study was carried out to find out the temporal variation in the hydrography of the Cochin backwater of Puduveypu region and to find out the richness of the biodiversity of the area.

The value of salinity in the backwaters of Puduveypu showed a wide fluctuation. The maximum value was recorded in the second half of January. The salinity showed considerable reduction during the period of March-April, 2011 due to Pre-monsoon showers. . Water temperature showed peak values during pre-monsoon period and with the onset of monsoon the value decreased. High pH was observed during the monsoon season while low values were observed during N.E. monsoon and pre-monsoon period. Alkalinity showed an increasing trend during the pre-monsoon, post monsoon and N.E. monsoon seasons but a decreasing trend was observed during monsoon season. Total hardness ranged between 22.22 mg $CaCO_3$/l and 710.01 mg $CaCO_3$/l. Dissolved oxygen showed high values during monsoon and post monsoon period. During the N.E. monsoon period the dissolved oxygen showed a decreasing pattern and reached a minimum of 2.1mg/l in the second half of February. The higher values of nitrate-N were observed during post monsoon and monsoon season. Seasonal variation of nitrite

was not that much pronounced. The phosphate value ranged between 2.2 µg at/l and 5.8 µg at/l during the study period. The maximum value of silicate-Si was recorded during the last phase of the monsoon.

Turbidity ranged between 11.11 NTU and 40.4 NTU. It showed a negative correlation with transparency. Transparency value of the study region falls within a range of 30 cm. to 47 cm. Primary productions showed a wide range from 32 mgC/m3/day to 3707 mgC/m3/day. The highest value of chlorophyll was observed during the second half of July and the minimum value was observed during the second half of October.

The sediment pH value ranged between 7.02 and 8.3 with an average of 7.78. The analysis revealed that sediment of the Puduveypu region contains maximum sand followed by silt and clay.

Mangrove species like *Rhizophora mucronata, Rhizophora apiculata, Rhizophora conjugate, Brugiuera cylindrical, Brugiuera gymnorhiza, Sonerasia caseolaris, Sonerasia alba, Avicennia officianalis, Exocearia agallocha, Acanthus ilicifolius, Clerodenterum innerme, Premma latifolia,* and *Acrostichum aureum* were found in the study area. , *Avicennia officianalis* contribute 70% of the total population of mangrove. *Penaeus monodon, P. indicus, Metapenaeus dobsonii, M. monoceros, Feneropenaeus indicus, Penaeus semisulcatus, Macrobrachium equidens, M. idella* have been identified from the study area. Crabs in the study area include Scylla serrata, Scylla tranquebarica, Thalamita creneta, Charybdis annulata, Sesarma quadratum, Uca vocans. Bivalves includes *Lamellidens* *sp., Villorita Sp.* and Cirriped in the study region include Balanus. 36 species of finfishes were collected during the study period. The fishes can be categorized into 10 order and 26 families.