ECOLOGY OF MANGROVE PATCHES IN THE VEMBANAD LAKE AT PANANGAD

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DEPARTMENT OF FISHERY HYDROGRAPHY

COLLEGE OF FISHERIES

PANANGAD, COCHIN

Dedicated To
My Beloved Parents,
Brothers, sister-in-law &
Prince

DECLARATION

I hereby declare that this thesis entitled **"ECOLOGY OF MANGROVE PATCHES IN THE VEMBANAD LAKE AT PANANGAD"** is a bonafide record of research work done by me during the course of research and that the thesis has not 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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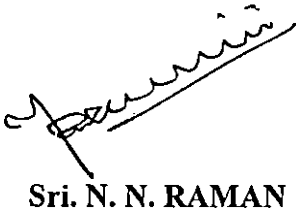

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Monalisha

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Introduction

1. INTRODUCTION

Kerala has been endowed with an extensive system of backwaters, lakes, lagoons and estuaries. Mangroves are seen as a protective cover in estuaries. Mangroves are complex ecosystem which thrives well at sheltered places where the substratum consists of shifting, changing and muddy saline environment. Mangrove forests have attracted much scientific attention and curiosity due to strange morphological and anatomical adaptations, special physiology (high osmotic potential of cell sap, reaction to salinity, desalination, viviparity) seed and seed dispersal and survival, species succession in time and zonation in space (vertical and horizontal) and paleo-history of the shores and biological assemblages. Basically the word mangrove is formed from two Portuguese words, "Mangue" and the English "grove". The 'mangue' is used for individual species of mangrove habitat and thus the word mangrove can be said to be a 'grove' of mangrove species (trees and shrubs).

Macnae (1968) coined a new term for the mangroves viz., 'mangal' for mangrove community and retained the 'mangrove' for only individual species. Mangrove forests along the coastline are among the world's most productive ecosystems. These are often called as 'tidal forests', 'coastal woodlands' or 'oceanic rainforests' (Kathiresan and Qasim, 2005). Mangroves are woody plants that grow normally in tropical, sub-tropical latitude along the land-sea interface, bays, estuaries, lagoons, backwater, and in the rivers, reaching upstream up to the point where the water still remains saline.

Mangrove ecosystem is a complex, intertidal, halophilous, wetland ecosystem, which is a natural reservoir of biodiversity constituting a bridge between the terrestrial and aquatic ecosystems. The mangrove-associated fauna and microorganisms are interdependent and

would not survive in isolation if any one component of the ecosystem is disturbed. The micro-flora and fauna associated with the system serve in controlling pH, leaching of metals and nutrient cycling (Ananthakrishnan, 1982).

The mangroves harbour a rich community of plankton, which form the source of food for crabs, prawns and fishes. They also form the feeding, breeding and nursery ground for many marine and fresh water fishes for the juvenile stages of finfish and shellfish (Lakshmi *et al.*, 2000; Marakala *et al.*, 2005). They clean polluted water, prevent floods and banks erosion, reduce the fury of waves and wind, recharge groundwater and provide unique habitat for a wide variety of fauna and flora associated with them. 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 average organic matter production is approximately 20 g/m^3/day (Kathiresan, 1998), which is seventy times more than that of oceanic water. Mangrove produces nearly one million tones of crabs, shrimps, molluscs and fin fishes annually, which is equivalent to the world fish production (FAO, 1998). Mangrove areas are ecologically fragile due to constantly fluctuating dynamics of environmental factors besides the pollutants from seaward and landward areas (Marakala *et al.* 2005).

The mangroves play an important role in the formation of detritus which is consumed by variety of marine and estuarine organisms. At the same time the specialized root system of mangroves develop muddy or silty substratum as a result of accretion (Untawale and Parulekar, 1976).

On the west coast of India there are extensive estuarine systems of brackish water of which Vembanad Lake is the largest. The backwater of Kerala support as much biological productivity and

diversity as tropical rain forest. They are responsible for the high fish production in Kerala. Cochin backwaters situated at the tip of the northern Vembanad lake is a tropical positive estuarine system extending between 9° 40′ and 10° 12′ N and 76° 10′ and 76° 30′ E with northern boundary at Azeekode and southern boundary at Thanneermukkam bund. Salinity gradient in the Cochin backwaters supports diverse species of flora and fauna depending on their capacity to tolerate oligohaline, mesohaline or marine conditions.

Low lying swamps and tidal creeks dominated by sparse patches of mangroves with their nutrient rich physical environment, support larvae and juveniles of many economically important species. Backwaters also act as nursery grounds of commercially important prawns and fishes. The fields around the backwater are suitable for aquaculture. These areas support traditional, seasonal and perennial pond.

India has a total area of 4,461 km² under mangroves. About 59% are found along the east coast (Bay of Bengal), 23% on the west coast (Arabian Sea) and the remaining 18% on the Bay Islands (Andaman & Nicobar Islands in Bay of Bengal) (Kathiresan, 2008). There are three major types of coastal settings on which mangroves in India exist and they are:

(i) **Deltaic:** The deltaic mangroves occur along the east coast (Bay of Bengal) where the mighty rivers (Ganga, Brahmaputra, Mahanadi, Krishna, Godavari and Cauvery) make deltas.

(ii) **Backwater-estuarine:** The backwater estuarine type of mangrove exists in the west coast (Arabian Sea) which is characterized by typical funnel shaped estuaries of major rivers (Indus, Narmada and Tapti, with delta formation is almost absent) or backwaters, creeks and neritic inlets.

(iii) **Insular:** The insular mangroves are present in Bay Islands, where many tidal estuaries, small rivers, neritic islets and lagoons support a rich mangrove flora.

These three environments have different physical and chemical structure of the substratum (Joshi and Jamale, 1975). Mangroves are large and widespread on the east coast of India due to the nutrient-rich alluvial soil formed by the rivers and a perennial supply of freshwater along the deltaic coasts. The east coast has a smooth and gradual slope which provides area for colonisation of mangroves, whereas the west coast has a steep and vertical slope (Kathiresan, 2008). State-wise distribution of mangrove in km^2 is given in Table1.

Table 1: State-wise cover of mangroves forest (km^2) in India, (FSI, 2003)

Sl. No.	State/UT	Very dense mangrove	Moderately dense mangrove	Open mangrove	Total
1.	Andhra Pradesh	0	15	314	329
2.	Goa	0	10	0	10
3.	Gujarat	0	198	762	960
4.	Karnataka	0	3	0	3
5.	Kerala	0	3	5	8
6.	Maharashtra	8	44	64	116
7.	Orissa	0	160	47	207
8.	Tamil Nadu	0	18	17	35
9.	West Bengal	892	894	334	2,120
10.	Andaman&Nicobar	262	312	97	671
11.	Daman & Du	0	0	1	1
12.	Pondicherry	0	0	1	1
	Total	1,162	1,657	1,642	4,461

Mangroves are the forest ecosystem of tropical and subtropical regions of the world. A rich biodiversity is observed in the mangroves. Creeks are areas where huge amount of organic detritus is build up, a

considerable quantity sinks to the bottom together with phytoplankton and zooplankton, finally to rest on the sediment water interface. Thus even if estuarine floor doesn't have primary production of its own, it gets large quantity of organic matter by sinking and horizontal transport, on which a vast variety of bottom living organisms subsist and they are popularly called benthos. They enrich coastal biodiversity, yield commercial forest products coastlines, and support coastal fisheries (Kathiresan and Bingham, 2001). There may be no other group of plants with such highly developed adaptations to extreme conditions of high salinity, extreme tides, strong winds, high temperatures and muddy, anaerobic soils. The mangroves create a unique ecological environment that hosts rich assemblages of species. Globally, the mangroves habitats continue to disappear (Kathiresan, 2008).

The entry of tidal water regularly from the sea, the enrichment of 30 estuaries and backwaters with the regular supply of fresh water flowing from the 44 perennial rivers create a peculiar ecological environment leading to the development of mangrove vegetation on the fringes of the backwaters, estuaries and creeks. The important species reported are *Acanthus ilicifolius, Acrostichum aureum, Avicennia marina, A. officinalis, Bruguiera gymnorrhiza, B. parviflora, Ceriop tagal, Derris trifoliata, Excoecaria indica, Kandelia candel, Lumnitzera racemosa, Rhizophora mucronata, R. apiculata and Sonneratia caseolaris* (Shaly, 2003).

Patches varying exist along the sides of the railway line especially in the Trivandrum, Quilon, Ernakulam-Allepey and Thanur-Kasargode sector. In most places the vegetation is in a very narrow linear strip. Bigger bits are available in some parts especially on the sides of the line from Mahe to Dharmadom, Pazhayangadi, Ezhimala, Payyanur, Edakkad and so on. These are comparatively bigger mangrove vegetation. The Quilon strip has a length of 0.75 km. and a

varying width of 1-10m from the water front. The total extent of this may be around 2 ha. Kumarakam which is declared as a bird sanctuary supports a narrow belt of approximately 1km long mangrove vegetation along the fringe of Vembanad Lake varying in width from 10-20m. These areas come approximately to 4 ha including marshy patches.

The Vypeen area in Ernakulam district supports about 10 ha of mangroves. These form a part of the naturally accreted area called Puduveypu at the southern tip of Vypeen Island located on the North-Western bank of Cochin bar-mouth. In Kerala some of the mangrove vegetation is under the forest department. In Ernakulam disrtict the land called "Mangala Vanam" also supports a good amount of mangrove vegetation.

Narrow strips of mangrove exist near College of Fisheries, Panangad. No concerted efforts have been made to study its ecological aspects and to highlight the beneficial aspects of mangrove in this area hence the present study was carried out.

The main objectives of the study were:

a) to identify the floral composition of the mangrove in the study area.
b) to identify the fishes, prawns, crabs and molluscs available in the study area.
c) to study the seasonal variation of hydrographical parameters like water temperature. pH, dissolved oxygen, alkalinity, primary productivity, nutrients and sediments which supports the mangrove system.

Review of Literature

2. REVIEW OF LITERATURE

2.1 HYDROGRAPHICAL PARAMETERS

Hydrography of the Cochin backwater was studied by several workers (Ramamirtham and Jayaraman, 1963; Cheriyan, 1967; Josanto, 1971; Sreedharan and Salih, 1974; Balakrishnan and Shynamma, 1976; Menon *et al.,* 2000; Varma *et al*, 2002; Vijyakumar, 2003; Haridevi *et al.*, 2004; Renjith *et al.*, 2004 and Anon, 2004). Among the numerous lagoons and estuaries of Kerala coast, Vembanad Lake is the largest estuarine system, which is one of the most productive estuarine systems in the tropical environment (Qasim *et al.*, 1969).

During post-monsoon season the estuary behaves like a partially mixed estuary (Sankaranarayanan *et al.*, 1986). During monsoon season, due to influx of large volume of fresh water inflow and the intrusion of saline water estuarine circulation takes place. During pre-monsoon season when the freshwater flow to the estuary is almost negligible, the estuary becomes a well mixed type (Joseph and Kurup, 1990; Rasheed *et al.*, 1995; Anon, 2004).

The environmental conditions of the seasonal and perennial prawn filtration ponds were studied by several workers. The important studies include Paulinose *et al.* (1981); Sankaranarayanan *et al.* (1982); Gopinathan *et al.* (1982); Mathew (1987); Singh (1987); Gopalakrishnan *et al.* (1988); Jose *et al.* (1988); Joseph (1988); Nair *et al.* (1988); Balasubramanian *et al.* (1995); Venkatesan *et al.* (2001); Sudheer (2003) and Susheela *et al.* (2006).

Mangroves are seen all along the Indian coast. On the west coast of India many river basins form mangrove in the estuarine environment. Different aspects of mangroves on the west coast have been studied by Jagtap (1987); Sunilkumar (1995); Goldin *et al.* (1996); Sheeba *et al.* (1996); Badarudeen *et al.* (1998); Lakshmi *et al.* (2000); Manjappa *et al.*

(2003); Thivakaran *et al.* (2003); Rajesh *et al.* (2005). Several workers have studied mangrove on the east coast (Ramadhas and Sundararaj, 1981; Sundararaj and Krishnamurthy, 1981; Selvam *et al.*, 1991; Kathiresan *et al.*, 1996; Chinnadurai and Fernando, 2003; Enemulhoq *et al.*, 2003; Kumar *et al.*, 2006; Prasad and Ramanathan., 2008 and Senthilkumar *et al.*, 2008). Ecology of mangroves has also been studied by Untawale *et al.* (1973); Joshi and Jamale (1975); Untawale and Purulekar (1976) and Marakala *et al.* (2005).

2.1.1 Water Temperature

The surface water temperature follows the change in the air temperature. Maximum evaporation takes place in the post-monsoon season at Cochin (Balakrishanan, 1957). The influx of fresh water into the estuarine system is not the sole factor in bringing down water temperature in estuarine system, but the cold water from the sea may also be a significant factor (Sankaranarayanan and Qasim, 1969). With the onset of the south-west monsoon sharp decline in temperature was noted while persistently high temperature was observed was observed during pre-monsoon (Menon *et al.*, 1971; Singh, 1987; Jayachandran and Joseph, 1988; Kumary *et al.*, 2007). Lakshmanan *et al.* (1982) noticed sharp variation in temperature during the onset and withdrawal of the south-west monsoon.

Nair *et al.* (1988) reported that the annual variation in temperature in paddy-cum-prawn culture fields was small (~5°C) and did not affect the environment. Temperature range between 24°C and 33°C was observed at Mandovi-Zuari estuarine system by Padmavati and Goswami (1996). According to Prabhadevi *et al.* (1996) the seasonal variation in water temperature showed high values in pre-monsoon and low values during monsoon. The range of temperature was between

27°C and 35°C at the surface and bottom water at Kayamkulam backwaters and Arattupuzha coast.

Varma *et al.* (2002) observed a bimodal pattern with the annual range from 27°C to 35°C. Anon (2004) reported that a bimodal annual variation and the highest temperature were observed during the pre-monsoon months (March – April). They did not show wide fluctuations and temperature ranged between 28.4°C and 33.5°C in the Panangad region of Vembanad Lake.

Temperature influences the development and survival of the mangroves in the early stages. Mangroves attain maximum growth only under tropical condition where atmospheric temperature in the coldest months is greater than 20°C and seasonal fluctuation does not exceed 5°C. Mangroves have been reported to grow in latitudes where the average sea surface temperature is 24°C. Any further rise in temperature may lead to spreading of only some species, provided that the direction of ocean currents facilitates the dispersal of their seeds. However, very high temperature are not favourable as leaves of mangroves are sensitive to temperature and their photosynthetic capacity gets reduced, falling to zero at leaf temperature of 38-40° C (Gopinathan and Selvaraj, 1996; Kathiresan and Qasim, 2005).

According to Kumar *et al.* (2006) difference in temperature, in general was due to the factors such as solar radiation, cloud cover intensity and direction of wind and thermal changes by tidal currents. During the summer season 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.

2.1.2 Hydrogen-ion concentration (pH)

pH is an important parameter controlling fish life. It is an important chemical factor affecting metabolism and other physiological processes of aquatic organisms. pH range of 6.5-9.0 has been reported to be the most ideal for fish culture (Jhingran, 1982; Boyd, 1990; Venketesan *et al.,* 2001). Nagarajaiah and Gupta (1983) recorded pH range between 7.0 and 8.4 in brackish water ponds along the Nethravati estuary. pH was low during the 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 (Banerjee and Roychoudhury, 1966).

Padmavati and Goswami (1996) observed pH values in surface and bottom layers varied from 6.9 to 8.2 in Mandovi-Zuari system of Goa. Sheeba *et al.* (1996) reported pH range from 6.46 to 8.64 in the mangrove area of Cochin backwater. Diurnal 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. A positive relationship was observed between pH and temperature of pond water (Das *et al.*, 2000).

Marakala *et al.* (2005) reported pH range of 7.08 and 7.63 in mangrove area in south-west coast of India. Tripathy *et al.* (2005) reported that pH ranged between 7.19 and 7.58 in the Gautami-Godavai mangrove area of Andhra Pradesh. Kumar *et al.* (2006) studied Muthupettai mangrove in Tamil Nadu and found that salinity decreased due to fresh water inflow and thereby reduces pH level and was 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 – 2004) and 6.0-10.5 during post tsunami (2005) period in an interior prawn filtration field in Cochin. pH in mangrove area varied

from 6.6 to 7.6 whereas in estuary it was slightly more alkaline ranging between 7.01 and 8.8 in Cochin backwater (Joseph *et al.*, 2008).

2.1.3 Dissolved Oxygen

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 increases in salinity and temperature. Comparatively higher dissolved oxygen was found during monsoon months (Qasim *et al.*, 1969; Haridas *et al.*, 1973; Pillai *et al.*, 1975). Kurian (1972) reported that dissolved oxygen was always supersaturated at the surface and owing to the shallow nature of the estuary and mixing of water, it seldom goes below 2.5ml/l even at the bottom. Kumaran and Rao (1975) reported that annual range from 0.6 to 5.8ml/l with high value in the monsoon period in Cochin backwater. Pillai *et al.* (1975) showed a distinct pattern of seasonal fluctuations in Vembanad Lake. He observed annual range between 1.10ml/l and 5.9 ml/l with comparatively high values of dissolved oxygen during south-west monsoon (June-August) and the lowest value during pre-monsoon period.

Dissolved oxygen is functionally involved in the biological processes of the estuary, 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.

Dissolved oxygen values were low in the mangrove biotope comparing with the estuarine and neritic biotopes (Panneerserselvam *et al.*, 1979). Dissolved oxygen value is an indicator of productive water body. It is an important factor for the aquatic life and reflects the physical and biological processes prevailing in the water (Trivedy and Goel, 1984). The diurnal variation of oxygen values showed the typical

pattern ranging from 0.5 to 8.9ml/l and from 0.1 to 7.08ml/l in two prawn filtration ponds (Balasubramanian *et al.*, 1995).

The distribution of dissolved oxygen depends upon salinity and shows an inverse relation with salinity (Nasnolkar *et al.*, 1996). Padmavati and Goswami (1996) observed that dissolved oxygen values varied between 1.1 and 5.9ml/l with higher values during the monsoon months in Mandovi-Zuari estuarine system. Sheeba *et al.* (1996) reported that dissolved oxygen ranged between 2.00 and 8.75ml/l in the mangrove areas of Cochin backwater. Higher dissolved oxygen values were observed during the monsoon season when compared with pre-monsoon values and it might be due to intrusion of fresh water from rivers and resultant mixing and circulation of water (Lakshmi *et al.*, 2000).

The levels of dissolved oxygen in the mangrove water are a function of the biological respiration. In summer, due to high temperature, biological activities rates would be doubled, resulting in the consumption of a substantial amount of dissolved oxygen. During monsoon seasons, the rapid circulation of water would facilitate the dissolution of atmospheric oxygen into the water column thus increasing the dissolved oxygen levels. High temperature increases salinity of water by evaporation and reduces dissolved oxygen level due to increased rates in the biological function of the ecosystem (Prasad and Ramanathan, 2008). Joseph *et al.* (2008) reported that dissolved oxygen content in mangrove area ranged between 1.4 and 6.4mgO_2/l while in estuary it ranged between 4.9 and 8 mgO_2/l in Cochin backwater area.

2.1.4 Salinity

Salinity is defined as the total amount of solid material in grams contained in 1kg of seawater, when all the carbonates have been

converted to oxides, all the bromine and iodine replaced by chlorine and all the organic material oxidized (Forch *et al.*, 1902).

Salinity distribution results from the combined action of water movement induced by fresh water discharge, tidal variation and mixing. Salinity varies from a well mixed to stratified type. The hydrographical conditions of the Vembanad Lake have a well- defined seasonal pattern in salinity variations (Ramamirtham and Jayaraman, 1963; Qasim and Gopinathan, 1969). About 70% of rainfall in the Cochin occurs during south-west monsoon and so during this season there is strong flow of freshwater and the salinity of water is very much reduced. During the south-west monsoon (June-September/October) the range in salinity was very high 0.39-34.25‰ (Kurian, 1972).

Varma *et al.* (2002) analyzed long term daily variations in salinity at a station near Panangad jetty and recorded a salinity range between 0 and 32‰. Sankaranarayanan and Qasim, (1967); Ramaraju *et al.* (1979); Udayavarma *et al.* (1981); Joseph and Kurup, (1990); Rasheed *et al.* (1995) reported that salinity values were maximum in pre-monsoon months in Cochin backwater. Anon (2004) reported that fresh water condition during the period from June-August, when river runoff was very high and then salinity increased with subsequent drop in October due to north-east monsoon. Maximum salinity was reported during pre-monsoon. Salinity is one of the important water parameters that regulates the quality of waters and determines the extent of dissolution of gases, hydrogen ion concentration and other characteristics of brackish water (Vijayakumar *et al.*, 2000).

Gopinathan *et al.* (1982) and Venkatesan *et al.* (2001) observed an annual salinity range of 1‰-27‰ in seasonal and perennial prawn culture fields of Cochin estuarine system. Sudheer (2003) found that average salinity of an interior prawn filtration field in Cochin is around 15.2‰.

Mangroves are facultative halophytes. Salinity determines the distribution and zonation of the species, their productivity and growth of mangrove forest within the ecosystem since each species has got its salinity tolerance. Changes in salinity are normally controlled by weather, hydrology, rainfall, topography and tidal flooding. The salinity of the bottom sediment is a function of local precipitation, subterranean seepage, terrestrial runoff, evaporation, and tidal flushing. Because these factors vary considerably in many regions, the salt concentration in most mangrove swamps soils fluctuates markedly (Gopinathan and Selvaraj, 1996; Kathiresan and Qasim, 2005). High salinity controls the biological activities by reducing the availability of nutrients (Prasad and Ramanathan, 2008).

2.1.5 Total alkalinity

Total alkalinity mainly depends on carbonates and bicarbonates of Calcium and Magnesium (Chakrabarty *et al.*, 1959). The alkalinity is defined as the quantity of hydrogen in millimole (mmol) to neutralize the weak bases in 1kg of seawater. The capacity of a solution to neutralize a dilute acid to termed as total alkalinity in terms of $CaCO_3$ (Grasshoff *et al.*, 1983).

The average range of alkalinity of Chilka Lake was from 26.8ppm to 122ppm (Banerjee and Roychoudhury, 1966). The alkalinity generally assumes higher values during summer months and starts decreasing with the advent of monsoon. Mathew (1987) reported higher values of total alkalinity with wide fluctuations in some prawn culture fields. The values ranged between 10 and 130ppm in perennial fields recording high values during pre-monsoon and low values during the monsoon months.

Panneerselvam *et al.* (1979) found an alkaline pH during the study period from the mangrove biotope of Porto Novo. Susheela *et al.* (2006) found that total alkalinity ranged between 25 and 75 ppm during 2005

and recorded minimum value of 15 ppm during 2003 – 2004 in an interior prawn filtration field in Cochin. Alkalinity in mangroves varied from 68 to 216mg$CaCO_3$/l and in estuarine area value ranged between 18 and 317mg$CaCO_3$/l in Cochin area (Joseph *et al.*, 2008).

2.1.6 Primary productivity

Primary production gives valuable information about the fishery resources of the aquatic systems. Primary productivity in 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). Pillai *et al.* (1975) observed comparatively lesser rates of production during the south-west 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.

Pillai *et al.* (1975) reported that considerable seasonal variation in primary production with post-monsoon season as the peak period recording maximum of 125mgC/m^3/hr and lesser value were observed during south-west monsoon in Vembanad Lake. Basheer *et al.* (1996) explained the seasonal variations in the primary productivity of a pond receiving sewage effluents. Anon (2004) showed a trimodal pattern with maximum values during November, July and April a maximum gross production was 183.33mgC/m^3/hr. Renjith *et al.* (2004) observed maximum primary production during postmonsoon season and minimum during monsoon season.

2.1.7 Nutrient

The seasonal variability of the nutrient in the backwater demands an understanding of the freshwater discharge into the system, which is chiefly controlled by the spectacular regime of the rainfall during the

monsoon months. This provides a general mechanism underlying not only the nutrients distribution, but also the other environmental features. Nutrient content was high during monsoon months (Sankaranarayanan and Qasim, 1969). Sreedharan and Salih (1974) also found marked seasonal change influenced by local precipitation and land runoff. Maximum concentrations of nutrients are during monsoon season with decrease during dry season. Saraladevi *et al.* (1983) studied the nutrients like phosphate, nitrite, and nitrate in four estuaries in Kerala. She found that inorganic phosphate did not show any clear pattern or pronounced seasonal variations and showed an increase in nitrate content during monsoon in all the estuaries.

Lakshmanan *et al.* (1987) reported that concentration of nitrite, nitrate and phosphate exhibit pronounced seasonal variation distribution. Marakala *et al.* (2005) studied nutrients, nitrite, nitrate, and phosphate. Silicate ranged from 0.07 to 0.54mg-at/l, 2.32 to 9.76mg-at/l, 0.36 to 1.64mg-at/l and 29.8 to 114.77mg-at/l respectively in the mangrove fringe in south-west coast of India.

Anon (2004) studied nutrient distribution at Panangad region of Vembanad Lake. The range of Phosphate-P, Nitrate-N, Nitrite-N and Silicate-Si were below detectable level to 4.85µmol/l, 0.07 and 3.06µmol/l, 0 to 4.18µmol/l and 20.94 to 82.24µmol/l respectively during pre monsoon. During south-west monsoon the range was from undetectable level to 17.3 µmol/l, 0.60 to 18.29 µmol/l, 0 to 3.24 µmol/l and 8.17 to 197.08 µmol/l respectively in the same area. During postmonsoon range was from not detected 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.

Silicon is associated with the heavy silt load of the estuary (Sankaranarayanan and Qasim, 1969). Joseph (1974) reported that nutrient distribution in the Cochin harbour showed marked seasonal

variations. Sankaranayanan and Qasim, (1969); Nagarajaiah and Gupta, (1983); Anirudhan *et al.* (1987); Anirudhin and Nambisan, (1990) reported negative correlation between silicate and salinity. Silicate concentration increased during monsoon and decreased during post and pre-monsoon seasons (Anirudhan and Nambisan, 1990).

Phosphate and silicate contribution in the estuary is largely dependent on external sources such as fresh water discharge and land drainage. Joseph and Pillai (1975) reported that phosphate concentration ranged between 0 and 32 µg at/l in Vembanad Lake. Sheeba *et al.* (1996) found phosphate range of 18.97 and 20.22µmol/l around mangroves areas in Nettor.

Nitrate is thermodynamically the most stable oxidation level of N_2 in the presence of O_2 in sea water, hence nitrate was found to be high compared to nitrite and if it is unutilized, it can also accumulate (Rajendran and Venugopalan, 1977; Sheeba *et al.,* 1996). Selvam *et al.* (1994) opined that the mangrove community may also remove large amount of inorganic nutrients from detritus.

Selvaraj *et al.* 2003 reported higher phosphate and nitrate concentration in Cochin backwater. Anon (2004) found negative correlation between phosphate, silicate and nitrate with salinity which indicates that these nutrients are terrestrial in origin. By assessing Gautami-Godavari mangrove estuarine ecosystem, Tripathy *et al.* (2005) reported a high concentration of nutrients which revealed the importance of this zone as a source of nutrient to the adjacent coastal ecosystems. The ranges of nutrients are SiO_4-Si ranged between 68.6 to 139.0µM, PO_4-P ranged between 1.89 and 5.85µM, NO_2-N ranges between 1.21 and 6.19µM and NO_3-N ranges between 7.17 and 16.2µM in the mangrove areas.

2.2 SEDIMENT CHARACTERISTICS

In an aquatic ecosystem the sediment acts as the storage reservoir of nutrient materials in water. The replenishment of these nutrients in time and their consequent removal greatly helps in the biological cycle of the system. Such an exchange of the nutrients depends upon the characteristics of the sediments and the hydrographic features of the estuary (Gupta *et al.*, 2001). In the Cochin backwater there is a wide range of substratum 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 and also on the distribution of fauna (Kurian, 1972).

The pH of the mangrove sediment is governed by the concentration of reduced ions and manganous hydroxides and carbonates, carbonic acid and humic acid (Patric asnd 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. Minimum pH value was reported during pre monsoon months and which increased during monsoon indicating an enhanced microbial activity in summer month in mangrove area in Cochin backwater (Shaly, 2003).

The composition of sediment varied markedly from place to place in Cochin backwater (Josanto, 1971). Sediment of Vembanad Lake was studied by Murty and Veerayya (1972) and found four types of sediments like sands, silty sands, silty-clays and clayey silts having higher organic matter when grain size is finer. Pillai (1977) based on the investigation in Cochin backwater, categorises sediment into clayey silt with very little sand, sandy, (sand, slit, clay) in equal proportion and sandy mud. Kotmire and Bhosale (1979) analysed the sediment of

mangrove area at Deogad and Mumbra and recorded 83.42% sand at Deogad while the sediment from Mumbra had 81.17% of sand.

Nagarajaiah and Gupta (1983) reported, in general, reduction in the organic carbon content during the post-monsoon and pre-monsoon months. The value ranged between 0.65 and 4.25%. The high carbon values recorded during July 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 Mandovi 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).

Aravindakshan *et al.* (1992) found that values of sand-silt-clay proportion in prawn culture field were not significantly altered by the monsoonal influx. Sunilkumar (1995) observed that in Cochin backwater, in general, the percentage of sand was high and relatively lower percentage of slit and clay may be due to constant tidal flushing in the fringing area.

Ramanathan (1997) found that the sand and silt constituted 70-90% of mangrove sediment followed by clay at Pitchavaram. 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. Organic carbon represents the organic matter in the sediment and this is of potential significance for aquatic productivity. Estimation of organic carbon 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).

Sudheer (2003) analysed substratum of an interior prawn filtration pond at Panangad area of Cochin and found that it was sandy with low silt and clay fraction during most of the months. 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 increase percentage of sand during premonsoon 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 minimal at Panangad area.

Ansel *et al.* (1972) reported that organic carbon of sand was low during monsoon and reached peak values in sand and surf water at the south-west coast during June/July due to heavy rain, resulting in erosion of organic materials in sand getting washed into the water. The organic matter content in bottom soils increases with increasing water depth (Boyd, 1977). Sajan and Damodaran (1981) studied organic matter content in sediments of Ashtamudy Lake. It varied from 0.3% to 12.25% dry weight sediment. Jagtap (1987) studied organic matter in mangrove environment of Gao. He found that there was a marked spatial and temporal variation in the distribution of organic matter in the mangrove environment.

Mathew (1992) reported that organic carbon content in pond nearer to the Cochin estuarine system ranged between 2.41-3.79%. Satyanarayana *et al.* (1993) studied the main cause for the increase of organic matter in fine particle. Nasnolkar *et al.* (1996) studied sediment of Mandovi estuary and the organic carbon ranged between 1.04 and 32.77mg/g. Total organic carbon at mangrove area of Cochin showed the values ranging between 0.17% and 4.05% (Sunilkumar, 1996).

Badaruddeen (1997) reported that total organic carbon ranged between 0.64 and 7.94% in mangrove area of Kerala. Chinnadurai and

Fernando (2003) found that total organic carbon content ranged between 1.0 and 9.76mgC/g. Shaly (2003) reported that total organic carbon ranged between 6.2% and 11.7% in Cochin mangrove area. Total organic carbon in mangrove areas at Cochin backwater ranged between 2.2 and 6.7% dry weight (Joseph *et al.*, 2008).

Materials and Methods

2. MATERIALS AND METHODS

Information on various physico-chemical and biological processes, which control the prevailing environment conditions of the region, will eventually help to understand the ecological changes. There is no fundamental data available in the ecology of mangrove ecosystem of Panangad region. Therefore, in order to know the ecological condition of the mangrove area and backwater, data has been collected on the hydrographical, meteorological and soil characteristics and also flora and fauna covering monsoon, post-monsoon and pre-monsoon seasons. For comparison data from the backwater was also collected.

A perennial prawn filtration pond (Plate 1 A) having an area of 0.75 ha and 50cm depth near the College of Fisheries, Panangad with a rich canopy of mangrove vegetation on the southeastern part has been taken as mangrove area. The mangrove area is connected freely with backwater (Plate 1 B) by sluice gate where continuous exchange of water takes place. Mangrove area is designated as station I and backwater as station II.

The study period was from July 2008 to April 2009. Water samples were collected fortnightly, in the morning hours 7.30-8.30 am. Collection of sediments, netting for fishes, prawns, crabs etc were done on monthly basis. The mangrove area being a shallow water body vertical variation in the hydrographical parameters was not considered as opined by Sankaranarayanan *et al.* (1982) and Nair *et al.* (1988). Hourly meteorological data was collected by Automatic Weather Station (AWS), located at College of Fisheries. The methods for collecting water samples, sediments, netting and collection of mangroves are discussed below.

3.1 METEOROLOGICAL PARAMETERS

During study period meteorological parameters like maximum temperature, minimum temperature, rainfall and relative humidity were collected from AWS. The values were obtained from hourly observation taken by Automatic Weather Station (EMCON make) instrument installed inside College campus (Plate 2).

3.1.1 Maximum temperature

Maximum temperature is the highest air temperature attained by the air and usually occurs in the early afternoon.

3.1.2 Minimum temperature

Minimum temperature is the lowest air temperature attained by the air. It usually occurs during late night or early morning.

3.1.3 Rainfall

Daily total rainfall data was calculated by adding up hourly data recorded in the Automatic Weather Station for 24 hrs from 9am to 8am on next day.

3.1.4 Relative humidity

Relative humidity is the ratio of the actual amount of water vapor present in unit volume of air to the water holding capacity of the air at that particular temperature expressed in percentage. Relative humidity recorded at 9.00 am. and 6.00 pm. was taken for analysis.

3.2 HYDROGRAPHICAL PARAMETERS

Data on hydrographical parameters like temperature, pH, dissolved oxygen, salinity, total alkalinity, nutrients were collected by methods given below.

3.2.1 Water temperature

The surface water temperature was measured by using a mercury thermometer.

3.2.2 Hydrogen ion concentration (pH)

pH was determined using a digital pH meter (Systronice, MK VI). The instrument was calibrated each time before taking reading with pH 4.0 and 9.2

3.2.3 Dissolved oxygen

For finding out dissolved oxygen standard Winkler's method (Strickland and Parson, 1972) was used. Surface water sample was collected *in situ* in 125ml clean oxygen bottles without trapping of air bubbles. Immediately DO is fixed by Winkler's reagents.

3.2.4 Salinity

Salinity estimation was done by using Knudsen-Mohr titration method (Grasshoff *et al.*, 1983). Silver nitrate standardization was done by standard seawater I.A.P.S.O and Potassium chromate used as indicator.

3.2.5 Total alkalinity

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

3.2.6 Primary production

Gaarder and Graan's light and dark bottle method was used for primary productivity estimation. Three dissolved oxygen bottles were

taken, two light bottles and one dark bottle having a capacity of 125 ml. These bottles are filled without trapping air bubbles. Dissolved oxygen in the light bottle was initially estimated. The other two bottles are kept for 4 hours incubation in a tray filled with water in the same sampling site. After 4 hours incubation bottles were taken out and dissolved oxygen was estimated. Dissolved oxygen estimation was done by titrimetric method (Strickland and Parsons, 1972). The difference of dark and light bottle gives the gross primary productivity.

3.2.7 Nutrients

Samples were collected in clean bottles (250 ml) from the surface water of Station I and II and were stored in an ice box with ice and transferred to freezer till analysis to prevent the nutrient loss. Nutrients like Nitrate-N, Nitrite-N, Phosphate-P, and Silicate-S were analyzed by following standard photometric methods (Grasshoff et al., 1983) using UV-VIS spectrophotometer (JASCO, V-530). 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 determination, reaction of nitrite with an aromatic amine leading to the formation of a diazonium compound which couples with a second aromatic amine to form an azodye (Grasshoff *et al.,* 1983). Phosphate and reactive Silicon were estimated by standard Molybdenum blue method (Grasshoff *et al.,* 1983).

3.3 SEDIMENT ANALYSIS

Sediment samples were collected by using Van Veen grab having a biting area of 0.042 m^2 for determination 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. After proper washing with distilled water it is air

dried and stored in air tight self sealing polythene covers to determine soil texture.

3.3.1 Sediment pH

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

3.3.2 Total organic carbon

Total organic carbon was determined by back titration method (Gaudette and Flight, 1974).

3.3.3 Sediment texture

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

3.4 NETTING

Cast net was used to catch fishes, shellfishes and crabs. From both stations five cast netting were done and species sorted out and identified up to genus or species level (Chhapgar, 1957; Francis Day *et al.*, 1978; Fisher and Bianchi, 1984; Munro, 1982). Netting was done monthly. Fishes and prawns length were noted down to know the size range which contributed to the catch and to ascertain the relative abundance.

3.5 MANGROVE PLANTS

Plants were identified upto genus or species level based on literature (Anupama and Sivadasan, 2004; Singh and Odaki, 2004)

3.6 STATICSTICAL ANALYSIS

To study the relationship between different hydrographic parameters, linear correlation coefficients ('r') were worked out (Snedecor and Cochran, 1968). The computed values of correlation coefficient ('r') between any two variables were tested for significance at 1% and 5% level separately for mangrove area and backwater. The data on water quality was subjected to statistical analysis employing ANOVA technique to assess significant different existed between water quality parameters between seasons and within seasons. t-Test was carried out to compare between mangrove area and backwater.

Plate 1 (A) Mangrove area (Station I)

Plate 1 (B) Backwater (Station II)

Plate 2 Automatic Weather Station

Results

4. RESULTS

4.1 METEOROLOGICAL PARAMETERS

4.1.1 Maximum temperature

During the study period mean maximum temperature ranged between 29.26°C (July, 2008) and 33.46°C (March, 2009) (Table 2; Fig 1). Mean maximum temperature ranged between 29.26°C (July, 2008) and 30.79°C (September, 2008) during south-west monsoon. In post-monsoon season maximum temperature ranged between 31.11°C (October, 2008) and 32.18°C (January, 2009) whereas during pre monsoon season temperature ranges between 32.51°C (February, 2009) and 33.46°C (March, 2009).

The highest temperature recorded during the study period was 35.4°C in April, 2009 (Table 2; Fig 1) and the lowest value of highest temperature was recorded during August, 2008 (30.91°C).

4.1.2 Minimum temperature

Mean minimum temperature attained lowest value of 19.37°C in January, 2009. The mean minimum temperature during south-west monsoon ranged between 22.18°C (September, 2008) and 22.45°C (August, 2008). It then increased during October, 2008 but there was a gradual decrease there after till January, 2009. February recorded mean minimum temperature of 22.36°C (Table 2, Fig 1).

Lowest minimum temperature ranged between 20.19°C (September, 2008) and 16.8°C (January, 2009) (Table 2, Fig 1).

4.1.3 Rainfall

The maximum rainfall recorded during the study period was 117.06 mm (July, 2008) and minimum is 0.81 mm (February, 2009).

Total rainfall was during July, 2008 to September, 2008 period was 215.08 mm (Table 2; Fig 1). The total rainfall during the post-monsoon seasons was of 114.57 mm with maximum during October, 2008 (82.89 mm).

4.1.4 Relative humidity

Comparing the morning and the evening data of relative humidity it could be understood that relative humidity was more during morning hours. Relative humidity during morning hours ranged between 84.01% (January, 2009) and 98.90% (August, 2008) and it ranged from 74.1% to 98.53% during evening. The mean maximum relative humidity was 98.90% in August, 2008 during morning and 98.53% in the same month during evening hours. The mean minimum relative humidity was 84.01% in January, 2009 during morning hours and 74.1% during evening in the same month (Table 2, Fig 1).

Relative humidity ranged between 97.63% (July, 2008) and 98.90% (September, 2008) during south-west monsoon. Post-monsoon it ranged between 84.01% (January, 2009) and 97.47% (October, 2008).

4.2 HYDROGRAPHICAL PARAMETERS

4.2.1 Water temperature

4.2.1.1 Mangrove area

Water temperature of the mangrove area fluctuated between 24.0°C (first half of August 2008) and 30.5°C (second half of March 2009). Water temperature was generally low during the monsoon months with a slight increase in early post-monsoon and then decreased due to winter effect (July, 2008 to first half of January, 2009). Comparatively high water temperature was recorded during pre-monsoon (second half of January, 2009 to second half of March, 2009)

(Table 3, Fig 2). Pre-monsoon season recorded higher temperature in comparison with south-west monsoon and post-monsoon (Table 7, Fig 16). Average temperature during the study period was 28.03°C (Table 11).

4.2.1.2 Backwater

Water temperature of the backwater area showed similar fluctuations during different months in comparison with mangrove area. The minimum was recorded during second half of July, 2008 and first half of August, 2008 (26°C) and maximum during first half of April, 2009 (31.0°C) (Table 4, Fig 2). Seasonal variation showed similar pattern as seen in mangrove area (Table 8, Fig 16). Average temperature during the study period was 28.72°C (Table 11).

Water temperature showed significant positive correlation with salinity (r=0.54*), alkalinity (r=0.49*) and primary productivity (r=0.56*). It showed negative correlation with dissolved oxygen (r=-0.61**), silicate (r=-0.48*), phosphate (r=-0.56*), nitrite (r=-0.77**) and nitrate (r=-0.54*) in mangrove area (Table 12). In backwater water temperature did not show any significant correlation with any of the hydrographical parameters (Table 13).

The t-Test showed no significant difference in water temperature between mangrove area and backwater (Table 14).

ANOVA showed that there was significant difference between monsoon, post-monsoon and pre monsoon with regard to temperature variation (Table 15A) in mangrove area. But there was no significant difference between three seasons in backwater (Table 16A).

4.2.2 Hydrogen ion concentration (pH)

4.2.2.1 Mangrove area

pH was alkaline throughout the study period. Maximum pH was recorded during first half of January, 2009 (8.23) and minimum of 7.04 during first half of October, 2008 (Table 3, Fig 3). Seasonal variation of pH was low during south-west monsoon in comparison with post-monsoon and pre-monsoon seasons (Table 7, Fig 17). Average pH during the study period was lesser 7.49 in mangrove area than backwater, 7.56 (Table 11).

4.2.2.2 Backwater

pH showed more or less similar pattern both in backwater and mangrove area in almost all months except second half of September and first half of October in comparison with mangrove area. Maximum pH was recorded during second half of December, 2008 (8.25) and minimum pH was recorded during second half of October, 2008 (7.09). Seasonal variation pattern showed similar pattern in comparison with mangrove area (Table 8, Fig 17). Average pH during the study period was 7.56 (Table 11).

pH showed positive correlation with salinity (r=0.74**), alkalinity (r=0.67**), primary productivity (r=0.53*) and negative correlation with silicate (r=-0.77**), phosphate (r=-0.5*) and nitrate (r=-0.78**) in mangrove area (Table 12). pH showed highly significant positive correlation with salinity (r=0.71**) and alkalinity (r=0.71**). It showed negative correlation with silicate (r=-0.68**) and nitrate (r=-0.51*) in backwater (Table 13).

The t-Test showed that there was no significant difference between mangrove area and backwater (Table 14).

ANOVA showed that no significant difference between monsoon, post-monsoon and pre monsoon in mangrove area (Table 15B) and found significant difference between seasons in backwater (Table 16B).

4.2.3 Dissolved oxygen

4.2.3.1 Mangrove area

Maximum dissolved oxygen was recorded during second half of July, 2008 (4.51ml/l) and minimum during first half of October, 2008 and second half of February, 2009 (1.54ml/l) (Table 3, Fig 4). Average dissolved oxygen was minimum during pre-monsoon season in comparison with south-west monsoon and post-monsoon seasons (Table 7, Fig 18). Average dissolved oxygen during the study period was 2.67ml/l (Table 11).

4.2.3.2 Backwater

Maximum dissolved oxygen was recorded during second half of July, 2008 (4.1ml/l). Minimum dissolved oxygen was recorded during pre-monsoon season recording 1.54ml/l (first half of February, 2009 and second half of March, 2009) (Table 4, Fig 4). Monsoon season recorded higher dissolved oxygen in comparison with post-monsoon and pre-monsoon seasons (Table 8, Fig 18). Average value of dissolved oxygen was high in backwater (2.74ml/l) in comparison with the mangrove area (2.67ml/l) (Table 11).

Dissolved oxygen showed positive correlation with nitrite ($r=0.67^{**}$) in mangrove area (Table 12). It showed positive correlation with silicate ($r=0.75^{**}$) and nitrate ($r=0.79^{**}$) and negative correlation with salinity ($r=-0.78^{**}$) and alkalinity ($r=-0.78^{**}$) in backwater (Table 13).

There was no significant difference between the mangrove area and backwater in dissolved oxygen according to t-Test (Table 14).

ANOVA showed no significant difference between monsoon, post-monsoon and pre monsoon in mangrove area (Table 15C) but significant difference between three seasons in backwater (Table 16C).

4.2.4 Salinity

4.2.4.1 Mangrove area

Salinity recorded maximum during second half of March, 2009 (21.61‰) and minimum during second half of July, 2008 (1.03‰) (Table 3, Fig 5). Average salinity was highest during pre-monsoon seasons in comparison with monsoon and post-monsoon seasons (Table 7, Fig19). Average salinity during the study period was 11.99‰ (Table 11).

4.2.4.2 Backwater

Maximum salinity was recorded during first half of December, 2008 (24.02‰) and minimum of 1.02‰ during second half of October, 2008 (Table 4, Fig 5). Seasonal variation showed similar pattern with mangrove area (Table 8, Fig 19). Average salinity was 14.26‰ (Table 11).

Salinity showed positive correlation with water temperature (r=0.54*), pH (r=0.74**), alkalinity (r=0.92**) and primary productivity (r=0.81**) negative correlation with silicate (r=-0.98**), phosphate (r=-0.69**), nitrite (r=-0.69**) and nitrate (r=-0.96**) in mangrove area (Table 12). It showed positive correlation with pH (r=0.71**) and alkalinity (r=0.96**) and negative correlation with dissolved oxygen (r=-0.78**), silicate (r=-0.96**) and nitrate (r=-0.93**) in backwater (Table 13).

The t-Test showed that there was no significant difference between mangrove area and backwater (Table 14).

ANOVA showed significant difference between the monsoon, post-monsoon and pre monsoon in both the stations (Table 15D, 16D).

4.2.5 Total alkalinity

4.2.5.1 Mangrove area

Alkalinity was minimum during south-west monsoon and increased in post-monsoon and pre monsoon. Maximum value of 200mg$CaCO_3$/l was recorded during second half of January, 2009 and second half of February, 2009 (Table 3, Fig 6). Seasonal variation showed that pre-monsoon recorded highest value in comparison with monsoon and post-monsoon (Table 7, Fig 20). Mean value of alkalinity was 134.03mg$CaCO_3$/l (Table 11).

4.2.5.2 Backwater

Alkalinity showed similar fluctuation during different months in comparison with mangrove area. Maximum value was 187.5mg$CaCO_3$/l recorded during first half of January, 2009 and first half of March, 2009 and minimum value was recorded during second half of August, 2008 (37.5 mg$CaCO_3$/l) (Table 4, Fig 6). Seasonal variation showed similar pattern with mangrove area recorded maximum during pre-monsoon season (Table 8, Fig 20). Mean value of alkalinity was 122.22mg$CaCO_3$/l (Table 11).

Alkalinity showed positive correlation with water temperature (r=0.49*), pH(r=0.67**), salinity (r=0.92**) and primary productivity (r=0.84**) in mangrove area (Table 12). It showed positive correlation with pH (r=0.71**) and salinity (r=0.93**) and negative correlation with silicate (r=-0.95**) and nitrate (r=-0.92**) in backwater (Table 13).

t-Test showed that there was no significance difference between the two stations (Table 14).

ANOVA showed that the there was significant difference between monsoon, post-monsoon and pre monsoon in both the stations (Table 15E, 16E).

4.2.6 Primary productivity

4.2.6.1 Mangrove area

Primary productivity was maximum during the pre-monsoon when the light intensity was maximum and minimum during south-west monsoon due to low light intensity. Maximum value of 4500.25mgC/m^3/day was recorded during first half of March, 2009 and minimum during first half of September, 2008 (950.9mgC/m^3/day) (Table 3, Fig 7). Seasonal variation showed that pre-monsoon recorded highest value in comparison with monsoon and post-monsoon (Table 7, Fig 21). Primary productivity was more (mean value of 2740.16mgC/m^3/day) in mangrove area in comparison with the backwater (Table 11).

4.2.6.2 Backwater

Primary productivity showed similar fluctuations. Maximum value of 3300.15 mgC/m^3/day recorded during first half of March, 2009 and minimum value of 320.21mgC/m^3/day second half September, 2008 (Table 4, Fig 7). Seasonal variation showed similar pattern with mangrove area (Table 8, Fig 21). Average primary productivity during the study period was 1694.09mgC/m^3/day (Table 11).

It showed positive correlation with water temperature (r=0.56*), pH (r=0.53*), salinity (r=0.81**) and alkalinity (r=0.84**) and negative correlation with silicate (r=-0.82**), nitrite (r=-0.6**) and nitrate (r=-0.84**) in mangrove area (Table 12). It showed negative correlation with dissolved oxygen (r=-0.49*) and nitrate (r=-0.51*) in backwater (Table 13).

The t-Test showed that there was significant difference between the mangrove area and backwater (Table 14).

ANOVA showed that there was significant difference between monsoon, post-monsoon and pre monsoon in both the stations (Table 15F, 16F).

4.2.7 Nutrients

4.2.7.1 Silicate-Si

4.2.7.1.1 Mangrove area

Silicate concentration recorded maximum during the first half of September, 2008 (219.91µmol/l) and minimum value of 2.79µmol/l during first half of January, 2009 (Table 3, Fig 8). Seasonal variation showed that average value was highest in south-west monsoon in comparison with post-monsoon and pre-monsoon seasons (Table 7, Fig 22). Average value during the study period was 98.80µmol/l (Table 11).

4.2.7.1.2 Backwater

Maximum concentration was recorded during first half of September, 2008 (196.68µmol/l) and minimum value of 2.38µmol/l during first half of January, 2009 (Table 4, Fig 8). Seasonal variation showed that average value was highest during the south-west monsoon month in comparison with post-monsoon and pre-monsoon (Table 8, Fig 22). Average concentration of silicate during the study period was 90.9µmol/l (Table 11).

Silicate-Si showed positive correlation with phosphate (r=0.65**), nitrite (r=0.62**) and nitrate (r=0.96**) and negative correlation with water temperature (r=-0.48*), pH (r=-0.77**), salinity (r=-0.98**), alkalinity (r=-0.92**) and primary productivity (r=-0.82**) in mangrove area (Table 12). It showed positive correlation with dissolved oxygen

(r=0.75**), nitrate (r=0.92**) and negative correlation with pH (r=-0.68**), salinity (r=-0.96**), alkalinity (r=-0.95**) in backwater (Table 13).

The t-Test showed that there was no significant difference between the mangrove area and backwater (Table 14).

ANOVA showed that there was significant difference between monsoon, post-monsoon and pre monsoon in both the stations (Table 15G, 16G).

4.2.7.2 Phosphate-P

4.2.7.2.1 Mangrove area

Maximum concentration of 5.8µmol/l was recorded during first half of August, 2008 and minimum concentration of 1.96µmol/l was recorded during first half of January, 2009 (Table 3, Fig 9). Seasonal variation showed that Phosphate-P concentration was highest during south-west monsoon in comparison with post-monsoon and pre-monsoon (Table 7, Fig 23). Average concentration throughout the study period was 3.76µmol/l (Table 11).

4.2.7.2.2 Backwater

Fluctuations showed similar pattern in comparison with mangrove area. A maximum concentration of 5.08µmol/l recorded during second half of December, 2008 and a minimum concentration of 0.62µmol/l was recorded during first half of January, 2009 (Table 4, Fig 9). Seasonal variation showed that average concentration was highest during south-west monsoon followed by pre-monsoon and post-monsoon (Table 8, Fig 23). Average concentration during the study period was 3.06µmol/l (Table 11).

Phosphate-P showed significant positive correlation with silicate (r=0.65**), nitrite (r=0.61**), nitrate (r=0.69**) and negative

correlation with water temperature (r=-0.56*), pH (r=-0.5*), salinity (r=-0.69**), alkalinity (r=-0.63**) in mangrove area (Table 12). In backwater it did not showed any significant correlation with any of the hydrographical parameters (Table 13).

The t-Test showed that there was no significant difference between the stations (Table 14).

ANOVA showed that the there was significant difference between monsoon, post-monsoon and pre monsoon in mangrove area but no significant difference was seen in the backwater (Table 15H, 16H).

4.2.7.3 Nitrite-N

4.2.7.3.1 Mangrove area

Nitrite-N showed maximum concentration of 3.6µmol/l during second half of July, 2008 and minimum concentration of 0.32µmol/l recorded during second half of January, 2009 and second half of February, 2009 (Table 3, Fig 10). Seasonal variation showed that average concentration was comparatively higher in south-west monsoon followed by post-monsoon and pre-monsoon seasons (Table 7, Fig 24). Average concentration recorded during the study period was 1.2µmol/l (Table 11).

4.2.7.3.2 Backwater

A maximum concentration of 2.9µmol/l recorded during first half of April, 2009 and minimum was recorded during first half of October, 2008 (0.14µmol/l) (Table 4, Fig 10). Pre-monsoon showed highest average concentration followed by south-west monsoon and post-monsoon seasons (Table 8, Fig 24). Average concentration during the study period was 1.06µmol/l (Table 11).

Nitrite-N showed significant positive correlation with dissolved oxygen (r=0.67**), silicate (r=0.62**), phosphate (r=0.61**), nitrate

(r=0.64**) and negative correlation with water temperature (r=-0.77**), salinity (r=-0.69**), alkalinity (r=-0.6**), primary productivity (r=-0.6**) in mangrove area (Table 12). While in backwater no significant correlation was found with any of the hydrographical parameters (Table 13).

The t-Test showed no significant difference between mangrove area and backwater Table 14.

ANOVA showed significant difference between monsoon, post-monsoon and pre-monsoon in mangrove area but not significant in backwater (Table 15 I, 16 I).

4.2.7.4 Nitrate-N

4.2.7.4.1 Mangrove area

Nitrate-N concentration was high during the south-west monsoon and it gradually decreased with the onset of post-monsoon and pre-monsoon. The maximum concentration of 16.01µmol/l recorded during second half of July, 2008 and a minimum concentration of 0.55µmol/l during first half of March, 2009 (Table 3, Fig 11). Seasonal variation showed that average concentration was highest during south-west monsoon followed by post-monsoon and pre-monsoon seasons (Table 7, Fig 25). Average concentration during the study period was 7.45µmol/l (Table 11).

4.2.7.4.2 Backwater

Nitrate-N showed similar fluctuation in comparison with mangrove area. The maximum concentration of 15.95µmol/l recorded during the second half of July, 2008 and minimum concentration of 0.34µmol/l was recorded during first half of March, 2009 (Table 4, Fig 11). Seasonal variation showed similar pattern with that mangrove area

(Table 8, Fig 25). Average concentration of 7.36µmol/l was recorded during the study period (Table 11).

Nitrate-N showed positive correlation with silicate (r=0.96**), phosphate (r=0.69**), nitrite (r=0.64**) and negative correlation with water temperature (r=-0.54*), pH (r=-0.78**), salinity (r=-0.96**), alkalinity (r=-0.89**), primary productivity (r=-0.84**) in mangrove area (Table 12). In backwater it showed positive correlation with dissolved oxygen (r=0.79**), silicate (r=0.92**) and negative correlation with pH (r=-0.51*), salinity (r=-0.93**), alkalinity (r=-0.92**), primary productivity (r=-0.51*) (Table 13).

The t-Test showed there was no significant difference between mangrove area and backwater Table 14.

ANOVA showed significant difference between monsoon, post-monsoon and pre monsoon in both the stations (Table 15J, 16J).

4.3 SEDIMENTARY CHARACTERISTICS

4.3.1 Sediment pH

4.3.1.1 Mangrove area

Sediment pH ranged between 6.73 (March, 2009) and 7.96 (November, 2008) with an average of 7.32 (Table 5, Fig 12). Seasonal variation showed that average pH was highest during post-monsoon followed by south-west monsoon and pre-monsoon seasons (Table 9, Fig 26).

4.3.1.2 Backwater

It ranged between 6.7 (April, 2009) and 8.01 (November, 2008) with an average of 7.34 (Table 5, Fig 12). Seasonal variation showed similar pattern in comparison with that of mangrove area (Table 10, Fig 26).

4.3.2 Total Organic Carbon (TOC)

4.3.2.1 Mangrove area

TOC ranged between 3.76% (February, 2009) and 9.44% (July, 2008) with an average of 7.68% (Table 5, Fig 13). Seasonal variation showed that post-monsoon recorded highest average TOC followed by south-west monsoon and pre-monsoon seasons (Table 9, Fig 27).

4.3.2.2 Backwater

TOC ranged between 3.28% (August, 2008) and 9.77% (July, 2008) with an average of 7.33% (Table 6, Fig 13). Average seasonal TOC was lowest during pre monsoon and highest during post-monsoon (Table 10, Fig 27).

4.3.3 Sediment texture

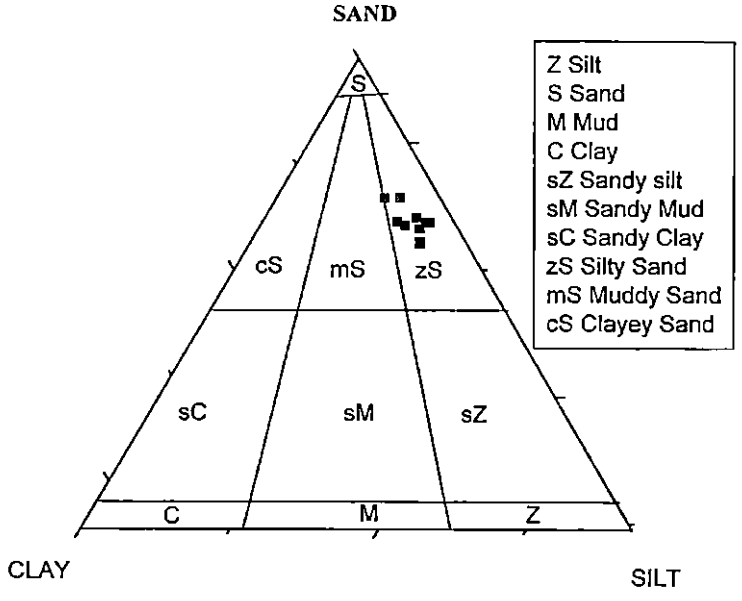
4.3.3.1 Mangrove area

Sand particles were seen in maximum concentration in the study area followed by silt and clay. Percentage composition of sand particles ranged between 78.15% (November, 2008) and 83.53% (April, 2009) with an average of 80.69% (Table 5, Fig 14). Average seasonal variation was highest during pre-monsoon and minimum during post-monsoon (Table 9, Fig 28).

Silt ranged between 10.93% (March, 2009) and 17.1% (November, 2008) with an average of 15.01% (Table 5, Fig 14). Average seasonal variation was highest during the south-west monsoon and lowest during pre-monsoon (Table 9, Fig 29).

Clay particles were minimum in composition. It ranged between 2.5% (August, 2008) and 5.75% (January, 2009) with an average of 4.28% (Table 5, Fig 14). Average seasonal variation was highest during

post-monsoon and lowest during south-west monsoon (Table 9, Fig 30). The substratum in the mangrove area was identified as silty sand (Folk, 1974). The Ternary diagram for sand, silt and clay is given below.



Ternary diagram showing the grain size distribution in the surficial sediment of mangrove area. Sediment nomenclature (Folk, 1974)

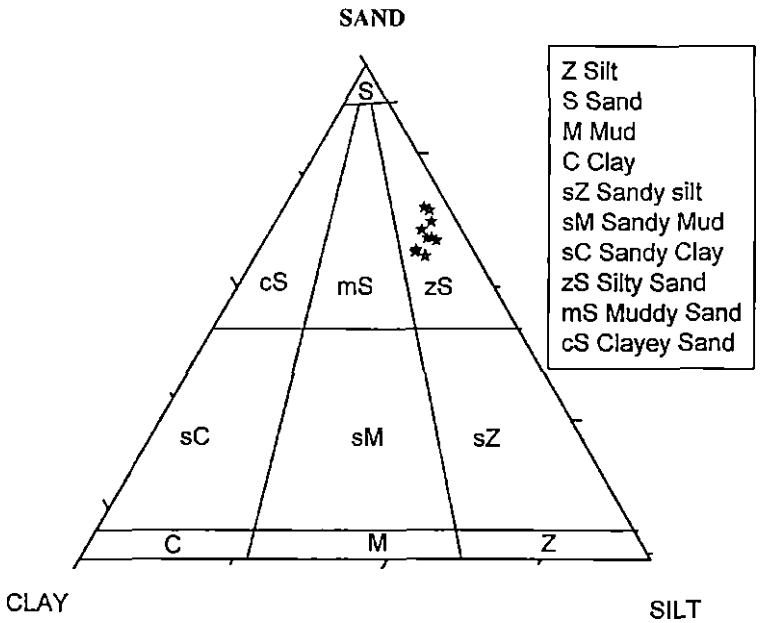
4.3.3.2 Backwater

Sand ranged between 78.45% (October, 2008) and 83.95% (August, 2008) with an average of 80.9% (Table 6, Fig 15). Average seasonal variation was highest during south-west monsoon and lowest during post-monsoon (Table 10, Fig 28).

Silt ranged between 13.68% (August, 2008) and 16.75% (January, 2009) with an average of 15.38% (Table 6, Fig 15). Average seasonal variation was highest during post-monsoon and lowest during south-west monsoon (Table 10, Fig 29).

Minimum percentage was contributed by clay. Maximum clay percentage was recorded during November, 2008 (5.75%) and minimum

during July, 2008 (2.01%) (Table 6, Fig 15). Average seasonal variation was highest during post-monsoon and lowest during south-west monsoon (Table 10, Fig 30). The substratum in the backwater was identified as silty sand. The Ternary diagram for sand, silt and clay is given below.



Ternary diagram showing the grain size distribution in the surficial sediment of backwater. Sediment nomenclature (Folk, 1974)

4.4 MANGROVE PLANTS

Mangrove plants are presented in Plate 3 to 5. The mangrove plants that have been identified from the study area are *Rhizophora mucronata, Avicennia officinalis, Brugiuera gymnorhiza, Brugiuera cylindrica, Excoecaria agallocha, Kandelia candel, Acrostichum aureum, Annona glabra, Wattakaka volubilis, Acanthus ilicifolius, Derris trifoliata, Ipomoea biloba.* Among these plants, the most abundantly found are

Rhizophora mucronata, Avicennia officinalis, Acrostichum aureum, Acanthus ilicifolius.

Rhizophora mucronata, Avicennia officinalis are found in the proximal zone which is towards the water front, subject to regular tidal effect where intensity of soil accumulation and inundation is a continuous process. The mangrove species in this zone are specially adapted with silt roots and prop roots for stability and anchorage, *Rhizophora mucronata. Avicennia officinalis* produces pnuematophores.

Brugiuera gymnorhiza, Brugiuera cylindrica develop a strong hold fast in the form of knee roots as a special adaptation for supporting the erect bole and they are found in the middle zone.

Excoecaria agallocha, Acrostichum aureum, Acanthus ilicifolius are found in the distal zone.

4.5 SHELLFISHES

Details regarding shellfishes are presented in Table 17. Prawns and crabs are presented in Plate 6. Prawns include *Metapenaeus dobsonii, M. monoceros, Fenneropenaeus indicus, Penaeus semisulcatus, Macrobrachium scabriculum, M. equidens, M. idella, Leptocarpus potamiscus.* The most commonly caught species is *F. indicus.* Abundance of *F. indicus* in different months is presented from Fig 31 to Fig 37. Bigger sizes of species were available from November, 2008 month till April, 2009.

Crabs includes *Scylla serrata, Thalamita creneta, Charybdis (Goniosoma) annulata, C. callianassa, Sesarma oceanica, Uca spp.*

Bivalves: *Lamellidens sp. Villorita sp.*, Cirriped: Balanus were found in the study area.

4.6 FISHES

The teleostean fishes identified come under 7 orders, 18 families, 30 species (Plate 7 to 10). The list of fishes is presented in Table 18 and the distribution of fishes in different months is given in Table 19. Mostly juveniles contributed to the fish catch.

Ambassis commersoni was found in abundance during south-west monsoon season. The lengths ranges of the fishes which contribute to the catches are given in table below:

Species	**Length (mm)**
Megalops cyprinoides	170
Anodontostoma chacunda	125
Stolephorus commersonii	100
Thryssa mystax	80
Mystus gulio	70-170
Zenarchopterus dispar	75
Ambassis commersoni	41-80
Leiognathus equulus	44-72
L. splendens	45-70
L. brevirostris	51-81
Secutor ruconius	54-56
S. insidiator	52-58
Gerres filamentosus	85-90
Carnx ignobilis	120
Carangoides chrysophrys	100
Scomberoides sp.	105
Lutjanus argentimaculatus	120-130
L. johni	120
Etroplus suratensis	120-150

E. maculatus	84-90
Oreochromis mossambicus	90-230
Scatophagus argus	72-87
Mugil cephalus	70-120
Liza parsia	82-110
Siganus javus	95-96
Butis butis	125
Glossogobius giuris	62-94
Oligolepis acutipennis	60-80
Cynoglossus sp.	75
Chelonodon fluviatilis	80

Catch contribution in three different seasons are:

South-west monsoon - *Ambassis commersoni, Leiognathus equulus, Etroplus suratensis, E. maculatus, Liza parsia, Mystus gulio, Glossogobius giuris, Gerres filamentosus.* Salinity ranged between 1.03‰ and 7.38‰ in mangrove area and between 1.1‰ and 10.25‰ in backwater.

Post-monsoon - *Ambassis commersoni, Oreochromis mossambicus, Etroplus suratensis, E. maculatus, Leiognathus equulus, Liza parsia, Oligolepis acutipennis, Leiognathus equulus, Secutor ruconius, S. insidiator, Chelonodon fluviatilis, Scomboroides sp. Stolephorus commersonii, Cynoglossus sp, Megalops cyprinoides.* Salinity ranged between 1.76‰ and 21.26‰ in mangrove area and between 1.02‰ and 24.02‰ in backwater.

Pre-monsoon - *Etroplus suratensis, Leiognathus equulus, L. splendens, L. brevirostris, Ambassis commersoni, Lutjanus argentimaculatus, Lutjanus johni, Zenarchopterus dispar, Anodontostoma chacunda, Scatophagus argus, Glossogobius giuris, Oligolepis acutipennis, Secutor ruconius, Carnx ignobilis, Mystus gulio,*

Siganus javus. Salinity ranged between 16.34‰ and 21.61‰ in mangrove area and between 18.65‰ and 23.62‰ in backwater.

4.7 POPULATION STRUCTURE OF *F. INDICUS* IN DIFFERENT MONTHS IN MANGROVE AREA

The size distribution of *F. indicus* was noted during the study period and the data collected for different months are recorded below:

Months	**Total numbers**
July	32
August	5
September	No specimen
October	2
November	42
December	38
January	3
February	7
March	61
April	44

Percentage size distributions of *F. indicus* in different months are presented in Fig 31 to Fig 37. In July the maximum percentage of size range was 50-60mm. In August it was 40-50mm and 60-70mm. In November 60-70mm and 70-80mm; December 80-90mm; February above 80-90mm; March above 100mm; April 90-100mm.

Table 2. Monthly variation of meteorological parameters

Parameters	Months									
	JULY 08	AUG 08	SEPT 08	OCT 08	NOV 08	DEC 08	JAN 09	FEB 09	MAR 09	APRIL 09
Mean Maximum temperature (°C)	29.26	29.6	30.79	31.11	31.61	32.11	32.18	32.51	33.46	32.93
Highest Temperature (°C)	31.49	30.91	32.14	32.77	33.2	34	34.5	34.2	35.2	35.4
Mean Minimum temperature (°C)	22.24	22.45	22.18	22.51	22.45	21.16	19.37	22.36	_	_
Lowest temperature (°C)	20.69	20.94	20.19	21.1	20.8	17.3	16.8	18.2	_	_
Total Rainfall (mm)	117.06	72.81	26.01	82.89	4.5	13.77	13.41	0.81	32.94	6.84
Relative Humidity (%) 9.00 a.m.	97.63	98.90	98.24	97.47	96.32	88.03	84.01	94.21	95.10	97.73
6.00 p.m.	91.96	98.53	95.41	96.99	95.63	84.87	74.1	83.57	87.81	93.73

Table 3. Fortnightly variation of hydrographical parameters in mangrove area

Periods	Temp. (°C)	pH	DO (ml/l)	Salinity (ppt)	Alkalinity ($mgCaCO_3/l$)	Primary productivity ($mgC/m^3/day$)
July2	25	7.45	4.51	1.03	87.5	1150.4
Aug1	24	7.3	4.02	1.53	75	1200.4
Aug2	28	7.15	4.19	3.7	75	1125.5
Sept1	28	7.3	1.67	1.1	75	950.9
Sept2	28	7.13	2.1	7.38	87.5	998.5
Oct1	28.5	7.04	1.54	8.58	125	3300.24
Oct2	28	7.12	2.51	1.76	112.5	3300.38
Nov1	29	7.44	2.6	8.69	125	1482.34
Nov2	28	7.4	2.1	8.38	125	1826.86
Dec1	29	7.6	2.93	13.79	112.5	3266.64
Dec2	27	7.86	2.93	16.9	175	3496.08
Jan1	27	8.23	2.79	21.26	175	3190.85
Jan2	29	7.57	2.37	20.87	200	3338.46
Feb1	28	7.57	2.23	21.24	162.5	3266.64
Feb2	30	7.51	1.54	21.14	200	4452.65
Mar1	28.5	7.72	2.1	20.54	187.5	4500.25
Mar2	30.5	7.85	2.65	21.61	162.5	4360.50
April1	29	7.65	3.211	16.34	150	4115.25

Table 3 (contd). Fortnightly variation of hydrographical parameters in mangrove area

Periods	Silicate (µmol/l)	Phosphate (µmol/l)	Nitrite (µmol/l)	Nitrate (µmol/l)
July2	185.2	5.1	3.6	16.01
Aug1	182.64	5.8	2.92	14.85
Aug2	166.8	4.1	1.13	13.3
Sept1	219.91	5.6	1.26	15.09
Sept2	156.538	3.53	0.84	14.12
Oct1	134.21	4.99	0.93	13.20
Oct2	187.07	4.06	1.24	12.05
Nov1	133.3	2.82	1.98	8.9
Nov2	145.62	3.08	1.23	9.85
Dec1	99.82	3.05	0.98	3.1
Dec2	52.04	4.88	1.42	3.45
Jan1	2.79	1.96	0.53	1.1
Jan2	8.95	2.45	0.32	1.6
Feb1	30.372	3.27	0.42	1.75
Feb2	18.72	2.99	0.32	1.65
Mar1	16.75	2.71	0.95	0.55
Mar2	17.9	3.22	0.53	1.6
April1	19.81	4.15	0.98	2.01

Table 4. Fortnightly variation of hydrographical parameters in backwater.

Periods	Temp. (°C)	pH	DO (ml/l)	Salinity (ppt)	Alkalinity ($mgCaCO_3/l$)	Primary productivity ($mgC/m^3/day$)
July2	26	7.2	4.1	2.3	50	1100.25
Aug1	26	7.2	3.3	1.11	62.5	1400.23
Aug2	28	7.16	3.9	3.2	37.5	890.25
Sept1	29	7.11	3.63	1.1	50	780.01
Sept2	30	7.68	3.21	10.25	87.5	320.21
Oct1	29.5	7.38	2.37	9.45	100	1217.45
Oct2	29	7.09	3.21	1.02	62.5	3216.48
Nov1	30	8.20	2.93	16.81	150	1963.63
Nov2	29	7.52	2.65	13.85	112.5	450
Dec1	29	8.15	2.79	24.02	150	861.53
Dec2	28	8.25	2.93	21.21	175	1500.17
Jan1	27	8.05	2.51	23.17	187.5	1322.29
Jan2	29	7.59	1.95	22.04	150	1484.16
Feb1	27.75	7.48	1.54	21.65	162.5	2195.65
Feb2	30.25	7.54	1.82	22.07	162.5	2450.5
Mar1	28	7.48	1.95	21.14	187.5	3300.15
Mar2	30.5	7.52	1.54	23.62	162.5	3125.25
April1	31	7.54	2.93	18.65	150	2915.48

Table 4 (contd). Fortnightly variation of hydrographical parameters in backwater

Periods	Silicate (µmol/l)	Phosphate (µmol/l)	Nitrite (µmol/l)	Nitrate (µmol/l)
July2	176.2	2.6	1.2	15.95
Aug1	175.41	4	0.9	14.25
Aug2	156.21	3.5	1.1	13.1
Sept1	196.68	3.7	1.24	15.12
Sept2	103.26	2.76	0.95	14.31
Oct1	114.84	3.73	0.14	13.07
Oct2	182.48	3.51	1.28	11.85
Nov1	77.45	2.61	1.01	8.8
Nov2	119.76	3.27	1.25	9.12
Dec1	54.01	2.71	1.01	3.1
Dec2	47.77	5.08	0.42	4.00
Jan1	2.38	0.62	0.21	1.1
Jan2	9.44	1.52	0.42	0.34
Feb1	47.12	2.82	0.42	1.6
Feb2	57.79	2.57	0.53	2.2
Mar1	31.85	2.71	1.16	0.34
Mar2	41.54	3.24	2.85	2.0
April1	42.01	4.06	2.90	2.26

Table 5. Monthly variation of sedimentary characteristics in mangrove area

Periods	Soil pH	TOC %	Sand %	Silt %	Clay%
July	7.55	9.44	80.69	16.42	2.89
August	7.25	9.3	80.63	16.87	2.50
September	7.2	4.87	79.89	16.22	3.89
October	7.77	8.74	78.35	17.01	4.64
November	7.96	8.46	78.15	17.1	4.75
December	7.83	8.38	80.26	14.57	5.17
January	6.88	6.94	80.75	13.6	5.75
February	7.02	3.76	81.17	15.23	3.6
March	6.73	7.74	83.47	10.93	5.6
April	7.02	9.15	83.53	12.43	4.04
Mean	7.32	7.68	80.69	15.01	4.28

Table 6. Monthly variation of sedimentary characteristics in backwater.

Periods	Soil pH	TOC %	Sand %	Silt %	Clay%
July	7.37	9.77	83.64	14.35	2.01
August	7.32	3.28	83.95	13.68	2.37
September	7.8	7.83	80.47	16.16	3.37
October	7.61	8.64	78.45	16.54	5.01
November	8.01	8.62	78.89	15.36	5.75
December	7.46	8.14	79.13	15.32	5.55
January	6.87	6.5	80.23	16.75	3.02
February	7.22	3.87	80.49	15.71	3.8
March	7.07	7.94	81.41	14.72	3.87
April	6.70	8.74	82.34	15.2	2.46
Mean	7.34	7.33	80.9	15.38	3.72

Table 7. Seasonal variation of hydrographical parameters in mangrove area

Parameters	Seasons	No. of observation (counts)	Minimum	Maximum	Mean	S.D
Temperature (°C)	Monsoon	5	24	28	26.6	±1.95
	Post-monsoon	8	27	29	28.19	±0.84
	Pre-monsoon	5	28	30.5	29.2	±1.04
pH	Monsoon	5	7.13	7.45	7.27	±7.27
	Post-monsoon	8	7.04	8.23	7.53	±7.53
	Pre-monsoon	5	7.51	7.85	7.66	±0.13
Dissolved Oxygen (ml/l)	Monsoon	5	1.67	4.51	3.3	±3.3
	Post-monsoon	8	1.54	2.93	2.47	±2.47
	Pre-monsoon	5	1.54	3.21	2.35	±2.35
Salinity (‰)	Monsoon	5	1.03	7.38	2.95	±2.71
	Post-monsoon	8	1.76	21.26	12.53	±6.87
	Pre-monsoon	5	16.34	21.61	20.17	±2.18
Alkalinity $mgCaCO_3$/day	Monsoon	5	75	87.5	80	±6.85
	Post-monsoon	8	112.5	200	143.75	±34.07
	Pre-monsoon	5	150	200	172.5	±20.54
Primary Productivity mgC/m^3/day	Monsoon	5	950	1200.4	1085.14	±105.71
	Post-monsoon	8	1482.34	3496.08	2900.23	±779.05
	Pre-monsoon	5	3266.64	4500.25	4139.06	±509.78
Silicate (µmol/l)	Monsoon	5	156.54	219.91	182.22	±24.12
	Post-monsoon	8	2.79	187.07	95.48	±67.42
	Pre-monsoon	5	16.75	30.37	20.71	±5.52
Phosphate (µmol/l)	Monsoon	5	3.53	5.8	4.83	±4.83
	Post-monsoon	8	1.96	4.99	3.41	±1.11
	Pre-monsoon	5	2.71	4.15	3.27	±0.54
Nitrite (µmol/l)	Monsoon	5	0.84	3.6	1.95	±1.23
	Post-monsoon	8	0.32	1.98	1.08	±0.52
	Pre-monsoon	5	0.32	0.98	0.64	±0.31
Nitrate (µmol/l)	Monsoon	5	13.3	16.01	14.67	±1.02
	Post-monsoon	8	1.1	13.2	6.66	±4.88
	Pre-monsoon	5	0.55	2.01	1.51	±0.56

Table 8. Seasonal variation of hydrographical parameters in backwater

Parameters	Seasons	No. of observation (counts)	Minimum	Maximum	Mean	S.D
Temperature (°C)	Monsoon	5	26	30	27.8	±1.79
	Post-monsoon	8	27	30	28.81	±0.92
	Pre-monsoon	5	27.75	31	30.5	±1.51
pH	Monsoon	5	7.11	7.68	7.27	±0.23
	Post-monsoon	8	7.09	8.25	7.78	±0.44
	Pre-monsoon	5	7.48	7.54	7.51	±0.03
Dissolved Oxygen (ml/l)	Monsoon	5	3.21	4.1	3.63	±0.38
	Post-monsoon	8	1.95	3.21	2.67	±0.39
	Pre-monsoon	5	1.54	2.93	1.96	±0.57
Salinity (‰)	Monsoon	5	1.1	10.25	3.59	±3.82
	Post-monsoon	8	1.02	24.02	16.45	±8.02
	Pre-monsoon	5	18.65	23.62	21.43	±1.81
Alkalinity $mgCaCO_3$/day	Monsoon	5	37.5	87.5	57.5	±18.96
	Post-monsoon	8	62.5	187.5	135.94	±41.42
	Pre-monsoon	5	150	187.5	165	±13.69
Primary Productivity mgC/m^3/day	Monsoon	5	320.21	1400.23	898.19	±400.30
	Post-monsoon	8	450	3216.48	1501.96	±826.61
	Pre-monsoon	5	2195.65	3300.15	2797.41	±462.77
Silicate (µmol/l)	Monsoon	5	103.26	196.68	161.55	±35.59
	Post-monsoon	8	2.38	182.48	76.02	±60.82
	Pre-monsoon	5	31.85	57.79	44.06	±9.45
Phosphate (µmol/l)	Monsoon	5	2.6	4	3.31	±0.61
	Post-monsoon	8	0.62	5.08	2.88	±1.37
	Pre-monsoon	5	2.57	4.06	3.08	±0.60
Nitrite (µmol/l)	Monsoon	5	0.9	1.24	1.08	±0.15
	Post-monsoon	8	0.14	1.28	0.72	±0.47
	Pre-monsoon	5	0.42	2.9	1.57	±0.42
Nitrate (µmol/l)	Monsoon	5	13.1	15.95	14.55	±1.07
	Post-monsoon	8	0.34	13.07	6.42	±4.91
	Pre-monsoon	5	0.34	2.26	1.68	±0.79

Table 9. Seasonal variation of sediment parameters in mangrove area

Parameters	Seasons	No. of observation (counts)	Minimum	Maximum	Mean	S.D
Sediment pH	Monsoon	3	7.2	7.55	7.33	±0.19
	Post-monsoon	4	6.88	7.96	7.61	±0.5
	Pre-monsoon	3	6.73	7.02	6.92	±0.17
TOC (Total organic carbon %)	Monsoon	3	4.87	9.44	7.87	±2.6
	Post-monsoon	4	6.94	8.74	8.13	±0.81
	Pre-monsoon	3	3.76	9.15	6.88	±2.8
Sand %	Monsoon	3	79.89	80.69	80.40	±0.45
	Post-monsoon	4	78.15	80.75	79.38	±1.32
	Pre-monsoon	3	81.17	83.53	82.72	±1.35
Silt %	Monsoon	3	16.22	16.87	16.50	±0.33
	Post-monsoon	4	13.6	17.1	15.57	±1.76
	Pre-monsoon	3	10.93	15.23	12.86	±2.18
Clay %	Monsoon	3	2.5	3.89	3.09	±0.72
	Post-monsoon	4	4.64	5.75	5.08	±0.50
	Pre-monsoon	3	3.6	5.6	4.41	±0.61

Table 10. Seasonal variation of sediment parameters in backwater

Parameters	Seasons	No. of observation (counts)	Minimum	Maximum	Mean	S.D
Sediment pH	Monsoon	3	7.32	7.8	7.5	±0.26
	Post-monsoon	4	6.87	8.01	7.49	±0.47
	Pre-monsoon	3	6.7	7.22	7.0	±0.27
TOC (Total organic carbon %)	Monsoon	3	3.28	9.77	6.96	±3.33
	Post-monsoon	4	6.5	8.64	7.98	±1.01
	Pre-monsoon	3	3.87	8.74	6.85	±2.61
Sand %	Monsoon	3	80.47	83.95	82.69	±1.93
	Post-monsoon	4	78.45	80.23	79.18	±0.76
	Pre-monsoon	3	80.49	82.34	81.41	±0.93
Silt %	Monsoon	3	13.68	16.16	14.73	±1.28
	Post-monsoon	4	15.32	16.75	15.99	±0.76
	Pre-monsoon	3	14.72	15.71	15.21	±0.5
Clay %	Monsoon	3	2.01	3.37	2.58	±0.70
	Post-monsoon	4	3.02	5.75	4.83	±1.25
	Pre-monsoon	3	2.46	3.87	3.38	±0.79

Table 11. Average hydrographical parameters during the study period

Parameter	Station	N	Mean	SD
Temperature (°C)	Mangrove area	18	28.03	±1.57
	Backwater	18	28.72	±1.44
pH	Mangrove area	18	7.49	±0.31
	Backwater	18	7.56	±0.37
Dissolved Oxygen (ml/l)	Mangrove area	18	2.67	±0.87
	Backwater	18	2.74	±0.77
Salinity (‰)	Mangrove area	18	11.99	±8.13
	Backwater	18	14.26	±9.03
Alkalinity mg$CaCO_3$/day	Mangrove area	18	134.03	±43.89
	Backwater	18	122.22	±51.90
Primary productivity mgC/m^3/day	Mangrove area	18	2740.16	±1306.49
	Backwater	18	1694.09	±964.97
Silicate (µmol/l)	Mangrove area	18	98.80	±76.56
	Backwater	18	90.9	±63.72
Phosphate (µmol/l)	Mangrove area	18	3.76	±1.13
	Backwater	18	3.06	±0.99
Nitrite (µmol/l)	Mangrove area	18	1.2	±0.87
	Backwater	18	1.06	±0.76
Nitrate (µmol/l)	Mangrove area	18	7.45	±6.01
	Backwater	18	7.36	±5.95

Table 12. Correlation between hydrographical parameters in mangrove area

Parameters	Water Temperature	pH	Dissolved Oxygen	Salinity	Alkalinity	Primary productivity	Silicate	Phosphate	Nitrite	Nitrate
Water Temperature	1	0.11	-0.61**	0.54*	0.49*	0.56*	-0.48*	-0.56*	-0.77**	-0.54*
pH		1	0.06	0.74**	0.67**	0.53*	-0.77**	-0.5*	-0.25	-0.78**
Dissolved Oxygen			1	-0.35	-0.42	-0.37	0.24	0.32	0.67**	0.27
Salinity				1	0.92**	0.81**	-0.98**	-0.69**	-0.69**	-0.96**
Alkalinity					1	0.84**	-0.92**	-0.63**	-0.6**	-0.89**
Primary productivity						1	-0.82**	-0.44	-0.6**	-0.84**
Silicate							1	0.65**	0.62**	0.96**
Phosphate								1	0.61**	0.69**
Nitrite									1	0.64**
Nitrate										1

* Significant at 5 % level (two tailed)

** Significant at 1 % level (two tailed)

Table 13. Correlation between hydrographical parameters backwater

Parameters	Water Temperature	pH	Dissolved Oxygen	Salinity	Alkalinity	Primary productivity	Silicate	Phosphate	Nitrite	Nitrate
Water Temperature	1	0.18	-0.34	0.34	0.26	0.27	-0.28	0.12	0.44	-0.24
pH		1	-0.26	0.71**	0.71**	-0.1	-0.68**	-0.21	-0.22	-0.51*
Dissolved Oxygen			1	-0.78**	-0.78**	-0.49*	0.75**	0.3	0.06	0.79**
Salinity				1	0.96**	0.31	-0.96**	-0.36	-0.01	-0.93**
Alkalinity					1	0.43	-0.95**	-0.31	-0.05	-0.92**
Primary productivity						1	-0.32	0.06	0.43	-0.51*
Silicate							1	0.43	0.05	0.92**
Phosphate								1	0.3	0.35
Nitrite									1	-0.05
Nitrate										1

* Significant at 5 % level (two tailed)

** Significant at 1 % level (two tailed)

Table 14. t-Test for comparing mangrove area and backwater

Parameters	t	df	Sig. (2-tailed)
Temperature (°C)	-1.385 (NS)	34	0.18
pH	-0.61 (NS)	34	0.55
Dissolved oxygen (ml/l)	-0.26 (NS)	34	0.8
Salinity (‰)	-0.79 (NS)	34	0.43
Alkalinity $mgCaCO_3$/day	0.74 (NS)	34	0.47
Primary productivity mgC/m^3/day	2.73**	34	0.01
Silicate (µmol/l)	0.34 (NS)	34	0.74
Phosphate (µmol/l)	2.00 (NS)	34	0.53
Nitrite (µmol/l)	0.53 (NS)	34	0.60
Nitrate (µmol/l)	0.05 (NS)	34	0.96

NOTE:
(NS) Not significant ($p>0.05$)
** Significant ($p<0.01$)

Table 15. ANOVA comparing hydrographical parameters in three seasons in mangrove area

(A) Temperature (°C)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	17.267	2	8.634	5.293*	0.018
Within season	24.469	15	1.631		
Total	41.736	17			

(B) pH

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	0.410	2	0.205	2.61 (NS)	0.107
Within season	1.177	15	0.078		
Total	1.587	17			

(C) Dissolved Oxygen (ml/l)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	2.813	2	1.406	2.122 (NS)	0.156
Within season	9.990	15	0.666		
Total	12.802	17			

Table 15 (contd). ANOVA comparing hydrographical parameters in three seasons in mangrove area

(D) Salinity (‰)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	746.000	2	373.000	14.790**	0.000
Within season	378.294	15	25.220		
Total	1124.294	17			

(E) Alkalinity ($mgCaCO_3/l$)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	22751.736	2	11375.868	17.064**	0.000
Within season	10000.000	15	666.667		
Total	32751.736	17			

(F) Primary productivity ($mgC/m^3/day$)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	23685017	2	11842508.26	33.311**	0.000
Within season	5332677.9	15	355511.863		
Total	29017694	17			

Table 15 (contd). ANOVA comparing hydrographical parameters in three seasons in mangrove area

(G) Silicate (µmol/l)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	65371.499	2	32685.750	14.308**	0.000
Within season	34266.354	15	2284.424		
Total	99637.853	17			

(H) Phosphate (µmol/l)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	7.865	2	3.932	4.309*	0.033
Within season	13.689	15	0.913		
Total	21.554	17			

(I) Nitrite (µmol/l)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	4.498	2	2.249	4.062*	0.039
Within season	8.305	15	0.554		
Total	12.803	17			

Table 15 (contd). ANOVA comparing hydrographical parameters in three seasons in mangrove area

(J) Nitrate (µmol/l)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	442.270	2	221.135	19.290**	0.000
Within season	171.953	15	11.464		
Total	614.223	17			

Table 16. ANOVA comparing hydrographical parameters in three seasons in backwater

(A) Temperature (°C)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	7.342	2	3.671	1.974 (NS)	0.173
Within season	27.894	15	1.860		
Total	35.236	17			

(B) pH

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	0.815	2	0.407	3.901*	0.043
Within season	1.566	15	0.104		
Total	2.381	17			

Table 16 (contd). ANOVA comparing hydrographical parameters in three seasons in backwater

(C) Dissolved Oxygen (ml/l)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	7.058	2	3.529	17.835**	0.000
Within season	2.968	15	0.198		
Total	10.026	17			

(D) Salinity (‰)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	864.026	2	432.013	12.416**	0.001
Within season	521.932	15	34.795		
Total	1385.959	17			

(E) Alkalinity (mg$CaCO_3$/l)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	31599.392	2	15799.696	16.691**	0.000
Within season	14199.219	15	946.615		
Total	45798.611	17			

Table 16 (contd). ANOVA comparing hydrographical parameters in three seasons in backwater

(F) Primary productivity (mgC/m^3/day)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	9549115.0	2	4774557.498	11.403**	0.001
Within season	6280627.3	15	418708.488		
Total	15829742	17			

(G) Silicate (µmol/l)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	37699.725	2	18849.862	9.028**	0.003
Within season	31318.797	15	2087.920		
Total	69018.522	17			

(H) Phosphate (µmol/l)

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	0.575	2	0.287	0.268 (NS)	0.769
Within season	16.092	15	1.073		
Total	16.667	17			

Table 16 (contd). ANOVA comparing hydrographical parameters in three seasons in backwater

(I) Nitrite

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	2.250	2	1.125	2.218 (NS)	0.143
Within season	7.608	15	0.507		
Total	9.859	17			

(J) Nitrate

Sources of variation	SS	df	Mean Square	F	Sig.
Between season	426.536	2	213.268	18.191**	0.000
Within season	175.855	15	11.724		
Total	602.392	17			

NOTE:
(NS) Not significant
* Significant at $p<0.05$
**Significant at $p<0.01$

Table 17. Distribution of prawns, crabs and molluscs during study period

Species	July	August	September	October	November	December	January	February	March	April
Fenneropenaeus indicus	+++	+		+	+++	+++	+	+	+++	+++
Metapenaeus monoceros	+	+								
M. dobsonii	+++	++	++	+			+	+		+
Penaeus semisulcatus	+									
Macrobrachium scabriculum	+									
M. equidens				+			+			
M. idella				++						
Leptocarpus potamiscus							+			
Scylla serrata		+	+	+	+	+	+			
Thalamita creneta							+			
Charybdis (Goniosoma) annulata			+		+					
C. callianassa						+				
Sesarma oceanica		+								+
Uca spp	+	+	+	+	+	+	+	+	+	+
Balanus	+	+	+	+	+	+	+	+	+	+
Lamellidens sp.	+									
Villorita sp.	+	+	+	+	+	+	+	+	+	+

NOTE: + Rare, ++ Common, +++ Abundant

Table 18. Checklist of Fishes caught during the study period

I. Order: Elopiformes

i) Family: Megalopidae

1. *Megalops cyprinoides*

II. Order: Clupeiformes

ii) Family: Clupeidae

2. *Anodontostoma chacunda*

iii) Family: Engraulidae

3. *Stolephorus commersonii*

4. *Thryssa mystax*

III. Order: Siluriformes

iv) Family: Bagridae

5. *Mystus gulio*

IV. Order: Beloniformes

v) Family: Hemiramphidae

6. *Zenarchopterus dispar*

V. Order: Perciformes

vi) Family: Ambassidae

7. *Ambassis commersoni*

vii) Family: Leiognathidae

8. *Leiognathus equulus*

9. *L. splendens*

10. *L. brevirostris*

11. *Secutor ruconius*

12. *S. insidiator*

viii) Family: Gerridae

13. *Gerres filamentosus*

ix) Family: Carangidae

14. *Carnx ignobilis*

15. *Carangoides chrysophrys*

16. *Scomberoides sp.*

x) Family: Lutjanidae

17. *Lutjanus argentimaculatus*

18. *L. johni*

xi) Family: Cichilidae

19. *Etroplus suratensis*

20. *E. maculatus*

21. *Oreochromis mossambicus*

xii) Family: Scatophagidae

22. *Scatophagus argus*

xiii) Family: Mugilidae

23. *Mugil cephalus*

24. *Liza parsia*

xiv) Family: Siganidae

25. *Siganus javus*

xv) Family: Eleotridae

26. *Butis butis*

xvi) Family: Gobidae

27. *Glossogobius giuris*

28.*Oligolepis acutipennis*

VI. Order: Pleuronectiformes

xvii) Family: Cynoglossidae

29. *Cynoglossus sp.*

VII. Order: Tetraodontiformes

xviii) Family: Tetraodontidae

30. *Chelonodon fluviatilis*

Table 19. Distribution of Fishes during the study period

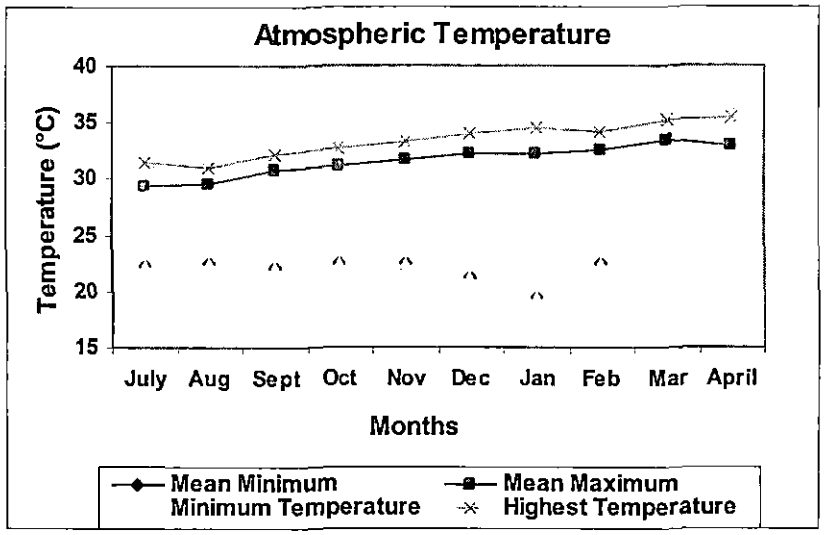
Species	July	August	September	October	November	December	January	February	March	April
Megalops cyprinoides						+				
Anodontostoma chacunda								+		
Stolephorus commersonii							+			
Thryssa mystax										+
Mystus gulio	+				+	+			+	
Zenarchopterus dispar								+		
Ambassis commersoni	+	+++	+++	++				+		
Leiognathus equulus	+			+		+		+	++	
L. splendens						+		+		
L. brevirostris									+	
Secutor ruconius						+			+	
S. insidiator						+				
Gerres filamentosus			+		+					+
Carnx ignobilis									+	
Carangoides chrysophrys									+	

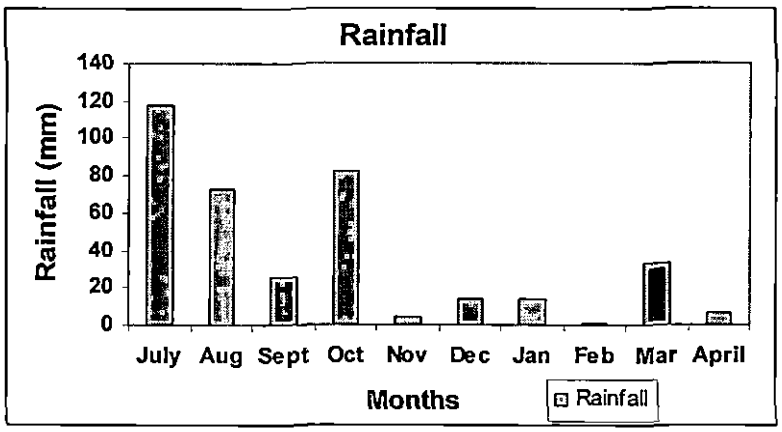
NOTE: + Rare, ++ Common, +++ Abundant

Table 19 contd. Distribution of Fishes during the study period

Species	July	August	September	October	November	December	January	February	March	April
Scomberoides sp.							+			
Lutjanus argentimaculatus					+			+		
L. johni									+	
Etroplus suratensis			+	+	+			+	+	
E. maculatus	+		+	+						
Oreochromis mossambicus				+	+	+				
Scatophagus argus							++			
Mugil cephalus							+	+		+
Liza parsia	+		+		+					
Siganus javus									+	
Butis butis			+							
Glossogobius giuris	+		++					+	+	
Oligolepis acutipennis					+	+			+	
Cynoglossus sp.						+				
Chelonodon fluviatilis						+				

NOTE: + Rare, ++ Common





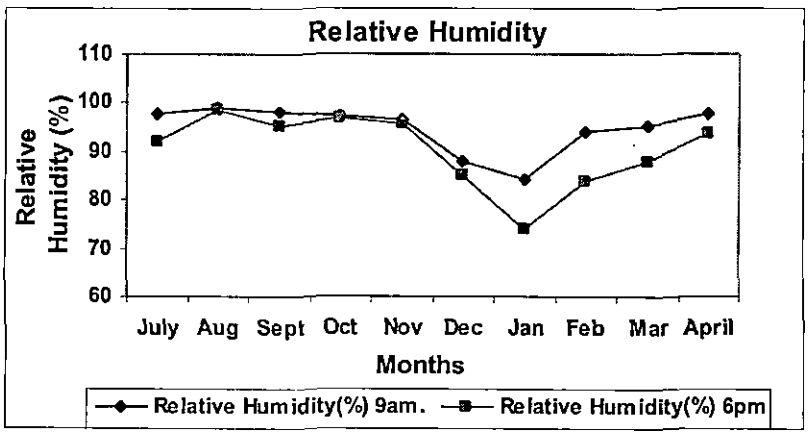


Fig 1. Monthly variation of meteorological parameters

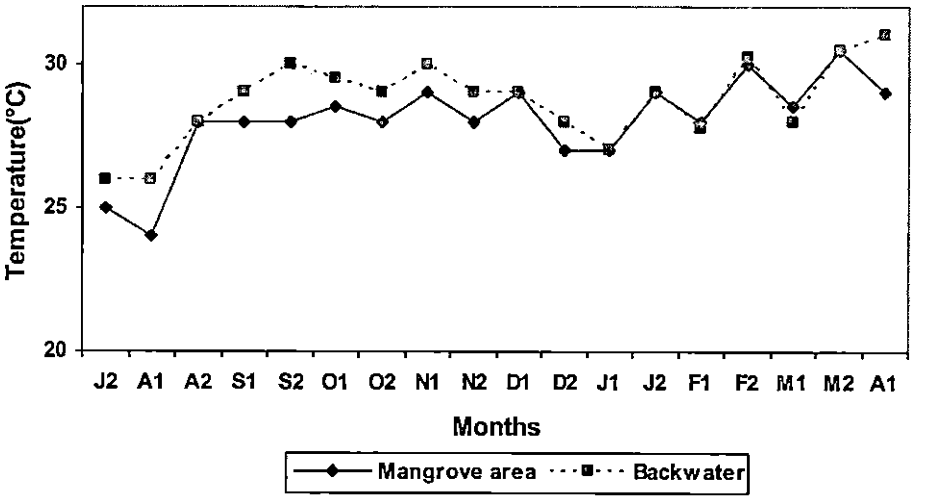


Fig 2. Fortnightly variation of water temperature

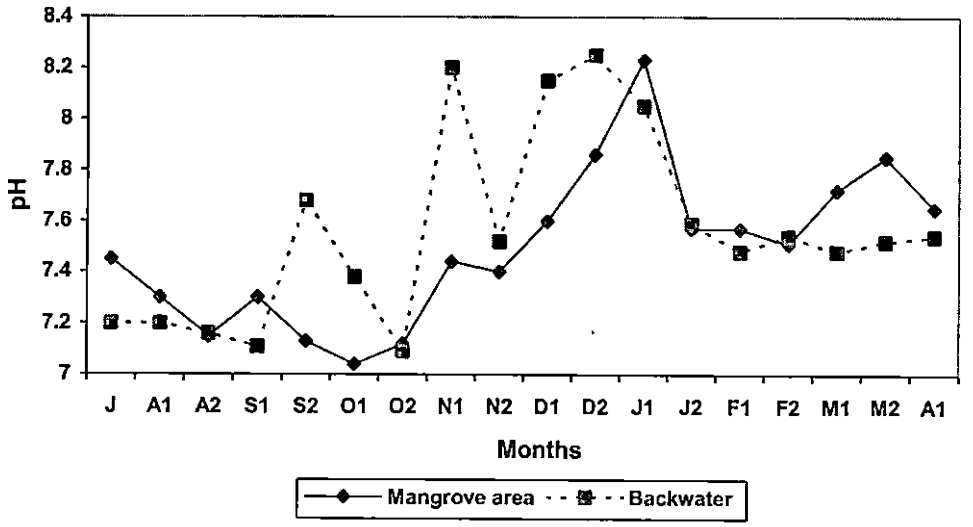


Fig 3. Fortnightly variation of water pH

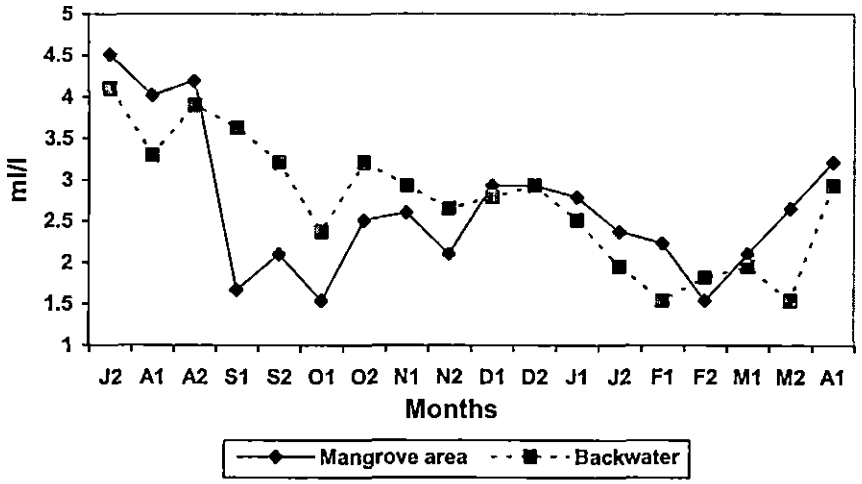


Fig 4. Fortnightly variation of Dissolved Oxygen

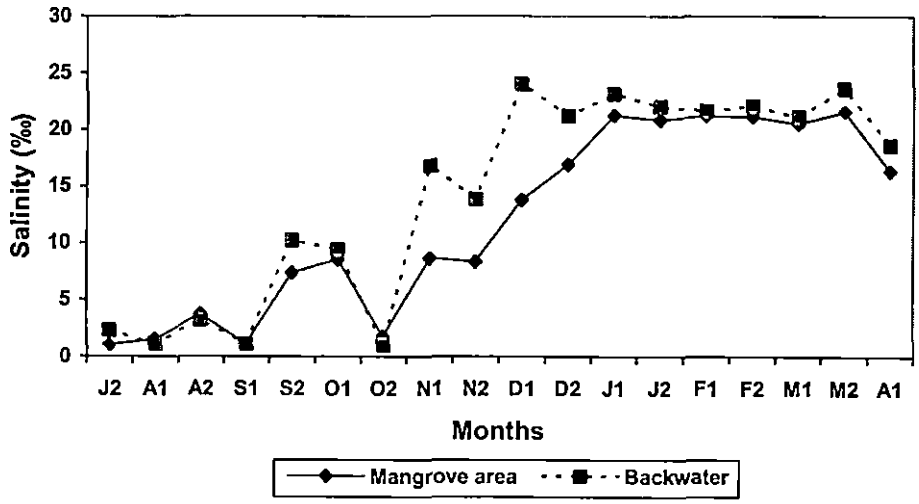


Fig 5. Fortnightly variation of Salinity

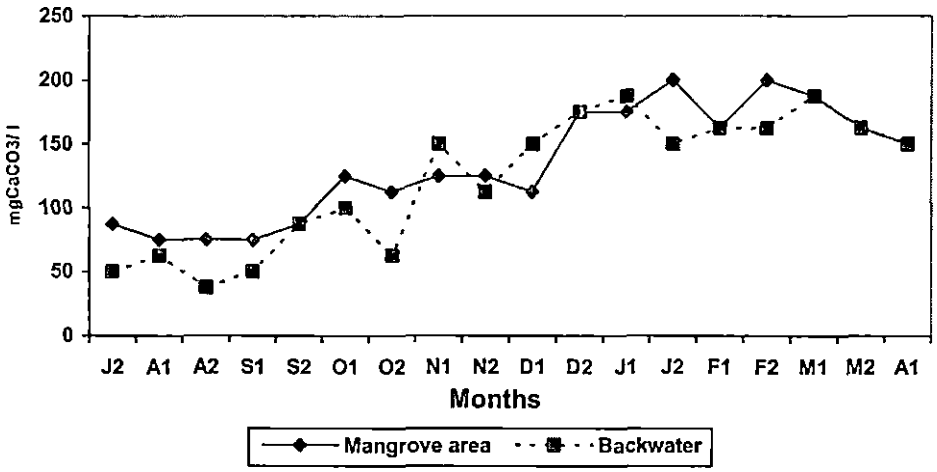


Fig 6. Fortnightly variation of alkalinity

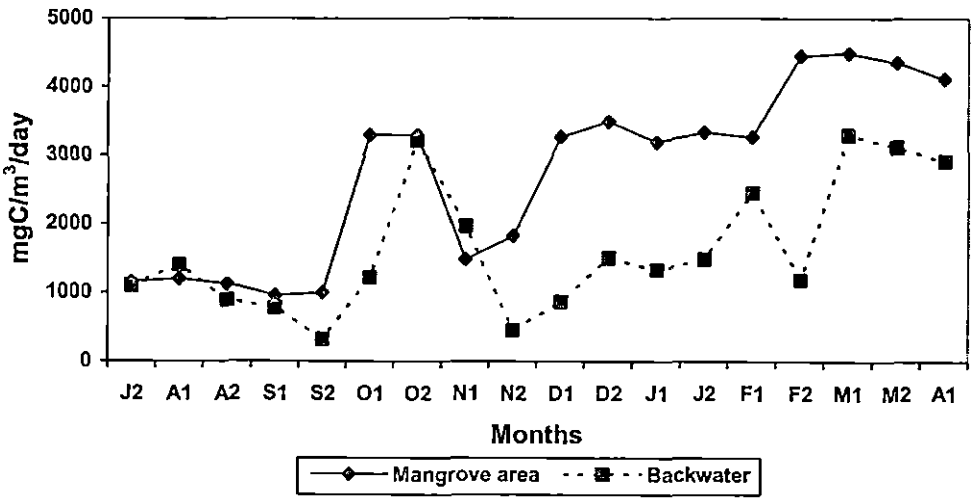


Fig 7. Fortnightly variation of primary productivity

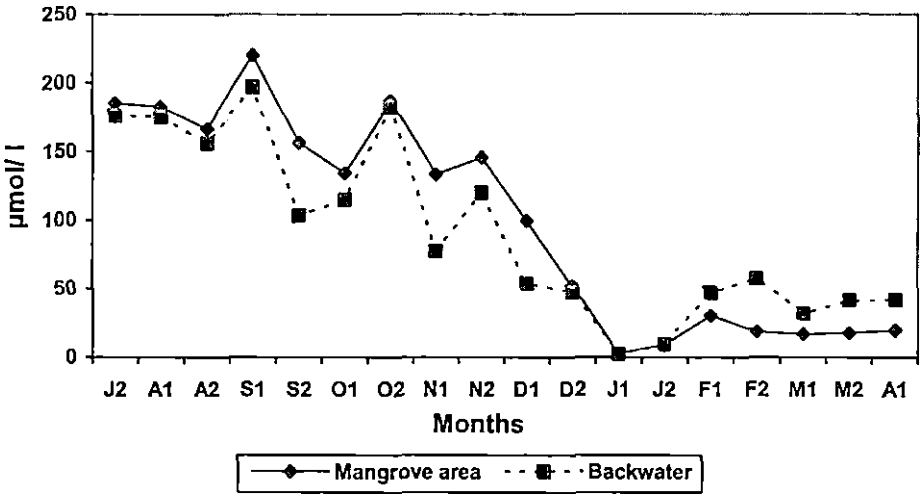


Fig 8. Fortnightly variation of silicate

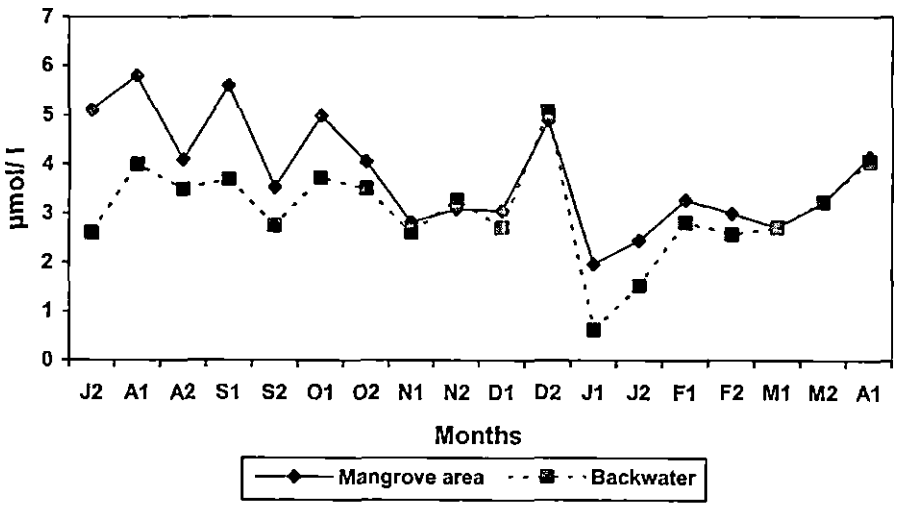


Fig 9. Fortnightly variation of phosphate

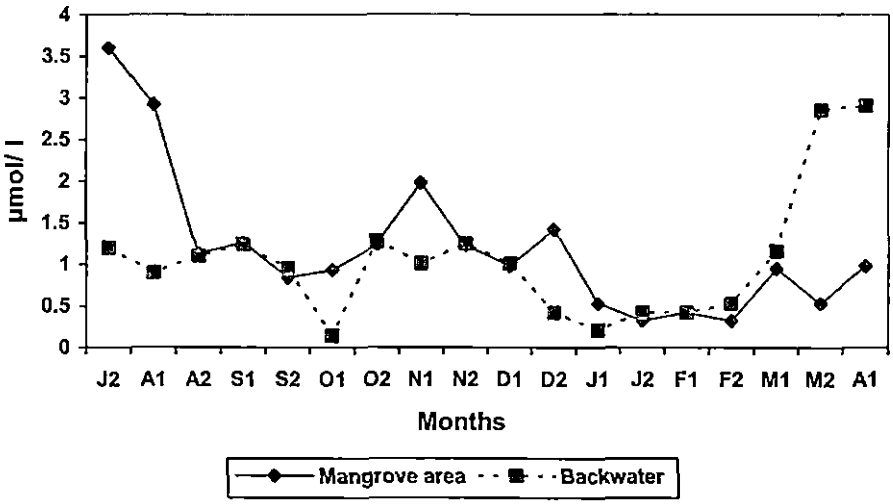


Fig 10. Fortnightly variation of nitrite

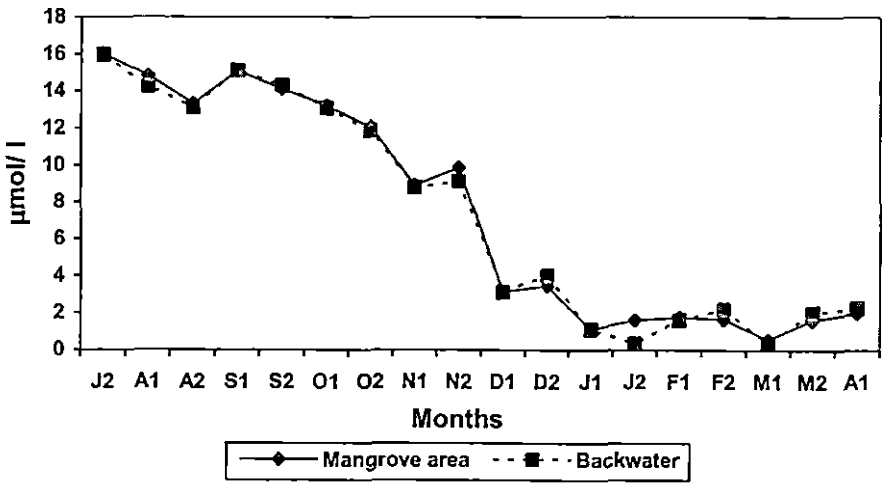


Fig 11. Fortnightly variation of nitrate

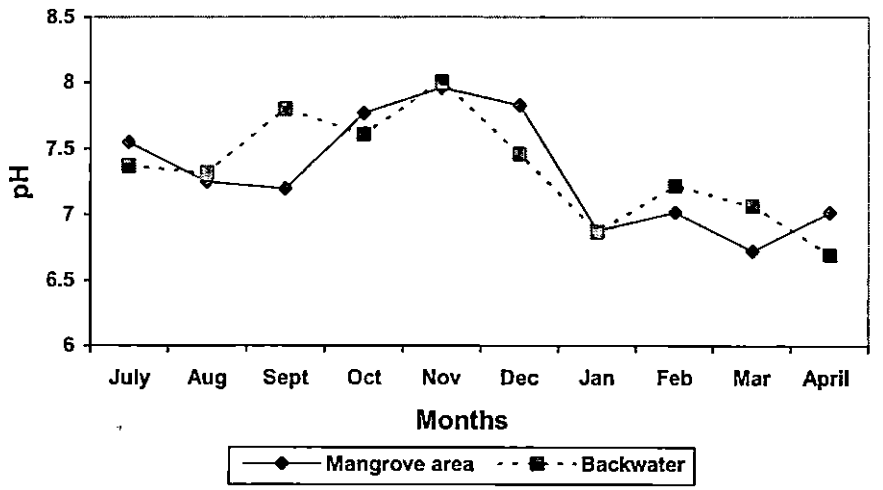


Fig 12. Monthly variation of sediment pH

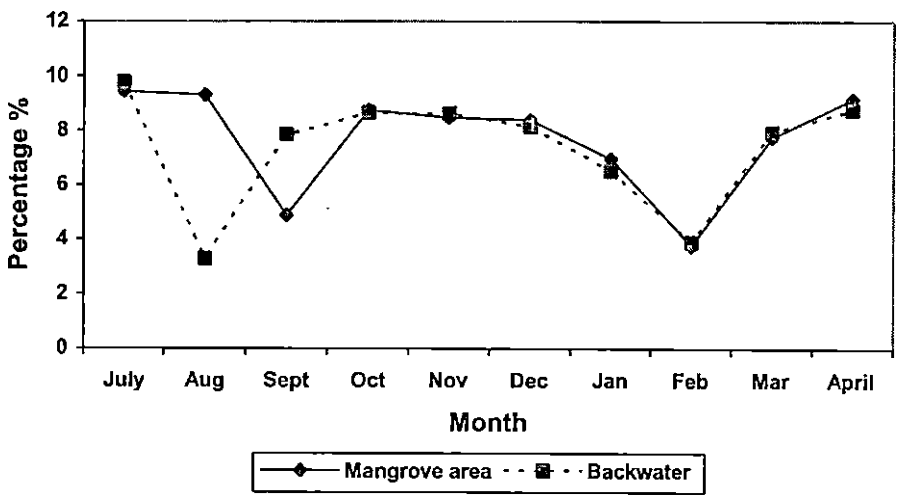


Fig 13. Monthly variation of Total Organic Carbon

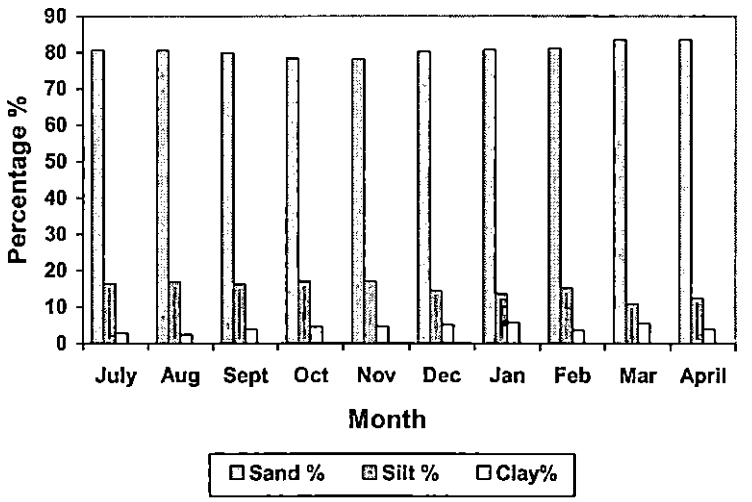


Fig 14. Monthly variation of sediment texture in mangrove area

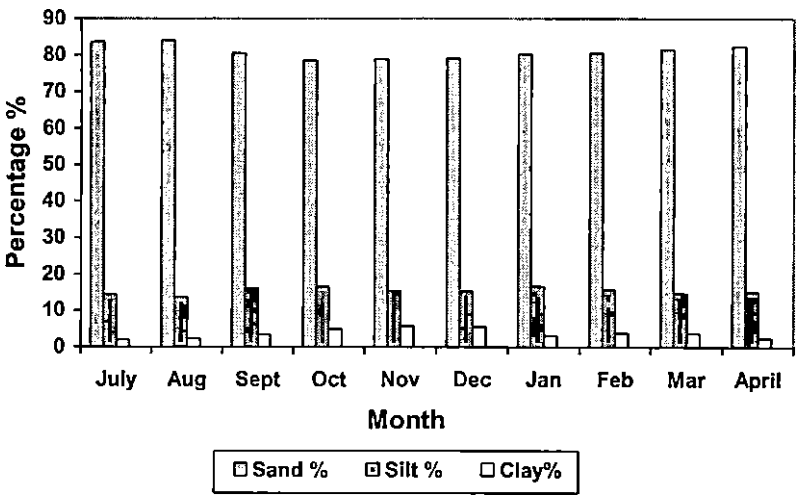


Fig 15. Monthly variation of sediment texture in backwater

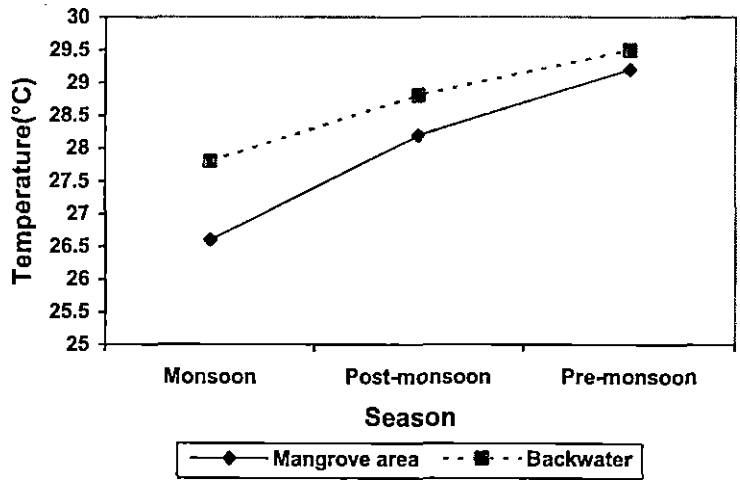


Fig 16. Seasonal variation of water temperature

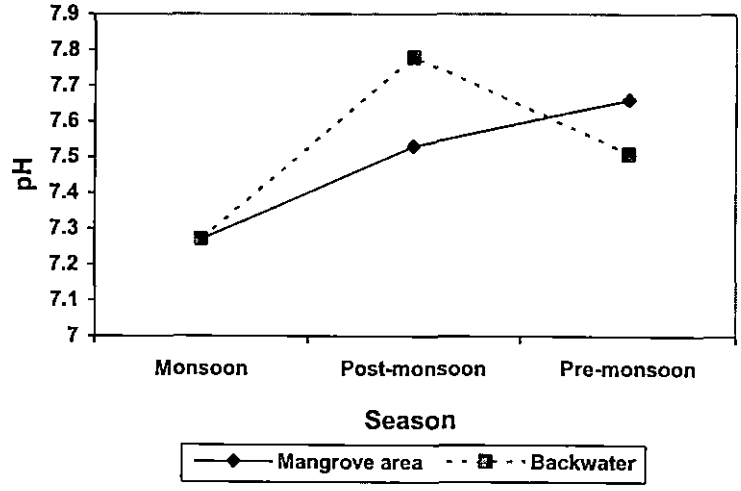


Fig 17. Seasonal variation of water pH

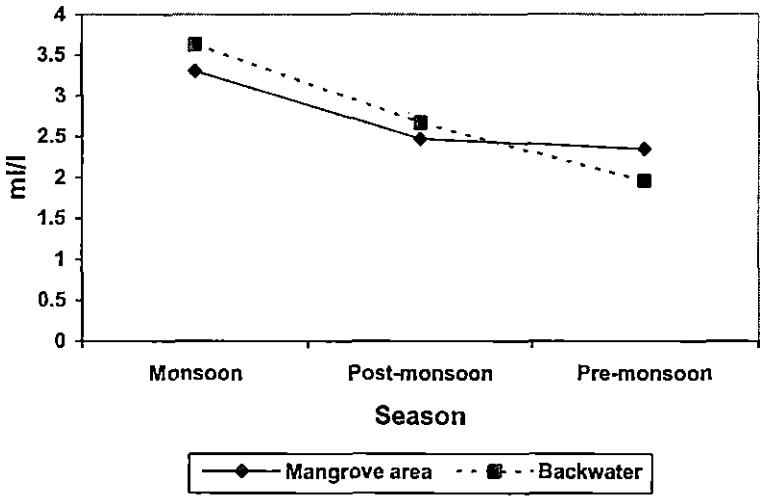


Fig 18. Seasonal variation of dissolved oxygen

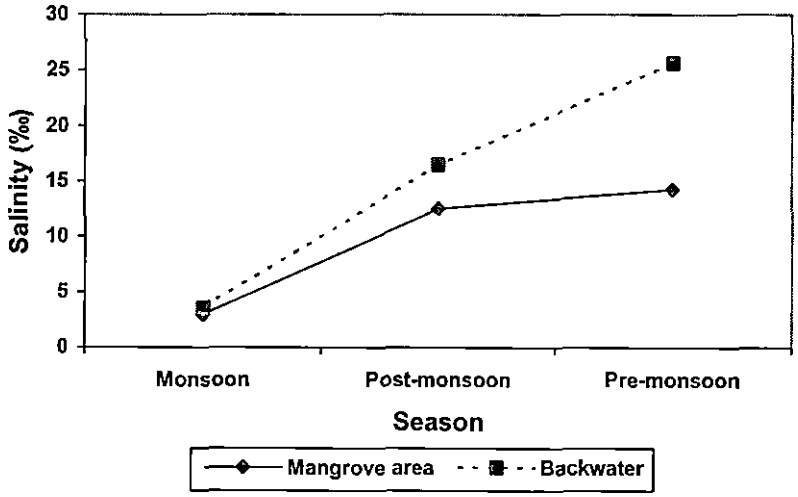


Fig 19. Seasonal variation of salinity

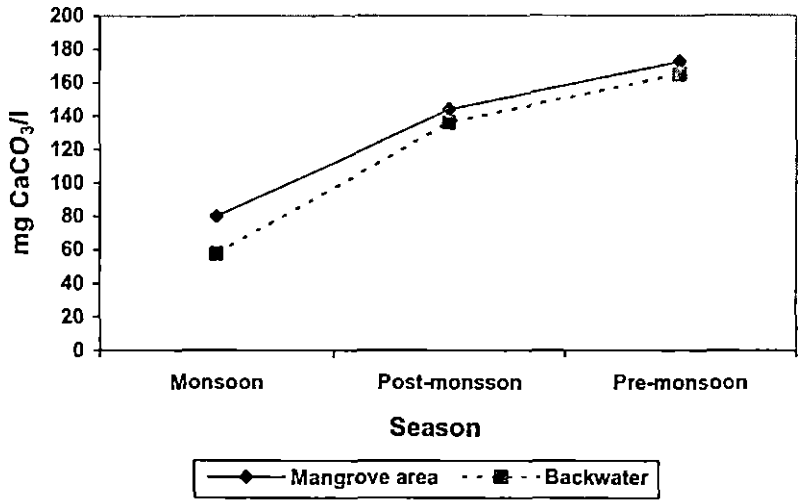


Fig 20. Seasonal variation of alkalinity

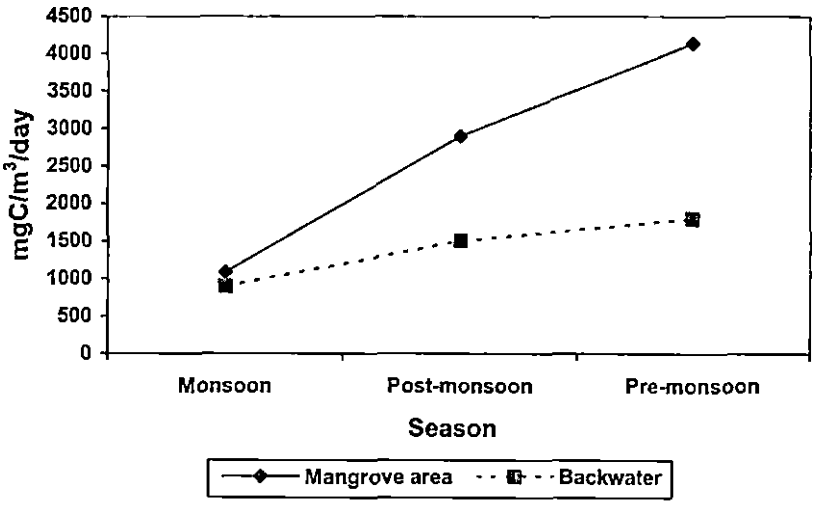


Fig 21. Seasonal variation of primary productivity

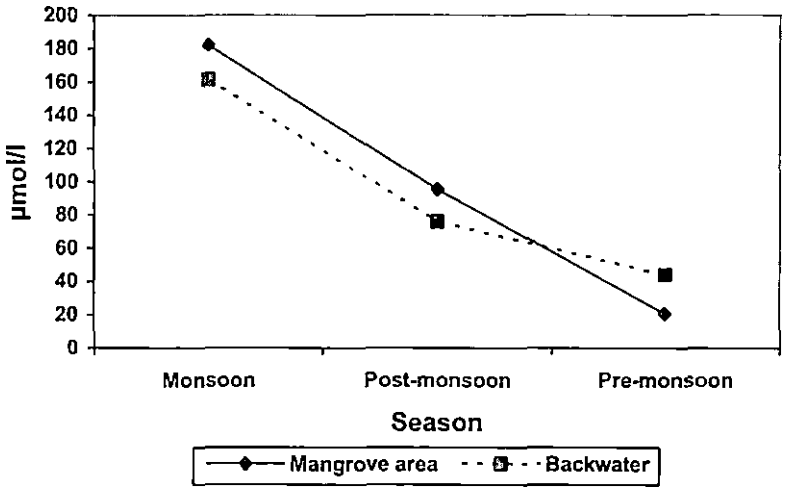


Fig 22. Seasonal variation of silicate

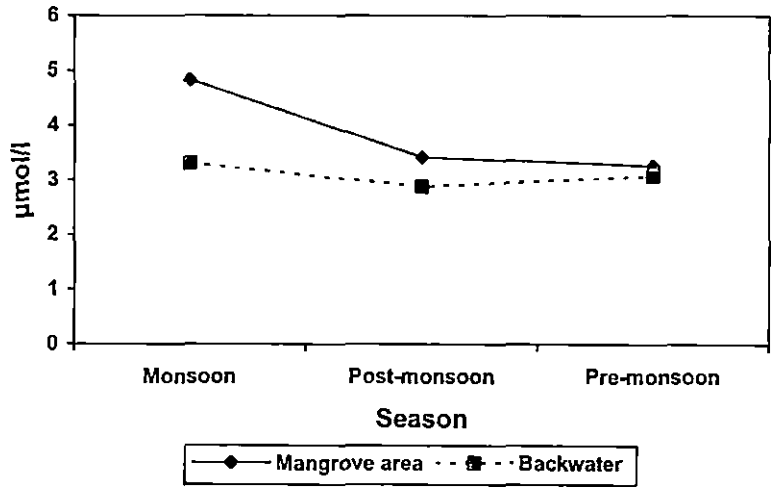


Fig 23. Seasonal variation of phosphate

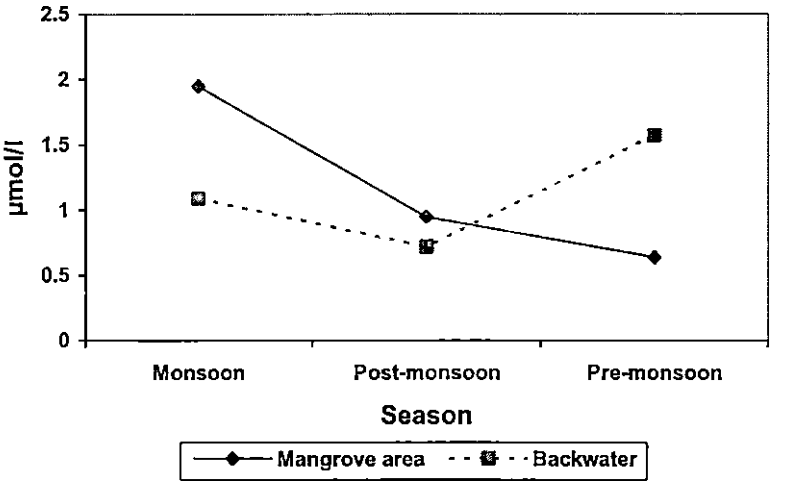


Fig 24. Seasonal variation of nitrite

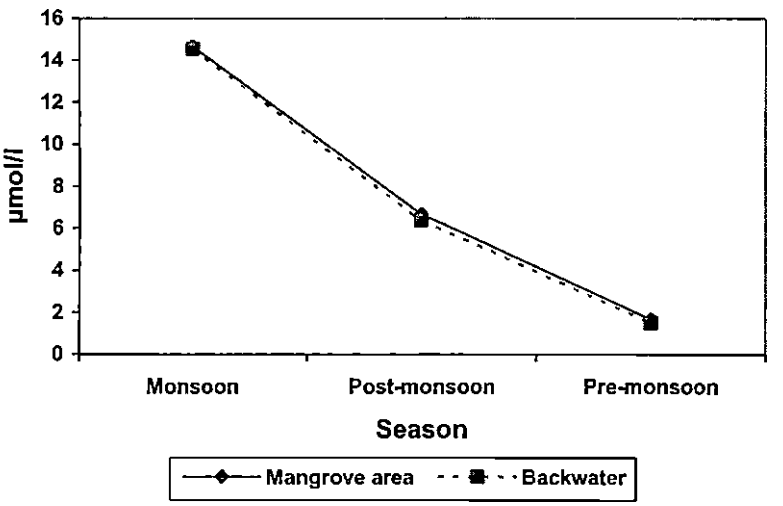


Fig 25. Seasonal variation of nitrate

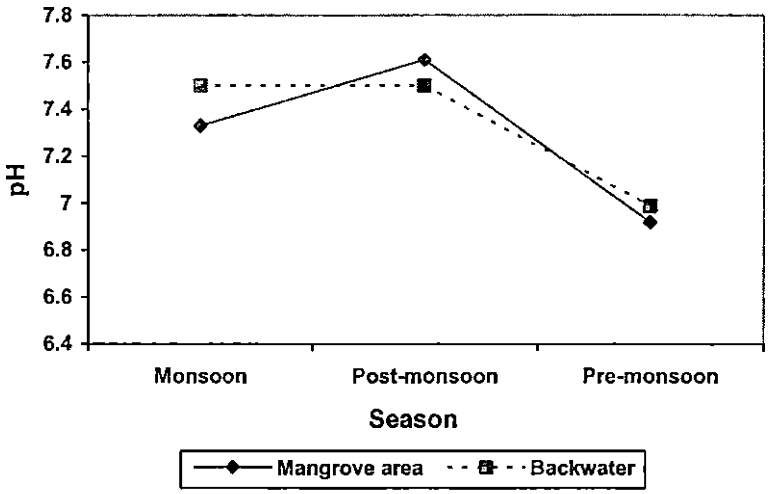


Fig 26. Seasonal variation of sediment pH

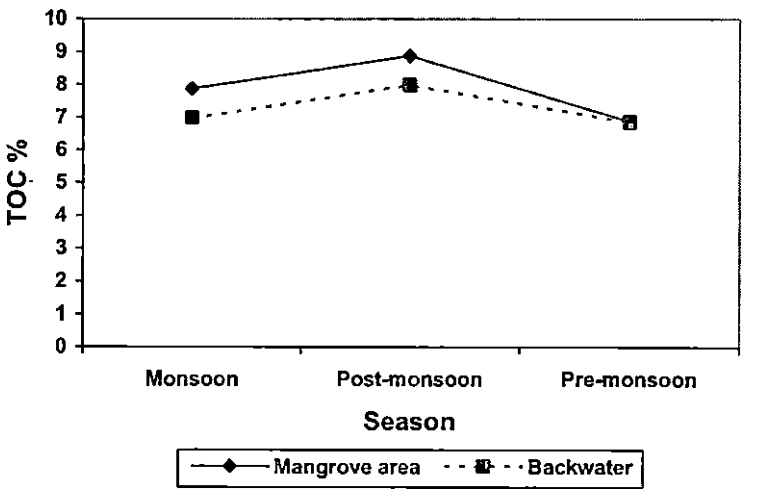


Fig 27. Seasonal variation of total organic carbon

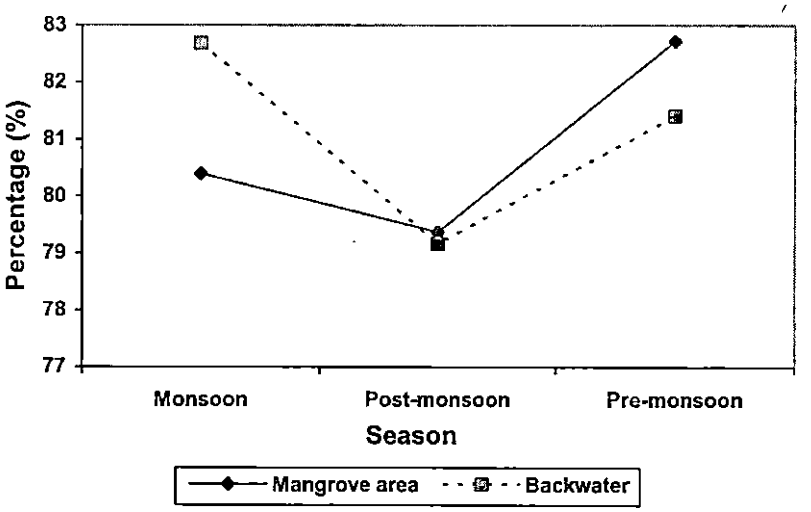


Fig 28. Seasonal variation of sand

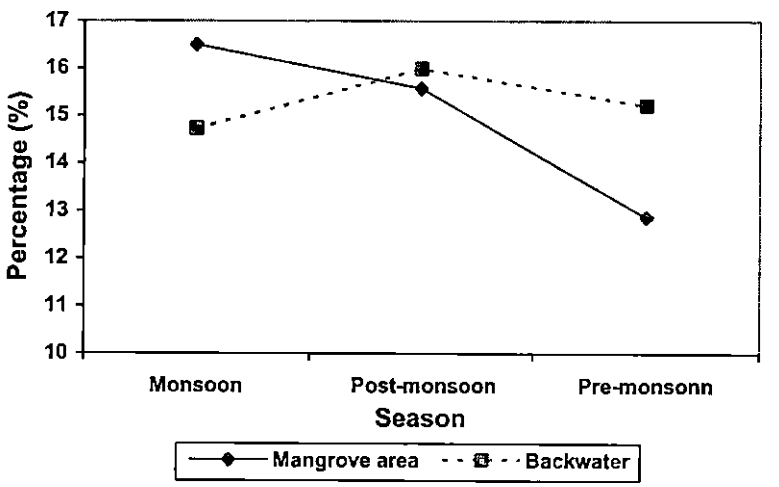


Fig 29. Seasonal variation of silt

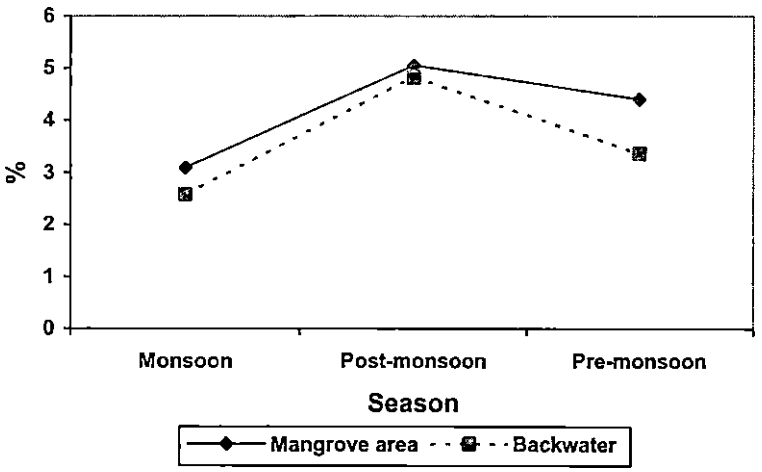


Fig 30. Seasonal variation of clay

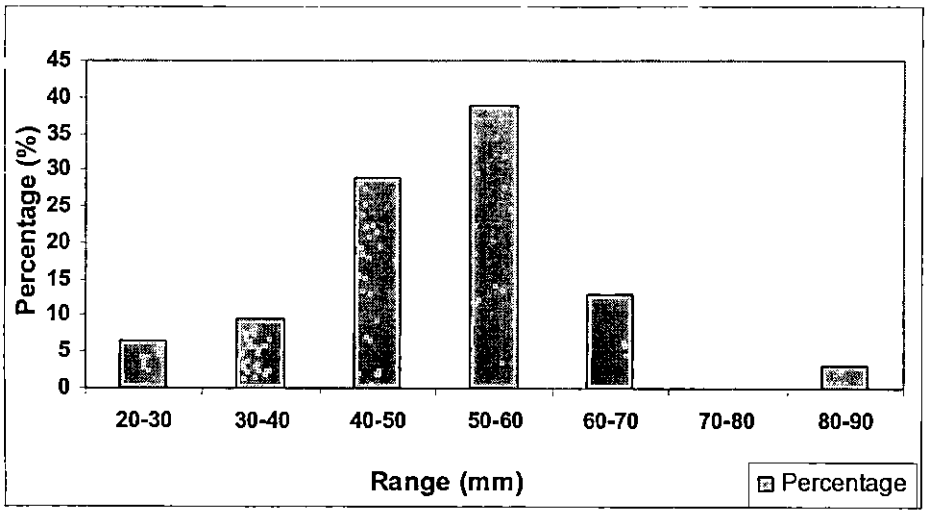


Fig 31. Percentage size distribution of *Fenneropenaeus indicus* in July

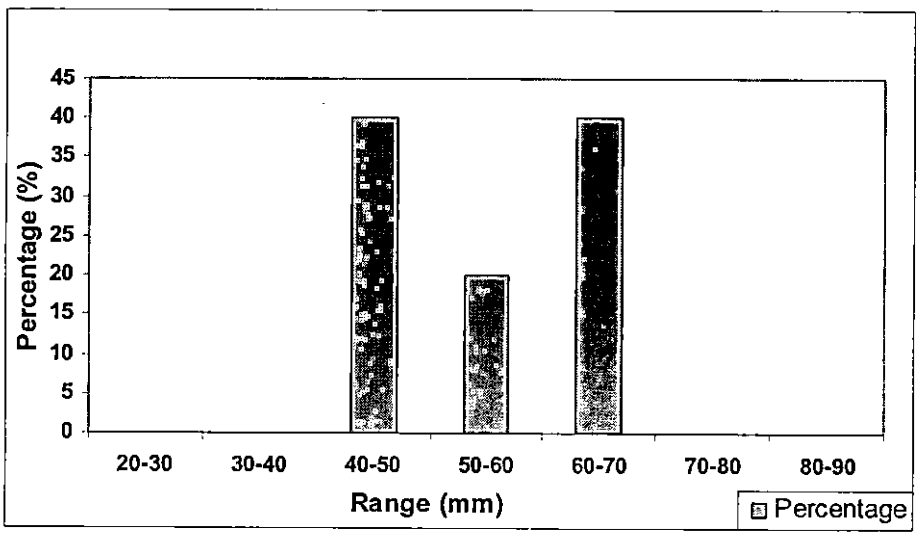


Fig 32. Percentage size distribution of *Fenneropenaeus indicus* in August

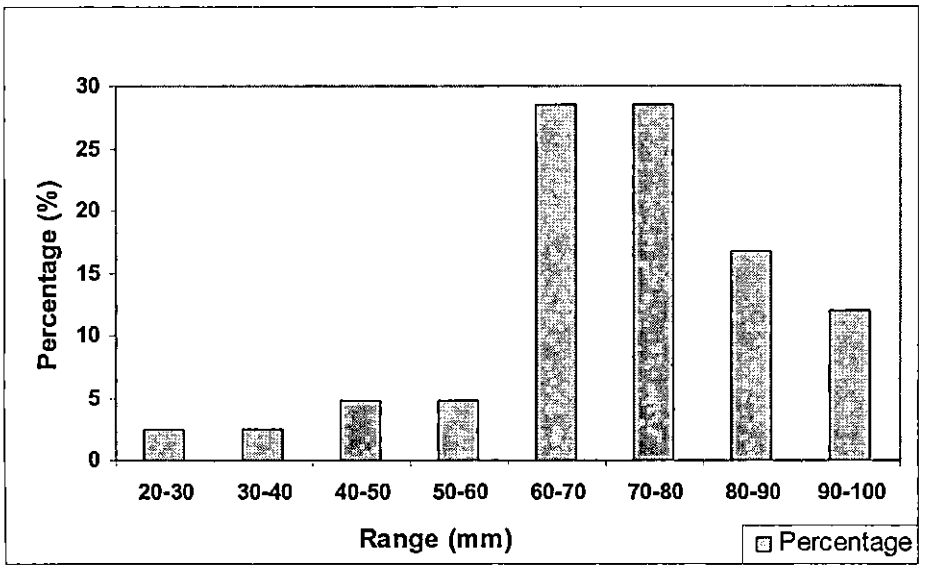


Fig 33. Percentage size distribution of *Fenneropenaeus indicus* in November

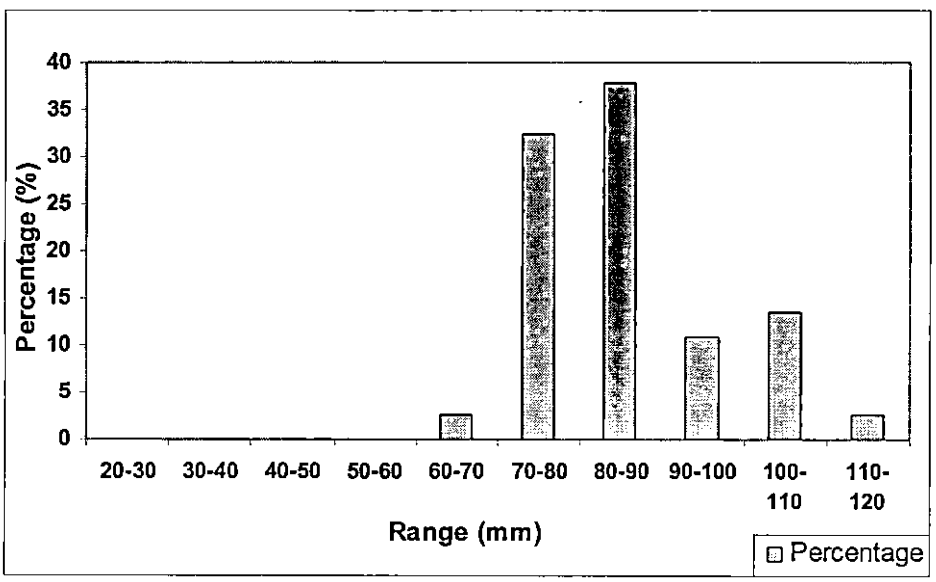


Fig 34. Percentage size distribution of *Fenneropenaeus indicus* in December

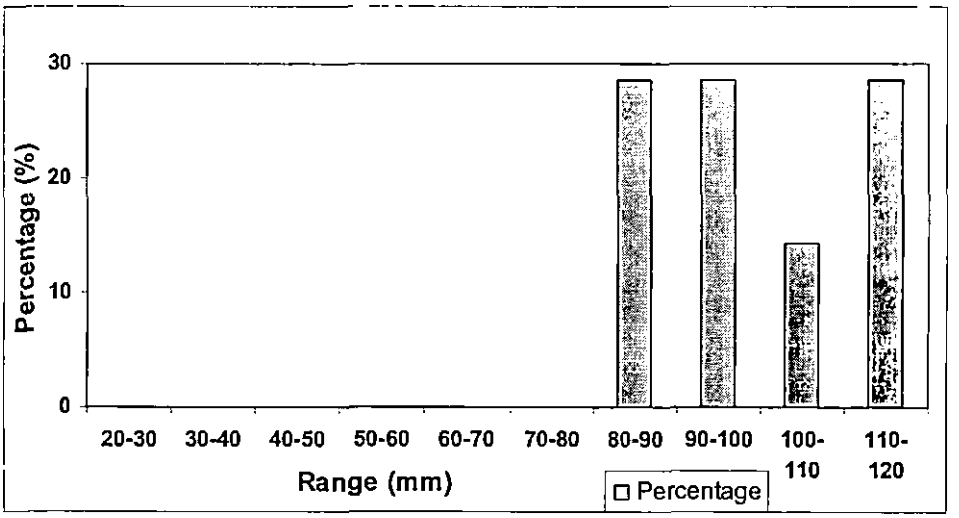


Fig 35. Percentage size distribution of *Fenneropenaeus indicus* in February

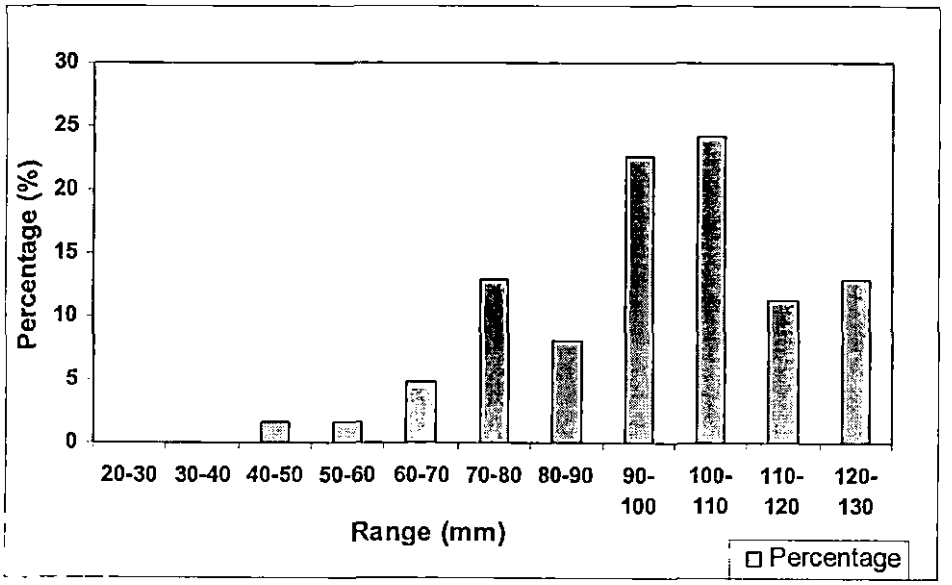


Fig 36. PercentagesSize distribution of *Fenneropenaeus indicus* in March

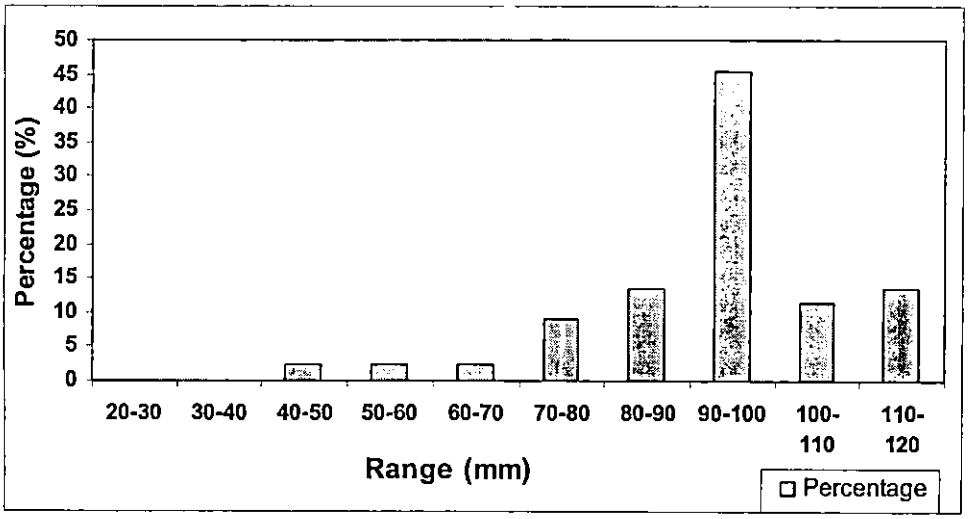


Fig 37. Percentage size distribution of *Fenneropenaeus indicus* in April

Kandelia candel

Rhizophora mucronata

Brugiuera cylindrica

Brugiuera gymnorhiza

Avicennia officinalis

Acanthus ilicifolius

Plate 3 Mangrove plants collected during the study period

Acrostichum aureum

Derris trifoliata

Ipomoea biloba

Wattakaka volubilis

Annona glabra

Viviparous seeds of *Kandelia candel*

Plate 4 Mangrove plants collected during the study period

Acanthus ilicifolius (runner)

Excoecaria agallocha

Root system of mangrove plants showing prop roots and pneumatophores

Viviparous seeds of *Rhizophora mucronata*

Plate 5 Mangrove plants collected during the study period

Macrobrachium idella

Fenneropenaeus indicus

Penaeus semisulcatus

Metapenaeus dobsonii

Thalamita creneta

Sesarma oceanica

Plate 6 Prawns and crabs caught during the study period

Caranx ignobilis

Stolephorus comersonii

Scomberoides sp.

Ambassis commersoni

Etroplus maculatus

Etroplus suratensis

Plate 7 Fishes caught during the study period

Oreochromis mossambica

Anadontostoma chacunda

Zenarchopterus dispar

Siganus javus

Butis butis

Scatophagus argus

Plate 8 Fishes caught during the study period

Leiognathus equulus

Gerres filamentosus

Liza parsia

Mugil cephalus

Lutjanus argentimaculatus

Lutjanus johnii

Plate 9 Fishes caught during the study period

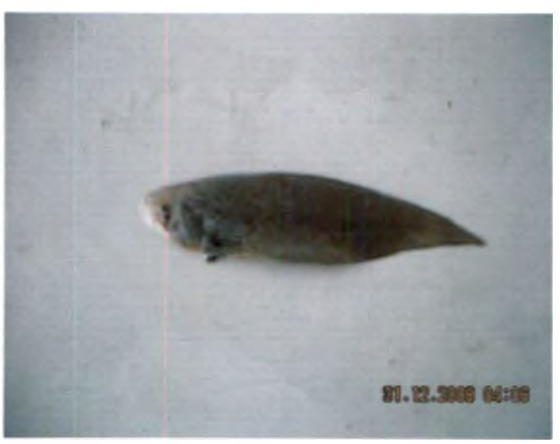
Mystus gulio

Chelonodon fluviatilis

Megalops cyprinoides

Glossogobius giuris

Secutor ruconius



Cynoglossus sp.

Plate 10 Fishes caught during the study period

Discussion

5. DISCUSSION

5.1 METEOROLOGICAL PARAMETERS

5.1.1 Maximum temperature

Highest air temperature was recorded during pre-monsoon season and it might be due to clear sky and less cloud cover. The lowest temperature recorded during monsoon season, associated with rainfall (Table 2, Fig 1). Similar observation was made by Menon and Rajan (1989).

5.1.2 Minimum temperature

Lowest air temperature was recorded during south-west monsoon period. It again decreased in the north-east monsoon period (Table 2, Fig 1). Lowest air temperature was recorded during January. Abbi *et al.* (1970) also observed similar pattern.

5.1.3 Rainfall

Seasonally Kerala receives maximum rainfall during south-west monsoon season (Jambunathan and Ramamurthy, 1973). During the present study also similar pattern was observed. During the study period July recorded maximum rainfall (117.06mm) and minimum in February (0.81mm) (Table 2, Fig 1).

5.1.4 Relative humidity

The atmosphere was humid throughout the study period. Relative humidity was maximum during the south-west monsoon period and lowest values were observed during pre-monsoon period (Table 2, Fig 1). Similar pattern was observed by Abbi *et al.* (1970) and Menon and Rajan (1989).

High values of relative humidity during the south-west and post-monsoon months may be due the presence of moisture laden south-west monsoon current.

5.2 HYDROGRAPHICAL PARAMETERS

5.2.1 Water temperature

The temperature of the surface water is always dependent on air temperature. Maximum temperature was observed during second half of March (30.5°C) and minimum during first half of August (24°C) in mangrove area and maximum during April (31°C), minimum during second half of July and first half of August (26°C) in backwater (Table 3 & 4, Fig 2). Cheriyan (1967) also reported minimum water temperature during the monsoon (24°C) and maximum during summer (32°C). Similar observation was reported by Kumary *et al.* (2007) in Adimalathura estuary.

Kumaran and Rao (1975) reported that monsoon rain and winter season caused a decrease in temperature in Cochin backwaters unless there was a break in the monsoon and temperature decreased from November-January due to winter effect. Similar observation was observed during the present study with lower value recorded during second half on December and first half of January in mangrove area and first half of January in backwater. The maximum water temperature was recorded during pre-monsoon in both the stations. Gopinathan *et al.* (1982), Sankaranarayanan *et al.* (1982) and Nair *et al.* (1988), Prabhadevi *et al.* (1996), Varma *et al.* (2002) and Haridevi *et al.* (2003) also reported similar trends in temperature.

Singh (1987) observed that temperature ranged between 24.5°C and 32.5°C which is well within the range for the present study.

Padmavati and Goswami (1996) also that reported temperature varied from 24°C and 33°C in Mandovi-Zuari system of Goa.

5.2.2 Hydrogen ion concentration (pH)

During the study period pH ranged between 7.04 and 8.23 in mangrove area and between 7.09 and 8.25 in backwater (Table 3 & 4, Fig 3). Sheeba *et al.* (1996) reported that pH ranged between 6.46 and 8.64 in mangroves areas of Cochin backwaters. Lower values of pH were observed during south-west monsoon and comparatively high values during post-monsoon and pre-monsoon. Similar observations were made by Banerjee and Roychoudhury (1966) in Chilka Lake. In the present study mean pH was maximum during post-monsoon period. Shaly (2003) also recorded similar trend in mangrove fringe creek water of Cochin.

pH showed significant positive correlation with salinity, alkalinity, primary productivity and negative correlation with Silicate-Si and Nitrate-N in mangrove area (Table 12). pH showed highly significant positive correlation with salinity, alkalinity and negative correlation with silicate-silicon and nitrate-nitrogen in backwater (Table 13). (Sankaranarayanan *et al.* 1982 and Kumar *et al.* 2006) reported significant positive correlation between pH and salinity. pH values at the mangrove creek water showed a significant negative correlation with concentration of Nitrate-N (Shaly, 2003). A significant correlation was obtained between pH and primary productivity in mangrove area which agrees with Balasubramanian *et al.* (1995).

5.2.3 Dissolved oxygen

Dissolved oxygen is an essential factor in the aquatic ecosystem. The solubility of oxygen in water is mainly influenced by temperature

and salinity. Solubility of Oxygen decreases with increase in salinity and temperature. Low values of dissolved oxygen noticed during pre-monsoon months when the salinity and temperature values were high, may be due to the above relationship. Dissolved Oxygen was maximum during south-west monsoon then showed decreasing trend and then showed minor fluctuations. Gradual increase in Dissolved Oxygen was observed during pre-monsoon period (Table 3 & 4, Fig 4). Haridas *et al.* (1973); Pillai *et al.* (1975) and Haridevi *et al.* (2003) reported high Dissolved Oxygen values during the monsoon period and low values during the post-monsoon and early pre-monsoon periods from the Cochin backwaters.

Dissolved Oxygen was high during monsoon (Pillai *et al.*, 1975; Jayachandran and Joseph, 1988; Lakshmi *et al.*, 2000). This might be due to dissolving of atmospheric oxygen abundantly during monsoon. Singh (1987) also found low oxygen during pre-monsoon which increased with the onset of monsoon. Padmavati and Goswami (1996) reported that dissolved oxygen ranged between 1.1ml/l and 5.9ml/l in Mandovi-Zuari estuarine system. In the present study also same pattern was observed. During the study period values of dissolved oxygen (1.54ml/l) was estimated during post-monsoon and pre-monsoon seasons when water temperature was comparatively high in both the stations (Table 3 & 4, Fig 4).

Dissolved Oxygen values showed a negative significant correlation with salinity and temperature (Table 12 & 13). This agrees with findings of Weiss (1970) who mentioned that solubility of oxygen in water was mainly influenced by temperature and salinity and it decreased with increase in salinity and oxygen. Nasnolkar *et al.* (1996) also reported negative correlation between dissolved oxygen and salinity.

5.2.4 Salinity

Among all the hydrographical parameters salinity was found to be the most fluctuating parameter. During south-west monsoon low salinity values were estimated (Table 3 & 4, Fig 5). Similar finding have been reported by George (1958); Balakrishnan and Shynamma (1976); Ramaraju *et al.* (1979); Udayavarma *et al.* 1981; Sankaranarayanan *et al.* (1986); Joseph and Kurup (1990) and Anon (2004). Salinity increased during the post-monsoon and pre-monsoon periods. During this period water temperature was comparatively high with abundant sunlight. Salinity increased with increase in temperature due to evaporation of water thereby increasing salt concentration. Sankaranarayanan and Qasim (1967) reported maximum salinity in pre-monsoon season which agrees with the present findings. In the present study salinity ranged between 1.03‰ and 21.61‰ in mangrove area and ranged between 1.02‰ and 24.02‰ in backwater (Table 3 & 4, Fig 5). Varma *et al.* (2002) on analyzing long term daily variations at a station near Panangad Jetty reported salinity ranged between 0‰ and 32‰. Similar values had been reported by Sankaranarayanan et *al.*, (1982), Joseph (1988) and Sudheer (2003) from the culture fields in Cochin. Salinity range (2.50-31.05‰) reported was typical of brackish water ponds located along the Cochin backwaters which are influenced by monsoon rain and influx of freshwater from rivers (Pillai, 1977).

Salinity showed positive significant correlation with pH, alkalinity (Table 12 & 13) which indicates that increase in salinity resulted in a corresponding increase in pH, alkalinity. This might be due to the increase in the amount of dissolved salts.

5.2.5 Total alkalinity

Alkalinity showed low values during monsoon and it increased in post-monsoon and pre-monsoon. Similar trend had been reported by Silas and Pillai (1975). Banerjee and Roychoudhury, (1966) also observed a fall in alkalinity at Chilka Lake with the advent of monsoon. Alkalinity ranged between 75 and 200mg$CaCO_3$/l in mangrove area and between 37.5 and 187.5 mg$CaCO_3$/l in backwater (Table 3 & 4, Fig 6). Mean values of alkalinity was comparatively higher in mangrove area 134.03mg$CaCO_3$/l than backwater 122.22mg$CaCO_3$/l (Table 11). Mathew *et al.* (1988) reported wide fluctuations in a brackish water fish farm Cochin.

5.2.6 Primary productivity

Primary production was minimum during monsoon season which might be due to less intensity of light because of cloudiness during the season. Maximum primary productivity was estimated during pre-monsoon period which might be due to optimum light intensity and effective utilization of nutrients (Table 3 & 4, Fig 7). Pillai *et al.* (1975) also reported comparatively lesser rates of production during south-west monsoon and higher values during pre-monsoon in Vembanad Lake. Qasim *et al.* (1969), Gopinathan *et al.* (1984) and Anon (2004) observed trimodal pattern in primary production from Cochin backwaters. Anon (2004) further pointed out that primary production occurred in small pulses and without seasonal rhythm. According to Kathiresan (2000) the gross primary productivity in Pichavaram mangroves was 8gC/m^3/day.

Primary productivity showed positive correlation with water temperature, pH, salinity and alkalinity and negative correlation with silicate-Si, nitrite-N and nitrate-N in mangrove area (Table 12). It showed negative correlation with dissolved oxygen and nitrate-N in backwater (Table 13). Krishnakumari *et al.* (2002) also found significant

positive correlation of primary productivity with temperature and salinity in Mandovi-Zuari estuaries in Goa.

Primary productivity was higher in mangrove area than in backwater. The t-Test analysis showed that variation between the two stations was significant (Table 14).

ANOVA showed that seasonal variation between monsoon, post monsoon and pre-monsoon is highly significant in mangrove area and backwater (Table 15F & 16F). According to Pillai *et al.* (1975) primary productivity showed a pronounced seasonal variation.

5.2.7 Nutrients

Nutrients are usually not a limiting factor to productivity in mangrove waters. The water present in the mangrove areas has peculiar characteristics acquired during their long residence in the swamps (Shaly, 2003) and they contain a large amount of dissolved organic matter in the form of nutrient salts like nitrite, nitrate, phosphate and silicates. The nutrient content was high in the study area which is characteristic of mangrove ecosystem. Tripathy *et al.* (2005) also observed high concentration of nutrients in the mangrove estuarine ecosystem which reveal the importance of mangrove as a source of nutrients to the adjacent ecosystem. The availability of high concentration of nutrients might be the reason for the abundance of juveniles of fishes, prawns and molluscs. The seasonal variability of the nutrients in the backwater depends upon the freshwater discharge into the system, which is chiefly influenced by the rainfall during the monsoon months.

5.2.7.1 Silicate-Si

Highest concentration was recorded during monsoon season and minimum during post-monsoon season (Table 2 & 3, Fig 8). Lowest

silicate concentrations during post-monsoon season might be due to biological utilization which reduced silicate concentration in water. Comparatively low levels of nutrients during pre-monsoon indicate the absorption of these nutrients for high primary productivity (Table 3 & 4, Fig 7 & 8). Due to the mixing of the bottom sediments and land leaching during monsoon months might have resulted in observed high amount of silicate-silicon.

Silicate-Si showed positive correlation with phosphate, nitrite-N and nitrate-N and negative correlation with water temperature, pH, salinity, alkalinity and primary productivity in mangrove area (Table 12). It showed positive correlation with dissolved oxygen, nitrate-N and negative correlation with pH, salinity, alkalinity in backwater (Table 13). Sankaranarayanan and Qasim (1969) reported inverse relationship between silicate-Si and salinity in Cochin backwater. Similar finding was made by Anirudhan and Nambisan (1990) in Cochin estuary. Vijyakumar *et al.* (2000) also reported silicate-Si concentration showed inverse relationship with pH and salinity and direct relationship with nitrite-N and nitrate-N. High silicate-Si values were associated with low salinity of water and vice-versa, indicating an inverse relationship between the two.

ANOVA showed that there was significant difference between monsoon, post monsoon and pre-monsoon in both the stations (Table 15G, 16G). Similar observations were reported by Vijyakumar *et al.* (2000) in Mulki estuary.

5.2.7.2 Phosphate-P

Phosphate-P concentration was maximum during south-west monsoon and minimum during post-monsoon (Table 3 & 4, Fig 9). Mahajan and Mandloi (1998) also reported higher concentration during monsoon season. Joseph and Pillai (1975) found that phosphate ranged

between 0µg at/l and 32 µg at/l in the Cochin backwaters. The range obtained in the present study is agreeing with the above findings. Renjith *et al.* (2004) also reported decreased in nutrient content during pre-monsoon and late post-monsoon and they attributed this to the increased utilization of phosphate by phytoplankton.

Phosphate-P showed significant positive correlation with silicate-Si, nitrite-N, nitrate-N and negative correlation with water temperature, pH, salinity, alkalinity in mangrove area (Table 12). In backwater Phosphate-P did not show any significant correlation with any of the hydrographical parameters (Table 13). Phosphate-P showed negative correlation with salinity and positive correlation with nitrite-N and nitrate-N as observed by Vijayakumar *et al,* (2000). It agrees with present findings. Senthilkumar *et al.* (2008) also reported negative correlation between phosphate-P and salinity in Pichavaram mangrove forest.

5.2.7.3 Nitrite-N

Nitrite-N concentration was maximum during monsoon it then decreased during post monsoon and pre-monsoon to reach the minimum during late post-monsoon and pre-monsoon (Table 2 & 3, Fig10). The concentration of nitrite was much lower than that of nitrate-N, however, both followed similar trends in fluctuation. Sankaranarayanan and Qasim (1969) reported a trimodal cycle in Cochin backwater and peak occurred during a period when the system was dominated by fresh water. In present study also peak value was observed when fresh water was more (Table 3 & 4, Fig 10). Kumary *et al.* (2007) found nitrite-N ranged between 0.17µmol/l and 5.66µmol/l in Adimalathura estuary. The present observation is well within the range.

5.2.7.4 Nitrate-N

During the study period Nitrate-N was maximum during south-west monsoon and minimum during pre-monsoon in both the stations (Table 3 & 4, Fig 11). Lakshmanan *et al.* (1987) observed that nitrate-N concentration varying 0µg/l to 20.3µg/l in Cochin backwater.

Krishnakumari *et al.* (2002) reported negative correlation between nitrate and salinity. In the present study also nitrate-N was negatively correlated with salinity (Table 12 & 13).

Shaly (2003) reported nitrate-N concentration of surface waters showed seasonal variation at mangrove stations of Cochin. In the present study also ANOVA showed that Nitrate-N varying significantly with seasons in both the stations (Table 15J, 16J). Kumary *et al.* (2007) also reported significant seasonal variation of Nitrate-N in Adimalathura estuary.

5.3 SEDIMENT CHARACTERISTICS

5.3.1 Sediment pH

Mean sediment pH was maximum during post-monsoon and minimum during pre-monsoon in mangrove area (Table 9, Fig 26) and maximum during monsoon and minimum during pre-monsoon in backwater (Table 10, Fig 26). Decrease in pH during pre-monsoon might be due to enhanced microbial activity in summer months.

5.3.2 Total Organic Carbon (TOC)

Organic carbon in the soil would serve as an important indicator in determining the availability of detritus as food for the benthic fauna as well as for bottom feeding fishes and prawns. TOC ranged between 3.76% and 9.44% with an average of 7.68% in mangrove area and it

ranged between 3.28% and 9.77% with an average of 7.33% in backwater (Table 5 & 6). Shaly (2003) reported remarkably high TOC concentration in the surface sediment which ranged between 6.2% and 11.7% in mangrove fringe of Cochin. Joseph *et al.* (2008) reported TOC content in mangrove of Cochin ranged from 2.2% to 6.7%. TOC was maximum during monsoon in both the stations (Table 5 & 6). Similar observation was made by Manjappa *et al.* (2003) in mangrove areas of Nethravathi estuary. Nagarajaiah and Gupta, (1983) also observed high values during south-west monsoon and they attributed this to the accumulated dead and decaying planktonic organisms as a result of sudden drop in salinity during monsoon seasons and large amount of humus transported by the rivers and terrestrial land drainages during the monsoon

5.3.3 Sediment texture

Based on Folk (1974) the sediment found in the study area was classified as silty sand in both the stations. Sediment collected from the study area sand contributed maximum followed by silt and clay (Table 5 & 6, Fig 14 & 15). The present observation showed that sand was the dominant component of the substratum which agrees with the findings of Joseph (1988) and Sudheer (2003) based on their study in some prawn culture fields of Panangad region, which is connected to Cochin backwater.

Monsoon and pre-monsoon recorded higher sand percentage in comparison with post-monsoon. Sundaresan (1991) and Marakala *et al.* (2005) also reported an increased percentage of sand during pre-monsoon and monsoon.

5.4 MANGROVE PLANTS

Rhizophora mucronata, Avicennia officinalis, Brugiuera gymnorhiza, Brugiuera cylindrica, Excoecaria agallocha, Kandelia candel, Acrostichum aureum, Annona glabra, Wattakaka volubilis, Acanthus ilicifolius, Derris trifoliata, Ipomoea biloba have been identified from the study area. Kotmire and Bhosale (1979) reported *Avicennia officinalis, Sonneratia alba, Excoecaria agallocha* from Deogad and Mumbra creeks. Bopaiah and Neelakantan (1982) reported the presence of *Avicennia sp., Acanthus ilicifolius* mangrove plants near tidal pond in Karwar. Lakshmi *et al.* (2000) collected *Rhizophora mucronata, Avicennia officinalis, Brugiuera gymnorhiza, Excoecaria agallocha, Kandelia candel, Acrostichum aureum, Acanthus ilicifolius, Derris trifoliata, Ipomoea biloba* from mangrove ecosystem in Valapattanam river basin, Kerala. Badarudeen *et al.* (1998) also reported the presence of *Excoecaria agallocha, Derris trifoliata, Acanthus ilicifolius, Acrostichum aureum* in Kannur region southwest coast of India.

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 roots system, which form row towards water-front. Red mangrove creates an essential environment for the black mangroves-*Avicennia officinalis*. *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 these plants also play an important role in the enrichment of the substratum. *Rhizophora sp.* and *Avicennia sp.* can sustain high wave action and ultimately prevent erosion. *Brugiuera gymnorhiza* develop knee roots which come out of the substratum as support for the mangrove plant (Untawale *et al.*, 1973). *Rhizophora mucronata* flowers and fruits apparently at all the

times of the year (Singh and Odaki, 2004). *Excoecaria agallocha* do not show vivipary or vegetative propagation. It is the only mangrove of Western India which flowers in monsoon. It is possible that its seeds are carried by water currents and established themselves on the newly form islands (Joshi and Jamale, 1975). *Acanthus ilicifolius* are runners which flowers during November/December (Singh and Odaki, 2004).

5.5 SHELLFISHES

Metapenaeus dobsoni, M. monoceros, Fenneropenaeus indicus, Penaeus semisulcatus, Macrobrachium scabriculum, M. equidens, M. idella, Leptocarpus potamiscus have been identified from the study area. The penaeid prawns constitute an important fishery in the backwaters of Cochin of which *Metapenaeus dobsoni, M. monoceros* and *Fenneropenaeus indicus* are the most important ones. These prawns enters the backwaters qiute 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). They reported that most commonly caught species throughout the study period was *Fenneropenaeus indicus*. In present study also *Fenneropenaeus indicus* was most commonly caught. Bopaiah and Neelakantan (1982) also observed good numbers of *Fenneropenaeus indicus* juveniles. He also reported *Metapanaeus dobsoni* very large numbers in tidal pond in Karwar. Generally prawns are often observed to segregate in deeper water having lower temperature and this is particularly shown by the larger prawns towards the end of the April when water temperature exceeds 35°C in prawn culture ponds in Cochin backwater (Balasubramanian *et al.*, 1995).

Distribution of different sizes of *Fenneropenaeus indicus* in different months indicated that July catch constituted of maximum number of specimen in size range 50-60mm (Fig 31-37). In August size

range of 40-50mm and 60-70mm showed maximum. In November month smaller and lager sized specimens were available with maximum contribution by larger ones. From December month onwards maximum contribution was by larger sized specimens. But in April month it showed that the catch was less for larger size species. It might be due to migration of species to sea for maturation. Sediment characteristics showed that during the abundance of prawns soil pH, TOC, silt and clay were high (Table 5 & 6). These might have contributed favorable condition for prawn abundance.

During the present study also only juveniles were reported from mangrove and backwater area. The result also indicated that the juvenile prawns were found growing inside the pond. The mangrove area at Panangad was found productive and which supports a very good fishery and also function as a nursery ground.

5.6 FISHES

30 species of finfishes were collected during the study period (Table 18 & 19). The Order Perciformes contributed the maximum diversity (22 species) (Table 18). Nammalwar (2008) reported similar finding from his review of mangroves associated fishes diversity from Gulf of Mannar, Tamil Nadu *Liza parsia, Mugil cephalus, Etroplus, Ambassis commersoni, A. gymnocephalus, Siganus javus, Lutjanus fulviflammus, Epinephelus tauvina, Lates calcarifer, Arius subrostratus, Chanos chanos, Lethrinus nebulosus, Psasmmaperca waigiensis, Boleophthalmus boddarti, Therapon jarbua.*

Almost all fish catch in the present study was contributed to by juveniles. The role of mangroves as nursery grounds of fishes have been highlighted by Macnae (1974); Lakshmi *et al.* (2000); Vijayakumar *et al.* (2000); Roy (2003); Kathiresan and Qasim (2005); Marakala *et al.*

(2005); Kumary *et al.* (2007); Nammalwar (2008). Bopaiah and Neelakantan (1982) reported *Gerres filamentosus, Lutjanus johni, Ambassis sp., Mugil cephalus* in tidal pond in Karwar. Lakshmi *et al.* (2000) reported dominant fish species in mangrove ecosystem of Valapattanam includes *Mugil cephalus, Etroplus suratensis, Lutjanus sp.* and *Sciaenids.*

November to March period showed wide range of species diversity. During these months it is clear that water temperature, pH, dissolved oxygen, salinity, alkalinity and primary productivity were high showing making favourable condition for abundance of fishes in comparison with monsoon season. With the increases in salinity fishes like *Scomboroides sp. Stolephorus commersonii, Cynoglossus sp, Lutjanus argentimaculatus, L. johni, Anodontostoma chacunda, Scatophagus argus, Carnx ignobilis* and *Siganus javus* were found. The study indicates that the mangrove area of Panangad is highly productive, nutrient rich system functioning as a good nursery ground for aquatic resources.

Summary

6. SUMMARY

1. The present study was carried out in mangrove area and the adjacent backwater to identify the floral composition, fishes, prawns, crabs and molluscs available in the area and to study seasonal variations of hydrographical parameters which support the mangrove system.
2. Water samples were collected fortnightly, from July 2008 to April 2009, to analyze the water parameters such as water temperature, salinity, dissolved oxygen, pH, nitrite, nitrate, phosphate, silicate.
3. Collection of macrofauna like fishes, prawns, crabs and mollsucs, mangrove plants and sediments were made on monthly basis.
4. Monthly averages of meteorological parameters like maximum temperature, minimum temperature, rainfall and relative humidity were computed from hourly data collected by an Automatic Weather Station installed in the campus.
5. The correlation between different hydrographical parameters were found by statistical method.
6. To study seasonal variation of different water parameters of monsoon, post-monsoon and pre-monsoon periods ANOVA was applied.
7. The t-Test was carried out to compare the characteristics of mangrove area and backwater. From the results obtained it could be inferred that there was no difference in the hydrographical parameters between the two stations except primary productivity.
8. Mean temperature of the mangrove area was 28.03°C and it was 28.72°C in backwater. Minimum temperature was recorded in August and maximum in March in mangrove area. In backwater minimum temperature was recorded in July and August and maximum in April.

9. Throughout the study period, pH was in the alkaline phase. Maximum pH was recorded during post-monsoon in both the stations.

10. Dissolved oxygen was maximum during south-west monsoon. During the study period, the mean dissolved oxygen was 2.67 ml/l and 2.74 ml/l in mangrove area and backwater respectively. In the present study also, it could be seen that dissolved oxygen decreased with increased in temperature and salinity.

11. Salinity ranged between 1.03‰ and 21.61‰ in mangrove area and between 1.02‰ and 24.02‰ in backwater. Salinity showed positive correlation with temperature and negative correlation with all the nutrients. Salinity showed significant difference between seasons in both the stations. Mean salinity was 11.99‰ and 14.26‰ in mangrove area and backwater respectively.

12. Alkalinity showed minimum values during the south-west monsoon. It increased during post-monsoon and attained maximum value during pre-monsoon in both the stations.

13. Primary productivity increased with increased in temperature and light intensity and thus maximum value was recorded during pre-monsoon season in both the stations. Primary productivity was more in mangrove area than in the backwater.

14. Nutrients concentration was maximum during south-west monsoon. Nutrient concentration was higher in mangrove area than backwater. It showed inverse relationship with temperature, pH and salinity. Nutrients showed significant difference between the seasons in both the stations but phosphate and nitrite did not show significant difference in backwater.

15. Sediment pH was minimum during pre-monsoon period in both the stations recording 6.73 in mangrove area and 6.7 in backwater. Wide range in sediment pH was found during post-monsoon in both the stations.

16. Total organic carbon (TOC) was maximum during south-west monsoon. The mean value of TOC in mangrove area was 7.68% and 7.33% in backwater.

17. Substratum of the study area was identified as silty sand in both the stations. Sand contributed maximum percentage followed by silt and clay in both the stations. Sand percentage was maximum during pre-monsoon, silt during monsoon and clay during post-monsoon in mangrove area. In backwater sand was found maximum during monsoon, silt and clay during post-monsoon.

18. The mangrove plants like *Rhizophora mucronata, Brugiuera gymnorhiza, Brugiuera cylindrica, Avicennia officinalis, Acrostichum aureum, Acanthus ilicifolius,* were most commonly found in the study area.

19. The most commonly captured prawn species was *Fenneropenaeus indicus.*

20. *Scylla serrata* and *Uca spp.* were most commonly found crabs in the study area.

21. Cirriped: Balanus, bivalves: *Lamellidens sp., Villorita sp.* were found in the study area.

22. 30 species of finfishes were collected during the study period. The Order Perciformes contributed the maximum diversity. Almost all fish catch in the present study was contributed to by juveniles. November to March period showed wide range of species diversity.

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ECOLOGY OF MANGROVE PATCHES IN THE VEMBANAD LAKE AT PANANGAD

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The present study was carried out in mangrove area and backwater connected to the backwater through a sluice gate where mangrove patches are present. The study was undertaken in order to identify the floral composition, fishes, prawns, crabs and molluscs found in the area. The seasonal changes of hydrographical parameters like DO, pH, water temperature, alkalinity, salinity, primary productivity, silicate-silicon, phosphate-phosphorus, nitrite-nitrogen and nitrate-nitrogen and the sediment characteristics like sediment pH, total organic carbon, sediment texture were also studied. The mangrove species found in the study area were identified.

Water temperature was minimum during south-west monsoon and maximum was during pre-monsoon. Average water temperature was lesser in mangrove area. Negative correlation was found between dissolved oxygen and all the nutrients. Through out the study period pH was alkaline. pH increased with increase in salinity and alkalinity. Dissolved oxygen was high during monsoon when compared with pre-monsoon period. It decreased with increased in salinity. Maximum salinity recorded during pre-monsoon when there was less freshwater intrusion. Average salinity was higher in backwater. Salinity showed negative correlation with all the nutrients. Alkalinity minimum value was observed during south-west monsoon it increases in post-monsoon and attained maximum during pre-monsoon. Alkalinity is higher in mangrove area. Primary productivity was maximum when light intensity was maximum. Average concentration of nutrients was higher in mangrove area. Maximum concentration was seen when inflow of freshwater was more.

Sediment pH was minimum during pre-monsoon. Average sediment pH was lower in mangrove area than to backwater. Average Total organic carbon was maximum during post-monsoon in mangrove area and backwater. Sediment texture showed that substratum was silty sand in both the stations. When sand percentage increased total organic carbon was lowered.

t-Test was done to compare significant difference between mangrove area and backwater. It showed that there was no significant difference with any of the hydrographical parameters between the two stations except primary productivity.

ANOVA was conducted separately for two stations to compare significant difference between three seasons- monsoon, post-monsoon and pre-monsoon. In mangrove area pH and dissolved oxygen did not showed significant seasonal difference. In backwater water temperature, phosphate and nitrite did not show any seasonal difference.

Dominant mangrove plants include *Rhizophora mucronata, Brugiuera gymnorhiza, Brugiuera cylindrica, Avicennia officinalis, Acrostichum aureum, Acanthus ilicifolius.* Prawns and crabs were abundant. Among prawns *Fenneropenaeus indicus* was caught through out the study period. Among crabs *Scylla serrata* and *Uca spp.* were commonly found. Balanus, *Lamellidens sp.*, *Villorita sp.* were also seen in the study area. 30 species of fishes were identified from the study area and major contribution was by fishes belonging to the Order Perciformes. Mostly juveniles contributed to the fish catch.