As on land, plants are the producers in the sea and on them depend all marine living resources and the basic sustainability of the ecosystem. Primary production is performed by chlorophyll bearing plants ranging from tiny phytoplankton or the microalgae to the great kelps through the process of photosynthesis (Aziz et al., 2003). It is well known that the production of phytoplankton and zooplankton in the sea has a great bearing on the fish yield.

The backwaters of Kerala comprise a system of inter-connected lagoons, bays and swamps penetrating the main land. The total area of the Cochin backwaters is estimated to be c.500 sq km. Rough estimates show that fish landing from the Kerala backwaters amount to 14,000t -17,000t per year (George, 1995).
Environmental features such as monsoon, upwelling, temperature, salinity, dissolved oxygen and nutrients play a vital role in the primary production initially and subsequently at the secondary and tertiary levels. Physico-chemical parameters of the aquatic ecosystem exert a direct influence on the growth and distribution of flora and fauna (Pillai, 1993). Investigations on physico-chemical or hydrographical characters conducted along the west coast of India as well as the entire Arabian sea clearly established the importance and influence of these parameters in the marine environment (Banse, 1959; Jayaraman et al., 1959; Ramamirtham and Patil, 1965; Gopinathan and Joseph, 1980; Ramesh Babu et al., 1980; Sen Gupta et al., 1980; Rao, 1984; Desousa and Singbal, 1986; Rivonker et al., 1990; Nair and Balchand, 1992; Pillai, 1993; Meschanov and Shapiro, 1998; Morrison et al., 1998).

Among the various environmental factors, the south west monsoon of India is of critical importance in the production of phytoplankton and zooplankton especially in the inshore upwelling areas. It has been known that intense monsoon triggers the strong upwelling along the south west coast of India.

In addition to the natural changes which bring about variations in physical and chemical parameters of water, human interventions also create powerful disturbances in the marine environment. Fishing is the major
anthropogenic activity in the sea (Jennings and Kaiser, 1998; Jennings et al., 2001). The modern commercial fishery is characterized by the steady growth of active fishing methods especially trawling and Purse seines. Trawling and dredging are known as the most destructive fishing practices which cause a number of direct and indirect changes in ecosystem. The continuous sweeping of the fishing grounds by the trawl nets disturbs the bottom habitat of flora and fauna. Trawling during monsoon results in the destruction of spawning population of commercially important resources, thus adversely affecting the subsequent recruitment.

Cochin backwaters, one of the major estuarine systems are connected with the Laccadive Sea by a gut at Cochin which can be dredged and deepened for navigational purposes (Bristow, 1967). Unlike other tropical estuaries, importance of Cochin backwaters has grown considerably because of the Cochin harbour and the shipyard situated near its mouth. Hence, the study of the impact of anthropogenic activities such as trawling in this water system is of dynamic importance both commercially and scientifically. It is against this background that the present study was initiated with an objective to assess the impact of trawlers on the microalgae at four selected stations, three along the Vembanad Lake and one in the open ocean. Water samples from the surface as well as bottom were analysed for the various physico chemical and biological parameters to estimate the extent of the impact of trawling on them.
According to Odum et al. (1982) understanding of the hydrography and nutrient cycling in the coastal areas is complicated by the continual mixing of water masses with different physico-chemical properties. A seasonal feature noticed in the sea off Cochin is the alternation between upwelling which brings up nutrients and sinking. The study by Shah (1973) confirms that, at off Cochin, intense upwelling takes place during June, July and August and the residual effects of upwelling are discernible in September and October. Sinking starts in November and continues up to the end of February. Stable conditions are seen in March and April when the upper layers warm up leading to the formation of weak thermal gradient. So far as drainage is concerned, the sea off Cochin is influenced by the backwater run off. The hydrography of the backwater system, especially the port area has been studied by Shah (1961), Ramamirtham and Jayaraman (1963), Cherian (1967) and Qasim (1973).

Environmental conditions in most of the tropical coastal areas are largely governed by marked seasonal changes induced by the monsoon cycle (Sarkisyn and Djioev, 1974). The rainfall data obtained from the meteorological department showed that the monsoon season contributed 68.4% and 48.32% of the total rainfall during the first and second year of study respectively, with its peak during June. Fresh water discharge depends on the amount of precipitation during the active south west monsoon period (Balakrishnan and Shynamma, 1976). Figueredo and Giani (2001) concluded that climatic changes especially
rainfall were important to explain the seasonal variations observed, acting both as a disturbing as well as diversity improving factor. The distribution and succession of phytoplankton are influenced by seasonal variations in rainfall and its subsequent effect on the spatial distribution of salinity (Twomey and John, 2001).

Atmospheric and surface water temperatures are the important environmental factors and the annual variations in atmospheric and surface water temperatures were found to be less pronounced in the studied sites. During the summer season, the solar radiation and clear sky enhanced the atmospheric temperature where as during the monsoon season, rainfall and cloudy skies bring down the atmospheric temperature and consequently the water temperature to the minimum. Similar observations were made by Govindasamy and Kannan (1991).

Seasonal variations were observed in water temperature which exhibited a correlation with atmospheric temperature as suggested by Zingade (1981). Experiments carried out to determine the effect of trawling on the water temperature of the four sites studied showed a uniform trend with its peak during the pre-monsoon followed by the post monsoon period. A considerable decrease in temperature was observed in the monsoon months of July and August during the course of study. Both surface waters and bottom waters exhibited similar pattern in the attribution of temperature. After the
experimental trawling, the bottom water showed a slight increase where as the surface water showed an insignificant decrease in temperature, compared to that of before trawling samples. Qasim et al. (1969) observed no significant variation in temperature in Cochin estuary except a decrease in temperature associated with rain fall.

The thermal stratifications can influence phytoplankton growth through the mixed layer depth (Bub et al., 2001). According to Gopinathan (1972) and Balakrishnan & Shynamma (1976) the temperature as such has no direct influence on phytoplankton production. Temperature can only be a regulatory factor if both light and nutrients are in excess (Strickland, 1965). Alam et al. (2001) observed that the temperature acts as the most important limiting factor for filament length and cell size in most of the phytoplankton community.

pH is one of the key abiotic factors that serve as an index for the water quality studies. It is an important hydrological feature indicating the level of dissolved carbon dioxide in the water which in turn reflects the activity of phytoplankton and the level of dissolved oxygen in the sea (Skirrow, 1975). Despite the biological activity, the buffer properties of the water are sufficient to keep the pH of the aquatic system stable. It is therefore a notable feature of the marine environment that conditions are remarkably constant over great areas and marine plants and animals have correspondingly wide distribution. Hence, an attempt was made to examine whether there occurred any alteration
in the pH after experimental trawling was carried out. The data showed higher pH values during the post monsoon with peak values during monsoon at all the stations during the course of study. In the after trawling water samples, a negligible increase in the pH values was noticed which was more evident in the bottom when compared to the surface. The observations in the present study corroborate with the previous studies conducted in the area by Harikrishnan (1997) and Suresh Kumar (1998). Rionker et al. (1990) pointed out trifle variations in pH during their study conducted along the west coast of India. The heavy rainfall, by bringing in considerable dilution of water and increasing the buffer effect, induces fluctuations in the pH (Shashikant and Raina, 1990). Rao et al. (1993) opined that photosynthetic utilization of carbon dioxide increases the pH of the surface waters.

One of the most obvious variable factors influencing primary production is the amount of solar energy reaching the surface of the sea. Significance of light on the primary production in the seas has been well documented by Ryther (1956), Russell – Hunter (1970) and Vishniac (1971). The effect of radiation entering the sea surface depends on the altitude of the sun and the changing weather patterns. The average daily radiation falling in the Cochin area is approximately within a range of 250 – 550g cal / 111cm² / day (Qasim et al., 1968). Bright sunlight was available throughout the year in the study sites except in the monsoon season when the sky may be overcast. In the present
study, the maximum light extinction coefficient was observed during the
monsoon season and the lowest during the pre-monsoon season. The depth of
the euphotic zone can be limited by the presence of phytoplankton themselves,
or other dissolved and particulate material. A clear inverse relationship between
the Secchi disc depth and the quantity of phytoplankton had been noted by Shah
(1973). However, Kufel (1998) observed no significant relationship between
chlorophyll, nutrient concentration and Secchi disc visibility. The wide spread
seasonal variations in the light extinction coefficient as observed in the present
study were due to the fresh water influence and the upwelling. This lends
support to the earlier findings of Chandran and Ramamoorthy (1984a).

The Secchi disc readings showed a decrease in the euphotic zone at all
stations after trawling was carried out. The increase in the light extinction
coefficient in the after trawling samples was more pronounced in the monsoon
season. Monsoon season is characterized by maximum turbidity as noticed by
many workers (Dutta et al., 1954; Bais and Agarwal, 1995). The decrease in
transparency of the samples collected after trawling operations can be attributed
to the disturbance of the bottom sediments, leading to the drifting of sediments
there by reducing the light visibility. Higher transparency leads to greater
photosynthesis (Sana et al., 2001) and the distribution of phytoplankton species
(Lung’ayia et al., 2000; Shin and Jae-ki, 2003). Twomey and Thompson (2001)
opine that physical conditions such as high flow rate, greater turbidity, lower
temperature, greater light attenuation contribute to the lower phytoplankton growth rate.

Salinity is found to be one of the most important limiting factors which exert profound influence on the phytoplankton composition, thereby on primary production. Salinity of Cochin backwaters is influenced by the monsoon and the influx of fresh water from the rivers. Estimation of the salinity in the surface and bottom waters in the study stations indicated that Station I was predominantly fresh water during the monsoon season with the lowest salinity values. All stations recorded the highest salinity values during the pre monsoon followed by post monsoon periods and lowest values during the monsoon months. These findings were in strong agreement with the earlier studies (Rama mirtham and Patil, 1965; Ramesh Babu et al., 1980; Rivonker et al., 1990). Monsoon season is characterized by low salinity, low oxygen, and low temperature and high turbidity at near shore waters (Gopinathan and Joseph, 1980). Govindasamy and Kannan (1991) recorded high salinity at Pitchavaram mangroves, south east coast of India during the summer season and attributed it to the low amount of shallow coastal area and high atmospheric temperature. Similar findings were reported earlier by Chandran and Ramamoorthy (1984b) along the Porto novo coast. On the contrary, Ramesh Babu et al. (1980) pointed out the lowering of salinity (<34%) in the coastal water of Kerala in the summer months. Vertical distribution of salinity showed high salinity at the bottom
which was in accordance with the observations of Kurup and Varadachari (1975), Joseph and Kurup (1990) and Rivonker et al. (1990). Salinity measured at the surface and bottom showed no significant variation after the trawling was carried out.

The concentration of dissolved oxygen is one of the most indispensable parameters in determining water quality and the distribution and abundance of various algal species. The presence of dissolved oxygen in water may be due to direct diffusion from air or photosynthetic activity of autotrophs or due to both (Shastri Yogesh and Pendse, 2001).

It is evident from the experimental data that the dissolved oxygen in the stations studied showed more or less uniform distribution with pre-monsoon and post monsoon seasons registering higher values of oxygen than the monsoon season. A similar report was given by Jayaraman et al. (1959) in the coastal waters of Kerala. The oxygen concentration in the surface as well as bottom waters showed slight decrease after trawling and the decrease was more pronounced at station I. In general, monsoon period registered lower values of dissolved oxygen at all stations. This lowering may be due to heavy rainfall and river run off from land as well as intense upwelling widely seen in this region as reported by Pillai (1993). Gopinathan and Joseph (1980) also reported low dissolved oxygen content during the monsoon months. Relatively low values of temperature and dissolved oxygen indicate the presence of upwelling. Banse
(1959) and Sankaranarayanan and Qasim (1969) reported heavy upwelling in this region during the south west monsoon. According to Banse (1959) upwelling effects were high during July and August and bring low oxygenated bottom water to the surface. Low temperature, low salinities and low dissolved oxygen were reported by Banse (1972) and Varadachari et al. (1974) during May and September while studying the seasonal changes of hydrographic parameters due to upwelling in the west coast of India. The decrease in the oxygen concentration in the after trawling samples both at the surface and the bottom could be due to the mixing of the surface and bottom water by the churning action and the increased rate of respiration by the plankton organisms in the well aerated waters. Greater solubility of oxygen in waters was observed when the temperature and salinity were low (Rochford, 1951). As noticed in the current investigation, increased dissolved oxygen concentration during post monsoon season was observed by Rochford (1951), Chandran and Ramamoorthy (1984b) and Govindasamy and Jayapaul Azariah (1997). They assigned it to the higher photosynthetic activity of phytoplankton during the season.

Nutrients are essential to life in the sea and among them nitrogen and phosphorus are the most essential elements (Tyrell, 1999; Naqvi and Jayakumar, 2000). Nutrients regulate biological processes by limiting or enhancing the organic productivity in almost all types of aquatic environments.
(Redfield, 1955). The availability of nutrients to phytoplankton is determined by hydrographic factors (Svedrop, 1955).

Choudhury and Panigrahy (1991) were of the opinion that the distribution and behaviour of nutrients in the coastal environment particularly in the near shore waters and the estuaries exhibit considerable seasonal variations depending on the local conditions like rainfall, quantum of fresh water inflow, tidal incursions and some biological activity such as phytoplankton intake and regeneration.

During the present study, a higher value of nitrate was recorded in the month of July at all stations. Lesser values were noticed in the pre monsoon as well as post monsoon months. Nitrate-nitrogen determined in the bottom water was slightly higher than that of the surface. Sankaranarayanan and Qasim (1969) observed the first peak of plankton abundance in the Cochin backwaters during the monsoon months which coincided with the maximum concentration of phosphates and nitrates in the estuary. The distribution of nitrates and phosphates observed in the present study strongly agrees with the results of previous studies conducted in the Kerala waters by Subramanyan (1958), Damodaran (1973) and Desousa et al., (1996). The studies conducted along the east and west coast of India too showed the high nutrient concentration during the monsoon months (Jayaraman and Seshappa, 1957; Qasim, 1977; Nair et al., 1989; Burkill et al., 1993; Madhupratap et al., 1996). The higher concentration
of nitrates during monsoon and lower proportion during summer may be because of the surface run off due to rains (Singh, 1960; Swarnalatha and Narsing Rao, 1998) or due to phytoplankton excretion (Rajasegar, 2003), oxidization of ammonia and reduction of nitrate (Sujatha Mishra et al., 1993; Kannan and Kannan, 1996). Sankaranarayanan and Qasim (1969) attributed the biological destruction as the cause for the lower nitrate concentrations in summer. Govindasamy et al. (2000) observed high concentration of nitrate during pre monsoon and attributed it to the addition of nitrogenous nutrients mainly by fresh water and terrestrial run off during pre monsoon showers as predicted by Ho and Barret (1977) and Segar and Hariharan (1989). There also exists a strong association periods of low salinity and high nitrate in the present study which was reported earlier by Govindasamy et al. (2000).

The increase in nitrates in the surface and bottom waters as a result of trawling could be assigned to the process of nutrient regeneration from the bottom. During the process of dragging the trawl nets, the bottom sediments rich in nutrients are released and these nutrients in the dissolved form caused the increase in their content in the water column.

Experiments carried out to determine the impact of trawling on the phosphate content in the four selected stations showed primary peak during the monsoon months and the lowest values in the pre monsoon period. Bottom waters were found to have more phosphate than the surface though occasionally
some changes were observed. The high concentration of inorganic phosphate during the monsoon may be promoted by the liberation of inorganic phosphates from the sediments under high oxygen tension and also enrichment by monsoonal floods (Foster et al., 1978; Chandran and Ramamoorthy, 1984a). A low concentration of inorganic phosphates obtained during the pre monsoon season is due to the biological activities which transform phosphates into other fractions of phosphates mainly for the utilization by phytoplankton (Mackenzie and Gillespie, 1986).

A two fold increase in the phosphate concentrations was observed at all stations in the post monsoon and pre monsoon period after trawling was carried out. The augmentation of phosphates in the bottom as well as surface waters can be referred to as the release of this nutrient from the sediments at the bottom. The adsorption/absorption of phosphates onto the re-suspended particulates and the extent of geochemical control play an important role in the distribution of this nutrient. The change in the content in turn plays a dominant bio-environmental role (Balchand and Rasheed, 2000).

Phosphate-phosphorus is found in rich quantities in the finer sediments with abundant inorganic matter, while the degeneration of the organic matter releases the phosphates (Windom, 1976 and Rao et al., 1976). Water movements due to winds and currents transport the nutrients from the surface to the bottom (Sen Gupta et al., 1979; Shetyl et al., 1991). Besides the wind and
currents, upwelling also takes the lion’s share to transfer nutrients from bottom to surface water (Banse, 1959). High nutrient concentration has been reported in the south west coast of India due to upwelling (Banse, 1959; Qasim, 1977; Muraleedharan and Kumar, 1996). D’Souza and Sastry (1975) reported high phosphate values in the Arabian Sea during the south west monsoon period and also registered a high phosphate concentration at the surface in the upwelled areas. In the present study, the high nutrients observed during monsoon months reveal that monsoon has a marked influence in the distribution of nutrients in the coastal waters. Concentrations of nitrates and phosphates in the surface and bottom waters in the present study also strengthen the above concept.

The silicate concentration showed marked seasonal fluctuations with high values in the rainy season and the lowest values during the pre-monsoon period. Trawling operation was found to increase the silicate concentration at all stations in the bottom water, while the values at surface showed a slight decrease after trawling.

The higher value of silicates recorded during monsoon was due to the addition of silica material by land run off caused by flooding as suggested by Rajasegar (2003). The increase in silicate concentration in the bottom water as a result of trawling operations may be due to the addition of silicate from the disturbed bottom sediments. The low concentration during summer season could be attributed to uptake of silicates by phytoplankton for their biological
activity (Gouda and Panigrahy, 1991). Silicon contribution in the estuary is largely dependent on the external sources such as river discharge and land drainage (Desousa et al., 1981; Anirudhan and Nambisan, 1990). Yang et al. (2002) found that the primary production of the phytoplankton is determined by the quality of silicate assimilated by them. The dissolution of particulate silicon carried by the river, the removal of soluble silicate by adsorption and coprecipitation of soluble silicon with humic compounds and iron are some of the processes that cause the depletion of silicates when river water mixes with sea water (Stephens and Oppenheimer, 1972).

The total dissolved solids in the waters at the four stations showed seasonal variations with higher values during monsoon and post monsoon and lower values during the pre monsoon periods. Vertical distribution in the total dissolved solids did not show much variation down the water columns. Station I registered the highest value during July and the lowest value was recorded in the month of May at station IV. The water samples collected after trawling showed a moderate increase in the concentration of total dissolved solids with maximum increase at station I and minimum at station IV. The higher concentrations of total dissolved solids recorded during the rainy season may be due to the addition of solids from the run off water. According to Kwang - Guk An et al. (2003), the major mechanism regulating the total dissolved solids, a measure of ionic salinity, in the system is diluted by monsoon inflow. The
decline in the total dissolved solids in the waters at station IV may be due to the decrease in the calcium and bicarbonate concentration among all the cations and anions. Marker (1977) conceives that the quantity of solids in the water system is proportional to the degree of pollution.

High total dissolved solids were reported by Harsha and Malammanavar (2004) in Chitradurga River and Shastri Yogesh and Pendse (2001) in Dahikhuta reservoir. According to Rao (1970), alkaline ponds are richer in solids than acidic ones. In the opinion of Pearsall (1932), the sea water temperature, conductivity and total dissolved solids did not act as a limiting factor for photosynthesis.

In a marine environment carbon dioxide or bicarbonates will not be a limiting factor, as only about 1% of the inorganic carbon in the sea water is utilized. Inorganic carbon can be a limiting factor only if exclusively used in the un-dissociated form (Fogg, 1975). In the opinion of Tiwari et al. (2001a), the quantum of water discharged, velocity and transparency, temperature and free carbon dioxide influence the occurrence and abundance of algae. Here an attempt was made to examine whether there occurred any alteration in the level of free carbon dioxide during the trawling activities. Distinct seasonal variations were observed in the carbon dioxide content at all the four stations with its maximum concentration at station I during November. No trace of carbon dioxide was detected in the samples collected from stations I and II, during the
months of February, March, May, September and October 1999. Station III recorded no free carbon dioxide during May, August, October 1998 and March, May and September 1999, while the months of March and August 1998, May, August and September 1999 revealed no free carbon dioxide at station IV. Increased rate of free carbon dioxide diffusion from the water column to the atmosphere at increased temperature conditions has been advocated by Welch (1952) and Unni (1972). Bottom water samples showed higher values of free carbon dioxide throughout the study period. In general, free carbon dioxide was found to have increased in the samples collected after trawling.

Shastri Yogesh and Pendse (2001) have observed the absence of free carbon dioxide at all stations studied from August to November at the Dahikhuta reservoir, Calcutta. Though complete absence of carbon dioxide in the alkaline waters was reported at the Gopalasamy pond at Chitradurga, Karnataka (Schwoerbel, 1991; Harsha and Malammanavar, 2004), waters showed free carbon dioxide in the morning samples due to the biotic respiration. Higher biomasses of phytoplankton during certain months exert profound influence on the oxygen and carbon dioxide levels of water (Sahu and Behera, 1995). Shashikant and Raina (1990) suggest that the fluctuations in the free carbon dioxide values correspond directly with the fluctuations in the standing crop of phytoplankton. As the number of phytoplankton increase the amount of free carbon dioxide decreases due to greater utilization of free carbon
dioxide for the photosynthetic activity. Free carbon dioxide exhibits a prominent inverse relationship with the amount of dissolved oxygen in the water. The relationship between free carbon dioxide and dissolved oxygen may be governed by reduction in the autochthonous oxygen supply, decomposition of aquatic vegetation, continuous use in respiration by the flora and fauna and to some extent by the mixing of the water (Qadri and Yousuf, 1978; Swarup and Singh, 1979).

Cochin backwaters face serious environmental threats by the way of intertidal land reclamation, pollution discharge, expansion for harbour development, dredging activities, urbanization and due to many other factors (Gopalan et al., 1983). Biochemical oxygen demand of any aquatic system is a measure of its extent of pollution.

Biochemical Oxygen Demand measured in the study areas showed high values during the pre monsoon months and the lowest values during monsoon. Water samples collected after trawling showed slight increase in the BOD at all stations, with the highest during pre monsoon of the first year at station II. The lowest value was found during the monsoon of the second year at station I. In the present investigation, the dissolved oxygen in the bottom as well as the surface waters fluctuated due to the availability of decomposing material such as detritus mixed with organic wastes at the bottom and suspended decomposing material in the water column. Owing to the high temperature
during the pre monsoon months, the process of decomposition is accelerated with the uptake of dissolved oxygen. It can be stated that the oxygen consumed by the decomposition of organic matter is often reflected in the disappearance of oxygen from the deep strata of the water body (Pickard, 1961; Williams, 1966). This view is supported by the fact that oxygen content was always low at the bottom waters.

The Biochemical Oxygen Demand recorded in the present study varied with season and station. At station II and III, BOD increased gradually during the pre-monsoon season. Maximum uptake of oxygen was observed in the bottom where the organic wastes get decomposed. With the onset of pre monsoon high temperature regime was initiated which lasts up to the beginning of monsoon. The variation in the BOD may also be due to the quality and quantity of sewage as well as the tidal effects. Vijayan et al. (1976) observed that the seasonal change in the temperature of water has very significant effect on the dissolved oxygen and hence the BOD values as well. This is more pronounced in the pre monsoon than the rest of the year.

The increase in the BOD values in the after trawling samples may be due to the accelerated microbial mineralization process influenced by high release of organic wastes and the oil and grease. Similar views were given by Ortega and Steege (1995). Valsaraj et al. (1995) observed a decrease in the DO with high BOD and low species diversity with a greater abundance of the blue green
algae at the mouth of river Cooum due to maximum pollution. Higher BOD was observed throughout the study period in the Chitradurga River by Harsha and Malammanavar (2004). In many of these investigations carried out in the industrially polluted waters and other marine habitats, nutrient enrichment and high BOD values were observed. Similar observations were made in the Vishakapatinam harbour by Ganapathy and Satyanarayana Rao (1962). According to Rao et al. (1993), high BOD is an indicator of sewage organic pollution.

Crude oil is a mixture with complexity little realized by most biologists. When crude oil is mixed with water, a much more physically and chemically complicated mixture is formed. The bulk of the oil is non-polar and forms into spheres of various sizes. Compounds then partition between oil droplets and water (Shaw, 1977). It has been shown that crude oil droplets in water are coated by a layer of water molecules (Malcom and Cammaert, 1981), which prevents the drops from coalescing with each other. In the current investigation, oil and grease were detected only at stations II, III and IV during certain months at the surface and bottom waters. Station II recorded the presence of oil and grease in the surface waters during February, March, July and August of 1998 as well as the months of January and July 1999. In the bottom waters October and December of 1998 and February, October and December of 1999 also witnessed oil and grease. At station III surface waters, oil and grease were
detected in March and September of 1998 and February and August of 1999 while at the bottom waters July and October of 1998 and March and July of 1999 showed its occurrence. During September 1998 and October of 1999 station IV manifested the presence of oil and grease in the surface as well as bottom waters. Stations II, III and IV are the waterways well exploited for fishing and dredging activities by commercial trawlers and dredgers. The frequency of occurrence of oil and grease was more at station II followed by station III during the period of observation. The oil and grease recorded at the surface as well as the bottom samples showed slight decrease after trawling.

The microalgal community as primary producers has to play a significant role in the biotic and abiotic interactions of any aquatic ecosystem. Whenever a community is exposed to pollutant, responses can occur because individuals acclimate to pollutant causing changes and selection can occur favouring resistant genotypes, thus resulting in the changes in the community structure. Joseph and Joseph (2002) studied the variations in the micro algal community in the oil refinery effluent holding ponds. High concentration of PAH in the Cochin harbour was reported by Paul et al. (1998) and categorized it as the main toxic component of crude oil polluting the marine environment. High oil content was reported by Ouseph (1997) in the Neendakara region of South Kerala coast. Mathew and Solomon (1996) reported the depletion of zooplankton in the northern Arabian Sea due to the large scale oil slicks. In the
present study a slight decrease in the amount of oil and grease in the trawled waters was noticed and it may be due to the dissociation of polycyclic hydrocarbons into the surrounding water in dissolved or particulate forms. Benthic organisms ingesting the sediment particles accumulate the polycyclic aromatic hydrocarbons leading to high body burdens and thus functioning as a link to transport these contaminants in the food webs (Menon and Menon, 1991).

It is therefore clear that the predictions on the effect of crude oil on aquatic organisms cannot be based on the toxicity of individual compounds alone. The study of the metabolism of individual compounds must be integrated clinically (Gruger et al., 1981). Fishes have the capacity of avoiding an unsuitable environment (Anderson et al., 1979). Webber et al. (1979) found that juvenile English sole did not avoid the oil contaminated sediment. In the case of animals such as flat fish which live in contact with sediments it may be immaterial whether the fish are able to avoid the oiled areas. If they stay there, they will be affected (Fletcher et al., 1981). If they avoid the area they will lose that amount of habitat. Either way, there is an impact on the marine population until the hydrocarbons returns to a no effect level.

The importance of plankton in fisheries is well established, as they play an important role in the biosynthesis of organic matter (primary production) in the aquatic system which directly or indirectly serves all the living organisms of
the water body as food (Sadguru Prakash, 2001). According to Natarajan (1979) and Adams et al. (1983) the fish yield potentiality of the reservoirs is dependent on the primary production.

The works of D’Souza and Sastry (1975) and Qasim (1977) revealed that the Arabian Sea is the most productive part of the world’s oceans and the primary productivity and the quantum of standing crop being comparatively higher than the average values encountered in the world oceans. In the Arabian Sea, the highest primary production is observed in the south west coast of India due to the availability of enormous nutrients and minerals and the special climate prevailing in this region (Ryther and Menzel, 1965; Subramanyan and Sarma, 1965).

The estimation of the primary production at the four stations indicates that the primary production was high in the surface waters compared to the bottom. In the water samples collected after trawling, an increase in the rate of GPP, NPP and CR was observed and the effect was more at the bottom than the surface. The gross primary production fluctuated from season to season and from station to station, the lowest being recorded during the pre monsoon period while it was high during the monsoon and post monsoon period. The gross primary production was slightly higher in the surface waters than the bottom waters. Gross production was found to be increased after trawling. Station I recorded the highest production while station IV the lowest. The
highest values were recorded in July while the lowest in February at all stations. Gross production minus respiration equals to net production. Ryther (1969) opines that the gross production is an intangible quantity while the net production is the real production of organic matter which is added to the environment and hence of real concern to the ecologist and it is the potential source of energy which can be transferred to the next trophic level.

India is blessed with an extensive wealth of lucustrine fishery resources consisting of numerous reservoirs and lakes. Sreenivasan (1966) and Rao et al. (1993) observed that high organic production of the lake was correlated with the high nutrient status of the waters. Higher algal population due to the increased nutrient concentration and warmer temperatures was observed in the Nicco Park Lake at Bhubaneswar by Tanushree Dhua and Patra (2006). However, productivity appears to be highly variable and limited by salinity (Suresh and Mathew, 1999). Harvey et al. (1934) remarks that in the surface waters of the tropical and subtropical ocean, there is a sufficiency of light all the year round but plant growth is limited throughout the year by lack of nutrient salts. The International Indian Ocean Expedition highlighted the importance of the surface production in the Arabian Sea (Ryther et al., 1966). In the equatorial region, the removal of surface water by currents set up by trade winds causes a slow upward movement of deep waters. High rate of primary production is found in the northern and western Arabian Sea.
The potential productivity of the benthic microalgae in the Cochin estuary was analysed by Sreekumar and Joseph (1997) and Sivadasan and Joseph (1998a, b). Gopinathan et al. (2001) reported more production in the coastal waters along the west coast of India. Fluctuations in the physicochemical parameters and primary production in the eastern Arabian Sea were discussed by Pillai et al. (2000).

In the present study the monsoon season showed an increase in the NPP to a maximum at station I and III, while at stations II and IV the peak values were found in the post monsoon period. Station I recorded the maximum NPP in the month of August, while the lowest was registered at station IV in February. Surface waters registered slightly higher values when compared to the bottom waters. The same trend has been observed by Sreekumar and Joseph (1997) and Sivadasan and Joseph (1998a). D'Souza and Sastry (1975) reported high primary productivity during post monsoon periods and Smith et al. (1991) noticed the lowest primary production during May in the Arabian Sea. This is in agreement with the present work. The high productivity in the monsoon and post monsoon periods is due to the accumulation of enormous amount of nutrients and minerals in the coastal water from river discharges (Subramanyan and Sarma, 1965).

The NPP determines the fertility of the sea and is also used for the assessment of potential fishery resources. Though extensive work has been
carried out in the Cochin estuary especially on physical, chemical and biological aspects, issues dealing with the impact of trawling is in its infancy. After trawling, the NPP recorded at surface and bottom waters showed an increase at all stations with station I showing a maximum and station IV a minimum increase in the annual average. The increase in the NPP values could be due to the mixing up of surface and nutrient rich bottom water leading to increased rate of primary production, in these waters.

The community respiration at surface waters recorded station wise showed peak values at station I and II in September, at station III in April and at station IV during October and December. Station I recorded the highest and station IV the lowest annual average. Community respiration in the surface and bottom waters recorded its maximum during the monsoon period at stations I, II and III while at station IV it was during the post monsoon period. Minimum values of CR in surface water were recorded during the pre-monsoon at stations I, II and IV while it was during the post monsoon period at station III.

In the brackish water in Sunderbans, Sana et al. (2001) observed that the GPP of the canal was limited at the surface and the respiratory demand was higher than production even in the photic zone. Higher rate of respiration which exceeded production has been reported in the Antarctic polar front region (Dickson and Orchardo, 2001). In the present study, community respiration showed minimum increase in the after trawling samples which could be due to
the increase in the rate of respiration of the flora and fauna. The change in the habitat that has arisen as a result of the trawling activity brings about intense perturbations on the sea bottom resulting in the killing or destroying of the benthic organisms. This causes perceptible changes to the bottom sediment structure (Thrush et al., 1995; Tuck et al., 1998).

Over the vast oceans of the world, it is the phytoplankton alone which is effective as a primary producer. The rate of primary production can be measured either directly or indirectly by estimating the standing stock of phytoplankton and using a conversion factor or by estimating the primary chlorophyll.

Sivadasan and Joseph (1998b) determined the potential productivity of the benthic microalgae in the Cochin estuary in terms of chlorophyll a. Gopinathan et al. (1994) discussed the usefulness of chlorophyll a as a measure of standing crop of phytoplankton and the role of nutrients in the organic production in the inshore areas of Tuticorin. Fluctuation in the physico-chemical parameters and the primary production in terms of chlorophyll a was discussed by Pillai et al. (2000).

The analysis of chlorophyll a for a period of two years (Jan 1998 – Dec 1999) revealed seasonal variations with high values recorded at the monsoon and the post monsoon periods in the surface as well as the bottom samples with
station I recording the highest and station IV the lowest. Minimum values were recorded at all stations during the pre-monsoon period. The high chlorophyll pigment concentration obtained in the monsoon and post monsoon months in the present investigation also points to the intense productivity during these periods. Nair and Balchand (1992) observed high chlorophyll a concentration during the south west monsoon period. The increased chlorophyll a concentration obtained in the monsoon and pre monsoon periods in the present observation also agrees with the view that seasonal variations have a genuine influence on the growth and development of the phytoplankton in the marine environment.

The chlorophyll a content was found to be elevated in both the surface as well as the bottom waters after trawling was carried out. At the bottom, a two fold increase was observed during the monsoon periods at station I and II and during the post monsoon period at stations III and IV. Station I recorded the maximum increase in chlorophyll a and station IV the minimum increase as a result of trawling.

In general, it may be stated that reduced chlorophyll content points to the reduction in primary production, disruptions in the abundance of plankton leading to the changes in biomass and also invariably refers to the changes in photosynthetic activity. Changes in chlorophyll content due to trawling are brought about by the turbulent effect on the churning of the medium thereby...
causing increase in turbidity which would counteract on the system in two ways – reduction in transparency inhibiting light penetration and the presence of particulates in the medium which alters the status of pigment production (Jones, 1981; Bokuniewicz, 1982; Tosswel and Webber, 1984).

Generally bottom samples are greatly affected by trawling activities than the surface samples. It was particularly noted that a seasonal peak of chlorophyll a concentration in bottom samples occurred which may be due to the replenishment of bottom waters with benthic micro flora.

In the present study, among the chlorophyll pigments, chlorophyll a was found to be more dominant followed by chlorophyll c both at the surface as well as bottom water samples. The concentration of chlorophyll b was found to be the lowest. The distribution of chlorophyll b showed maximum values during the post monsoon period and minimum values during the pre monsoon season at all the stations. Chlorophyll b in the surface water after trawling showed slight decrease in the values while at the bottom a negligible increase in the concentration of chlorophyll b was recorded in the post monsoon period. The bottom water samples collected during monsoon as well as the pre monsoon showed not much variation in chlorophyll b although an insignificant decrease was observed during the monsoon season at stations III and IV. The chlorophyll b bearing flora was mildly affected by the trawling activities.
Higher value of chlorophyll c was found in the surface waters than in the bottom. At the surface, stations I and III registered peak values during the monsoon period while stations II and IV during the post monsoon period. At the bottom, the peak values were registered during the post monsoon seasons at all stations except station III where it was during monsoon. The chlorophyll c concentration was found to be increased in the surface and bottom water samples after trawling in all stations except at station IV where a decrease was recorded in the surface samples during the pre monsoon and monsoon of the first year. In the bottom water, a two fold increase in the chlorophyll c concentration was observed during the monsoon season at all stations. This may be due to the abundance of blue green algae and diatoms.

Carotenoids play an important role in the photosynthesizing process as accessory pigments. During the present study, carotenoids showed similar distributional pattern as that of the chlorophylls with higher values in the surface waters. At surface, a primary peak was observed during the post monsoon season except at station I where it was during monsoon. At bottom, all stations registered maximum values during the post monsoon period and minimum values during pre monsoon season. In the surface water samples collected after trawling, station I showed maximum increase and station IV the minimum. At the bottom waters, an average two fold increase was observed during the monsoon season of the first year at station I, while it was during the
post monsoon of the second year at station II. The variations in the carotenoid concentration after trawling were similar to that of chlorophyll $a$.

Trawling is a major anthropogenic activity at sea and it brings about several changes to the physico chemical parameter, which may give rise to wide changes in the productivity (Riemann and Hoffmann, 1991). The heavy disturbance on the sea bed by intensive trawling operations, accounts for the loss of benthic micro flora from the sediment surface, which play a significant role in the benthic primary productivity (Cahoon et al., 1993 and Pusceddu et al., 2005). The increase of the chlorophyll pigments in the present study also demonstrates the release of these photosynthetnic pigments during trawling. Thus in long term, it can be postulated that the heavy loss of the microorganisms may take place which may lead to the decline of primary productivity at the sea bottom thereby resulting in the decrease of food resources for other benthic organisms in the higher trophic level in the benthic ecosystem.

Considering the role of atmospheric inputs and terrigenous inputs in modifying the coastal environments as of paramount importance, often affording the role of a supportive parameter towards impact assessment from the rigid boundaries of an estuary, the flora and fauna of the region are found to be important assessment factors. As vital forms, an estuarine watershed constitutes an important part of the ecosystem occupied by benthic
agglomerates probably under stress from a number of environmental factors such as the physical nature of sediments, availability of food (organic detritus and nutrients), the temperature, latitudinal position, day length and biotopic instability (Fischer, 1961).

Most tropical estuaries exemplify a characteristic food web commonly involving benthic organisms. Any process which is likely to institute originative changes on the bottom life system of an estuary will particularly have long standing impacts on the ecosystem as a whole (Kurian et al., 1975; Mc Cauley et al., 1976; Flint, 1984; Amson, 1988). In establishing the geographical boundaries of an estuary, the bottom bed is invariably a rigid but ecosensitive plane where benthic fauna have established a way of propagation. The susceptibility of alteration could range from minute elements to destabilizing conditions of major preponderance such as impact assessments by processes like pollution discharges, material excoriation and bottom current disturbances which would contrive definite signals (Rosenberg, 1977; Nichols et al., 1990). In the opinion of Langton and Robinson (1990) within a seasonal cycle of reasonable duration many environmental factors have been delineated for their extent of influence on the survival and propagation of benthos. Another aspect reported and often to be reckoned with is the fact that for a given set of environmental characteristics, a process such as dredging would bring about an outcome where in the process triggers a rapid growth and propagation of
bottom fauna (Mc Call, 1977; Jones and Candy, 1981). Thus the study on the bottom fauna in relation to impacts due to trawling processes would lead to the generation of good evidence on the role of human interference with natural ecosystem and help to identify the cause effects for a major enterprise.

The zooplankton plays an important role as secondary producers and together with phytoplankton they support the vast assemblages of marine food chain with their diversity and complexity (Aziz et al., 2003). The analysis of the zooplankton count for a period of two years indicated that its concentration was slightly higher at the bottom waters than at the surface. The highest values were reported during the pre-monsoon period. High counts of zooplankton were recorded during the post monsoon periods with peak values at pre-monsoon at all stations. With the onset of south west monsoon a decrease in the zooplankton was observed at all stations in the surface as well as bottom waters. The biomass values fluctuate seasonally in correlation with the hydrographical conditions prevailing in the estuary. The zooplankton population reached their abundance along with the peak of the summer. The higher biomass values, always encountered at the areas in proximity to the month after the establishment of high salinity regime suggesting a more stable environment in this area unlike the month which is affected more by the mixing of the tides and turbulence. The linear decrease in the biomass towards the head of the estuary is correlated with that of salinity. Similar observations were made by George,
1958; Tranter and George, 1969; Haridas et al., 1973; Madhupratap and Haridas; 1975; Rajagopalan et al., 1986). Higher diversity in the zooplankton biomass occurred in the waters surrounding the atolls then in the lagoon (Madhupratap et al., 1979).

The organisms inhabiting the estuary can be expected to react and adapt to changes, physical, chemical or biological, in the environment. Studies on the hydrography of the estuary revealed that temperature fluctuations are not very significant in influencing the survival of zooplankton organisms (Haridas et al., 1973). The interrelationship between phytoplankton variability, nutrient and grazing factors are appended to be highly sensitive to seasonal periodicity (Shah, 1973; Karabin et al., 1997; Sanders et al., 2000; Peterson et al., 2001; Lau and Lane, 2002). Phototrophic and heterotrophic nanoplankton and microplankton were major taxa involved in partitioning carbon and energy in the pelagic food web (Selph et al., 2001). The zooplankton biomass was positively correlated with the phytoplankton biomass in the present study. Similar observations were made by Caron et al. (2000). Mathew et al. (1984) observed high values of zooplankton in the mud bank regions of Alleppey during July/August. The high occurrence of larvae of Penaeids and Actes during the post monsoon and pre monsoon periods was reported by Kuttyamma and Kurian (1982). David Raj and Ramamirtham (1981) reported increasing trends in fish eggs and larvae during the pre monsoon months and occasionally
during the monsoon months. Qasim (1970) is of the opinion that the zooplankton grazing in this estuary is not sufficient enough when compared to the amount of primary production, thus leaving a large surplus of basic food unutilized. This view is further supported by Pillai et al. (1975); Hejzler et al. (1997) and Bode et al. (2003).

In the present study the water samples collected after trawling operations showed an increase in the cell number at the surface as well as the bottom. However, at station II bottom waters registered a decrease in cell numbers during the pre monsoon period. According to Gislason (1995) towed fishing gears such as bottom and beam trawls will physically disturb the sea bed presumably changing the characteristics of the upper part of the sediment leading to alteration in microbial communities. Shallow water acts as a major site for primary productivity due to the easy penetration of light and immense source of nutrients and minerals. Bottom trawling which is highly destructive to the sea bottom removes the top layer of sediments, leading to the release of embedded nutrients and reduction in the organic matter load (Riemann and Hoffmann, 1991; Jones, 1992).

The Arabian Sea, characterized by strong seasonal monsoonal forcing and prolific meso-scale features is a complex hydrographic environment for plankton photosynthesis. Qasim et al. (1969) studied the organic production in the Vembanad estuary and concluded that gross production fell within a range
of 272 - 293gC/m²/year and an average of 281gC/m²/year. The phytoplankton population in a tropical estuary includes estuarine, marine and fresh water species which has the widest adaptability to any change in salinity of the external medium (Williams, 1966). However, clones isolated from sea do not survive in low salinities (Desikachary and Rao, 1972). Attempt made to find out the impact of trawling on the microalgae at the four stations in the Cochin estuary revealed that the monsoon and the post monsoon season were favourable to high phytoplankton growth at the surface waters. However the density of phytoplankton was maximum during the monsoon period at station I, III and IV in the bottom waters. In general both surface and bottom waters recorded their highest density of phytoplankton at station I during the monsoon period while station IV recorded the lowest density during the pre monsoon season. At the four stations studied, Bacillariophyceae was the largest group of phytoplankton which accounted about 86% of the total phytoplankton population where as the members of Chlorophyceae were only 3.2 - 13.3% of the total phytoplankton. Their distribution was seen during the monsoon season at stations I and II. Cyanophyceae was a poorly represented group present during all the seasons at stations I, II and III. *Dictyocha fibula* was the only Silicoflagellate reported at station III (bottom) and at station IV (surface and bottom).
Phytoplankton seasonal sequence was found to be correlated with environmental factors (Kagalou et al., 2001). Lung'ayia et al. (2000) reported the dominance of blue green algae during the rainy season which was replaced by diatoms as the dominant group in the dry season. However, the dominance of diatoms during most of the year was reported by Ansotegui et al. (2003). Temponeras et al. (2000) observed the dominance of chlorophyceae in the shallow lake in Dolerani (Greece) throughout the year. Sadchikov and Kozlov (1994) opined that with increasing trophicity, the contribution of nanoplankton to total plankton biomass increased. The influence of structural variations of species in any quantitative determination of phytoplankton blooms and the importance of cell size variation between different species are essential parameters to be considered in bloom determination (Mani et al., 1986).

The seasonal distribution of phytoplankton in the surface waters after trawling showed an increasing trend with maximum count during the monsoon of 1999 at station I. At bottom, more than two fold increase in phytoplankton population was recorded during the monsoon period of the second year. Maximum increase in the phytoplankton abundance in the bottom waters after trawling was computed at station I in November while minimum increase was noticed at station II in February. Station II witnessed the disappearance of *Prorocentrum micans* from the bottom waters while *Synedra ulna* was not reported in the surface waters at station IV after trawling.
The surface of the marine sediments is an important site of benthic production. In the present study the increase in phytoplankton species in the water samples collected after trawling indicated the disturbance of benthic algal groups during trawling. The release of benthic microalgae from the surface of the marine sediments due to the scraping action of bottom trawls will unquestionably reduce the benthic primary productivity (Gislason, 1995; Schwinghaman et al., 1996; Collie et al., 1997). Brylinski et al. (1994) demonstrated that biomass of benthic diatoms (measured as chlorophyll a) was significantly less in trawl door furrows on a muddy substratum in shallow water. Similarly Guillen et al. (1994) observed a reduction in primary productivity due to the loss of meadows on the sea bottom, the major source of primary production, during bottom trawling. Re-suspension of buried organic material by trawlers increase oxygen demand in the water columns in areas where dissolved oxygen is already limiting which significantly affects the growth of plankton and nekton (Watling et al., 2001). Thus the release of plankton from the sediment surface during bottom trawling may eventually reduce the benthic production in a long term period. Cahoon et al. (1993) reported the reduction in primary production by benthic microalgae after a disturbance in relatively shallow depths (below 40m). In the present study, the increased phytoplankton recorded in the after trawling water samples indicates that bottom disturbance paved the way for the dispersion of microalgae which
might have led to the reduction of benthic primary productivity after trawling. Rasheed et al. (2000) also noticed high chlorophyll values in the dredged bottom waters due to the transport of micro flora from sediments to the water column due to dredging.

Other important consequences of trawling include the reduction in the habitat complexity that accompanies the removal of sessile epifauna and the alteration on physical structure such as rocks and cobbles. This is in agreement with Korotkow and Martyschewcki (1977), Berghahn (1990), Bergman and Hup (1992), Kaiser and Spencer (1994), Thrush et al. (1995) and Collie et al. (1997). Trawling destroys the tubiforms which have the important role in maintaining the structure and oxygenation of muddy sediment habitats (Reise, 1981).

At a primary level the algal reproduction rate depends upon the irradiance and nutrient concentration and the grazing rate. Grazing depends on number of herbivores and the algal density. Reni and Bensam (1995) observed filamentous algae and diatoms as the major items in the guts of Etroplus suratensis. A reciprocal relation appears to hold good between zooplankton and phytoplankton, as the disappearance of the phytoplankton coincides with the abundance of zooplankton (Harvey, 1934). Each level of organisms in the food chain experience a rise in density and then a decline and is succeeded by the next level.
The process of trawling causes the scrapping of sediment surface generating heavy sediment plumes several meters high in the water column. This increases the turbidity. Proper light penetration is obstructed in turbid waters which may lead to the poor primary productivity, impaired growth of bottom vegetation and other benthic fauna. Hence optimally balanced trawling operations without any disturbance on the geographical stability can be recommended for the Cochin estuary.