TEMPORAL CHANGES IN THE WEATHER ELEMENTS AT PANANGAD REGION AND THEIR INFLUENCE ON THE HYDROGRAPHY OF A POND

By

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Dedicated To

My Beloved Parents, Brothers

and someone who inspired me

DECLARATION

I hereby declare that this thesis entitled " **TEMPORAL CHANGES IN THE WEATHER ELEMENTS AT PANANGAD REGION AND THEIR INFLUENCE ON THE HYDROGRAPHY OF A POND** " 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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EXTERNAL EXAMINER

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Introduction

1. INTRODUCTION

The physical properties of the atmosphere, by which the condition and behaviour of the atmosphere can be expressed, are referred to as weather elements. The important weather elements are air temperature, atmospheric pressure, wind, rainfall, relative humidity, cloudiness etc. The weather elements of a place continuously change and these vary from season to season, time to time and place to place. The changes in one or more weather elements influence the other weather elements also.

Appreciation of weather is a pre-requisite to resource management since all mitigations are weather sensitive. Land use planning, water management, cropping pattern and environmental pollution, are all vital areas where adequate knowledge of weather and climate is crucial. Hence forward planning in each and every sector must take into account the relevant meteorological factors. Knowledge of weather and climate, past, present and future, is thus indispensable for the successful planning and implementation of any worthwhile programme.

In Kerala seasonal variations are small in the case of pressure, temperature and humidity but significant in the case of cloudiness and rainfall (Menon and Rajan, 1989). Kerala is bounded by the Arabian sea on the west while the Western Ghats skirt it on the east, forming a continuous chain, more or less insulating it from the rest of the country.

The physical, chemical and biological characteristics of any pond show seasonal as well as diurnal variations. These changes are mainly due to the influence of changes in weather elements of that place. The atmospheric parameters, especially air temperature and wind influence the temperature, mixing and stratification of pond water. These in turn, have direct bearing on the important physico-chemical water quality parameters and on many biological processes.

In India, fish farming in small systems like ponds and tanks is a very common practice. The impact of weather elements on the hydrographic parameters of pond has not been properly investigated. Establishing relationship between lower atmospheric and pond hydrographic parameters will facilitate the prediction of pond water characteristics. This will help for efficient management of aquaculture ponds.

Even though information is available on the seasonal and spatial changes of atmospheric and hydrographic variables, the possible influence of atmosphere on the hydrographic conditions of a pond is very rare. The present study was undertaken with a view to find out the seasonal and diurnal changes of weather elements at Panangad region, such changes in the hydrographic parameters of a freshwater pond with an aim to bring out possible influence of weather elements on hydrographic conditions.

Such information will be useful for managing the hydrographic conditions for obtaining maximum production from the culture pond. Maintenance of healthy aquatic environment and production of sufficient fish food organisms in ponds are two factors of primary importance for successful fish culture operations. To keep the aquatic habitat favourable for existence, physical and chemical factors like temperature, pH, alkalinity, dissolved gases like hydrogen sulphide, methane working lethal on fish life, will exercise their influence individually or synergistically, while the nutrient status of water and soil play the most important role in governing the production of plankton organisms or primary production of fish ponds.

The present study was carried out in College of fisheries, Panangad, Cochin during the period of June 2003 to April 2004 which includes four meteorological seasons viz. southwest monsoon season (June-September), post monsoon season (October-November), northeast monsoon season (December-February) and pre monsoon season (March-April).

Review of Literature

2. REVIEW OF LITERATURE

2.1 METEOROLOGIAL PARAMETERS

The climate of Kerala is tropical maritime and monsoonal in character (Menon and Rajan, 1989). Many works have been done to explain the characteristics in the distribution of weather elements and its seasonal and spatial variations. Paul *et al.* (1990) discussed the fluctuation of atmospheric features in relation to monsoon activities. The impact of different meteorological conditions on human body was explained by Basu (1991). Srivastava *et al.* (1992) analysed the decadal trends in climate over India. While discussing the human comfort and the environment, Bindu *et. al.* (1995) explained the salient features of temporal variation of meteorological parameters over an urban coastal station in Cochin. Long- term variabilities of Sea level pressure over the Arabian Sea and Bay of Bengal during May were discussed by Singh and Chanchlani (1998). Bhujod *et al.* (2001) studied the trends in the frequency of surface temperature above and below certain threshold values over various stations in India. Similarly, Kale (2001) has studied the spatial and seasonal variation in weather within and near an urban conglomerate in Pune.

2.1.1 Air temperature

Sewell (1929) has stated that the air temperature over the open water of the Indian seas exhibited a clear double oscillation in the year, there being two maxima (one in April and the other in September-October) corresponding to the two dry hot seasons and two minima during the period of Southwest and Northeast monsoon.

Studying the seasonal changes in air temperature at Port Blair, Rangarajan and Marichamy (1972) stated that the air temperature exhibited a clear double oscillation in a year, the maxima occurring in November and April and two minima in September and December.

Singh *et al.*, (1980) reported that the air temperature is lowest at morning and higher in noon hours in Rihand reservoir (UP). The difference in the morning and noon air temperature was less in December and June, moderate in September and significantly more in March.

2.1.2 Maximum temperature

Abbi *et al.* (1970) found that in Narmada basin, maximum temperature was high in April and May (Pre monsoon). Mean daily maximum temperature slightly falls in August. From August to October, there is a slight rise in temperature. After October, the daily maximum temperature progressively falls and reached the lowest value in the month of January. After January, there is a progressive rise till they reach their highest in April / May.

Menon and Rajan (1989) mentioned that in Kerala during southwest monsoon the mean maximum temperature ranges between 28 and 30 ^{0}C. The highest maximum reached between 32 to 34 ^{0}C. During post monsoon period mean maximum temperature are of the order of 29 to 30 ^{0}C. In northeast monsoon the mean maximum temperature are of the order of 31 to 34 ^{0}C. The highest values are reached in later part of the season. During the pre monsoon period mean maximum temperature ranges between 30 to 32 ^{0}C in the coastal belt. The higher recorded maximum temperature ranges between 36 to 37 ^{0}C along the coast.

2.1.3 Minimum temperature

In Narmada basin, mean daily minimum temperature are lowest in the month of December / January and an increase progressively upto may. Afterwards, there is a continuous decrease in the mean daily minimum temperature till December / January (Abbi *et al.*, 1970).

Menon and Rajan (1989) mentioned that in Kerala, the mean minimum temperature remain between 22 to 24 ^{0}C while the lowest minimum goes down to 19 to 20 ^{0}C. During post monsoon, mean minimum temperature remain between 21 to 24 ^{0}C. In northeast monsoon, mean minimum temperatures are between 20 and 22 ^{0}C in December and January and 22 to 23 ^{0}C in February. The lowest minimum recorded between 16 to 19 ^{0}C in coastal areas. During pre monsoon period mean minimum temperature are in the orders of 24 to 26 ^{0}C from March to April.

3.1.4 Rainfall

Jambunathan and Ramamurthy (1973) stated that the southwest monsoon which gives India most of its rainfall (75% of total rainfall), sets first along the Kerala coast towards the end of May (31st May), it may vary within a margin of about 10 days on either side.

Parthasarathy (1984) explained the inter annual and long-term variability of Indian summer monsoon rainfall. Rajan (1988) explained the characteristics of rain spell at Cochin.

Menon and Rajan (1989) mentioned that, the West coast shows a maximum rainfall in the early morning and minimum in the evening during the monsoon.

A day with 0.25 mm or more rain is counted as rainy day (Menon and Rajan, 1989). They also mentioned that in Kerala monsoon commence in the month of June and extends to October and decrease in November. Northeast monsoon season is of lower rainfall intensity in Kerala. They recorded 321 cm rainfall in Ernakulam district. The synoptic features leading to record rainfall at a few places in Kerala were explained by Lakshminarayanan (1991).

Prasad (1970) stated that the diurnal variation of rainfall would depend on the diurnal variation of the atmospheric instability, moisture content, low-level convergence, and radiational cooling of the top of the cloud.

Prasad (1974) has studied the diurnal variation of rainfall over India. He concluded that the afternoon /evening maximum rainfall is caused by the solar heating of the surface of the earth.

3.1.5 Relative humidity

This is the ratio of the observed mixing ratio to that which would prevail at saturation at the same temperature (Byers, 1959).

Abbi *et al.* (1970) found that in Narmada basin, relative humidity is high and have about the same order in July, August, and September. In October, it is between 65 to 80% at the morning hours and 40 to 60% at the evening hours of observation. From November till January, it is of about the same order, ranging between 55 to 85% and between 30 to 50% at first and second hours of observation respectively. After January till April, the relative humidity registers a progressive fall but the trend reversed in May and June.

The relative humidity shows both seasonal and diurnal fluctuation (Menon and Rajan, 1989). Seasonally it reaches maximum during the southwest monsoon period when the diurnal variation is least. The lowest values occur during the northeast monsoon and pre monsoon. They mentioned that relative humidity is lowest in the afternoon around the maximum temperature approach and the highest during early hours at the time of occurrence of the minimum temperature.

Diurnal amplitude of relative humidity is defined as the difference between the highest and lowest values over the span of a day. The maximum mean diurnal amplitude is observed in February or March and primary minimum is seen in June or July. Secondary maximum of the mean diurnal amplitude is observed in December and secondary minimum is seen in September from Bangladesh (Mobassher *et al.*, 1996).

3.1.6 Cloudiness

Menon and Rajan (1989) mentioned that the clouding increases with the onset of the southwest monsoon. The sky remains more or less overcast under strong and vigorous monsoon conditions. During post monsoon, the cloud cover is less. Northeast monsoon season is the period of minimum cloud over Kerala. But in pre monsoon, clouding increases rapidly both in extent and thickness as the moisture content increases with the advance of the season. During monsoon clouds are varying between 2/10 and 9/10 (Pillai *et al.*, 2000).

3.1.7 Wind

Lafond (1962) mentioned that in South East Asia, the dominant wind systems are the northeasterly and southwesterly wind.

Westerly and southwesterly winds were dominated with strong wind speed in southwest monsoon season. The wind pattern changes with the withdrawl of the southwest monsoon from subcontinent. The wind blows in opposite direction from land to sea, this is the northeast monsoon (Menon and Rajan, 1989).

Rao and Rao (1962) recorded that the wind speed was steady and low throughout the night but it showed a steady rise through the morning hours in Waltiar along east coast. They also found that the wind speed declined from November till January when it reached minimum and a gradual rise till May.

Madan *et al.* (1992) reported based on a study of wind pattern at Leh that the surface wind picks up speed sometimes during the afternoon and continues to be strong throughout the evening and night and slows down sometime after the sunrise.

2.2 HYDROGRAPHICAL PARAMETERS

The first study of water quality of a fish pond in India was probably done by Sewell (1927) when he studied the mortality of fish in a Museum tank in Calcutta. Since then, many works have been carried out to understand the physico-chemical condition of inland water either in connection with fish mortality or as a part of general hydrological study. To mention a few of them, there are studies by Moyle (1946), Ganapati (1949), Mookherjee and Bhattacharya (1949), Ganapati *et al.* (1953), Chacko and Srinivasan (1954) and Banerjea (1967).

While studying the physico-chemical and biological conditions of a pond in Calcutta, Saha *et al.* (1971) found considerable seasonal variations in water quality. Limnology of a temple tank at Thiruvananthapuram was studied by Anithakumari and Aziz (1989). Saha *et al.* (1990) studied ecological changes and its impact on fish yield of Kulis beel in Ganga basin. Impact of environmental stress on fresh water fisheries resources was extensively studied by Jhingran (1991). Rana and Sengupta (1996) explained the possible correlation between water temperature, pH, ammonia and primary production with fish growth performance in beels. He also made an attempt to assess the limnological characters of two beels of Nadia district (West Bengal) in relation to fish growth and total annual fish yield.

The hydrographic condition of water bodies like rivers, lakes, backwaters, estuaries and its spatial and temporal changes were extensively studied (Cheriyan, 1967; Qasim and Gopinathan, 1969; Josanto, 1971; Manoj Kumar, 1988; Varma *et al.*, 2002; Sudheer, 2003; Dept. of Fishery Hydrography, 2004 etc.).

2.2.1 Water temperature

The water temperature is considered to be one of the important factor in aquatic environment. Fluctuation in day and night temperature affects the solubility of dissolved gases, which in turn help in complete intermixing of the water column and is reflected in better productivity.

Water temperature is a very important physiological parameter as it affects all metabolic, physiological activities and life processes of different trophic levels of pond ecosystem. In addition, it also affects the speed of the chemical changes in soil and water and diurnal variations have great bearing on productivity (Dhirendra, 2002).

Menon *et al.* (1971) reported that with the onset of monsoon there was decrease in surface temperature in Cochin backwater and a certain amount of uniformity was maintained in temperature till the end of the monsoon. An increase in temperature towards the beginning of post monsoon was well indicated. Temperature was found high throughout the later half of the post monsoon and pre monsoon. Parameswaran *et al.* (1971) recorded lowest temperature in January from a freshwater pond in Assam.

Annigeri *et al.* (1979) recorded that the annual temperature variation exhibited a bimodal distribution with the primary and secondary peak in April / May and October / November periods and their falls during August / September and December / January from coastal waters of North Kanara.

Sankaranarayanan *et al.* (1982) found that the temperature was low during the southwest monsoon in prawn filtration fields of Kerala. The minimum temperature was recorded during December-January. The low temperature observed during these months was due to the winter effect. In general higher temperature was recorded during the pre monsoon season and also during the post monsoon season.

Water temperature played an important role in influencing the periodicity, occurrence and abundance of phytoplankton as it had a direct relationship with total plankton (Tirpathi and Pandey, 1990).

The surface temperature in the Chilka Lake shows a seasonal cycle. The diurnal variation of surface temperature get maximum round about 14:00 hr., two hours after the time of maximum solar radiation and minimum during the early hours of the day (Ramanadham *et al.*, 1964).

2.2.2 pH

pH of water is considered to be one of the most important chemical factors affecting the productivity of a pond. It has direct effects on fish growth as well as growth and survival of food organisms. Hence, to achieve good fish production pH of the water should be monitored regularly to ensure its optimum range of 6.5 and 8.5.

McCombie (1953), observed high pH values during blooming period of phytoplankton. pH remains more or less constant at 8.0 throughout the year with a slight variation in river Yammuna at Allahabad. The upper limits are observed in months, March to June and November to December, whereas the lower values are recorded in September when maximum turbidity values are also registered (Chakrabarty *et al.*, 1959). A near neutral condition of pH (6.5-7.5) is most favourable for fish production (Banerjea, 1967).

Parameswaran *et al.* (1971) recorded a steady increase of pH from December–January to March–April in a freshwater pond of Assam. They attributed this to shifting of carbonate-bicarbonate equilibrium to alkaline side due to phytoplankton bloom.

Diurnal variation of pH reached peak value during the afternoon and declined gradually in the evening reaching low levels during the late night and lowest pH was observed in the morning hours. A positive graphic relationship was observed between pH and temperature of pond water (Das *et al.*, 2000).

2.2.3 Secchi depth

In aquaculture ponds, turbidity from planktonic organism is often desirable, to a certain extent where as that caused by suspended particle is generally undesirable (McCombie, 1953).

Almost all problems related to dissolved oxygen in fish culture ponds are the consequences of heavy plankton blooms (Boyd *et al.*, 1978). Suitable plankton densities result in Secchi disc visibilities of 30 - 60 cm. The probability of problems with low dissolved oxygen concentration increases as Secchi disc visibility decreases below 30 cm. In ponds with Secchi disc visibilities of 10 – 20 cm, dissolved oxygen concentration may fall so low at night that fish are stressed or even killed (Romaire and Boyd, 1978).

2.2.4 Water depth

Parameswaran *et al.* (1971) recorded maximum depth of water from a freshwater pond in Assam during southwest monsoon months after which there was a considerable fall with minimum depth in pre monsoon period.

Jindal and Kumar (1993) recorded that the maximum depth of pond occurs during monsoon and lowest in summer. They recorded a maximum depth of 1.5m in monsoon and lowest of 0.75m during summer in a freshwater pond in Himachal Pradesh.

2.2.5 Primary productivity

Among the physico-chemical factors influencing aquatic productivity, pH, alkalinity, dissolved gases like oxygen and carbon dioxide and dissolved inorganic nutrients like nitrogen and phosphorus are important (Banerjea, 1967). He also mentioned that the maintenance of higher gross and net primary productivity values helps in better growth of fishes in pond. Marchichamy *et al.* (1985) mentioned that the primary production in inshore waters of Tuticorin indicated three distinct peak periods, first during January-March, the second during June-August and the third during October-December. Basheer *et al.* (1996) also explained the seasonal variations in the primary productivity of a pond receiving sewage effluents. Presence of nutrient elements in optimum concentration and thereby production of phytoplankton and algal bloom may be the possible reason for the high productivity in pond (Saha and Mandal, 2004).

It is well known that the rate and extent of organic production in a water body are normally controlled by several factors and it is the collective action of all these that result in the primary production. Factors such as temperature, nutrient availability and physiological condition of the plankton affect primary production. The diurnal variation observed in primary productivity was with higher rates in the afternoon during summer months and during forenoon in the winter months in river Godavari (Rajyalakshmi and Premswarup, 1975).

2.2.6 Total Alkalinity

Total alkalinity mainly depends on carbonates and bicarbonates of Calcium and Magnesium (Chakrabarty *et al.*, 1959). While studying the physico-chemical condition of river Yammuna at Allahabad, higher values were observed between December and July (204-270 ppm). A fall is then registered in August, which may probably due to the maximum rainfall resulting in great dilution of water. A steady rise is noticed from September onwards (Chakrabarty *et al.*, 1959).

The plankton population in ponds was maximum during the months December to April/May, coinciding with the higher concentration of total alkalinity and nutrients of pond water, which may mainly be attributed to the concentration of water due to evaporation (Parameswaran *et al.*, 1971). They also mentioned that due to high rainfall in monsoon month resultant dilution of nutrients in ponds might account for the low production in monsoon months.

Mathew (1987) reported higher values of total alkalinity with wide fluctuations in some prawn culture fields. The values ranged from 10 to 130 ppm in perennial fields. High values recorded during pre-monsoon and low values were recorded during the monsoon months.

2.2.7 Dissolved oxygen

While studying the physico-chemical condition of a culture pond in Assam, Lakshmanan *et al.* (1967) noted that the dissolved oxygen was at the highest level in ponds during colder months due to the low temperature and intense photosynthetic activities of phytoplankton bloom, and fall of dissolved oxygen in pre monsoon period is attributed to the warming up of water, death and decay of plankton and presence of other organic matter. The dissolved oxygen content of water in pond was generally high in the winter months and least in the summer months (Parameswaran *et al.*, 1971).

Among the chemical substances in natural waters, oxygen is probably one of the most important critical factor both as regulator of metabolic processes of plant and animal community and as an indicator of water quality. Dissolved oxygen along with turbidity could provide information about the nature of an ecosystem better than any other chemical parameters (Hutchinson, 1975). He also observed that the dissolved oxygen concentration of more than 5 ppm would favour good growth of flora and fauna.

According to Pillai *et al.* (1975) and Dept. of Fishery Hydrography (2004), dissolved oxygen showed a distinct pattern of seasonal fluctuations in the Vembanad Lake and adjacent waters. Comparatively high values were found during southwest monsoon (June-August) due to the renewal of water because of heavy rainfall and freshwater discharge to the estuary and low values during pre monsoon season due to the increased temperature, which reduces the solubility. The post monsoon period appeared to be more stable with lesser variations.

Annigeri *et al.* (1979) and mentioned that the dissolved oxygen showed two peaks and two falls during a year in coastal waters of North Kanara, the peaks occurring in July/August and November/January and falls during August-December and March-April respectively.

Inspite of longer duration of photosynthetic activity of submerged plants during summer which ought to have resulted in higher values of dissolved oxygen, the levels recorded were low which may be due to loss of dissolved oxygen to the atmosphere, utilization of oxygen in faster decomposition of organic matter and the higher rate of respiration by heterotrophic organisms. The increase in oxygen value during monsoon and winter months in Suraka Lake (Ballia) may be due to rainfall and prolific growth of phytoplanktonic algae and also due to low temperature (Swarup and Singh, 1979).

Singh (1987) found that the seasonal and perennial fish ponds in Cochin had low oxygen values during the pre monsoon and the values increased with the onset of monsoon.

2.2.8. Nutrients

Nitrogen a major constituent of protein occupies a predominant place in aquatic ecosystem. Though a relatively minor constituent, phosphorus is often considered to be the most critical single element in the maintenance of aquatic productivity (Moyle, 1946). Dissolved inorganic nitrogen (nitrate and nitrate form) in the range of 0.2 to 0.5

mg/l may be considered favourable for fish productivity and the phosphorus fertility for aquatic productivity ranges from 0.05 to 0.20 mg/l (Moyle, 1946). In natural waters, silicon remains in silicate form. Normally, 1-30 mg/l silicate-silicon or more have been reported from natural waters (Moyle, 1946). At high temperature and pH, the solubility of silica greatly increases. As silica has been an important structural constituent of diatoms and many sponges, it is able to regulate their growth (Moyle, 1946).

The nutrient status of both water and soil play the most important role in governing the production of planktonic organism in fish ponds (Banerjea, 1967). The plankton population in ponds was maximum during the months December to April/May, coinciding with the higher concentration of total alkalinity and nutrients of pond water, which may mainly be attributed to the concentration of water due to evaporation (Parameswaran *et al.*, 1971).

Joseph (1974) reported that nutrients in the Cochin harbour showed marked seasonal variation, phosphate showed very high concentration during the pre monsoon and it is decreased with the intensification of southwest monsoon. Dept. of Fishery Hydrography (2004) has also seen marked seasonal variations in nutrients from Vembanad Lake. Maximum concentrations were obtained during June-August (monsoon season). The nutrients decreased in September.

2.3 RELATION BETWEEN WEATHER AND HYDROGRAPHICAL PARAMETERS

The water temperature of the ponds is influenced by changes in the atmospheric temperature. This is because small masses of water body react quickly to the change in the atmospheric temperature (Welch, 1952).

Hutchinson (1957) had inferred that light penetration in a freshwater ecosystem was mainly affected by the intensity of light at water surface and dissolved and undissolved material in the water.

Rao and Rao (1962) found direct relation between the wind force and air temperature and water temperature. The higher the wind, the higher will be the air and water temperature. They reached their minimum value in morning and gradually increased upto afternoon and thereafter a gradual fall. They also found that an increase in wind force at Waltiar coast could cause an increase in the height of the waves thereby increasing the mixing between upper and lower level of water.

Lafond (1962) mentioned that the winds and marine conditions bring up the nutrient rich bottom water and create a favourable condition for primary productivity in Southeast Asian waters. He also mentioned that in addition to rainfall and radiation, other marine meteorological conditions such as creation of vertical movement in order to bring nutrient up from deeper water are important for enrichment of primary production.

Ramanadham *et al.* (1964) mentioned that the surface temperature of Chilka Lake shows a seasonal cycle closely related to the air temperature. The diurnal variation of the surface temperature depends on factors like Cloudiness and wind velocity. Varkey John (1976) also noted similar trend from river Kallayi in Kerala.

Light penetration is an important physical factor. As the primary production is a photochemical reaction energized by light, the availability light in a fish pond greatly influences its productivity (Banerjea, 1967).

The nitrites attain the peak before heavy rains (in June). The relationship between silicates and rainfall is strictly parallel, with the difference that heavy rains occur much ahead of the occurrence of the peak silicates. As the peak of the nutrients do not occur contemporarily to the peak of rainfall, it is reasonable to think that the rainfall does not cause these peaks though it seems to affect it (Noble, 1968).

Due to the cloudy weather and as a result of it, less photosynthetic activity and concentration of dissolved oxygen remained very low. Excess of oxygen accumulated during the daytime and reached it maximum, while respiration of the whole biota in the night exhausted it. With no renewal possible during night in the absence of sunlight and photosynthesis, the dissolved oxygen concentration dropped down to minimum at early morning. This depletion in the night and over saturation in the day was mainly due to the abundance of blue green algae and other phytoplankton in a tropical fish pond at Aligarh (Khan and Siddiqui, 1970).

The fairly heavy monsoon during June to August and resultant dilution of the nutrients in ponds may account for the relatively low production of plankton in the monsoon months. With the onset of monsoon the pH showed a fall, apparently due to the dilution of water in ponds. The fluctuation in total alkalinity could be correlated with the phytoplankton pulses and decrease in water level due to evaporation (Parameswaran *et al.*, 1971).

Hours of sunshine and water temperature in general showed inverse fluctuation with depth of water bringing about changes in other chemical factors in water and also in biological productivity of the pond (Saha *et al.*, 1971). Studying the seasonal changes in air temperature at Port Blair, Rangarajan and Marichamy (1972) stated that the air temperature exhibited a clear double oscillation in a year, the maxima occurring in November and April and two minima in September and December. The surface temperature was invariably lower than the atmospheric temperature. The temperature of surface water steadily increased from January to April registering a sharp fall in May due to the onset of Southwest monsoon.

Varkey John (1976) found that during rainy season the water level rises in river Kallayi. He also stated that the water temperature showed a positive correlation to the seasonal cycle of atmospheric temperature. Singh *et al.* (1980) mentioned that the dissolved oxygen was low when the solar radiation and photosynthetic activity were retarded by the cloudy weather. The low value of primary productivity in Gadigarh stream during June/July was correlated with the turbidity, coupled with cloudy days of monsoon. It reduced the light intensity and incessant rains cut down primary productivity (Anand, 1982).

A distinct horizontal differentiation in the whole pond appeared under a wind speed of 2-4 m/sec, wind of higher velocity deleted the time-space differentiation mixing the whole water column in ponds (Zurek et al., 1991).

Jindal and Kumar (1993) recorded that the higher values of silicate during summer months because of their concentration at lower water level and increase in solubility of silica at higher temperature ($r = 0.573$). He also found that the amount of rainfall play a significant role in the fluctuation of physico-chemical characteristics of water either directly or indirectly.

Water temperature, oxygen saturation, ammonia nitrogen and phosphate concentrations, pH and partly phytoplankton density showed almost regular cycles with maximum values in the noon or evening hours in ponds. Minimum diel values were noted at night or early in the morning hours when the whole water stratum was almost homogenous or only small vertical gradient to the bottom (Szumiec *et al.*, 1995).

Air temperature can play as a significant indicator in assessing transparency of river. Rise and fall in transparency at upper Ganga stretch can be directly correlated with air temperature (Das and Jha, 1999).

Materials and Methods

3. MATERIALS AND METHODS

To study the temporal changes of the weather elements and its possible influence on the hydrographical condition of a culture pond a study was carried out during the four seasons viz. southwest monsoon season (June-September), post monsoon season (October-November), northeast monsoon season (December-February) and pre monsoon (March-April) at the College of fisheries, Panangad, Cochin (Kerala). Fortnightly samples for hydrographical parameters and daily observation at 03 UTC (0830 IST) and 12 UTC (1730 IST) for the meteorological parameters were carried out. Studies were conducted during the period from June 2003 to April 2004 involving the above-mentioned four meteorological seasons. The monthly average value of each parameter is reported here. Since the pond depth was below 1.41 m, vertical variation in hydrographical parameters were not considered as significant, as pointed out by Nair *et al.* (1988) in the case of paddy cum prawn filtration fields in Kerala. To study the diurnal variation, 24 hours observation was carried out at an interval of 3 hrs, once for each season. The study area is situated in between Panangad and Kumbalam (Fig. 1; Plate 1 and Plate 2). The methods used to collect the meteorological and hydrographical data for the present study are described below.

3.1 METEOROLOGICAL OBSERVATIONS

Meteorological parameters were observed daily at 03 UTC (0830 IST) and 12 UTC (1730 IST) for the parameters like minimum temperature, maximum temperature, wind speed, wind direction, relative humidity, wet bulb temperature, dry bulb temperature, rainfall and cloudiness, following the methods of Blair and Fite (1965) are described below.

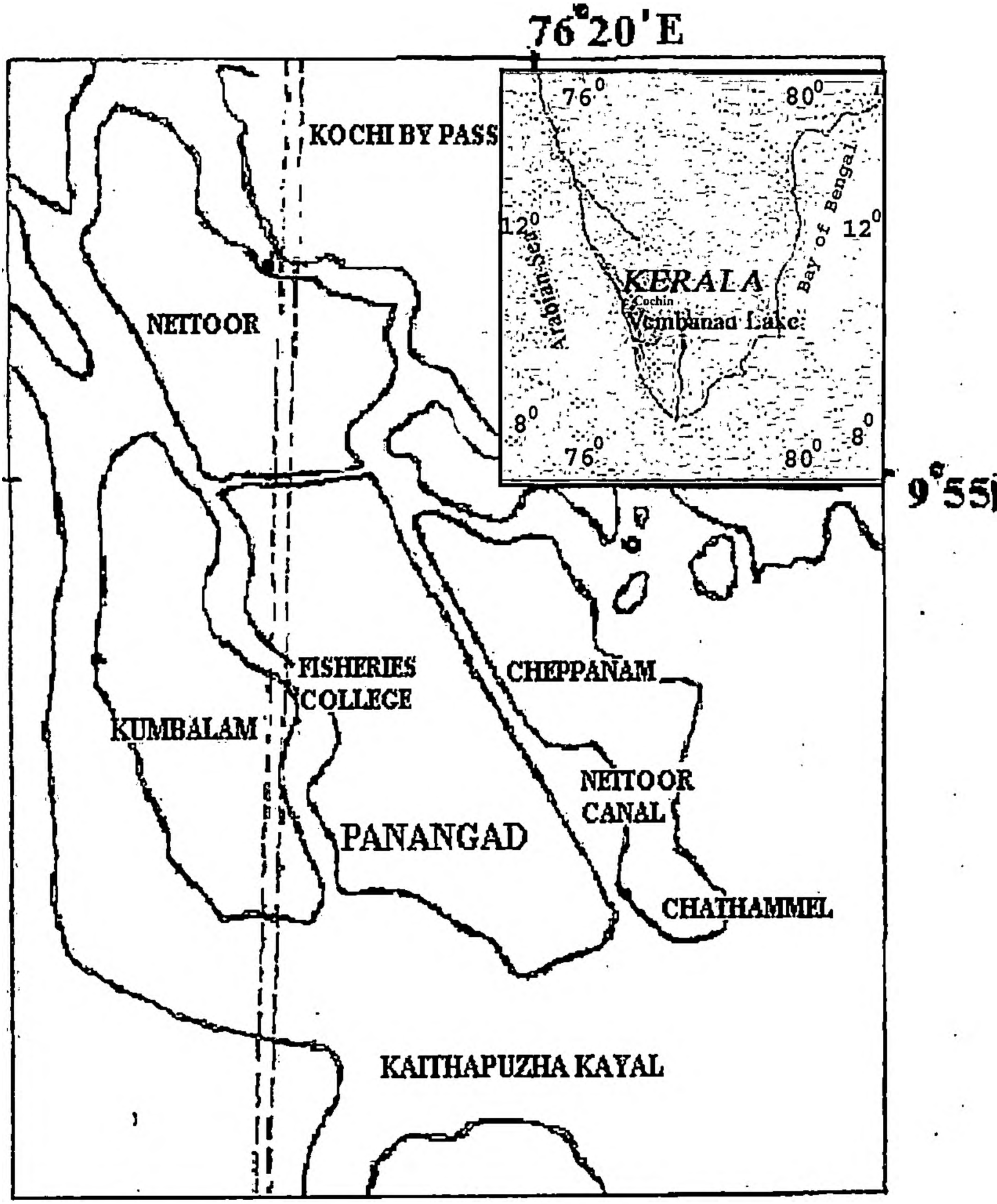


Fig. 1 Location of Study area

Rain gauge

Stevenson's screen

Wind vane

Anemometer

Plate 2. Meteorological Observatory

Freshwater Pond

Freshwater Pond (Another view)

Plate 3. Photographs of Freshwater pond

3.1.1 Maximum temperature

The maximum temperature is usually attained in early afternoon. Maximum thermometer is used to measure the maximum temperature attained of the day. This thermometer is like a dry bulb thermometer, except for a narrow constriction near the bulb. The constriction allows expansion of mercury to the bulb when temperature increases. This thermometer should be installed inside a Stevenson's screen horizontally to avoid the gravitational pull on the mercury column.

3.1.2 Minimum temperature

The minimum thermometer is an alcohol in glass thermometer and is used to measure the minimum temperature of the air, which occurs in night time. A movable metal piece of light weight, known as "index" is kept inside a capillary tube of the thermometer. The index is pulled down by meniscus of the alcoholic column, when the temperature falls. When temperature increases subsequently alcohol expands but the index remains at the lowest temperature position. This thermometer is installed inside a Stevenson's screen horizontally.

3.1.3 Rainfall

Rainfall was measured with the help of an ordinary rain gauge. This has a rim of 12.5 cm in diameter and is installed 30 cm above the ground level. The collecting funnel kept on the rim collects rainwater and the collected water goes to a collecting jar kept inside the outer cylinder. The rainwater is measured by pouring the collected water into graduated measuring jar.

A day with 0.25 mm or more rain is counted as rainy day (Menon and Rajan, 1989).

3.1.4 Wet bulb temperature

Wet bulb temperatures was taken at 8.30 a.m. (03 UTC) and 5.30 p.m. (12 UTC) by using wet bulb thermometer. Installation of this thermometer was done inside the Stevenson's screen vertically.

3.1.5 Dry bulb temperature

Dry bulb temperatures was taken at 8.30 a.m. (03 UTC) and 5.30 p.m. (12 UTC) by using dry bulb thermometer. Installation of this thermometer was also done inside the Stevenson's screen vertically.

3.1.6 Relative humidity

This is the ratio of actual amount of water vapour present in unit volume of air to the capacity of the air to the particular temperature expressed in percentage. From the dry bulb reading and depression of the wet bulb thermometer relative humidity can be found out from the table.

3.1.7 Cloudiness

Cloudiness was measured by the visual observation and it is expressed in okta. It is the clearness of the sky.

3.1.8 Wind speed

Wind speed is expressed in "knots" and 1 knot = 1 nautical mile/hour or 1.853 km/hr. The speed of the wind was measured by a cup anemometer. This consists of cups, which rotates about a vertical shaft. The rotation of cups per minutes is a measure of wind speed.

3.1.9 Wind direction

The 'wind vane' was used to obtain wind direction. The head of the arrow of the wind vane faces the direction from which wind blows. The direction of the wind is the direction from which it is blowing. The direction can be expressed either in degrees or in terms of the "direction from which it blows". The angle of the direction is measured from the north in a clockwise direction. Accordingly, northerly wind is known as $0^0/360^0$ wind, easterly wind as 90^0 wind, southerly wind as 180^0 wind and westerly wind as 270^0wind.

3.2 HYDROGRAPHICAL PARAMETERS

Hydrographical features like temperature, net and gross primary productivity, pH, transparency, depth of the water column, alkalinity, nitrate-nitrogen, nitrite-nitrogen, phosphate-phosphorus, reactive silica and dissolved oxygen were also studied. Surface water samples were collected using a clean plastic bucket for studying hydrographic parameters of the pond.

3.2.1 Water temperature

The surface water temperature was recorded using a precision thermometer, immediately after collecting the water.

3.2.2 pH

pH was determined using a digital pH meter. The instrument was calibrated using buffer solution having pH 4 and 7.

3.2.3 Secchi depth

A Secchi disc was used for determining the transparency of water column. It was lowered into the water and the depth at which it disappeared was noted. It was then slowly raised upwards and the depth at which it reappeared was noted. The average value of these two readings was calculated and expressed in centimeters.

3.2.4 Water level

Depth of the water column was measured using a graduated pole. The average depth of the 5 station of the pond can be taken as the depth of the water column and expressed in centimeter.

3.2.5 Primary productivity

The phytoplankton primary production was determined by using light and dark bottle method as detailed in Strickland and Parsons (1972). Narrow mouthed 125 ml bottles, one dark bottle and two light bottles were filled with pond water sample collected without trapping air bubbles and oxygen in the initial light bottle was fixed immediately. The second light bottle and the dark bottle were incubated in water for 3 hrs. in identical conditions. For this water was taken in a deep tray and the bottles were put in that for incubation. After the incubation period the bottles were taken out and the dissolved oxygen was fixed. The dissolved oxygen was determined and from these, the net and gross productions were calculated.

Primary productivity is the measure of the rate of carbon assimilation. The difference between the amount of oxygen produced through photosynthesis and that consumed through aerobic respiration is the net productivity. The difference in dissolved oxygen over time between the bottles stored in the light and in the dark is a measure of the total amount of oxygen produced by photosynthesis. The total amount of oxygen produced is called the gross productivity.

3.2.6 Total Alkalinity

Alkalinity was determined by acidimetric titration following standard methods (Lenore *et al.*, 1998).

3.2.7 Dissolved oxygen

Standard Winkler's method (Strickland and Parsons, 1972) was followed for the estimation of dissolved oxygen content of water samples. Surface water samples were collected in 125 ml clean oxygen bottles and care was taken to avoid trapping of air bubbles during collection.

3.2.8 Nutrients

For the estimation of nutrients water samples collected were stored in clean plastic bottles of 250 ml capacity. Nitrate-N, Nitrite-N, Phosphate-P and Silicate-Si were the nutrients estimated.

All these bottles were kept in a freezer to prevent the loss of nutrients during the storage.

Water samples collected in polythene bottles were analyzed in the laboratory following standard photometric methods using U.V-vis spectrophotometer (JASCO, V-530). Phosphate and Silicate were measured by standard molybdenum blue spectrophotometric method and nitrate was estimated by standard method by cadmium reduction followed by spectrophotometry. Nitrite was estimated based on the reaction of nitrite with aromatic amine (Grasshoff *et al.*, 1983).

3.3 DIURNAL OBSERVATIONS

Diurnal observations for all the above-mentioned meteorological and hydrographical parameters were carried out once in southwest monsoon (13th to 14th July, 2003), post monsoon (23rd to 24th November,

2003) and northeast monsoon (4^{th} to 5^{th} January, 2004) and pre monsoon (8^{th} to 9^{th} April, 2004) season at an interval of 3 hours observation.

3.4 ANALYSIS OF DATA

The monthly average value of each parameter is reported here. 5-day average was taken to find out the short-term fluctuations in air temperature, maximum temperature, minimum temperature and total rainfall.

3.4.1 Linear Correlation

To study the influence of meteorological parameters on the hydrographical parameters of the culture pond, linear correlation coefficients ('r') were estimated out (Snedecor and Cochran, 1965). The computed values of correlation coefficient between any two variables were tested for significance at 5% level.

The correlation coefficient ('r') was estimated by using following formula,

$$r = \frac{\Sigma xy - \Sigma x \, \Sigma y}{(\Sigma x^2 - \Sigma x/n) \; (\Sigma x^2 - \Sigma y/n)}$$

Results

4. RESULTS

4.1. MONTHLY VARIATIONS OF WEATHER ELEMENTS

4.1.1 Air temperature

The monthly mean air temperature showed the low values during southwest monsoon month and early part of the northeast monsoon period (December and January) where as the temperature maxima occurred during November and pre monsoon months (Table 1 ; Fig. 2 A). The highest mean value of 30.4 ^{0}C was observed in March and the lowest mean value of 26.3 ^{0}C was in the month of July.

Analysis of pentads for air temperature showed noticeable short-term fluctuations (Fig. 3a). The fluctuations are more in monsoon months and post monsoon period. The temperature in July is much lower than the air temperature experienced in January. Steady increase in air temperature could be noticed from January to middle of March.

4.1.2 Maximum temperature

During southwest monsoon period, the mean maximum temperature ranged between 29.7 and 30.7 ^{0}C, where as in post monsoon period, mean maximum temperature ranged between 30.1 and 31.5 ^{0}C. In northeast monsoon period, the mean maximum temperatures are the order of 31.8 to 32.8 ^{0}C (Table 1; Fig. 2 B). During the pre monsoon period, mean maximum temperature was 33.6 ^{0}C in April and 34.1 ^{0}C in March with the highest recorded maximum temperature of 35.8 ^{0}C in April.

Short-term fluctuations in maximum temperature can be seen in the pentad graph for maximum temperature (Fig. 3b). Maximum temperatures were less in southwest monsoon and post monsoon than the northeast and pre monsoon months.

4.1.3 Minimum temperature

The surface temperature registered appreciable falls during the period of southwest monsoon, but the minimum temperature continued to be high (Table 1; Fig. 2 C). The mean minimum temperature remains between 23 to 24 ^{0}C during this season while the lowest minimum goes down to 22 to 23.0 ^{0}C. During post monsoon period, mean minimum temperature remain between 23 to 24.0 ^{0}C. The lowest minimum goes down in November. In northeast monsoon season, mean minimum temperatures are between 21 and 22.5 ^{0}C in December and January and 23.1 ^{0}C in February. The lowest minimum of 18.5 ^{0}C recorded in January. During pre monsoon period mean minimum temperature are the orders of 24 to 25 ^{0}C from March to April. During the study period March was the hottest month of the season.

Short-term fluctuations in minimum temperatures could be seen in the pentad graph (Fig. 3c) drawn for minimum temperature. The minimum values were within the range of 22 and 24 ^{0}C in southwest and post monsoon months. Sudden drop of minimum temperature was observed by middle of January 2004.

4.1.4. Rainfall

The rainfall was more during the months of southwest monsoon month and early part of the post monsoon period, where as the less rainfall was observed during the northeast and pre monsoon period. Highest total rainfall of 451 mm was observed during the month of July and the lowest total of 4.2 mm was experienced during the month of March (Table 1; Fig. 2 D). During the southwest monsoon period, the lowest rainfall was in the month of September.

Rainy days were more during the months of southwest monsoon and early part of the post monsoon month i.e. in October. Where as the lowest number of rainy days was recorded during the northeast monsoon period and it remain less during the pre monsoon with an increasing trend (Table 1; Fig. 2 E).

Pentads for rainfall showed short-term fluctuations during southwest monsoon months (Fig. 3d). Rainfall was decrease after middle of October till the end of the of the observation period.

4.1.5 Relative humidity

Relative humidity was less in the afternoon and more in the morning hours of the day (Table 1; Fig. 2 F). The mean relative humidity was highest and of about the same order in July, August and September ranging between 80 to 90% at the morning hours and between 70 to 85% at the evening hours of observation. In October, it was 85.5% at the morning hours and 77% at the evening hours of observation. From November till January, it is of about the same order, ranging between 70 to 80% and between 60 to 70% at first and second hours of observation respectively. After January till early part April, the relative humidity registers a progressive fall. It ranged between 70 to 75 % in the morning hours and 60 to 65 % at the evening hours.

Even though short-term fluctuations were observed in the relative humidity (Fig. 1e), it was high during the southwest monsoon and post monsoon periods. Relative humidity decreased gradually from southwest monsoon and it was minimum by the middle of February 2004.

4.1.6 Cloudiness

The mean monthly cloudiness increased from 4 okta (in June) to 6 okta (in July). The skies remain more or less overcast under strong and vigorous monsoon conditions (Table 1; Fig. 2 G). During November cloud cover was less, compared to the previous phase of the southwest monsoon. Northeast monsoon season is the period of minimum clouding but in pre monsoon clouding increased with the advance of the season.

4.1.7 Wind

The wind speed was high during the southwest monsoon season (Table 1; Fig. 2 H). The mean value during this season ranged between 4.63 (in June) to 7.96 (in August) km/hour. The wind speed decreased from November till January and the lowest value was experienced in December. From Northeast monsoon period on wards it gradually increased till April. The lowest ranged between 2.89 to 2.97 km/hour during the northeast monsoon season.

During the southwest monsoon season westerly and southwesterly were dominated with strong wind speed. In October, the low level westerlies decreased in speed. In November they become light and northerly winds was observed. In northeast monsoon, northerly and north easterlies were dominated with especially in the morning hours. Varying winds could be noticed in the pre monsoon period with an increasing trend in speed.

Table. 1. Monthly variations of weather elements

Parameters	*JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.
Air temperature (°C)	27.6	26.3	27.40	27.7	27.5	28.3	27.6	27.4	28.8	30.4	30.2
Max. temperature (°C)	30.5	29.7	29.9	30.7	30.1	31.5	31.8	31.9	32.8	34.1	33.6
Highest temperature (°C)	32.0	31.9	31.5	31.7	31.6	32.8	33.2	33.0	33.9	35.8	34.3
Min. temperature (°C)	23.4	23.7	23.9	23.1	23.7	23.6	22.1	22.2	23.1	24.3	24.9
Lowest temperature (°C)	22.7	22.0	22.0	22.5	22.8	21.0	19.0	18.5	20.2	23.0	22.0
Total Rainfall (mm)	18.2	451	347.3	88.5	402.5	30.1	48.2	10.5	43.0	4.2	35.5
Rainy days	3	26	25	11	18	7	1	1	2	6	7
**RH (%) at 8.30 hr	83.3	86.1	86.1	80.2	85.5	75.6	75.1	73.3	70.6	71.3	73.0
**RH (%) at 17.30 hr	77.3	81.6	78.3	74.0	76.5	69.3	62.4	61.1	61.2	60.4	62.9
Cloudiness (Okta)	4/8	6/8	4/8	1/8	3/8	0/8	0/8	0/8	0/8	0/8	1/8
Wind speed (km/hr)	4.63	6.81	7.96	5.66	5.10	3.68	2.89	2.97	3.40	3.63	4.06

* Since collection of data started only on 28th June 2003 data of 4 days are considered.

(RH- relative humidity) ** Since morning and evening values are different, both are shown.

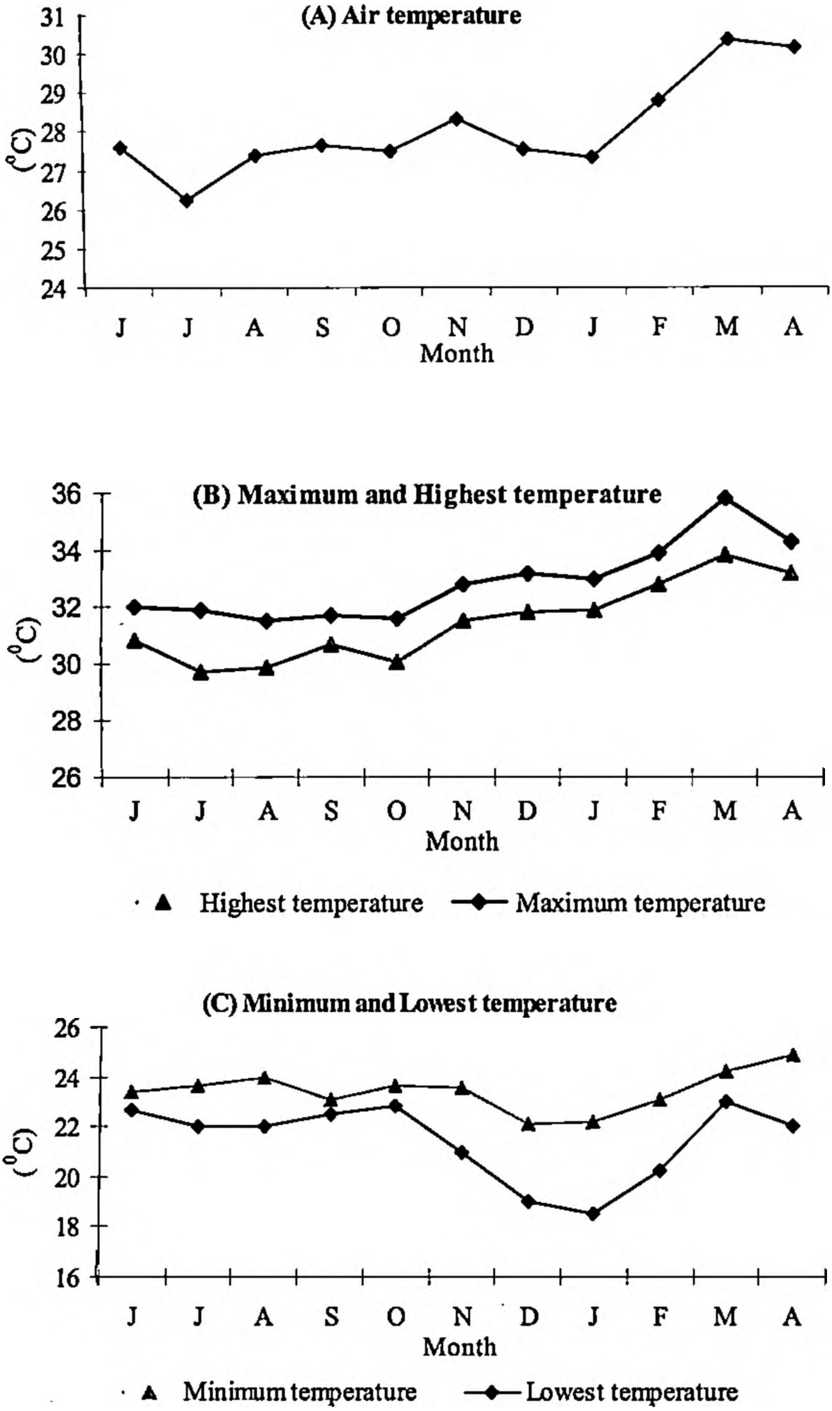


Fig. 2 Monthly variations of weather elements

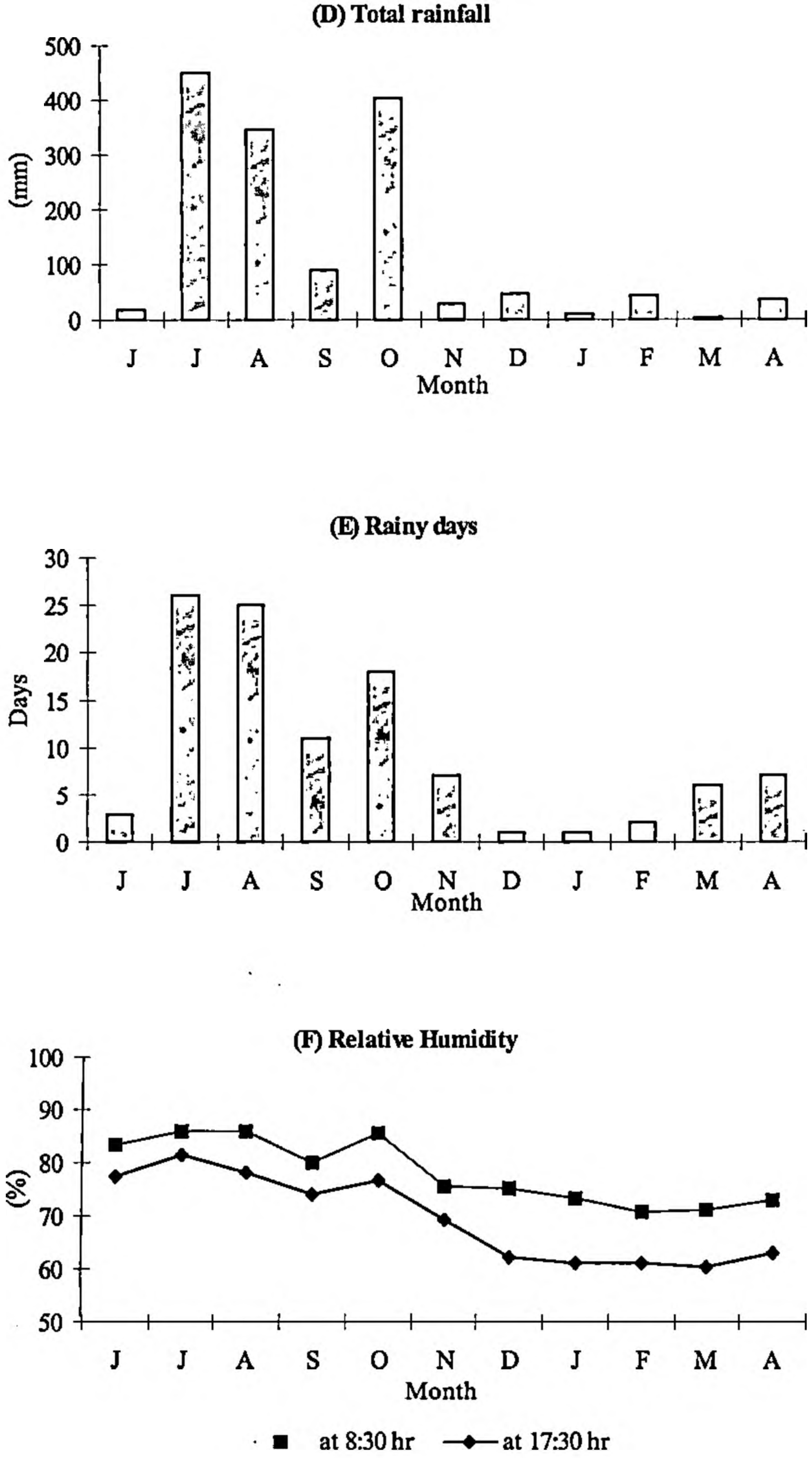
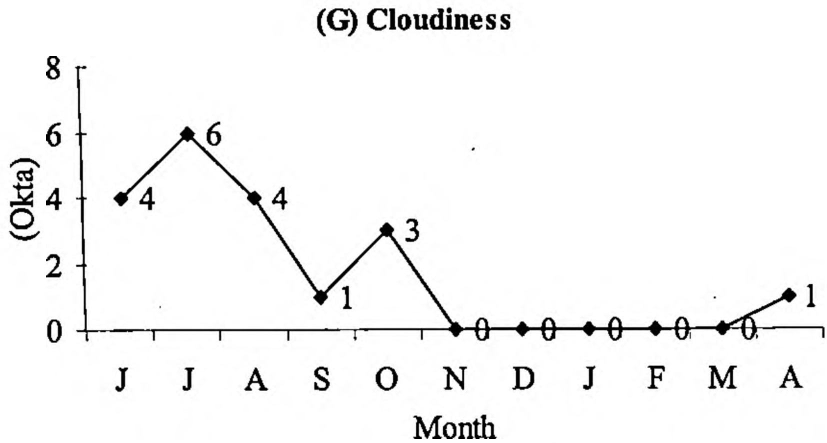


Fig. 2 (Contd.) Monthly variations of weather elements



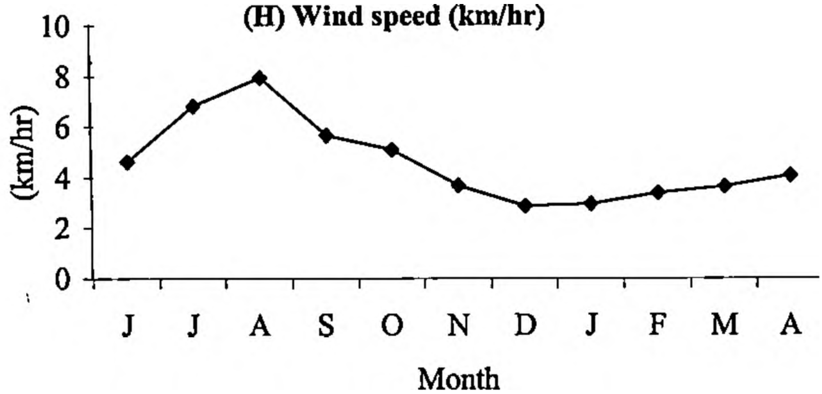


Fig. 2 (Contd.) Monthly variations of weather elements

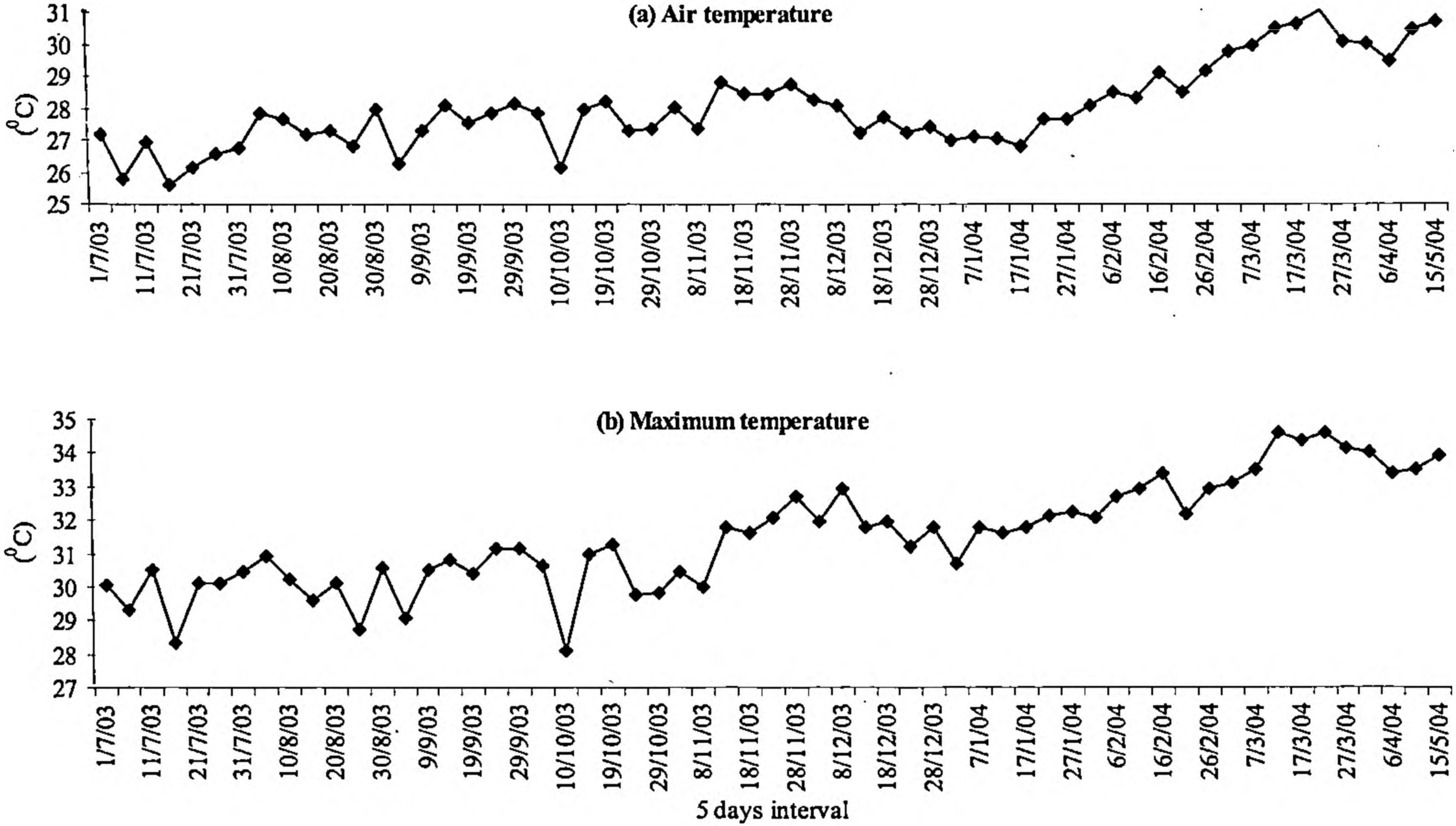
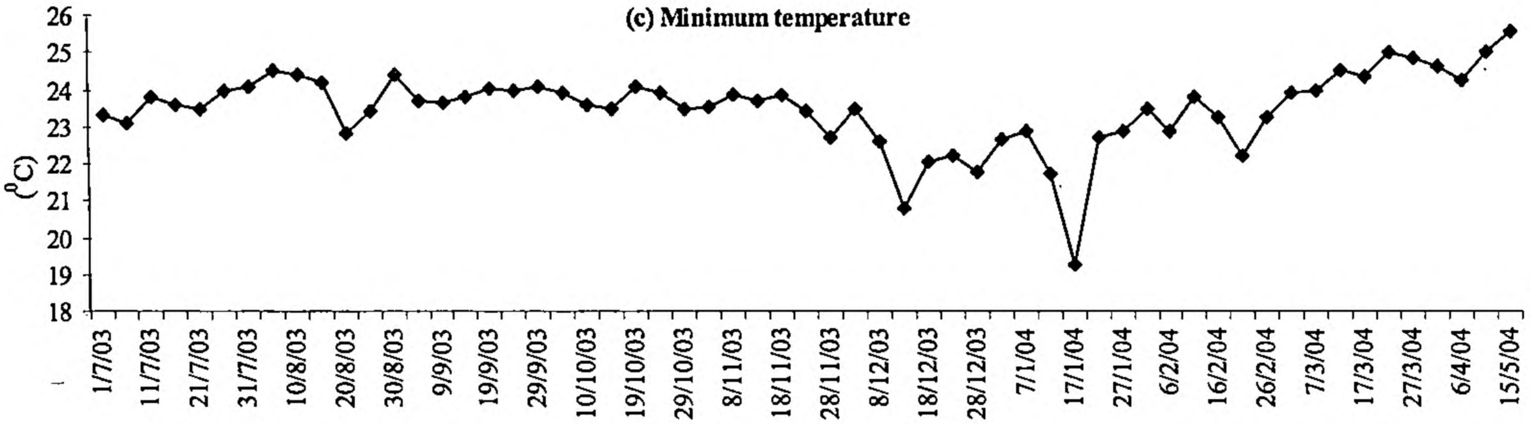


Fig.3 Pentads of weather elements



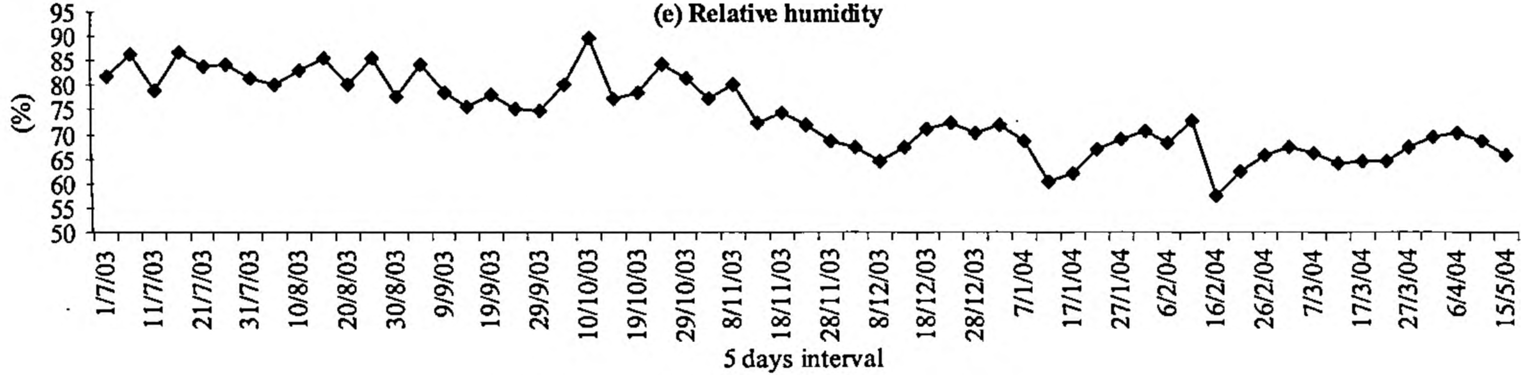


Fig.3 (Contd.) Pentads of weather elements

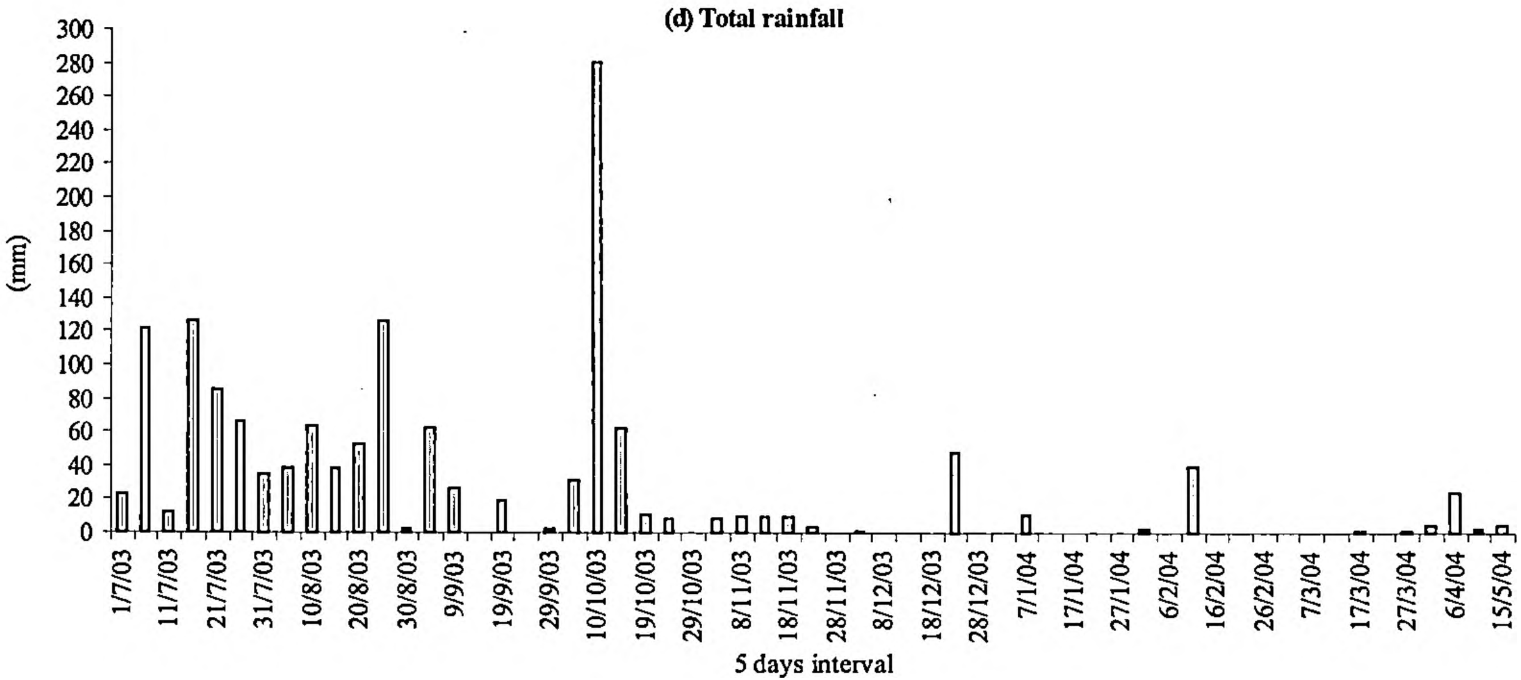


Fig.3 (Contd.) Pentads of weather elements

4.2 MONTHLY VARITIONS OF HYDROGRAPHICAL PARAMETERS

4.2.1 Water temperature

The water temperature in the pond varied from 26.9 ^{0}C (in January) to 29.1 ^{0}C (in March). There was a marked decrease in temperature during northeast monsoon season and the lowest was experienced during the month of January. During pre monsoon there was a gradual increase in temperature and the highest temperature of 29.1 ^{0}C was experienced in March. The low value of temperature also recorded in early part of the southwest monsoon. The temperature was also high in the September and November respectively (Table 2; Fig. 4 I). The average temperature during the study is 28.1 ^{0}C.

4.2.2 pH

The pH of the pond varied from 6.14 (in September) to 7.12 (in April) with an average of 6.73. The variation of pH was less with a difference of 0.98. It was observed that the lowest pH was observed during monsoon months. From post monsoon onward there was a steady rise in pH upto pre monsoon with a slight fall in February. The highest pH value was experienced in April where as the lowest value of 6.14 was observed in September (Table 2 ; Fig. 4 J).

4.2.3 Secchi depth

The transparency of the pond varied 10.0 and 57 cm with an average of 38 cm (Table 2; Fig. 4 K). The highest value of 57.2 cm and the lowest value of 10.0 cm were observed during June and April respectively. The higher values of transparency were observed during southwest monsoon period where as there was a gradual decrease in value from later part of southwest monsoon to till the pre monsoon period.

From later part of December onwards pond was infested with algal bloom till April. During the pre monsoon period, the plankton blooms were very high and bad smell was sensed from the pond.

4.2.4 Water level

Water level of the pond showed a remarkable variation from 58.5 to 140.5 cm, with an average of 110 cm (Table 2; Fig.4 L). The higher value of water recorded during southwest monsoon while the lower values were recorded during pre monsoon period. There was a gradual decrease in water level from southwest monsoon to pre-monsoon. The highest level of 140.5 cm was recorded in August while the lowest value of 58.5 cm was recorded in April.

4.2.5 Primary productivity

Gross primary production (GPP) showed an increasing trend from June to September with a fall in October and November. The higher values were recorded during months of northeast and pre monsoon period with a peak of 9.50 g C m^{-3} d^{-1} in March while the lowest value of 3.09 g C m^{-3} d^{-1} was experienced in October (Table 2; Fig.4 M). The average value of 5.36 g C m^{-3} d^{-1} was experienced during the study period.

Similar trend was also noticed in case of net primary production (NPP). The value ranges between 1.18 and 4.86 g C m^{-3} d^{-1} with an average of 2.72 g C m^{-3} d^{-1} (Table 2; Fig.4 N).

4.2.6 Total Alkalinity

Total alkalinity in the pond ranged from 39.2 to 81.7 ppm (Table 2; Fig.4 O) with an average of 62.23 ppm. The highest alkalinity was recorded in April and the lowest value was recorded in July. Relatively high values were observed during the post, northeast and pre monsoon months and it followed a gradual increasing trend. The values were irregular during the southwest monsoon period. Decrease in total alkalinity was recorded monsoon and the lowest value was experienced in July.

4.2.7 Dissolved oxygen

The dissolved oxygen value varied from 3.56 to 6.29 mg/l. The lowest value of 3.56 mg/l was recorded in April while the higher value showed bimodal in nature i.e. first in September and second in January (Table 2; Fig.4 P). It showed an increased during the southwest monsoon with a slight fall in post monsoon period and progressively increased during northeast monsoon. From February onwards there was a decrease till April. The average value during the study period was 5.08 mg/l.

4.2.8. Nutrients

4.2.8.1 Nitrate - N

The nitrate-N varied between 1.16 and 8.87 μ mol/l (Table 2; Fig. 4 Q). On an average nitrate content in the pond was found high (5.33 μ mol/l). The highest value of 8.87 μ mol/l and lowest value of 1.16 μ mol/l was experienced March and November respectively. Higher values were recorded during the months of southwest, northeast and pre-monsoon period. There was a general decrease in October and November.

4.2.8.2 Nitrite – N

Nitrite-N concentration varied between a wider range of 0.23 and 3.94 μ mol/l with an average of 1.17 μ mol/l (Table 2; Fig. 4 R). The lowest value of 0.23 μ mol/l was experienced in June with an increase upto September and then it showed an increasing trend. Higher values were experienced in later part of the northeast monsoon and pre monsoon with an extreme value of 3.94 μ mol/l in the month of April.

4.2.8.3 Phosphate – P

Phosphate values were found to be low except pre monsoon period. The values varied between zero and 8.24 μ mol/l with an average of 3.0 μ mol/l (Table 2; Fig. 4 S). The phosphate value was not detected and December. From January onwards, there was an increase in value and extreme value of 8.24 μ mol/l was experienced in April. During southwest monsoon phosphate was found to be steady with a minor fluctuation of 0.34 μ mol/l.

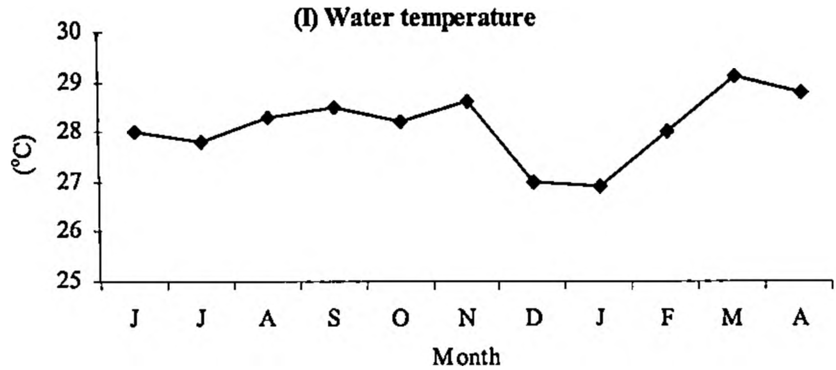
4.1.8.4 Silicate – Si

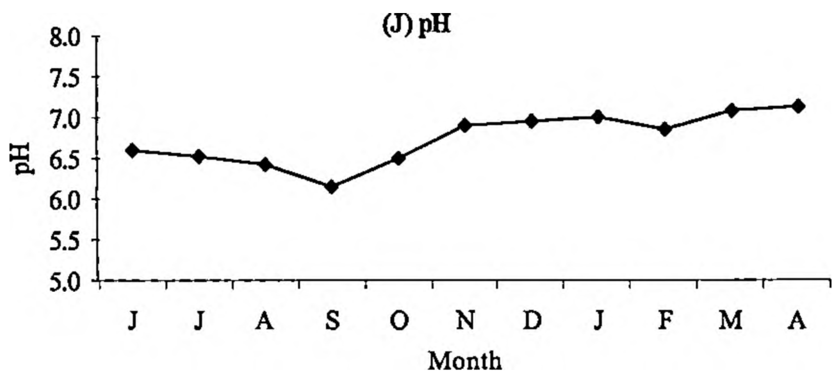
Silicate-Si concentration showed wide variation in different months. The value ranged between 11.23 and 88.74 μ mol/l with an average of 52.60 μ mol/l (Table 2; Fig.4 T). Silicate values were low during post monsoon months and high values were recorded during southwest monsoon, pre monsoon and later part of the northeast monsoon. The highest value of 88.74 μ mol/l was observed in the pre monsoon month of April and the lowest value of 11.23 μ mol/l was noticed in the post monsoon month (November).

Table. 2. Monthly variations of hydrographical parameters

Parameters	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.
Temperature (°C)	28.0	27.8	28.3	28.5	28.2	28.6	27.0	26.9	28.0	29.1	28.8
pH	6.59	6.52	6.42	6.14	6.49	6.89	6.95	7.01	6.86	7.07	7.12
Water level (cm)	108	135	140.5	129	132	126	116	105.5	87.5	72.5	58.5
Secchi depth (cm)	57	53.5	54.0	53.5	50.5	47.0	31.5	24.5	20.5	16.3	10.0
GPP (g C m^{-3} d^{-1})	3.15	3.61	4.07	4.24	3.09	3.40	5.83	5.92	6.99	9.50	9.20
NPP (g C m^{-3} d^{-1})	1.50	1.74	2.30	2.81	1.18	1.71	3.29	3.03	2.89	4.86	4.56
Alkalinity (ppm)	49.0	39.2	46.6	63.0	56.3	66.8	69.3	74.3	65.0	73.3	81.70
Dissolved oxygen (mg/l)	4.13	5.03	6.12	5.55	5.02	5.12	5.37	6.29	5.15	4.56	3.56
Nitrate-N (μ mol/l)	6.79	6.54	7.03	1.22	2.00	1.16	5.43	4.49	7.79	7.36	8.87
Nitrite-N (μ mol/l)	0.23	0.37	1.01	0.47	0.59	0.74	0.62	0.86	2.17	1.84	3.94
Phosphate-P (μ mol/l)	1.20	1.54	1.32	1.27	ND	ND	ND	1.25	2.83	6.34	8.24
Silicate-Si (μ mol/l)	83.6	65.7	65.8	55.2	31.5	11.23	15.16	27.05	56.03	78.56	88.74

ND – Not detected; NPP and GPP – Net and Gross primary productivity





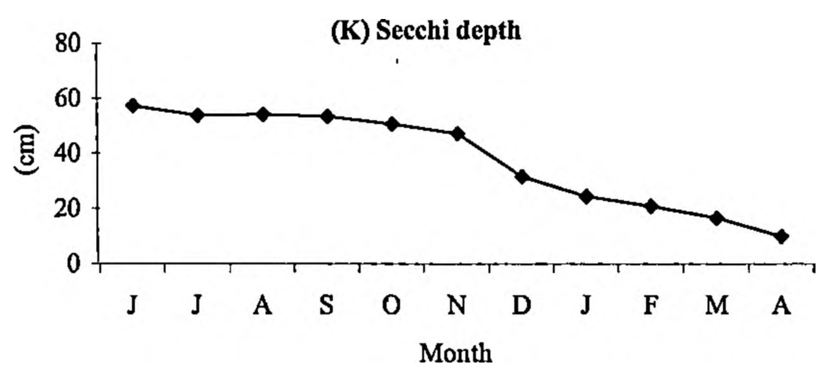
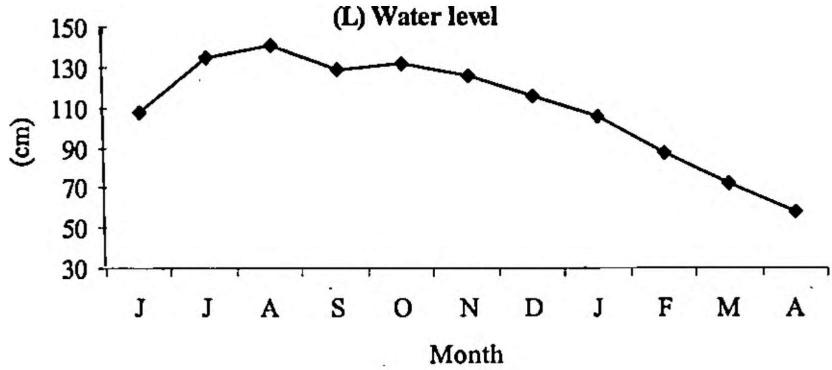
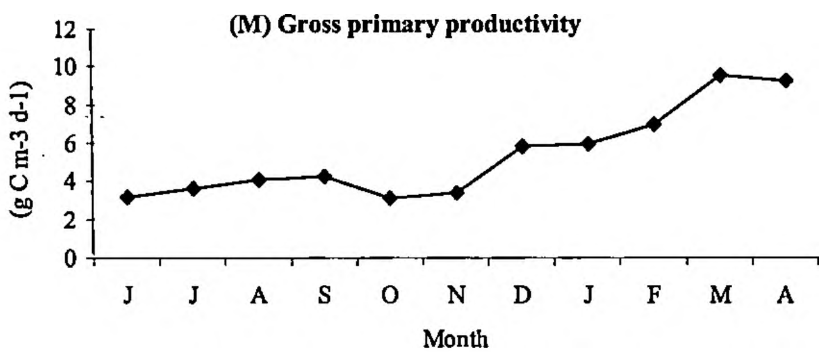


Fig.4 Monthly variations of hydrographical parameters





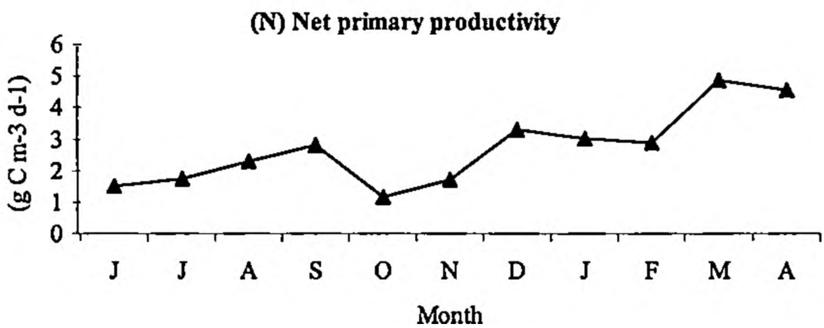
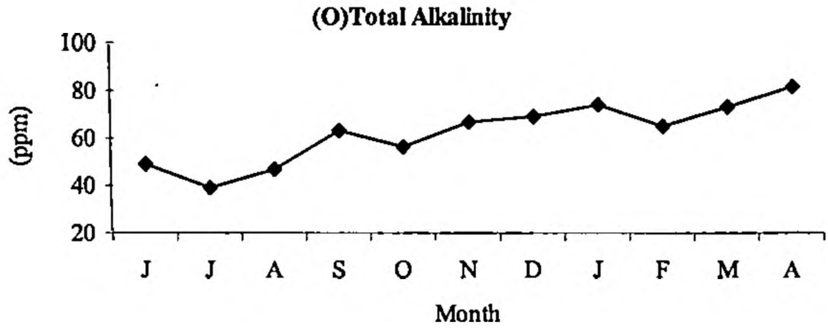
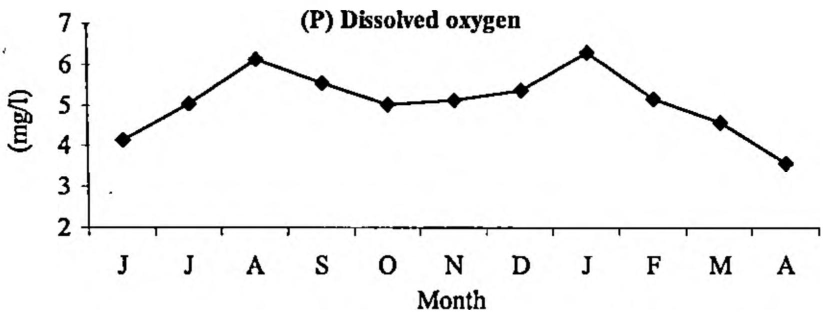


Fig. 4 (Contd.) Monthly variations of hydrographical parameters





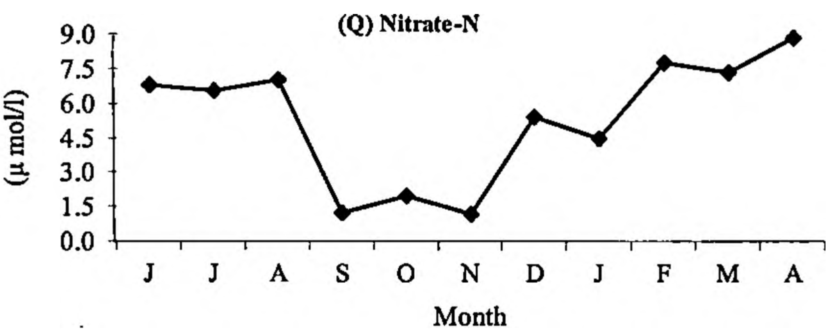


Fig. 4 (Contd.) Monthly variations of hydrographical parameters

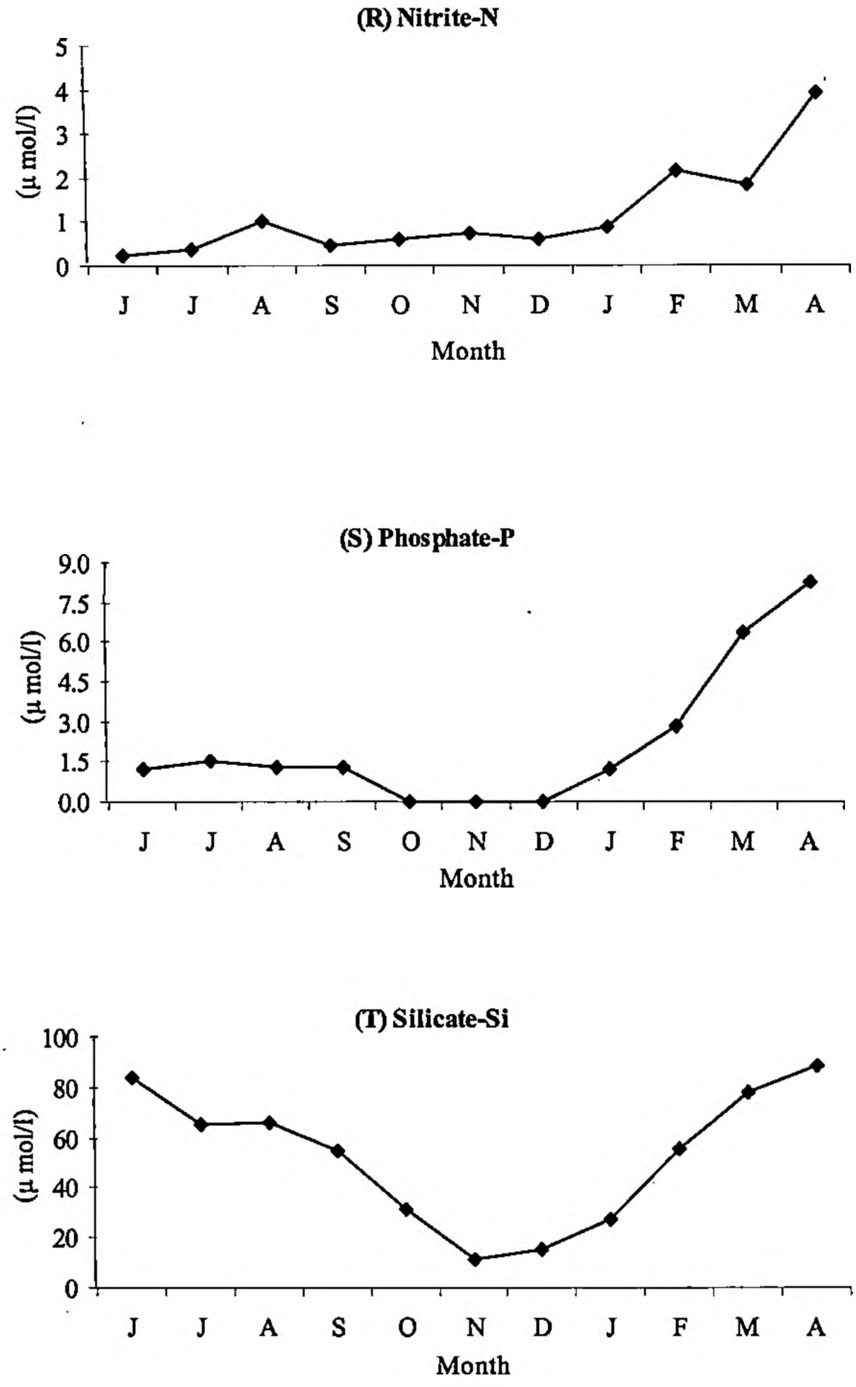


Fig. 4 (Contd.) Monthly variations of hydrographical parameters

4.3 CORRELATION BETWEEN WEATHER ELEMENTS AND HYDROGRAPHICAL PARAMETERS

a) Air temperature

Air temperature was positively correlated with pH (r = 0.843), water temperature (r = 0.641), alkalinity (r = 0.636), phosphate (r = 0.827), silicate (r = 0.464), nitrate (r = 0.414), gross primary productivity (r = 0.847) and net primary productivity (r = 0.785), where as negative correlation was observed with water level (r = - 0.879), transparency (r = - 0.773), dissolved oxygen (r = - 0.684), and nitrite (r = - 0.416). But 'r' values were significant (P>0.05) only in case of pH, water temperature, water level, water temperature, transparency, dissolved oxygen, alkalinity, phosphate, gross and net primary productivity.

b) Total rainfall

Rainfall was positively correlated with dissolved oxygen (r = 0.153), water level (r = 0.652), and silicate (r = 0.114). Where as it was negatively correlated with transparency (r = - 0.705), nitrate (r = - 0.054), water temperature (r = - 0.038), pH (r = - 0.635), phosphate (r = - 0.356), alkalinity (r = - 0.922), nitrite (r = - 0.416), gross primary productivity (r = - 0.633) and net primary productivity (r = - 0.672). But 'r' values were significant (P>0.05) only in case of pH, water level, transparency, alkalinity, gross and net primary productivity.

c) Relative humidity

Relative humidity is positively correlated with the water level (r = 0.810) and water temperature (r = 0.051), where as it showed negative correlation with the pH (r = - 0.599) But 'r' values were significant (P>0.05) only in case of water level.

d) Wind speed

Wind speed is positively correlated with water temperature (r = 0.235), dissolved oxygen (r = 0.215) and silicate (r = 0.388). But 'r' values were (P<0.05) not significant.

e) Cloudiness

Cloudiness is positively correlated with the water level (r = 0.636), water temperature (r = 0.069), transparency (r = 0.729), dissolved oxygen (r = 0.075), gross primary productivity (r = - 0.653) and net primary productivity (r = - 0.667). But 'r' values were significant for water level, transparency, gross and net primary productivity.

Table 3. Correlation between weather and hydrographical parameters
(Correlation coefficient values are not shown against the parameters, for which no physical meaning exists)

Parameters	Total rainfall	Air temp	Relative humidity	Wind speed	Cloudiness
PH	*-0.635	*0.843	-0.599	-	-
Water level	*0.652	*-0.879	*0.810	-	*0.636
Temperature	-0.038	*0.641	0.051	0.235	0.069
Secchi depth	*0.705	*-0.773	-	-	*0.729
Dis. Oxygen	0.153	*-0.684	-	0.215	0.075
Alkalinity	*-0.922	*0.636	-	-	-
Phosphate-P	-0.356	*0.827	-	-	-
Nitrate-N	-0.054	0.414	-	-	-
Nitrite-N	-0.416	-0.416	-	-	-
Silicate-Si	0.114	0.464	-	0.388	-
GPP	*-0.633	*0.847	-	-	*-0.653
NPP	*-0.672	*0.785	-	-	*-0.667

* denote statistical significance at 5% level

Since collection of data for weather elements started only on 28th June 2003, correlation analysis was excluded for June data.

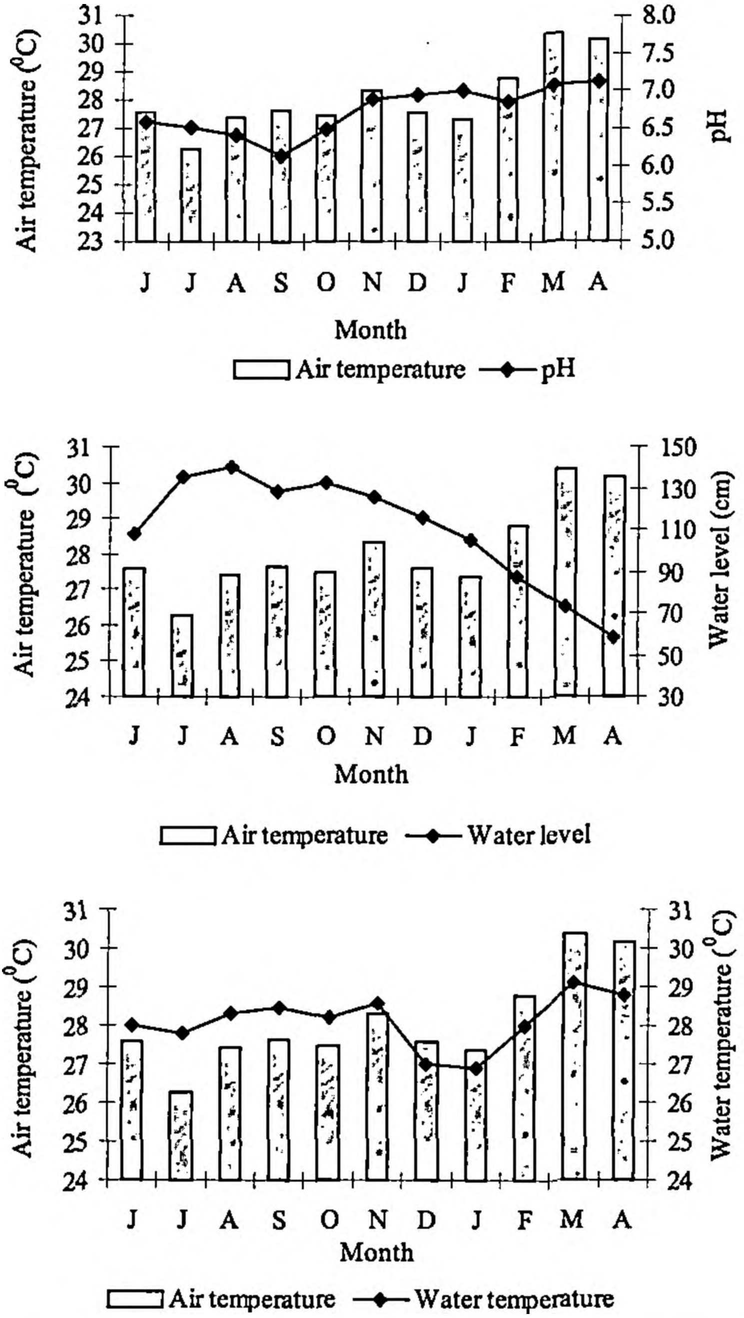
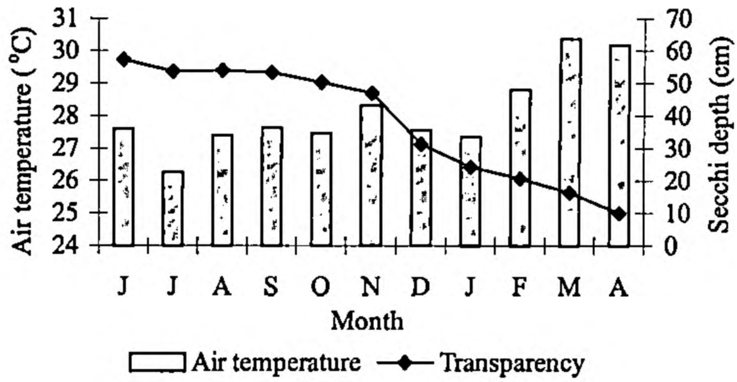
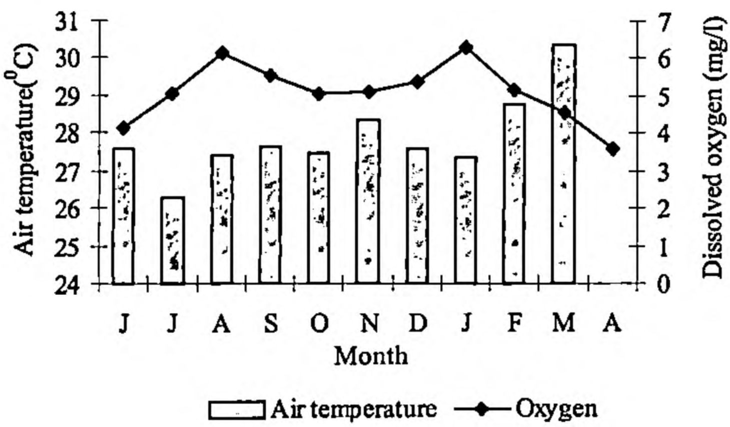


Fig. 5. Monthly variations of hydrographical parameters in relation to air temperature





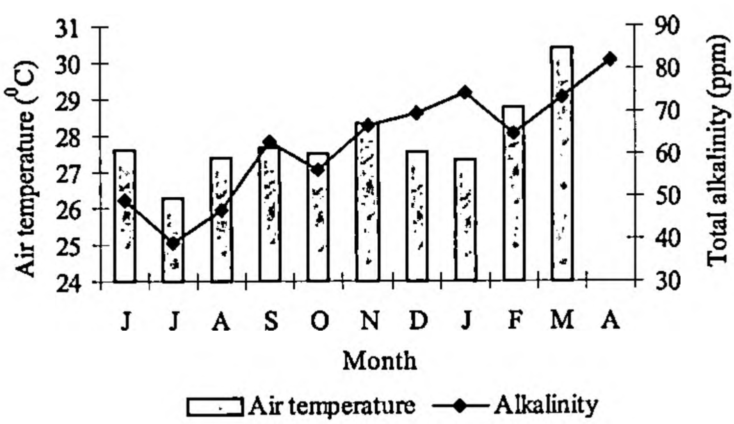
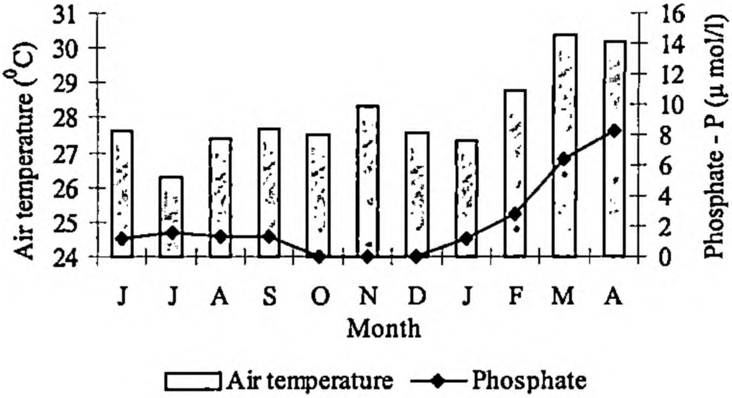
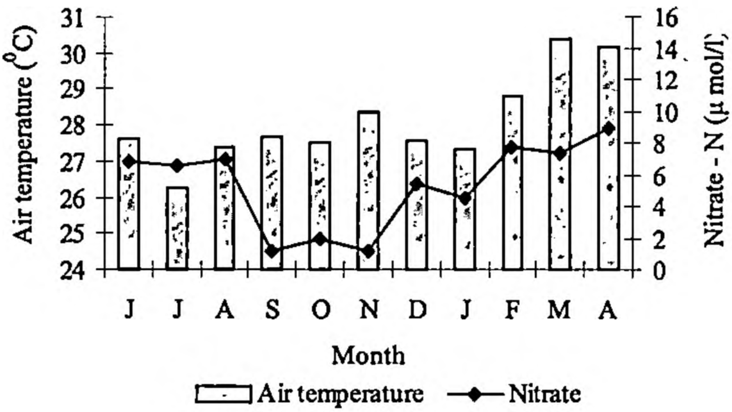


Fig. 5. (Contd.) Monthly variations of hydrographical parameters in relation to air temperature





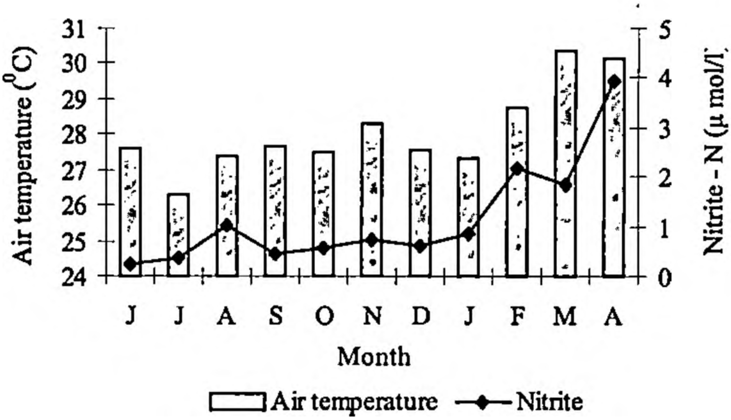
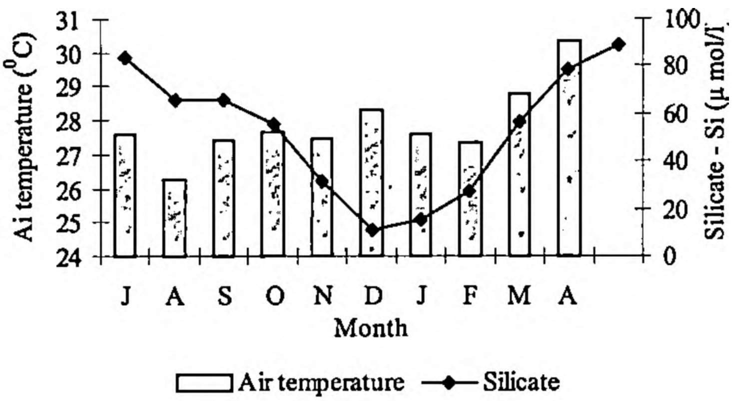
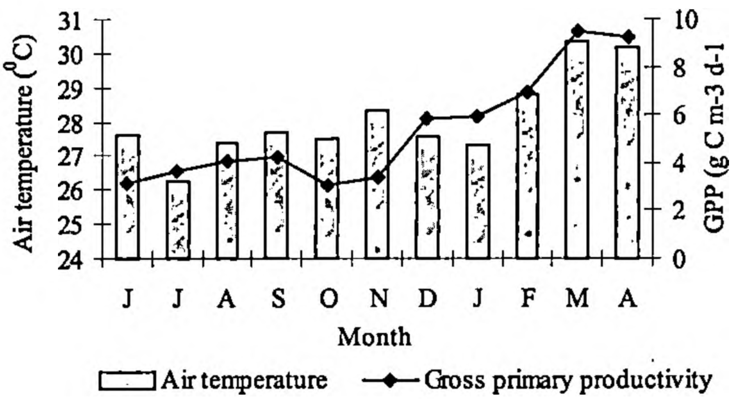


Fig. 5. (Contd.) Monthly variations of hydrographical parameters in relation to air temperature





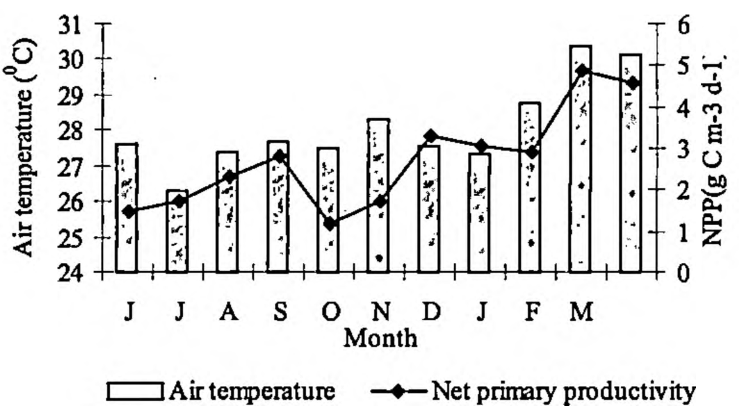
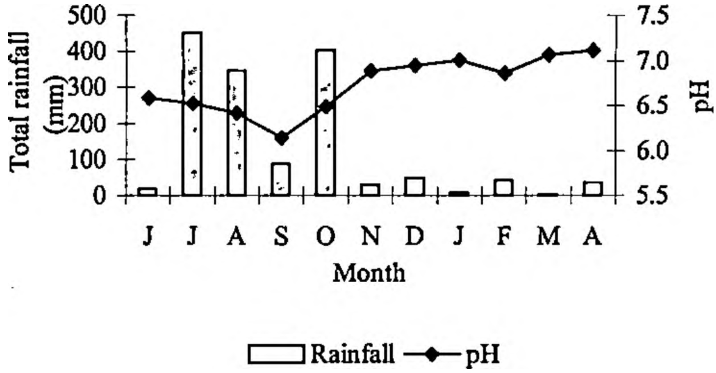
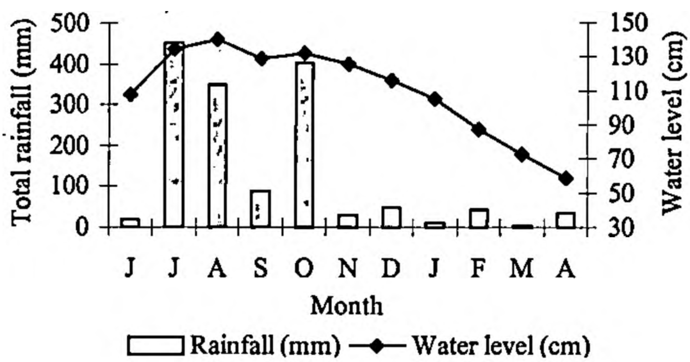


Fig. 5. (Contd.) Monthly variations of hydrographical parameters in relation to air temperature





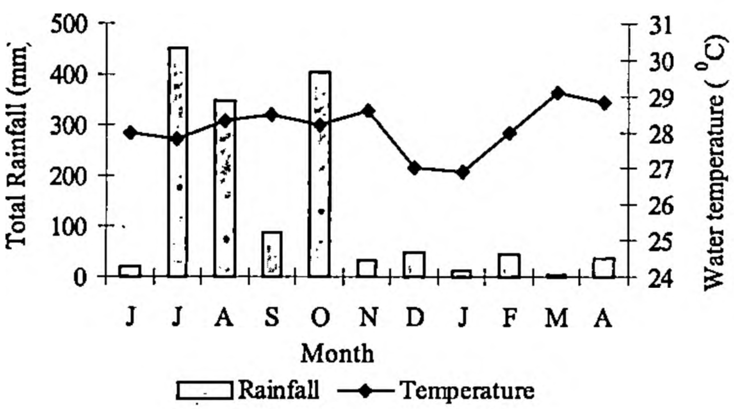


Fig. 6. Monthly variations of hydrographical parameters in relation to rainfall

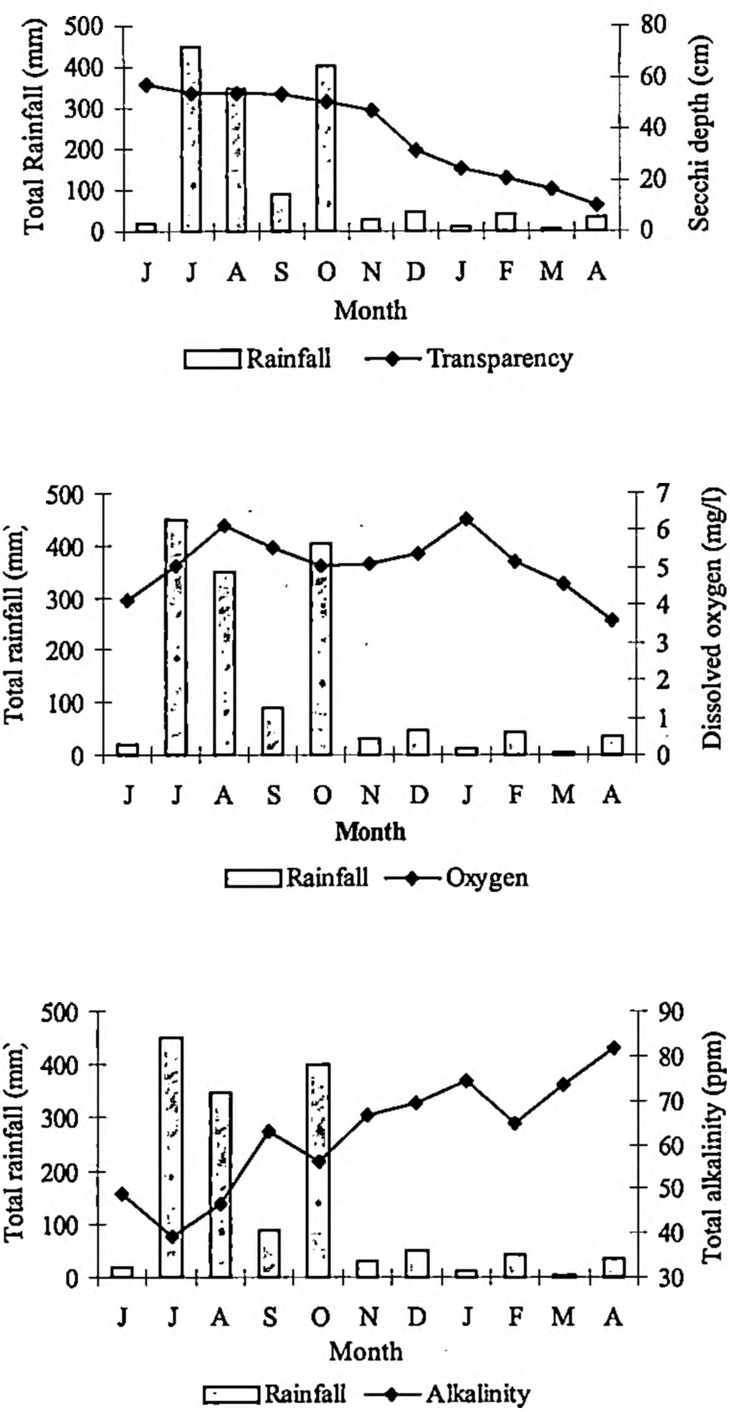


Fig. 6. (Contd.) Monthly variations of hydrographical parameters in relation to rainfall

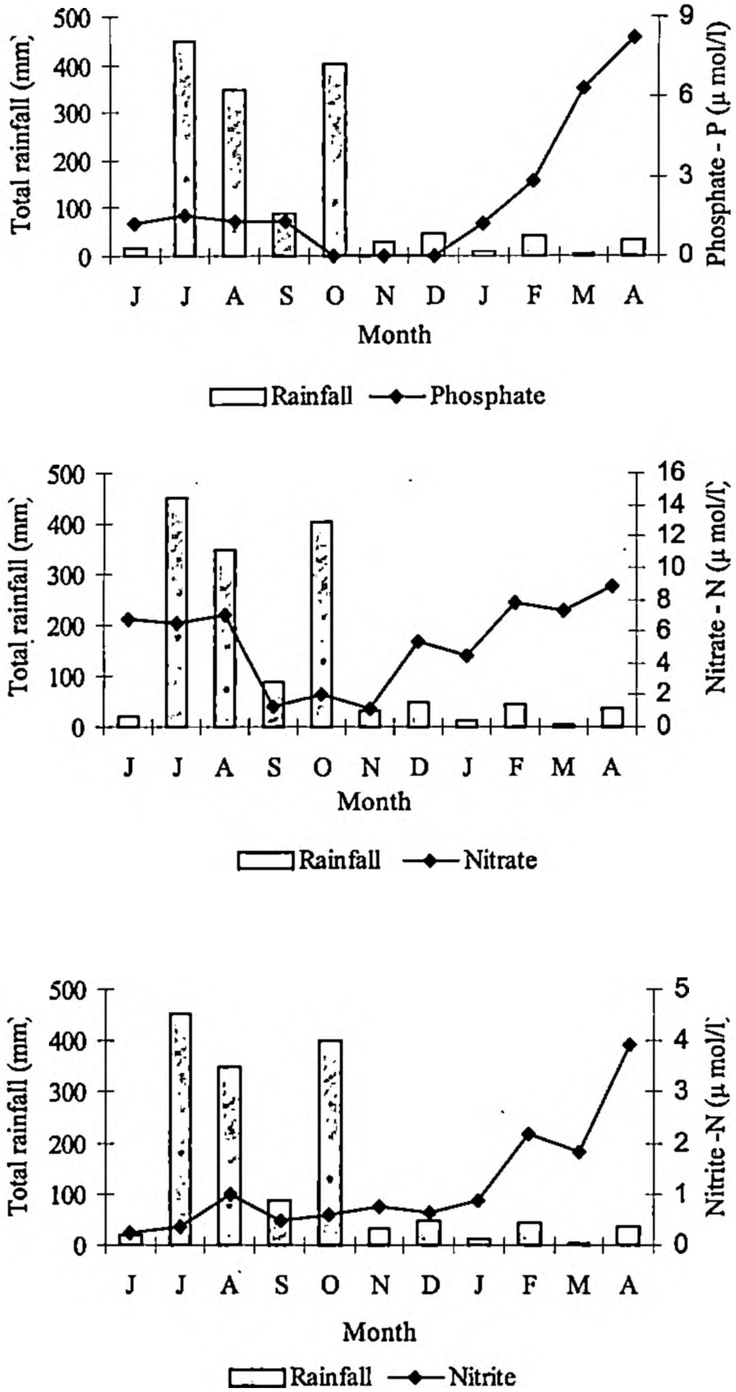


Fig. 6. (Contd.) Monthly variations of hydrographical parameters in relation to rainfall

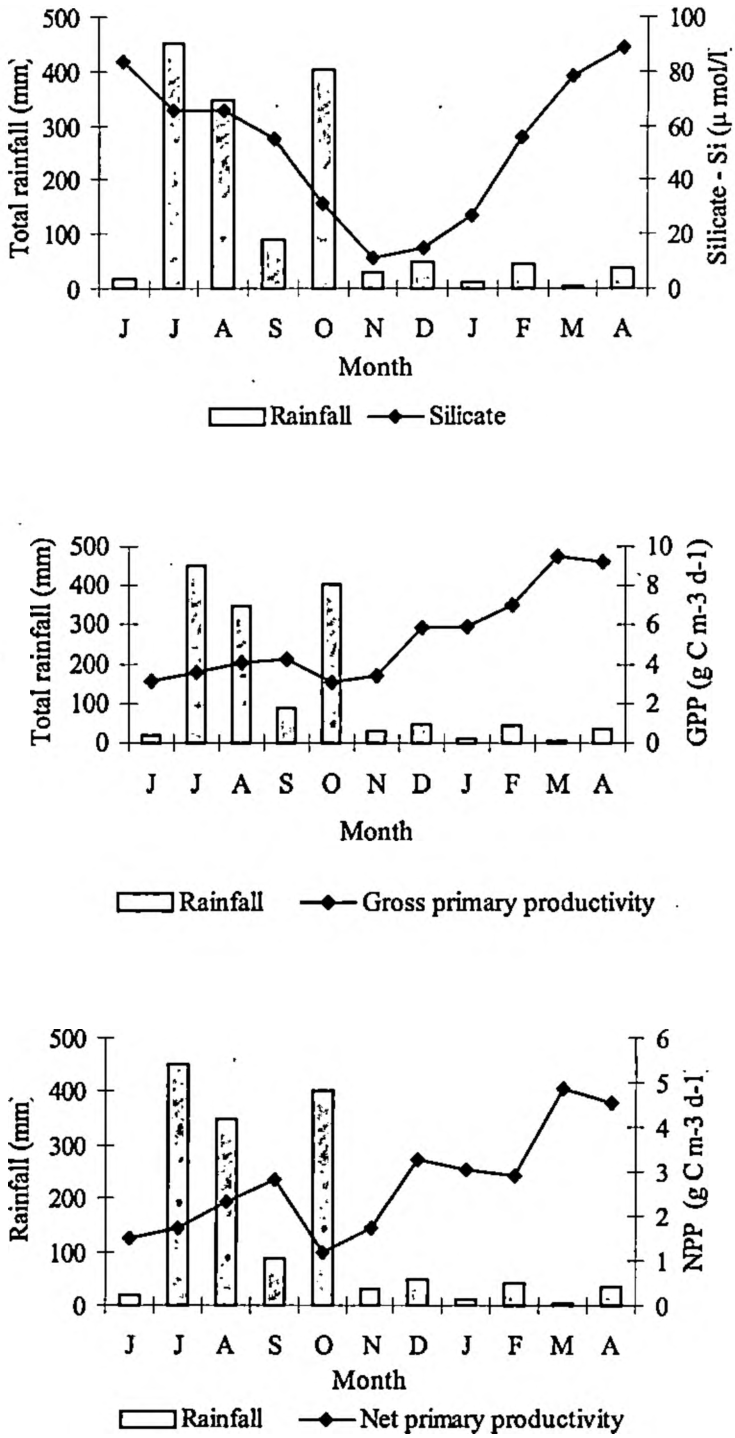
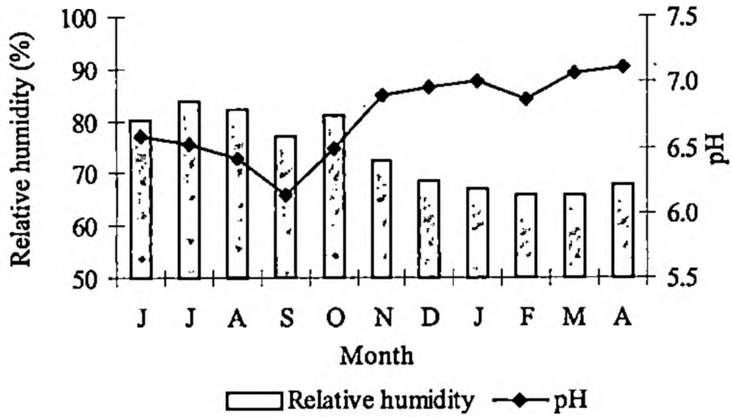
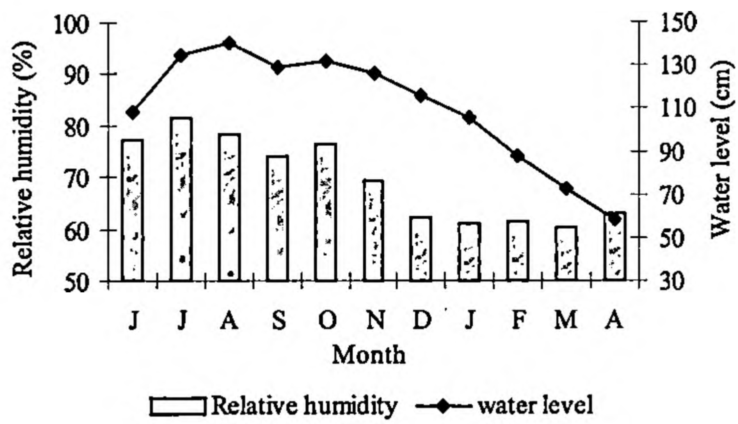


Fig. 6. (Contd.) Monthly variations of hydrographical parameters in relation to rainfall





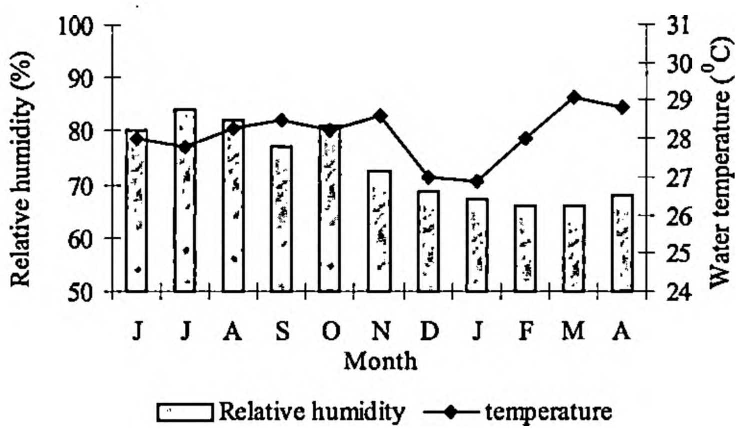


Fig.7. Monthly variations of hydrographical parameters in relation to relative humidity

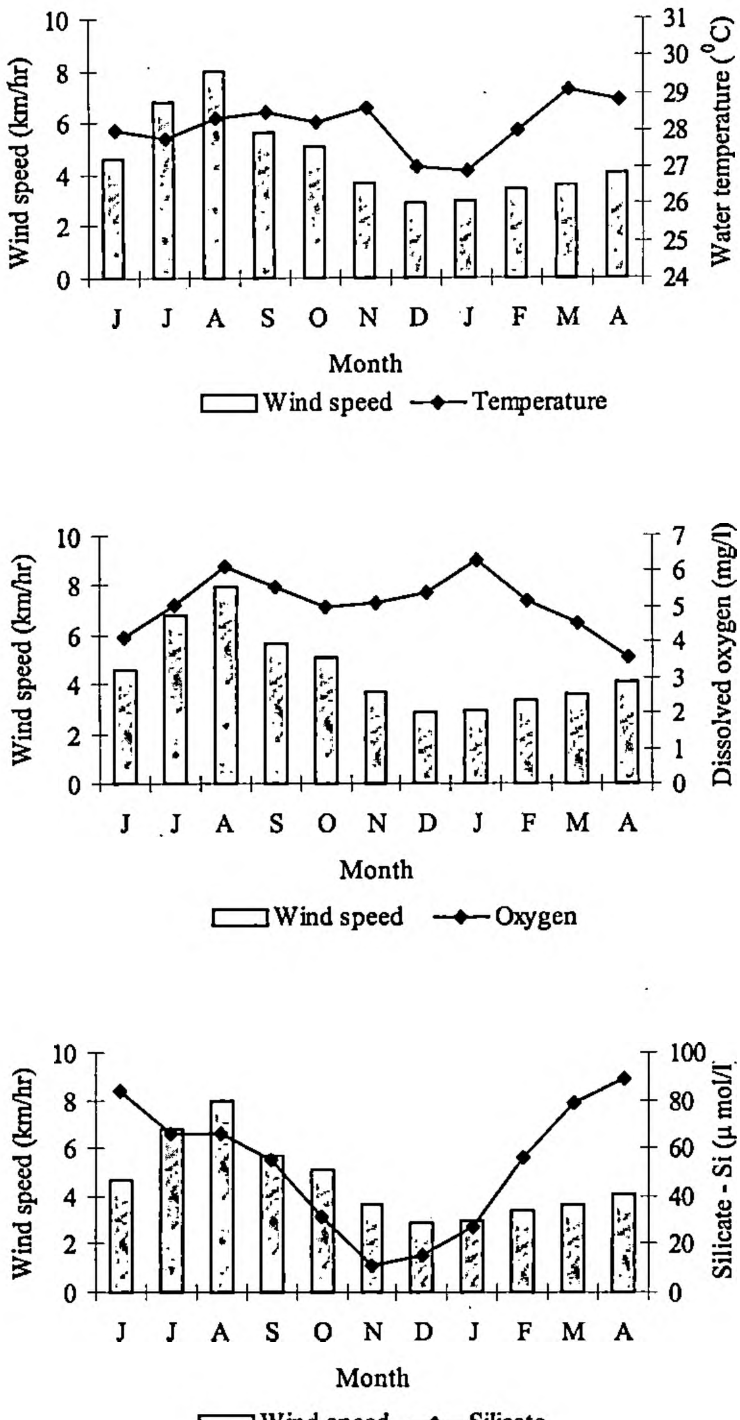


Fig. 8. Monthly variations of hydrographical parameters in relation to wind speed

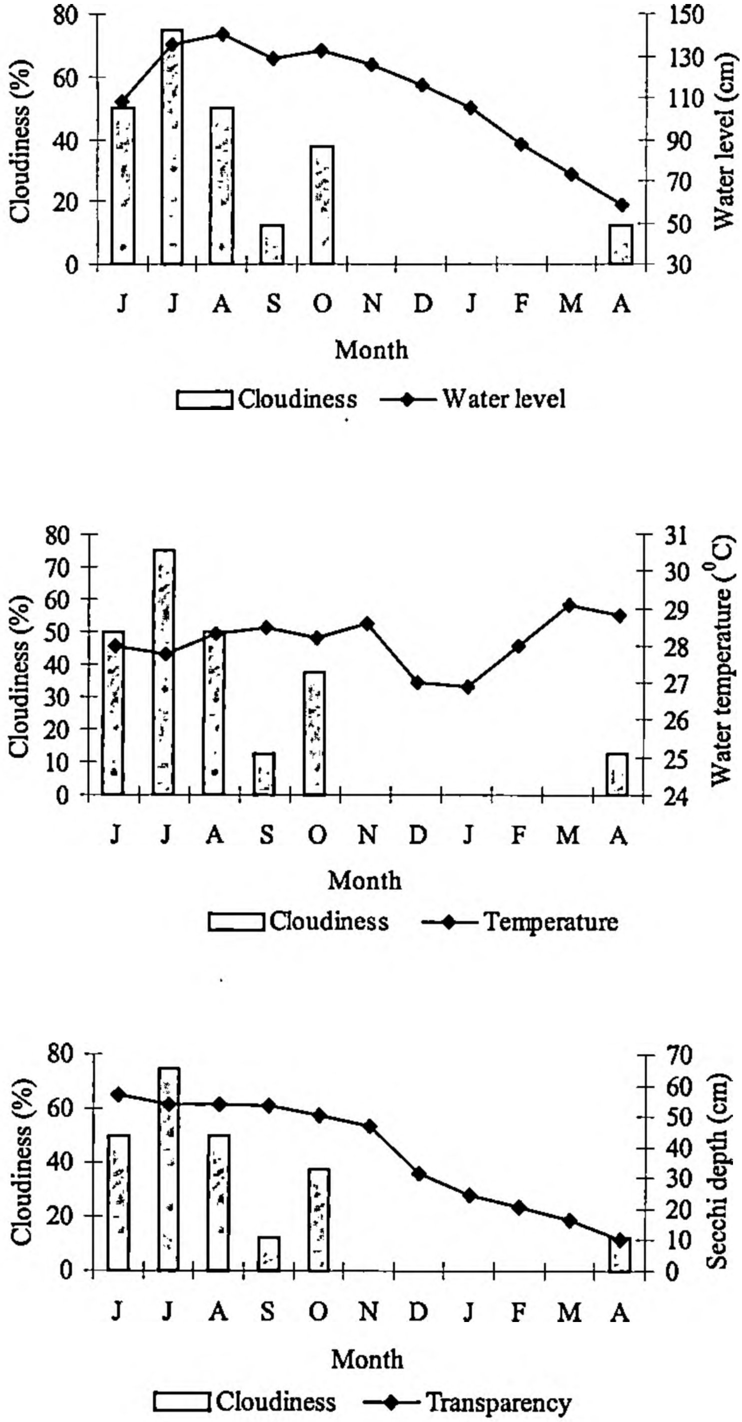


Fig.9. Monthly variations of hydrographical parameters in relation to cloudiness

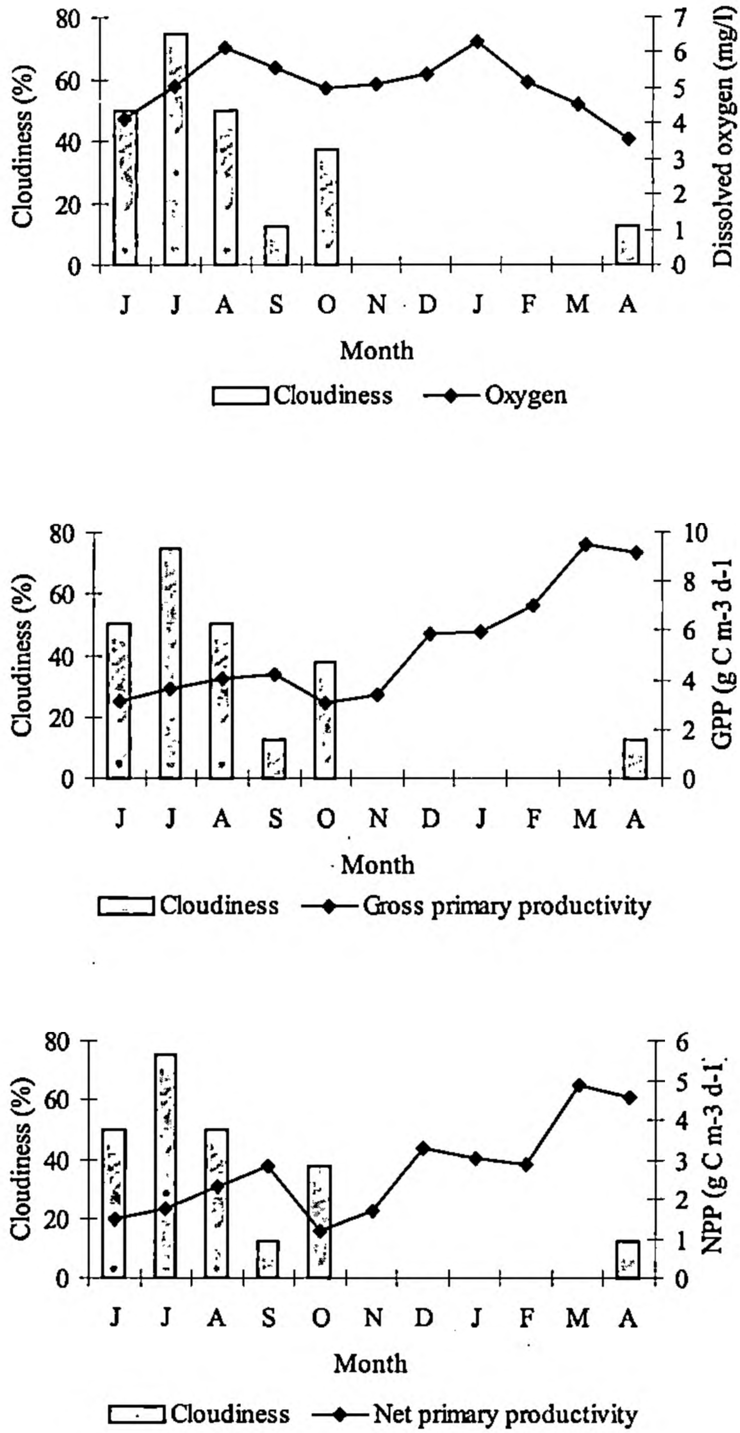


Fig.9. (Contd.) Monthly variations of hydrographical parameters in relation to cloudiness

4.4 DIURNAL CHANGES OF WEATHER ELEMENTS

4.4.1 Southwest monsoon (13th to 14th July, 2003)

(Table 4: Fig. 10)

a) Air temperature

Air temperature did not show any specific pattern. The highest value of 27.5 ^{0}C at 8:30 hr (13th July) and the temperature variation was irregular through out the day. During night the values gradually decreased and the lowest value of 24.5 ^{0}C was observed at 2:30 hr.

b) Rainfall

Rainfall showed a specific pattern. The rainfall increased from morning hour and shows its highest value of 12.4 mm at 11:30 hr (13th July). Then the values were decreased gradually and show its lowest values during the night hrs.

c) Relative humidity

Relative humidity showed its maximum value of 95% at 11:30 (13th July) and 2:30 (14th July) hrs. From 11:30 onwards there was a gradual decrease in % of the relative humidity and reached its second lowest value of 86% at 17:30 hr (13th July). The lowest value of 77% was observed at 8:30 hr (13th July). Whereas at night hours the value were remain high and increased gradually and showed its highest value at 2:30 hr (14th July) for the second time.

d) Cloudiness

The sky was clear at morning 8:30 hr (13th & 14th July). Overcast condition was observed during most of the time.

e) Wind

During the daytime wind was blowing at higher speed and the highest value of 10 km/hour was observed at 11:30 and 14:30 hrs (13th July). The westerlies wind dominated at afternoon and mid day hours but the north and northeasterly wind was observed at night and morning hours. At night the wind speed was least and at 2:30 hr (14th July) the weather was calm.

4.4.2 Post monsoon (23rd to 24th November, 2003)

(Table 5: Fig. 11)

a) Air temperature

The air temperature showed a specific pattern. It increased during the daytime and reached the highest value of 32.8 ^{0}C at 11:30 hr (23rd November). Afterwards it decreased gradually and reached the lowest value of 26.4 ^{0}C at 2:30 hr (24th November).

b) Rainfall

No rainfall was recorded during the observation period.

c) Relative humidity

The relative humidity decreased from morning hours and remained low during daytime. The lowest value of 50.0% was recorded at 11:30 hr (23rd November). In the night the relative humidity increased gradually and reached its highest value of 84% at the early morning hours.

d) Cloudiness

The sky was remaining clear throughout the day.

e) Wind

The wind speed increased gradually during daytime and showed its highest value of 6.0 km/hr at 17:30 hr (23rd November). During the night hours the speed of wind gradually decreased and the low values were observed in early morning hours. North easterlies were observed at night and early morning hours.

4.4.3 Northeast monsoon (4th to 5th January, 2004)

(Table 6; Fig.12)

a) Air temperature

The air temperature showed a specific pattern. It increased during the daytime and showed its highest value of 31.4 ^{0}C at 14:30 hr (4th January). Afterwards it decreased gradually and shows its lowest value of 24 ^{0}C at 5:30 hr (5th January) and then followed an increasing pattern.

b) Rainfall

No rainfall was recorded during the observation period.

c) Relative humidity

The relative humidity decreased from morning and remained low during daytime. The lowest value of 51.0% was recorded at 11:30 hr (4th January) whereas in night the relative humidity increased gradually and showed its highest value of 87% at the early morning hours.

d) Cloudiness

The sky was remaining clear throughout the day.

e) Wind

The wind speed increased gradually during daytime and reached the highest value of 6.0 km/hr at 14:30 hr (4th January). During the night hours the speed decreased and the calm weather was observed during the mid night hour. The weak westerlies dominated in the afternoon hours whereas the northerly and northeasterly winds were dominated at night and morning hours.

4.4.4 Pre monsoon (8th to 9th April, 2004)

(Table 7; Fig. 13)

a) Air temperature

Air temperature increased during the daytime and showed its highest value of 33.4 ^{0}C at 14:30 hr (8th April). Afterwards it decreased gradually and reached its lowest value of 26.1 ^{0}C at 5:30 hr (9th April) and then increased.

b) Rainfall

No rainfall was recorded during the observation period.

c) Relative humidity

The relative humidity decreased from morning and remained low during daytime. The lowest value of 61.0% was recorded at 11:30 and 14:30 hrs (8th April). At night the relative humidity increased gradually and showed its highest value of 84% at 5:30 hr (9th April).

d) Cloudiness

The sky was remaining clear throughout the day.

e) Wind

The wind speed increased gradually during daytime and showed highest value of 9.0 km/hr at 14:30 hr (9^{th} April). During the night hours the speed gradually decreased and the lowest speed of 2.0 km/hr was observed at 23:30 hr (8^{th} April). The south westerlies were dominated at afternoon whereas the north easterlies were dominated at night and morning hours.

Table 4. Diurnal variation of weather elements during Southwest monsoon

Parameters	13th July, 03						14th July, 03		
	8:30	11:30	14:30	17:30	20:30	23:30	2:30	5:30	8:30
Rainfall (mm)	1.2	12.4	7.8	0.2	2.0	0.0	0.0	4.0	0.0
Max. temperature (°C)	-	-	-	28.5	-	-	-	-	-
Min. temperature (°C)	24.0	-	-	-	-	-	-	-	23.4
Air temperature (°C)	27.5	25.0	25.0	26.0	25.0	25.0	24.5	24.7	26.4
Relative Humidity (%)	77.0	95.0	92.0	86.0	92.0	92.0	95.0	93.0	88.0
Wind speed (km/hr)	6.0	10.0	10.0	9.0	0.0	2.0	0.0	3.0	2.0
Wind direction	N	S	W	W	-	WSW	-	N	NNE
Cloudiness (Okta)	0/8	8/8	8/8	8/8	8/8	-	-	8/8	0/8

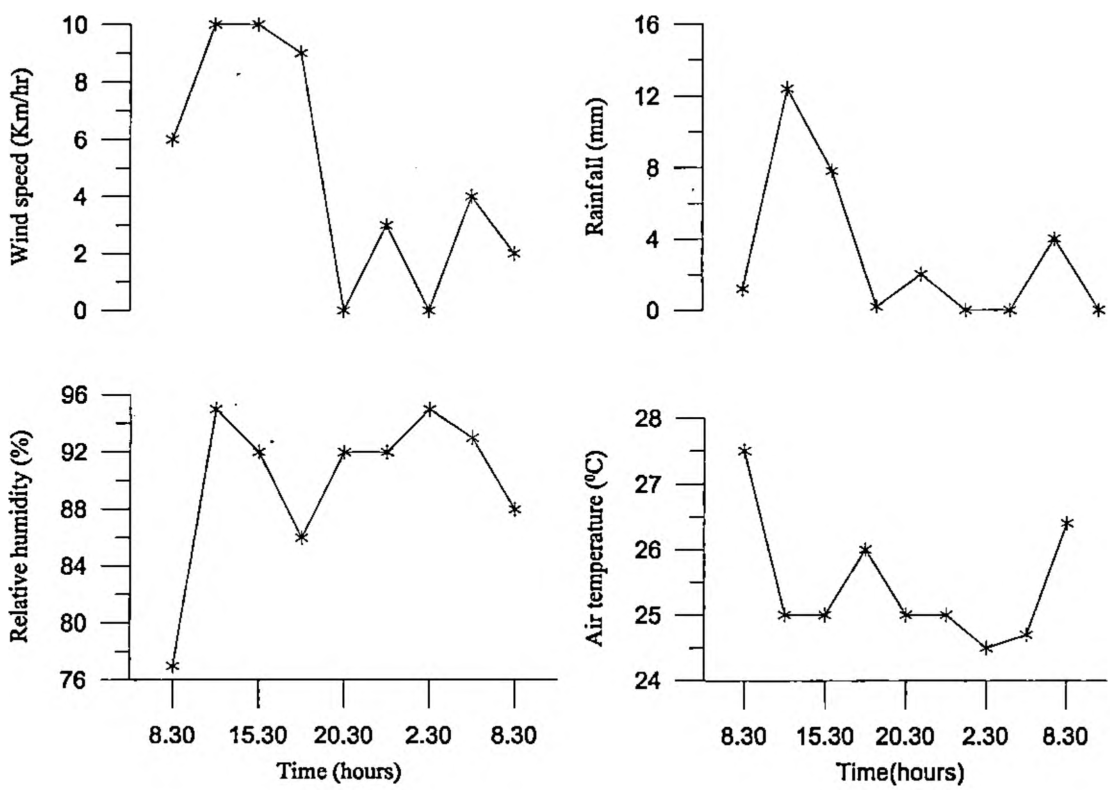


Fig.10. Diurnal variations of weather elements during Southwest monsoon

Table 5. Diurnal variation of weather elements during Post monsoon

Parameters	23rd November, 03						24th November, 03		
	8:30	11:30	14:30	17:30	20:30	23:30	2:30	5:30	8:30
Air temperature (°C)	28.0	32.8	32.2	30.0	27.6	26.9	26.4	26.7	27.0
Max. temperature (°C)	-	-	-	31.8	-	-	-	-	-
Min. temperature (°C)	22.9	-	-	-	-	-	-	-	23.1
Rainfall (mm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Relative Humidity (%)	70.0	50.0	61.0	62.0	81.0	81.0	84.0	84.0	77.0
Cloudiness (Okta)	0/8	0/8	0/8	0/8	0/8	0/8	0/8	0/8	0/8
Wind speed (km/hr)	3.0	0.0	2.0	6.0	4.0	2.0	3.0	1.0	1.0
Wind direction	NE	-	W	SSW	W	N	NNE	N	E

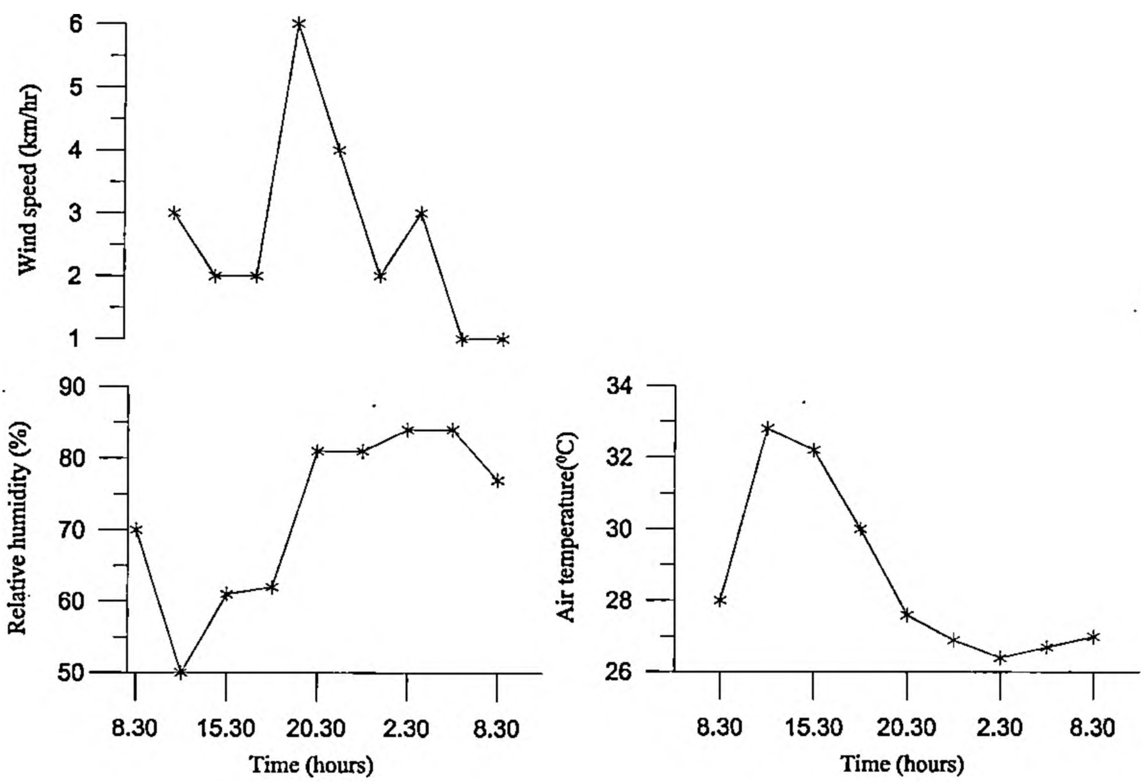


Fig.11. Diurnal variations of weather elements during Post monsoon

Table 6. Diurnal variation of weather elements during Northeast monsoon

Parameters	4th January, 04						5th January, 04		
	8:30	11:30	14:30	17:30	20:30	23:30	2:30	5:30	8:30
Air temp (°C)	24.4	30.6	31.4	29.8	26.0	25.9	24.8	24.0	26.0
Max. temperature (°C)	-	-	-	32.8	-	-	-	-	-
Min. temperature (°C)	23.2	-	-	-	-	-	-	-	23.2
Rainfall (mm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Relative Humidity (%)	75.0	51.0	54.0	59.0	84.0	87.0	87.0	86.0	68.0
Cloudiness (Okta)	3/8	0/8	0/8	0/8	0/8	0/8	0/8	0/8	0/8
Wind speed (km/hr)	1.0	2.0	6.0	5.0	0.0	0.0	1.0	3.0	2.0
Wind direction	NE	N	W	WSW	-	-	N-NE	N	NE

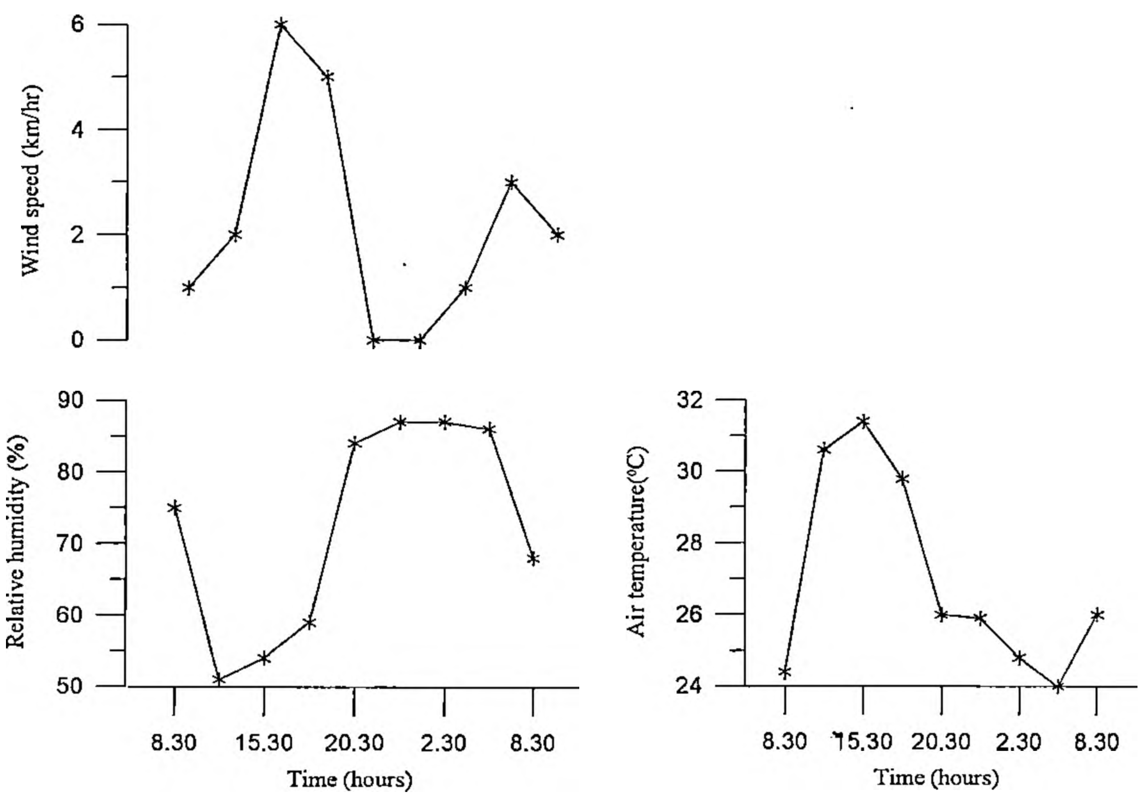


Fig.12. Diurnal variations of weather elements during Northeast monsoon

Table 7. Diurnal variation weather elements during Pre monsoon

Parameters	8th April, 04						9th April, 04		
	8:30	11:30	14:30	17:30	20:30	23:30	2:30	5:30	8:30
Air temperature (°C)	30.0	32.8	33.4	31.4	30.1	28.0	27.8	26.1	29.1
Max. temperature (°C)	-	-	-	33.5	-	-	-	-	-
Min. temperature (°C)	25.2	-	-	-	-	-	-	-	25.4
Rainfall (mm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Relative Humidity (%)	72.0	61.0	61.0	66.0	78.0	74.0	74.0	84.0	71.0
Cloudiness (Okta)	0/8	0/8	0/8	0/8	0/8	0/8	0/8	0/8	0/8
Wind speed (km/hr)	3.0	5.0	9.0	6.0	5.0	2.0	3.0	3.0	4.0
Wind direction	NE	W	SW	SSW	S	NE	NE	NE	N

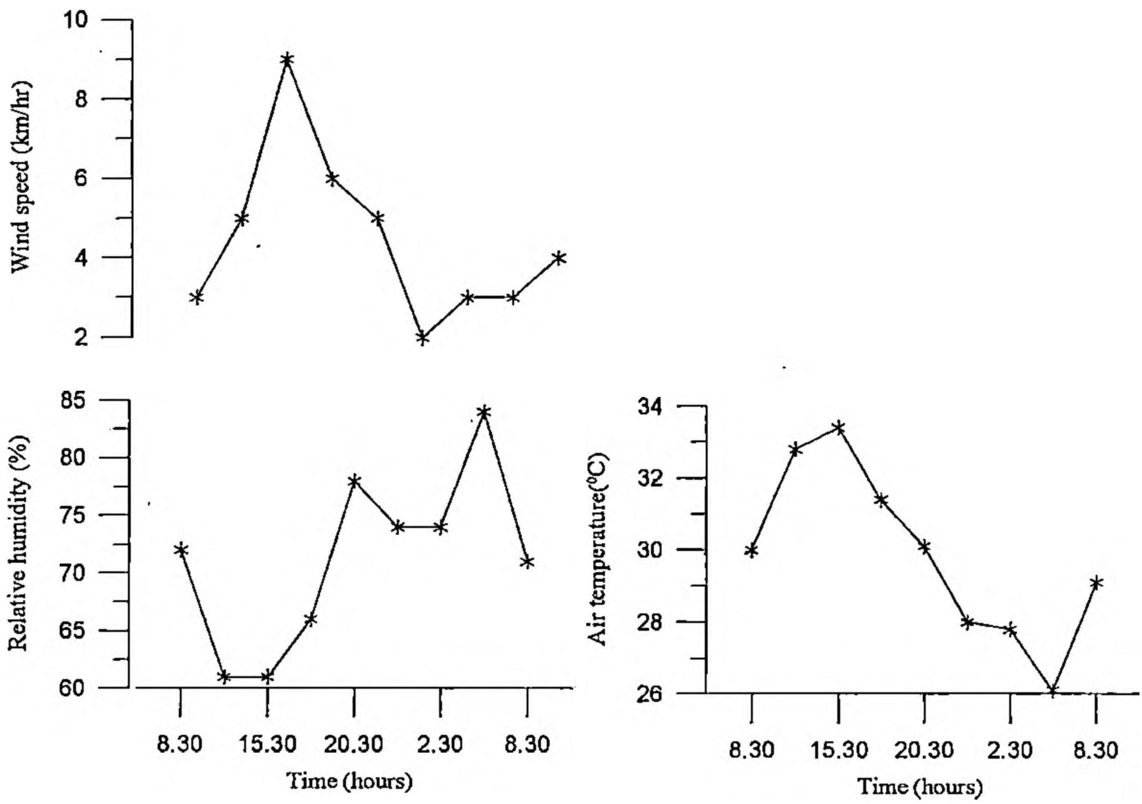


Fig.13. Diurnal variations of weather elements during Pre monsoon

4.5 DIURNAL CHANGES OF HYDROGRAPHICAL PARAMETERS

4.5.1 Southwest monsoon (13th to 14th July, 2003)

(Table 8; Fig 14)

a) Water temperature

The water temperature varied between 27.1 and 28.5 ^{0}C. The maximum value was observed at 17:30 hr (13th July). At night water temperature decreased and reached the minimum value of 27.10 ^{0}C is experienced at 2:30 hr (14th July). During daytime it showed an irregular variation.

b) pH

The diurnal variation of pH showed an irregular trend during daytime and the highest value of 7.23 was observed at 17:30 hr (13th July). There was a gradual decrease in value during the night hours and showed its lowest value of 6.35 at 5:30 hr (14th July). The pH varied between 6.35 and 7.23 with 0.88 as their range of variation.

c) Secchi depth

Transparency did not showed any specific pattern. During night hours, transparency observations were not taken due to unavailability of light. The lowest value of 50 cm was observed at 11:30 hr (13th July) where as the highest value of 54 cm was observed at 8:30 hr of next morning.

d) Primary productivity

Gross Primary productivity (GPP) showed an increasing pattern during daytime and the highest value of 3.95 g C m^{-3} d^{-1} was observed at 14:30 hr (13th July) and the lowest value of 2.95 g C m^{-3} d^{-1} was noticed at 5:30 hr (14th July). During night the observation were not taken due to unavailability of light.

Similar pattern was also observed in case of net primary productivity (NPP) and showed 2.05 and 1.30 g C m^{-3} d^{-1} as the highest and lowest values respectively.

e) Total Alkalinity

Alkalinity showed its minimum value of 34.30 ppm at 8:30 hr and maximum of 46 ppm at 11:30 and 14:30 hrs (13th July). There was a decrease in value at 17:30 hr (13th July) and then increased progressively upto mid night and showed its second highest value of 44.10 ppm.

f) Dissolved oxygen

The dissolved oxygen varied between 4.30 and 6.61 mg/l with 2.31 mg/l as their range of variation. During daytime it showed its highest value with an irregular variation where as at night it decreased gradually and became 4.30 mg/l at 2:30 hr (14th July). The highest value of 6.61 mg/l was observed at 17:30 hr (13th July).

g) Nitrate – N

The nitrate value varied between 6.30 and 7.27 μ mol/l with 0.97 μ mol/l as their range of variation. During daytime higher value was experienced with an irregular variation. In night hours, nitrate values were increased gradually and showed its highest value at 5:30 hr (14th July).

h) Nitrite - N

Variation of the nitrite did not show any regular pattern. It varied between 0.69 to 2.43 μ mol/l with 1.74 μ mol/l as their range of variation. The highest value was observed at 23:30 hr (13^{th} July) and the lowest value at 8:30 hr (14^{th} July).

i) Phosphate – P

The phosphate value of 1.49 μ mol/l was detected at 8:30 hr (13^{th} July) and after that the values became zero till next morning.

j) Silicate – Si

The silicate values were obtained with a range of 62.06 and 89.23 μ mol/l. During daytime it increased gradually and showed its highest value at 17:30 hr (13^{th} July). Then the value decreased followed by progressive increase upto next morning and showed the second highest value.

4.5.2 Post monsoon (23^{rd} to 24^{th} November, 2003)

(Table 9; Fig. 15)

a) Water temperature

The water temperature varied between 27.8 and 32.5 ^{0} C. During daytime it increased gradually and showed maximum value at 14:30 hr (23^{rd} November). At night it decreased to the minimum value of 27.8^0 C at 2:30 hr (24^{th} November)).

b) pH

The diurnal variation of pH showed a regular trend. During daytime it progressively increased and showed its highest value of 7.39 at 14:30 hr (23^{rd} November). There was a gradual decrease in value during the night hours and showed its lowest value of 6.82 at 5:30 hr (24^{th} November). The pH range varied between 6.82 and 7.39 with 0.57 as their range of variation

c) Secchi depth

During night hours, transparency observations were not carried out due to unavailability of light. The lowest value of 42 cm was observed at 8:30 hr (23^{rd} November). From morning onwards the values were increases and reached maximum of 46.8 cm at 14:30 hr (23^{rd} November).

d) Primary productivity

Gross Primary productivity (GPP) showed an increasing pattern during daytime and the highest value of 4.95 g C m^{-3} d^{-1} was observed at 11:30 hr (23^{rd} November) and the lowest value of 3.20 g C m^{-3} d^{-1} was noticed at 5:30 hr (24^{th} November). During night the observations were not carried out due to unavailability of light.

Similar trend was also observed in case of net primary productivity (NPP) and showed 2.45 g C m^{-3} d^{-1} at 14:30 hr and 1.05 g C m^{-3} d^{-1} at 5:30 hour as the highest and lowest value respectively.

e) Total Alkalinity

Alkalinity increased from morning 8:30 hr and showed its maximum of 75.6 ppm at 11:30 hr (23^{rd} November). Then it gradually and reached its minimum value of 58.8 ppm at 20:30 hr (23^{rd} November). During night there was a gradual increase in value till next morning. The range varied between 58.8 and 75.6 ppm with 16.8 as their range of variation.

f) Dissolved oxygen

The dissolved oxygen varied between 4.96 and 7.27 mg/l. During daytime it increased progressively and showed its highest value at 14:30 hr (23^{rd} November). It decreased gradually in the night and showed its lowest value of 4.96 mg/l at 2:30 hr (24^{th} November).

g) Nitrate – N

The nitrate value varied between 0.96 and 1.74μ mol/l with 0.78 μ mol/l as their range of variation. It did not showed any specific trend and lowest value was observed at 14:30 hr (23rd November). During night hours values were steady in nature and showed its highest value at 5:30 hr (24th November).

h) Nitrite - N

The nitrite value varied between 0.55 to 1.01 μ mol/l with 0.46 μ mol/l as their range of variation. It did not showed any specific pattern. The lowest value was observed at 14:30 hr (23rd November) and the highest value was observed at 5:30 hr (24th November).

i) Phosphate – P

Phosphate content was not detected during this period.

j) Silicate – Si

The silicate values were obtained with a range of 1.81 and 15.49 μ mol/l. During daytime it increased gradually and reached the highest value of 15.49 μ mol/l at 14:30 hr (23rd November), subsequently it decreased to reach the lowest value of 1.81 μ mol/l value at 2:30 hr.

4.5.3 Northeast monsoon (4th to 5th January, 2004)

(Table 10; Fig. 16)

a) Water temperature

The water temperature varied between 26.6 and 30.6 ^{0} C. During daytime it increased gradually and showed its maximum value at 14:30 hr (4th January). At night the values were decreased to the minimum value of 26.6 ^{0} C at 5:30 hr (5th November).

b) pH

During daytime pH increased gradually and the highest value of 7.40 was observed at 14:30 hr (4^{th} January). There was a gradual decrease in pH during the night hours and showed its lowest value of 6.75 at 5:30 hr (4^{th} January). The pH range varied between 6.75 and 7.40 with 0.65 as the range of variation

c) Secchi depth

During night hours, transparency observation was not taken due to unavailability of light. The lowest value of 22.5 cm was observed at 8:30 hr (4^{th} January) and then increased gradually and reached its maximum of 27.9 cm at 17:30 hr (5^{th} January).

d) Phytoplankton Primary productivity

Gross Primary productivity (GPP) showed an increasing pattern during daytime and the highest value of 7.65 g C m^{-3} d^{-1} was noticed at 11:30 hr (4^{th} January) and the lowest value of 4.42 g C m^{-3} d^{-1} was noticed at 5:30 hr (5^{th} January). During night the observation was not taken due to unavailability of light.

Similar trend was also observed in case of net primary productivity (NPP) and showed 3.75 g C m^{-3} d^{-1} at 17:30 hr and 2.30 g C m^{-3} d^{-1} at 5:30 hr as the highest and lowest value respectively.

e) Total Alkalinity

The total alkalinity ranged between 58.8 and 79.8 ppm. The maximum value of 79.8 ppm was recorded at 8:30 hr (4^{th} January) with an irregular variation throughout the day and lowest value of 58.8 ppm at 17:30 hr (4^{th} January). At night there was a constant value of 67.2 ppm and showed its second highest value of 75.6 ppm.

f) Dissolved oxygen

The dissolved oxygen varied between 4.18 and 10.26 mg/. During daytime it increased progressively and showed its highest value at 14:30 hr (4th January). Where as at night it decreased gradually and showed its lowest value of 4.18 mg/l at 2:30 hr (5th January).

g) Nitrate – N

The nitrate value varied between 1.26 and 1.82 μ mol/. During daytime value decreased gradually upto 14:30 hr (4th January). During night hours values were constant and lowest value of 1.26 μ mol/l at 5:30 hr (5th January). The highest value was obtained at 8:30 hr (4th January).

h) Nitrite - N

The nitrite value did not show any regular pattern. It varied between 0.46 to 0.96 μ mol/l with 0.36 μ mol/l as their range of variation. The highest value of was observed at 8:30 hr (5th January) and the lowest value at 2:30 hr (5th January).

i) Phosphate – P

Phosphate did not exhibit any specific pattern and they ranged between 0.67 and 1.97 μ mol/l. The phosphate showed its highest value at 8:30 hr (4th January) and the lowest value of 0.67 μ mol/l was observed at 2:30 hr (5th January).

j) Silicate – Si

The silicate values ranged between 10.67 and 15.83 μ mol/l. The highest value of silicate was observed at 8:30 hr (5th January) and lowest value at 5:30 hr (5th January).

4.5.4 Pre monsoon (8^{th} to 9^{th} April, 2004)

(Table 11; Fig. 17)

a) Water temperature

The water temperature varied between 27.4 and 34.5. During daytime it increased gradually and showed its maximum value at 17:30 hr (8^{th} April). At night it showed a decreasing trend and minimum value of 27.4 ^{0}C was experienced in early morning.

b) pH

During daytime pH increased gradually and the highest value of 9.48 was observed at 17:30 hr (8^{th} April). There was a gradual decrease in value during the night hours and showed its lowest value of 6.88 at 5:30 hr (9^{th} April). The pH varied between 6.88 and 9.48 with 2.6 as the range of variation.

c) Secchi depth

Transparency varied within a narrow range. During night hours, transparency observations were not taken due to unavailability of light. The lowest value of 6.0 cm was observed at 5:30 hr where as the highest value of 10.6 cm was observed at 17:30 hr (8^{th} April).

d) Phytoplankton Primary productivity

Gross Primary productivity (GPP) showed an increasing pattern during daytime and the highest value of 17.83 g C m^{-3} d^{-1} was noticed at 14:30 hr (8^{th} April) and the lowest value of 9.28 g C m^{-3} d^{-1} was noticed at 8:30 hr (9^{th} April). During night the observation were not taken due to unavailability of light.

Similar trend was also observed in case of net primary productivity (NPP) and showed 8.75 and 4.30 g C m^{-3} d^{-1} as the highest and lowest value respectively. But the lowest value was experienced at 5:30 hr (9^{th} April).

e) Total Alkalinity

The total alkalinity showed its highest value of 82.5 ppm at 8:30 hr (8^{th} April) and reached the lowest value of 60.5 ppm at 14:30 hr (8^{th} April). At night there was a constant increase in value till next morning. The alkalinity ranged between 60.5 and 82.5 ppm with 22.0 ppm as the range of variation.

f) Dissolved oxygen

The dissolved oxygen varied between 2.20 and 7.61 mg/l with 5.41 mg/l as their range of variation. During daytime it increased progressively and showed its highest value at 17:30 hr (8^{th} April). In the night it decreased gradually and showed its lowest value of 2.20 mg/l at 5:30 hr (9^{th} April).

g) Nitrate - N

The nitrate value varied between 3.18 and 8.37 μ mol/l with 5.19 μ mol/l as their range of variation. The lowest value of 3.18 μ mol/l was observed at 20:30 hr (8^{th} April). At night hours values were increased gradually and the highest was observed 8:30 hr (9^{th} April).

h) Nitrite - N

The nitrite value did not show any regular trend. It varied between 1.45 to 3.99 μ mol/l with 2.54 as their range of variation. The highest value of 3.99 μ mol/l was observed at 8:30 hr (9^{th} April) and the lowest value of 1.45 μ mol/l was observed at 11:30 hr (8^{th} April).

i) Phosphate – P

The phosphate value did not show any specific pattern. The highest value of 9.07 μ mol/l showed a decreasing trend from 20:30 hr (8^{th} April) and showed its lowest value of 4.18 μ mol/l at 14:30 hr (9^{th} April). During early morning hours the phosphate value remained high.

j) Silicate – Si

The higher silicate values were obtained with a range of 61.5 and 109.60 μ mol/l with 48.1μ mol/l as their range of variation. During daytime it increased gradually and showed its highest value at 14:30 hr (8^{th} April). At night silicate remain high with irregular variation.

Table 8. Diurnal variation of hydrographical parameters during Southwest monsoon

Parameters	13th July, 03						14th July, 03		
	8:30	11:30	14:30	17:30	20:30	23:30	2:30	5:30	8:30
Temperature (°C)	28.1	27.4	27.6	28.5	28.0	27.9	27.1	27.4	28.0
pH	6.62	7.04	7.00	7.23	6.96	6.66	6.58	6.35	6.49
Secchi depth (cm)	52.0	50.0	51.0	52.0	-	-	-	-	54.0
GPP (g C m^{-3} d^{-1})	3.13	3.38	3.95	3.30	-	-	-	2.95	3.20
NPP (g C m^{-3} d^{-1})	1.38	1.65	2.05	1.72	-	-	-	1.30	1.45
Alkalinity (ppm)	34.30	46.0	46.00	39.20	44.10	44.10	34.30	39.20	34.30
Dis. oxygen (mg/l)	5.16	5.08	5.62	6.61	4.96	4.30	4.30	4.63	5.00
Nitrate-N (μ mol/l)	7.12	6.30	6.90	6.96	6.54	6.90	6.78	7.27	6.60
Nitrite-N (μ mol/l)	0.69	1.43	0.81	1.45	1.81	2.43	1.15	0.72	0.76
Phosphate-P (μ mol/l)	1.49	ND	ND	ND	ND	ND	ND	ND	ND
Silicate (μ mol/l)	62.06	62.06	76.44	89.55	68.04	81.03	87.23	80.10	89.23

ND – Not detected; NPP and GPP – Net and Gross primary productivity

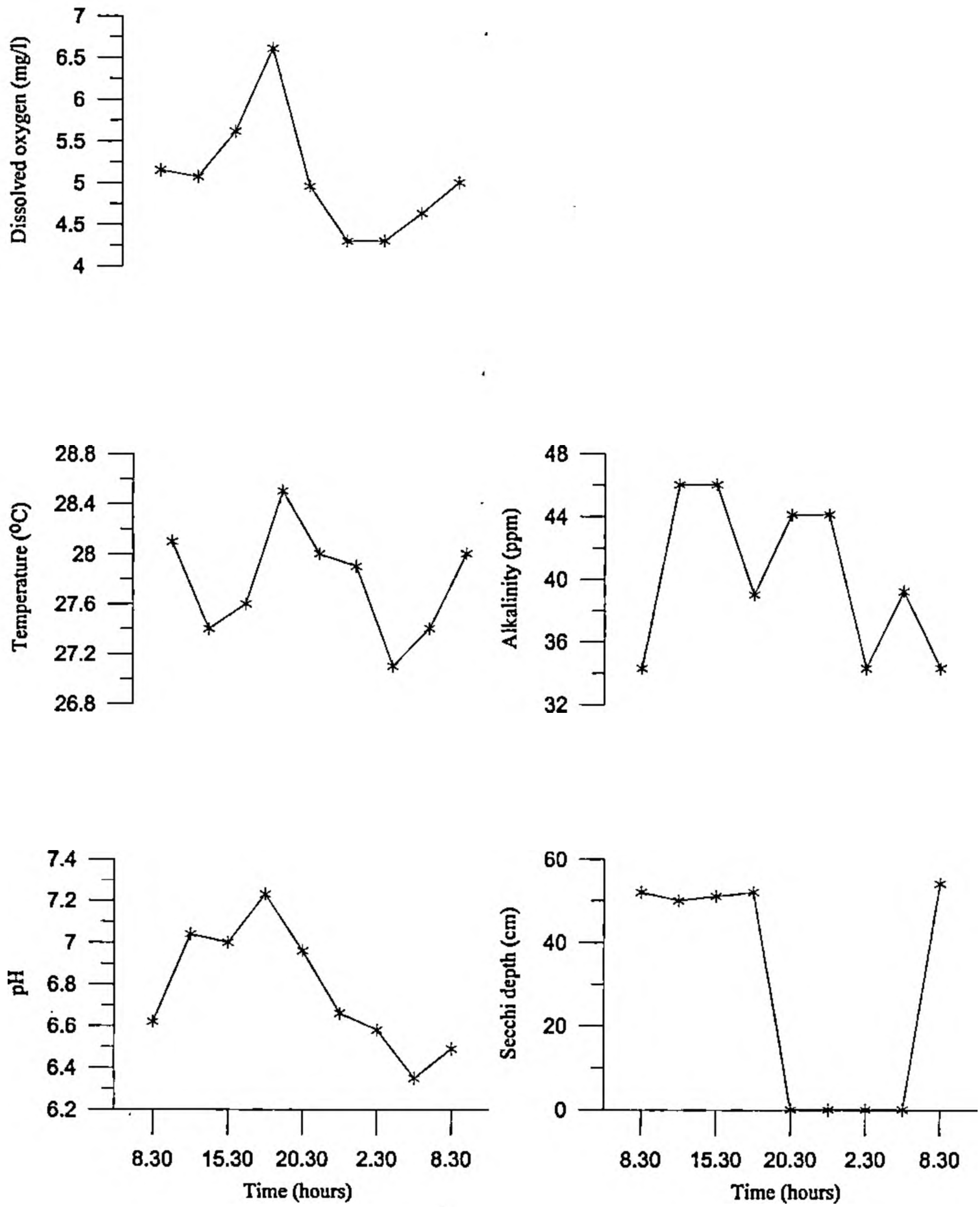


Fig.14. Diurnal variations of hydrographical parameters during Southwest monsoon

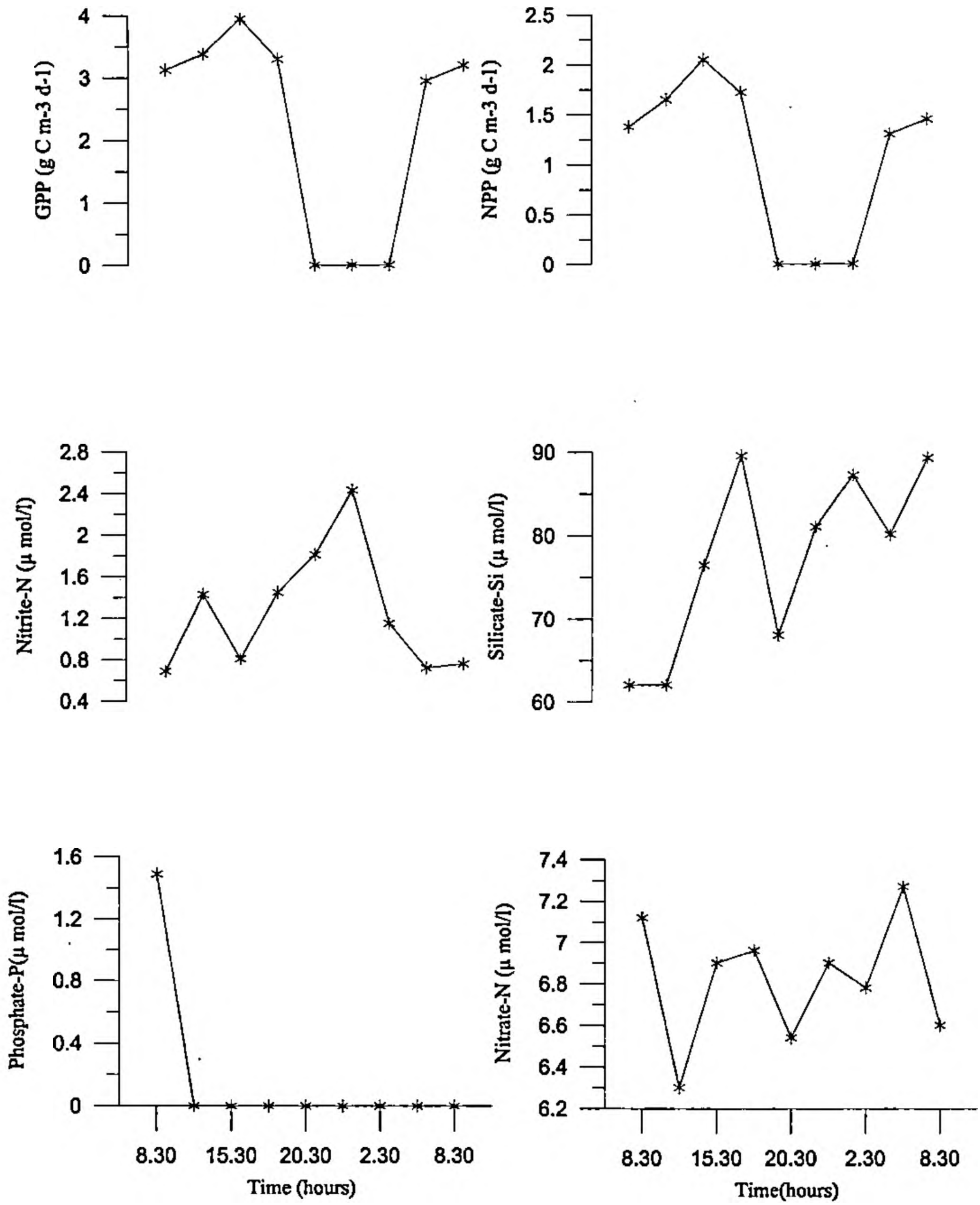


Fig.14. (Contd.) Diurnal variations of hydrographical parameters during Southwest monsoon

Table 9. Diurnal variations of hydrographical parameters during Post monsoon

Parameters	23rd November, 03						24th November, 03		
	8:30	11:30	14:30	17:30	20:30	23:30	2:30	5:30	8:30
Temperature (°C)	28.3	29.3	32.5	31.0	29.9	29.0	27.8	28.0	28.4
pH	6.89	7.20	7.39	7.27	7.00	6.88	7.16	6.82	6.91
Secchi depth (cm)	42.0	45.0	46.8	45.4	-	-	-	-	44.0
GPP (g C m^{-3} d^{-1})	3.85	4.95	4.40	4.05	-	-	-	3.20	3.92
NPP (g C m^{-3} d^{-1})	1.90	2.15	2.45	2.05	-	-	-	1.05	1.98
Dis. oxygen (mg/l)	5.29	5.95	7.27	6.61	5.95	5.45	4.96	5.12	5.45
Alkalinity (ppm)	71.4	75.6	71.4	71.4	58.8	63.0	67.2	71.4	71.4
Nitrate-N (µ mol/l)	1.05	1.08	0.96	1.17	1.26	1.08	1.20	1.74	1.44
Nitrite-N (µ mol/l)	0.74	0.60	0.55	0.71	0.64	0.74	0.90	1.01	0.85
Phosphate-P (µ mol/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silicate (µ mol/l)	12.35	15.43	15.49	11.95	08.12	07.31	01.81	6.96	6.90

ND – Not detected; NPP and GPP – Net and Gross primary productivity

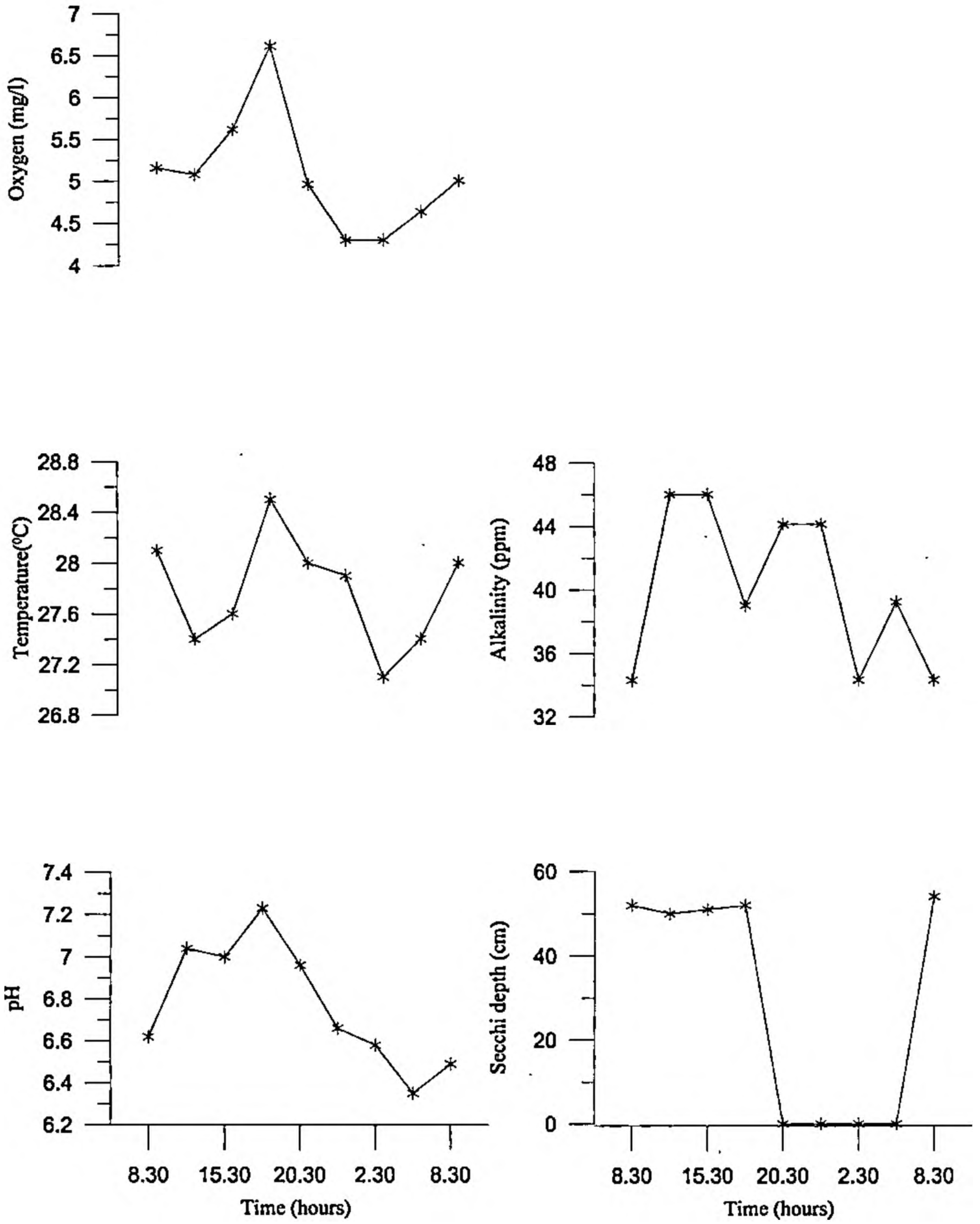


Fig.15. Diurnal variations of hydrographical parameters during Post monsoon

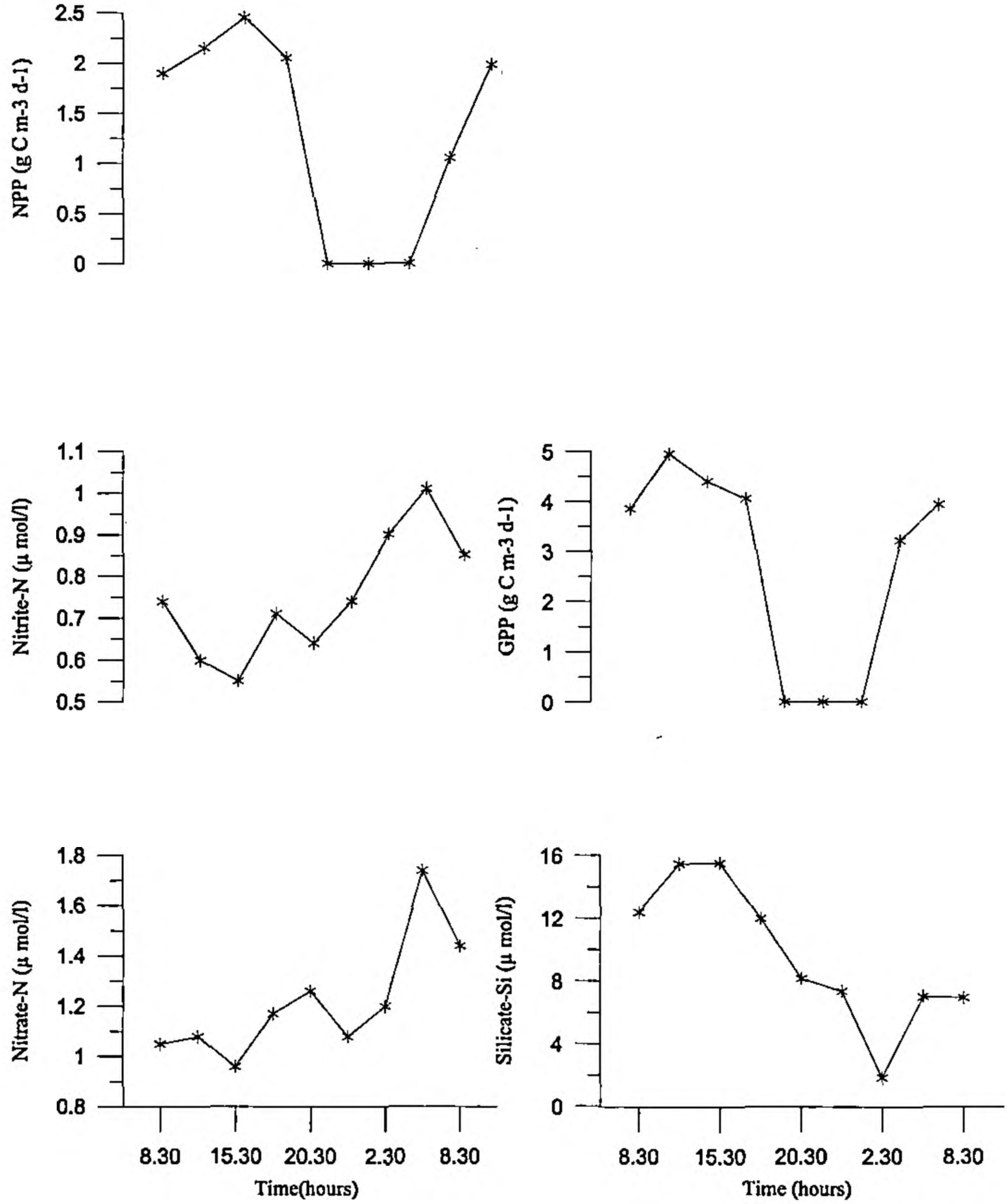


Fig.15. (Contd.) Diurnal variations of hydrographical parameters during Post monsoon

Table 10. Diurnal variations of hydrographical parameters during Northeast monsoon

Parameters	4th January, 04						5th January, 04		
	8:30	11:30	14:30	17:30	20:30	23:30	2:30	5:30	8:30
Temperature (°C)	26.9	29.0	30.6	29.7	28.6	28.0	26.9	26.6	27.0
pH	7.00	7.19	7.40	7.38	7.20	6.93	6.89	6.75	6.98
Secchi depth (cm)	22.5	24.5	27.9	26.5	-	-	-	-	26.5
GPP (g C m^{-3} d^{-1})	5.63	7.65	7.06	6.05	-	-	-	4.42	5.44
NPP (g C m^{-3} d^{-1})	2.74	3.05	3.75	3.21	-	-	-	2.30	3.13
Dis. oxygen (mg/l)	6.09	9.26	10.26	8.98	7.05	6.37	4.18	4.45	6.09
Alkalinity (ppm)	79.8	67.2	75.6	58.8	67.2	67.2	67.2	67.2	75.6
Nitrate-N (μ mol/l)	1.82	1.56	1.44	1.53	1.44	1.44	1.44	1.26	1.69
Nitrite-N (μ mol/l)	0.89	1.08	0.89	0.55	0.89	0.55	0.46	0.85	0.96
Phosphate-P (μ mol/l)	1.97	1.63	1.63	1.49	1.44	1.49	0.67	0.86	1.68
Silicate (μ mol/l)	15.02	13.28	11.89	13.22	10.91	14.33	14.15	10.67	15.83

ND – Not detected; NPP and GPP – Net and Gross primary productivity

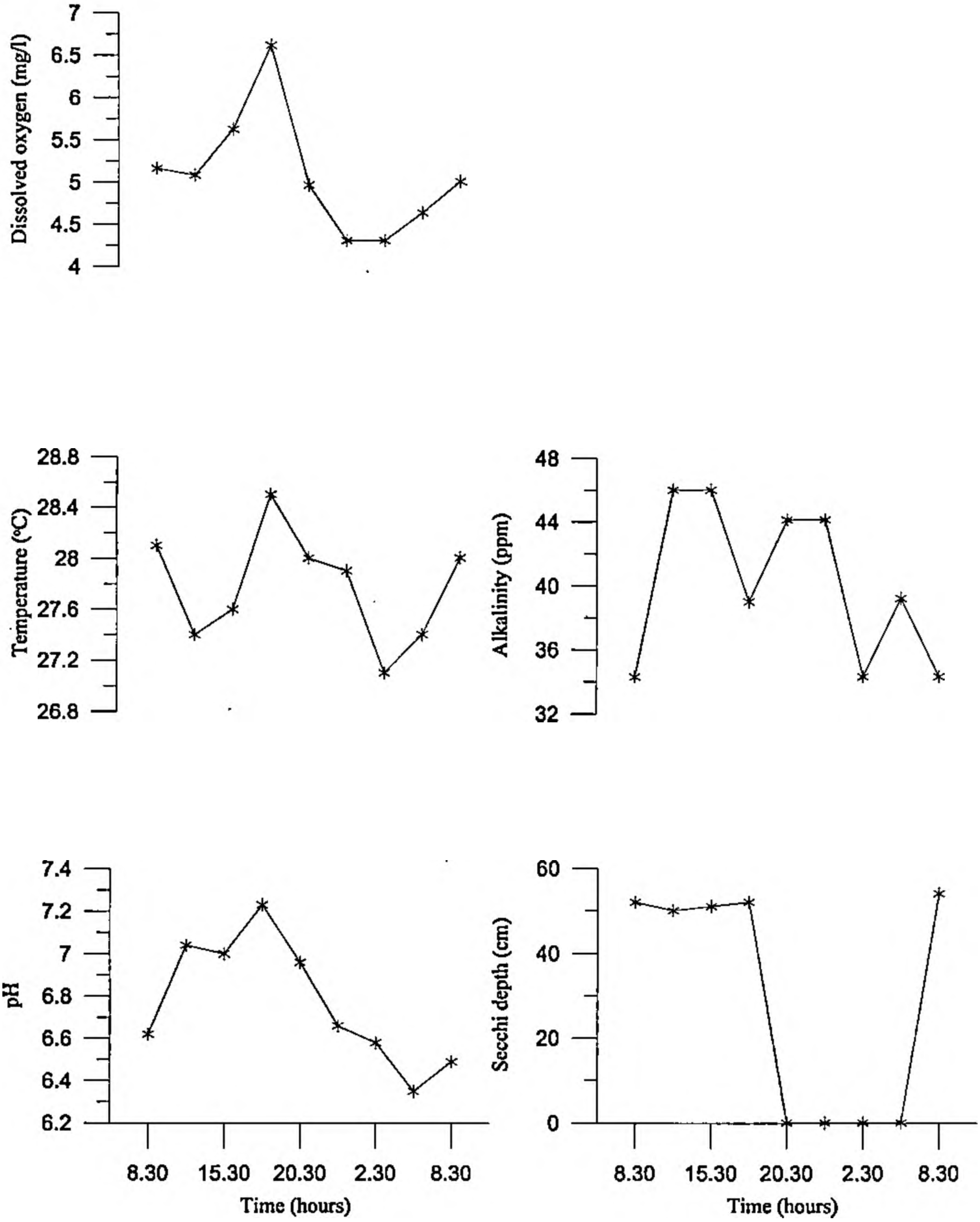


Fig.16. Diurnal variations of hydrographical parameters during Northeast monsoon

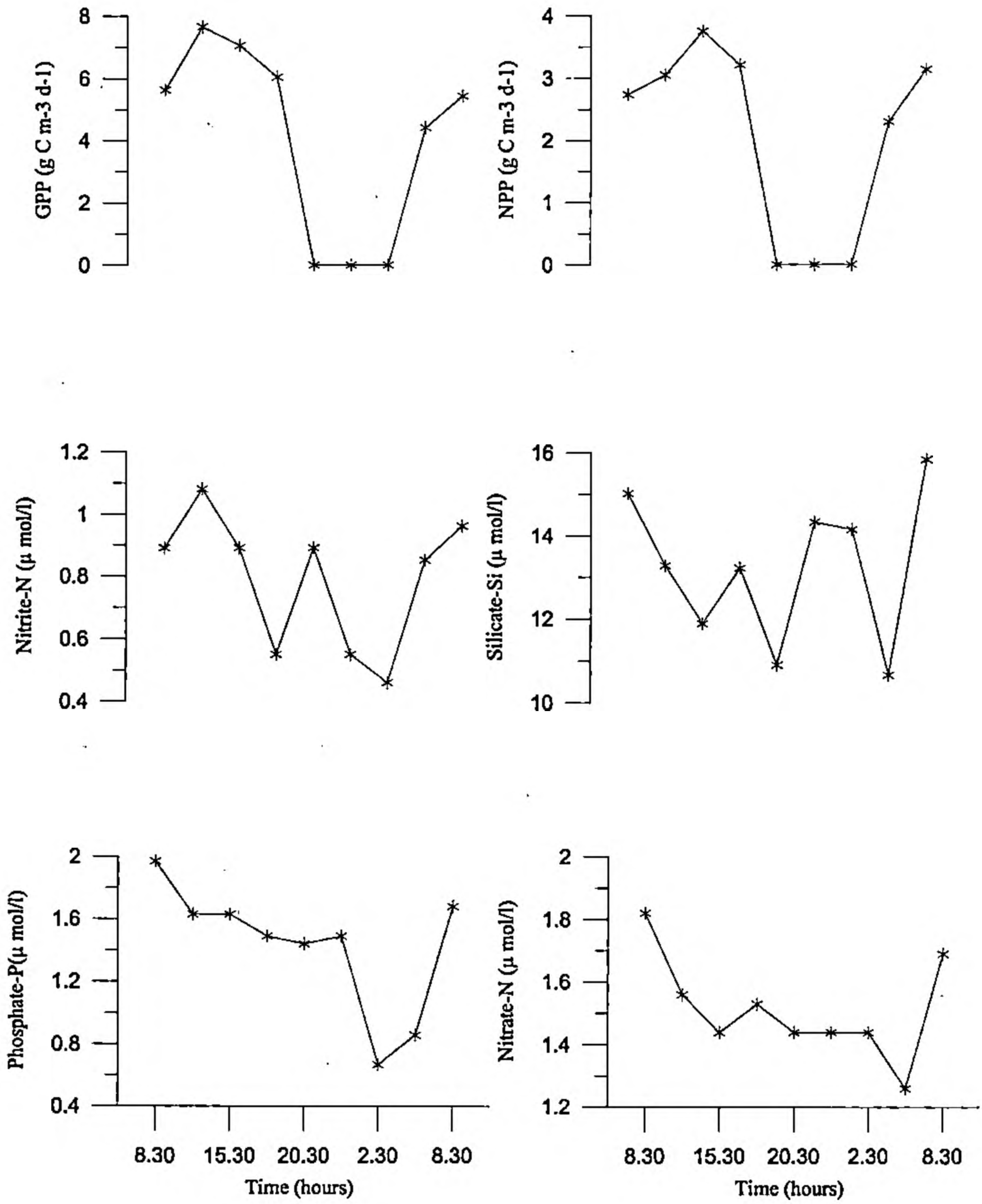


Fig.16. (Contd.) Diurnal variations of hydrographical parameters during Northeast monsoon

Table 11. Diurnal variations of hydrographical parameters during Pre monsoon

Parameters	8th April, 04						9th April, 04		
	8:30	11:30	14:30	17:30	20:30	23:30	2:30	5:30	8:30
Temperature (°C)	28.9	32.0	33.7	34.5	31.4	28.8	28.0	27.4	29.0
pH	7.04	8.12	9.42	9.48	8.75	7.22	7.06	6.88	7.07
Secchi depth (cm)	10.1	10.2	10.5	10.6	-	-	-	6.0	10.2
GPP (g C m^{-3} d^{-1})	9.28	10.53	17.83	10.53	-	-	-	8.57	9.13
NPP (g C m^{-3} d^{-1})	4.30	5.10	8.75	5.80	-	-	-	4.17	4.77
Dis. oxygen (mg/l)	3.56	5.83	6.15	7.61	5.21	3.56	2.60	2.20	3.56
Alkalinity (ppm)	82.5	71.5	60.5	66.0	66.0	71.5	71.5	79.6	82.5
Nitrate-N (µ mol/l)	8.07	7.58	6.06	3.86	3.16	4.23	6.67	7.39	8.37
Nitrite-N (µ mol/l)	3.11	1.45	2.23	1.93	2.16	2.35	2.28	2.67	3.99
Phosphate-P (µ mol/l)	8.64	5.82	4.18	4.44	9.07	6.13	7.38	8.83	8.06
Silicate (µ mol/l)	88.74	97.03	109.6	94.77	95.93	83.98	92.51	85.90	61.65

ND – Not detected; NPP and GPP – Net and Gross primary productivity

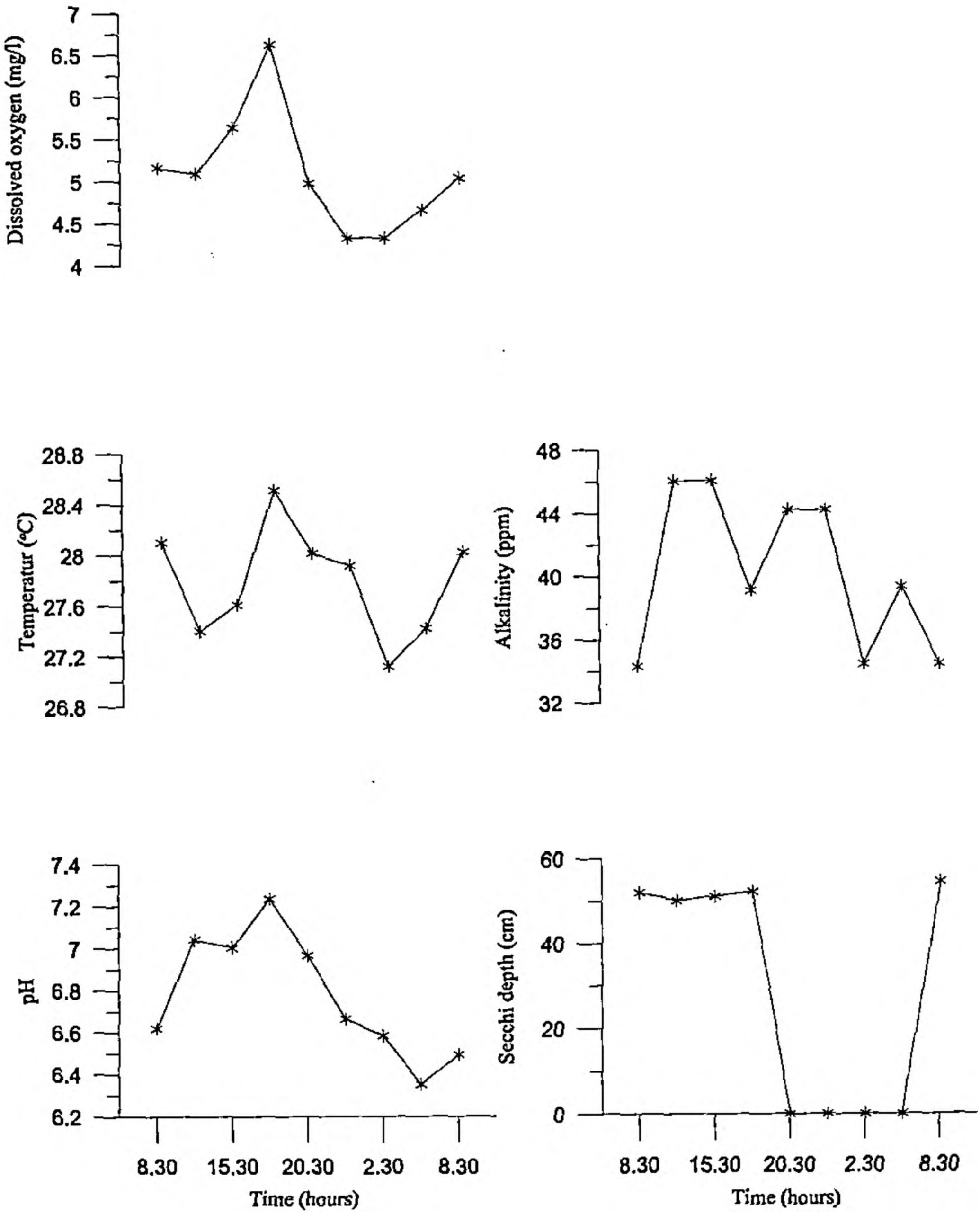


Fig.17. Diurnal variations of hydrographical parameters during Pre monsoon

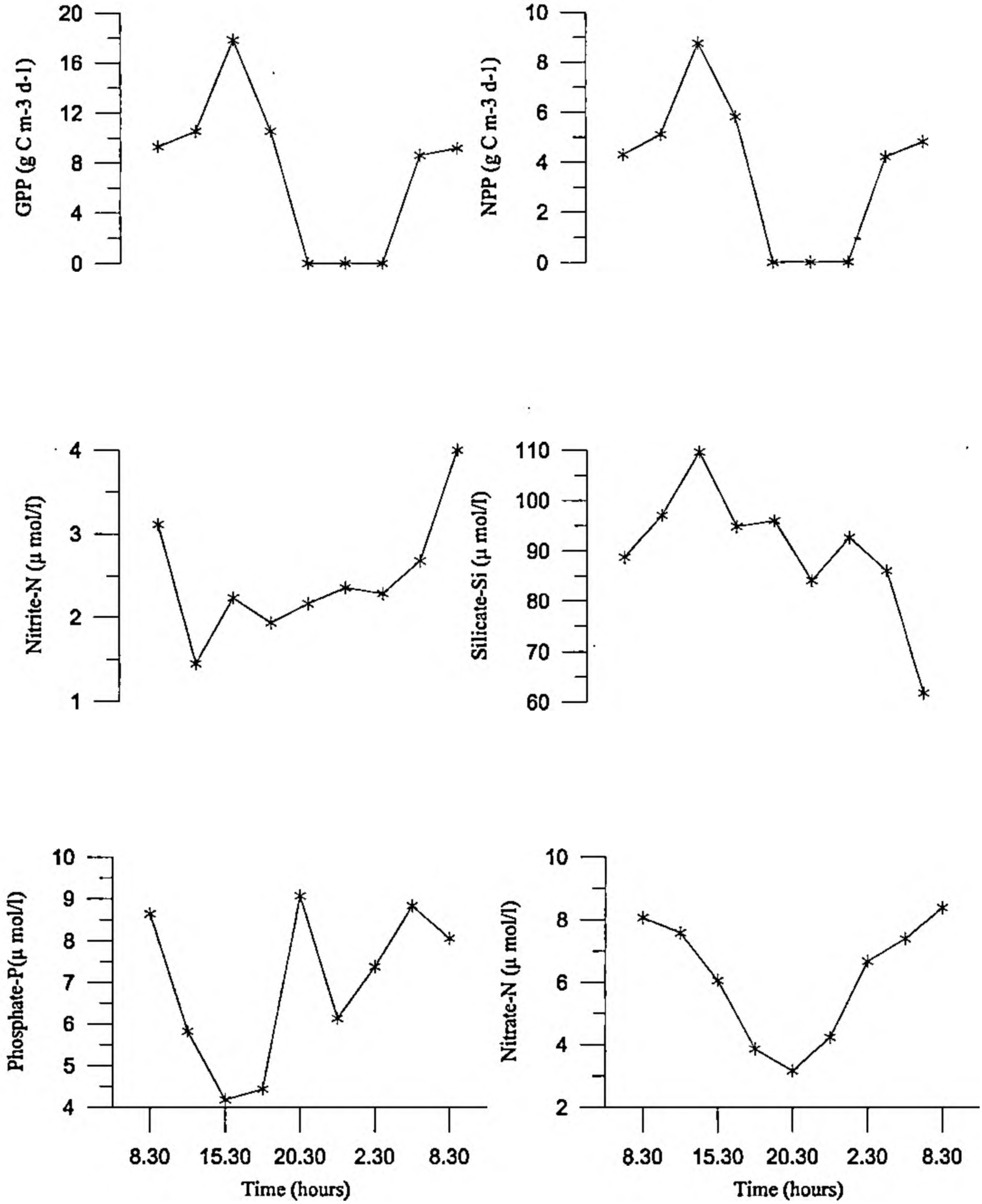


Fig.17. (Contd.) Diurnal variations of hydrographical parameters during Pre monsoon

Discussion

5. DISCUSSION

5.1 MONTHLY VARIATIONS OF WEATHER ELEMENTS

5.1.1 Air temperature

The mean air temperature exhibited a clear double oscillation, there being two maxima (one in November and other in March) but in September also high mean air temperature was observed inspite of getting low values during the other monsoon months. This can be attributed to the less rainfall during the month. The lowest values observed in northeast monsoon season. Sewell (1929) has stated that the air temperature over the open waters of Indian seas exhibited a clear double oscillation in a year, there being two maxima (one in April and other in September/October) and two minima during the period of southwest and northeast monsoons. The temperature of the surface water also follows a similar course and exhibits a clear double oscillation. A similar double oscillation has been reported by Prasad (1957) at Mandapam, Gulf of Mannar and by Rangarajan and Marichamy (1972).

Clouding during the southwest monsoon and October was the reason for the low temperature during those periods. Higher insolation was the cause for increased in air temperature in pre monsoon months.

5.1.2 Maximum temperature

The maximum temperature over the Panangad region was low in monsoon season due to higher rainfall. But during the late post monsoon, northeast monsoon and pre monsoon period the values remained high. The highest maximum temperature was observed in pre monsoon months. Menon and Rajan (1989) also made similar observations while studying the climate of Kerala. Abbi *et al.* (1970)

recorded similar findings while studying the meteorological condition over Narmada basin.

Pentad curve for maximum temperature (Fig. 3b) shows the pattern of short-term fluctuations of maximum temperature during all the seasons. Decrease in clouding during day time in northeast monsoon and pre monsoon periods might be a reason for higher temperature in those seasons.

5.1.3 Minimum temperature

Although the surface temperature at Panangad region registered appreciable fall with the onset of southwest monsoon, but the minimum temperature continued to be high. During post monsoon, mean minimum temperature remained high. The lowest minimum temperature decreased in late November. During northeast monsoon, mean minimum temperatures recorded lowest values. During pre monsoon period mean minimum temperature increased (Fig.2 C). Menon and Rajan (1989) also made similar observation while studying the climate of Kerala. Abbi *et al.*, (1970) recorded similar findings while studying the meteorological condition over Narmada basin.

Even though minimum temperature showed short-term fluctuations, the temperature range was between 22 and 24 ^{0}C (Fig. 3c) during the southwest monsoon, post monsoon and northeast monsoon.

The increase in minimum temperature during the pre monsoon period (Fig.2C and 3c) might be due to increase in cloudiness, which prevents escape of terrestrial radiation, there by retaining higher temperature.

5.1.4 Rainfall

Southwest monsoon was the period of maximum rainfall in Panangad (Cochin) and secondary maximum was experienced in post monsoon period. The lowest rainfall was in March and increased in increased progressively in April. Numbers of rainy days also followed similar pattern of rainfall but northeast monsoon season was the period of less number of rainy days. Menon and Rajan (1989) also made similar observation while studying the climate of Kerala. Jambunathan and Ramamurthy (1973) also stated that the southwest monsoon gives highest rainfall in Kerala.

Even though southwest monsoon and post monsoon are rainy seasons, noticeable short-term fluctuations in amount of rainfall could be seen in the pentad for rainfall. September was the month low rainfall of southwest monsoon period. From the pentad, it can be understood that there are no rainless months, during the period of observation.

5.1.5 Relative humidity

Seasonally, relative humidity at Panangad reached maximum during the southwest monsoon period. The lowest values occurred during the northeast and pre monsoon period. Menon and Rajan (1989) stated that climate of Kerala follows a seasonal pattern and similar findings have been observed. While studying Narmada basin, Abbi et al. (1970) found that the relative humidity was the highest in July, August September and October. From November till January, the lowest values were recorded. Similar trend was also observed in the present study.

High values of relative humidity during the southwest and post monsoon months may be due to the rainfall experienced during the period and moisture contribution of southwest monsoon wind.

5.1.9 Cloudiness

Cloud increased with the onset of the southwest monsoon and the skies remain more or less overcast in southwest monsoon period. In post monsoon period cloud cover was less, compared to the previous phase.

But in northeast monsoon season minimum cloud cover was observed. But in pre monsoon period clouding increased with the advance of the season. Menon and Rajan (1989) also made similar observations while studying the climate of Kerala.

5.1.7 Wind

The wind speed was high during the southwest monsoon season, decreased from November till January. The lowest value was experienced in December and thereafter it gradually increased till April. Menon and Rajan (1989) also made similar observations in Kerala.

During the southwest monsoon season westerly and southwesterly winds dominated. The low level westerlies of October and become light in November and northerly winds was observed. In northeast monsoon season, northerly and northeasterly winds were dominated, especially in the morning hours. Northeasterly, northwesterly and southerly winds were observed dominantly in pre monsoon period. Lafond (1962) mentioned that in South East Asia, the dominant wind systems were the northeasterly and southwesterly as was the case in the present study.

5.2 MONTHLY VARIATIONS OF HYDROGRAPHICAL PARAMETERS

5.2.1 Water temperature

The water temperature showed high values during pre monsoon months and November (post monsoon). Menon *et al.* (1971) and Annigeri *et al.* (1979) has reported similar findings from coastal waters of North Kanara. Sankaranarayanan *et al.* (1982) and Nair *et al.* (1988) reported similar trends in culture fields. The lowest temperature was recorded in January during the present investigation. The values observed during this period could be attributed to the winter effect.

Hydrography (2004) also recorded the highest temperature during April and lowest in July from Vembanad Lake. Parameswaran *et al.* (1971) had reported similar values for a freshwater pond and Annigeri *et al.* (1979) for coastal waters. There was a gradual increase in temperature from February with the advance of summer and the high values (>29 ^{0}C) were recorded during March due to the warm weather and maximum solar radiation during the period. Silas and Pillai (1975) also noted such a pattern and they attributed it to higher amount of solar radiation received during that period. With the onset of monsoon a sudden drop in water temperature was noticed in the surface layers concurrent with the heavy showers of monsoon in July and decrease in insolation. There was an increase in temperature during September and showing its secondary maximum in November, which might be due to the increase in insolation during post monsoon.

Statistically, significant positive correlation (r = 0.641) was observed between air and water temperature. The water temperature of the pond is influenced by the change in the atmospheric temperature. Small masses of water body quickly react to the change in the atmospheric temperature (Welch, 1952). Sewell (1929), Prasad (1957), Rangarajan and Marichamy (1972) had reported that the temperature of the surface water had clear double oscillation as in the case of air temperature. They observed a direct relationship between them. During the present investigation also same pattern has been observed.

5.2.2 pH

Water body is buffered largely by carbonate system involving carbon dioxide, bicarbonate and carbonate (Stumm and Morgan, 1970). A near neutral condition of pH (6.5-7.5) is most favourable for fish production (Banerjea, 1967). In the present study also pH showed a favourable range for fish production.

The high pH (> 6.9) values were recorded during northeast monsoon and pre monsoon period with a slight drop in February. High pH value was possibly due to the influence of high carbonate ratio in the carbonate system. It was noticed that with the onset of monsoon a sudden drop in pH. Parameswaran *et al.* (1971) recorded a steady increase of pH in pond from December / January to March / April. They attributed this to shifting of carbonate-bicarbonate equilibrium to alkaline side due to phytoplankton bloom. Low pH values confined to the southwest monsoon period was due to heavy rainfall. Similar trend was observed in the present study also.

A positive relation was observed between pH and air temperature by Das *et al.* (2000) from a freshwater pond in Assam. In the case of present study also air temperature showed significant positive correlation ($r = 0.843$) with pH. Statistically significant negative correlation was observed between rainfall and pH ($r = -0.635$). It may be due to the dilution of pH in increase rainfall. Relative humidity also showed negative correlated with the pH, but not significant.

5.2.3 Secchi depth

Factors affecting the transparency of the water in the pond are silt, planktonic organism and suspended organic matter (McCombie, 1953). In pond, turbidity from planktonic organism is often desirable to a certain extent where as that caused by suspended clay particle is generally undesirable. Boyd *et al.* (1978) had observed that almost all problems related to dissolved oxygen in culture ponds were the consequences of heavy plankton blooms. Such plankton densities result in Secchi disc visibilities of 30 to 45 cm. The probability of problems with low dissolved oxygen concentration increases as Secchi disc visibility decreases below 20 cm. In the present investigation, Secchi disc readings were within the range of 10–60 cm (Table 2 and Fig.4K)

Higher readings were recorded during monsoon, which could be attributed to low plankton production. Low values were observed during northeast and pre monsoon months, which was due to the increase in plankton bloom. Parameswaran *et al.* (1971) also recorded similar type of result from freshwater pond.

Statistically significant positive correlation was observed between transparency and air temperature (r = 0.843). Das and Jha (1999) mentioned that air temperature could play as a significant indicator in assessing transparency. Rise and fall in transparency at upper Ganga stretch can be directly correlated with air temperature. But rainfall showed significant (r = - 0.635) negative correlation.

5.2.4 Water level

The maximum depths of the pond occur during monsoon month after which there were a considerable fall to reach the minimum value in April. Higher depth was due to the heavy monsoon showers. As the rainfall decreases the water level also decreased. During pre monsoon temperature become maximum which leads to reduction in water level through evaporation. Parameswaran *et al.* (1971) and Jindal and Kumar (1993) reported similar trend in water level of pond in Assam.

Statistically significant positive correlation was observed between the water level and rainfall (r = 0.652 and relative humidity (r = 0.810). Because higher depth of water was due to the heavy monsoon and rainfall can be directly correlated with relative humidity. Significant negative correlation was observed with air temperature (r = - 0.879) because at higher atmospheric temperature evaporation was more and water level reduced.

5.2.5 Primary productivity

Among the physico-chemical factors influencing the primary productivity, pH, alkalinity, dissolved gases like oxygen and carbon dioxide and dissolved nutrients like nitrogen and phosphorus are important (Banerjea, 1967). Basheer *et al.* (1996) also mentioned that the temperature, light and nutrients are the important limiting factors for primary productivity, contributing to the variability within an aquatic ecosystem.

In the present investigation, primary productivity showed its highest value during northeast and pre monsoon period. Presence nutrient elements in optimum concentration and there by production of phytoplankton and algal bloom may be the possible reason for the high productivity during the northeast monsoon and pre monsoon season. Marichamy *et al.* (1985) and Saha and Mandal (2004) have supported these findings.

The low values of primary production during June and October are correlated with clouds of monsoon during and before the sampling, which reduced light intensity and cut down production. This observation agreed with the findings of Boyd (1979). A direct correlation between greater hours of sunshine and production of biomass, when maximum production was noted in pre monsoon followed by winter, the minimum was during the early monsoon period. Saha *et al.* (1971) also supported the present findings. Khan and Siddiqui (1971) also recorded a direct relation between phosphorus and primary productivity from a freshwater pond.

Statistically significant negative correlation was observed between gross primary productivity and total rainfall ($r = -0.633$) and cloudiness ($r = 0.653$), where as it showed positive correlation with air temperature ($r = 0.847$). Similarly significant negative correlation was observed between net primary productivity and total rainfall ($r = 0.672$), relative humidity (r = 0.731) and cloudiness (r = 0.667), where as it showed positive correlation with air temperature (r = 0.785). Khan and Siddiqui (1971) and Avola (1983) have recorded a direct relationship between temperature and primary production of a freshwater pond.

5.2.6 Total Alkalinity

Alkalinity of the water sample is defined as the capacity of the sample to neutralize strong acid to the designated pH. It is numerically expressed in ppm (parts per million) unit as equivalent $CaCO_3$. The availability of inorganic carbon for phytoplankton growth is related to alkalinity. Water with total alkalinity less than 20 ppm usually contains relatively little available carbon dioxide. Waters with total alkalinity of 20 to 150 ppm contain suitable quantities of carbon dioxide to permit plankton production (Boyd, 1979).

The highest alkalinity was recorded in April and the lowest value was recorded in July. Relatively high values were observed during the post, northeast and pre monsoon months and it followed a gradual increasing trend. Higher concentration of alkalinity may be attributed to decreased in water level. In monsoon when water level increases, the total alkalinity becomes diluted. These observations are in conformity with the findings of Chakrabarty *et al.* (1959) from Yammuna river, Sreenivasan (1966) from fish pond, Silas and Pillai (1975) from Cochin back water and Mathew et al. (1987) from prawn culture field. The high concentration of alkalinity during summer is due to decrease in water level due to evaporation. The effect of rainfall in decreasing bicarbonates is well known in freshwaters (Michael, 1969).

Statistically significant negative correlation was observed between total alkalinity and total rainfall (r = - 0.922). It may be dilution of the total alkalinity through rain. It showed significant positive correlation with air temperature (r = 0.636).

5.2.7 Dissolved oxygen

Dissolved oxygen is an essential factor in the aquatic eco system. The atmosphere is a vast reservoir of oxygen is only slightly soluble in water. The solubility of oxygen in water is mainly influenced by temperature. Solubility of oxygen decreases with increase in temperature. Low values of dissolved oxygen noticed during pre monsoon months when the temperature values were high, may be due to above relationship to some extent.

Although atmospheric oxygen will diffuse into water, the rate of diffusion is quite slow in the stagnation condition of the pond. Photosynthesis by phytoplankton is the primary source of dissolved oxygen in most aquaculture systems (Hepher, 1953; Boyd, 1979). The dissolution of oxygen from atmosphere caused by wind driven ripples and aeration at the surface may also contribute to this. The primary loss of oxygen from water body is caused by the respiration of organism and decomposition of organic matter and diffusion of dissolved oxygen in to the air.

In the present study the dissolved oxygen was at the highest level in ponds during colder months due to low temperature and intense photosynthetic activities of phytoplankton bloom and further fall of dissolved oxygen in pre monsoon is attributed to the death and decay of plankton and presence of organic matter. Lakshmanan *et al.* (1967) and Parameswaran *et al.* (1971) could note similar type of findings from freshwater pond. The increase in the oxygen value during monsoon and winter months may be due to rainfall and prolific growth of phytoplankton algae in the former and low temperature in later (Sreenivasan, 1966). The increase in dissolved value during monsoon may be due to the heavy rainfall. Swarup and Sing (1979), Pillai *et al.* (1975) and Annigeri *et al.* (1979) found similar type of findings in different water bodies.

Statistically significant negative correlation was observed between dissolved oxygen and air temperature (r = 0.684) where as it showed positive correlation with rainfall (r = 0.153), wind speed (r = 0.215) and cloudiness (r = 0.075), but they were not significant. A direct relationship exists between temperature and amount of dissolved oxygen in freshwater impoundments (Kato, 1941 and Itazawa, 1957). Thus it is likely that the temperature increases the photosynthetic rate there by resulting in direct relationship as observed in the present investigation also.

5.2.8 Nutrients

The nutrient status of both water and soil play the most important role in governing the population production of planktonic organism in fish ponds (Banerjea, 1967).

In shallow system, it is believed that one of the major factors governing the distribution of nutrients may be the variation in the regenerative property of the bottom mud, which is rich in organic matter due to biological and chemical oxidation (Sankaranarayanan *et al.*, 1988 and Nair *et al.*, 1988). In a shallow system, major recycling of nutrients is effected through the bottom sediments (Reddy and Sankaranarayanan, 1972).

5.2.8.1 Nitrate – N

Nitrate nitrogen content in the pond showed distinct seasonal fluctuation. A wide range of variations in the concentration of nitrate-nitrogen in freshwater pond was reported by George (1962) in a fish pond at Delhi.

In the present investigation high values were observed during pre monsoon, southwest monsoon and later part of northeast monsoon. Low values were observed in September and post monsoon period. Nair *et al.*

(1988) reported increasing trend in the nitrate-N values in the culture fields during monsoon months due to freshwater discharge through rain and land drainage, low values during the remaining period may be due to less drainage and high primary production. In the present investigation also similar trend was observed from the culture pond.

The plankton population was highest during the month of December/January to April/May, coinciding with the higher concentration of total alkalinity and nutrients of water. The present investigation is fully supported by Parameswaran *et al.* (1971) while studying the physico-chemical status of a freshwater pond in Assam and Swarup and Sing (1979) by their findings from limnological investigation in Suraka Lake. Zafar (1944) stated that when the organic matter decomposes in water it forms complex proteins that get converted into "nitrogenous organic matter" and finally into nitrates by bacterial activity.

Statistically negative correlation was observed between nitrate and total rainfall ($r = -0.054$) where as nitrate showed positive correlation with air temperature ($r = 0.414$).

5.2.8.2 Nitrite – N

In the present investigation high values were observed during northeast and pre monsoon months. Low values were observed during onset of monsoon (June/July) but it increased and the value was high in August with a fall in September. Then it again took an increasing trend. While studying the nutrient status of a pond, Parameswaran *et al.* (1971) stated that the plankton population in the pond was highest during the months of December/January to April/May, coinciding with the higher concentration of total alkalinity and nutrients of water.

Even though the nitrite value was low in June, as the monsoon progress the value increased. The decrease value in September may be due to less rainfall in that month. Nair *et al.* (1988) reported an increasing trend in the nitrite-N value during monsoon due to land drainage and freshwater discharge through rain.

Statistically no significant relation was observed.

*5.2.8.3 **Phosphate – P***

Phosphate content was found to be closely associated with that of nitrate with regards to its mode of fluctuation. The reason given for nitrate fluctuation is applicable to this also (Swarup and Sing, 1977).

High values of phosphate were observed during pre monsoon months while low values were observed during southwest monsoon. There was no detection of phosphate during post monsoon and December. While studying the nutrient status of pond, Parameswaran *et al.* (1971) stated that the plankton population in the pond was highest during December/January to April, coinciding with the higher concentration of alkalinity and nutrient status of water. The supply of nutrient appears to be dependent upon rain and land drainage. However high values of phosphate-phosphorus during winter was mainly due to the regeneration of phosphate in the pond.

Joseph (1974) reported from Cochin harbour that the rapid decline of the high phosphate value of pre monsoon months to nearly nil values by the silt brought in to the estuary by the freshwater drainage. Sankaranarayanan and Qasim (1969) recorded high phosphate concentration in the estuary during pre monsoon months and low values during the monsoon months. Low to complete absence of inorganic phosphate recorded during present investigation in monsoon months may be due to the onset of monsoon and subsequent removal of phosphate from the solution by silt brought into the pond by land drainage through rain.

Statistically negative correlation was observed between phosphate and rainfall (r = - 0.356) but it not significant. Phosphate showed significant positive correlation with air temperature (r = 0.827) in the present study.

5.2.8.4 Silicate – Si

The silicate values were high during monsoon and as the season advanced to post monsoon season a decrease in silicate silicon is observed. From December onwards it increases and shows it highest value in April. While studying physico-chemical characteristics Parameswaran *et al.* (1971) stated that the plankton population in the pond was highest during the month of December/January to April, coinciding with the higher concentration of alkalinity and nutrient status of water.

Jindal and Kumar (1993) recorded that the higher values of silicate during summer month, were because of their silicate concentration at lower water level and increased in solubility of silica at higher temperature (r = 0.573). In present investigation also similar type of observation was found and silicate shows a positive correlation with air temperature (r = 0.464). Even though this value is not significant, it is very near to the significant level. Qasim and Sankaranarayanan (1969) reported that silicon content of backwater is high when the considerable freshwater discharge and land drainage.

Statistically silicate did not any significant correlation with the observed weather elements but all showed positive correlation.

5.3 DIURNAL VARIATIONS OF WEATHER ELEMENTS

5.3.1 Air temperature

The air temperature showed its maximum at afternoon hour and showed its low value during night and early morning hours (Sing *et al.*, 1980). In the present study also similar result was observed for all seasons except July 13th and 14th. This irregular variation of temperature is due to the effect of cloudy weather in combination with rainfall. The difference in air temperature was also less than those noted in November, January and April. Due to the cloudy weather and rain, which allowed less intensive heating during the day. Khan *et al.* (1971) also found similar findings while studying diurnal variation of a pond at Aligarh.

5.3.2 Rainfall

Rainfall on 13th to 14th July was more in morning and noon hours. During the season with heavy clouding during night and early morning maximum also exist due to the radiational cooling from the top of the clouds. While studying the diurnal variation of rainfall in India Prasad (1970) also mentioned similar results. There was no diurnal rainfall and sky was clear representative in the days of observation for post monsoon (November), northeast monsoon (January) and pre monsoon (April) season.

5.2.3 Relative humidity

Relative humidity decreased as the day advanced to reached the lowest value in the afternoon around the maximum temperature approach. The highest relative humidity was observed at the time of occurrence of minimum temperature.

5.2.4 Cloudiness

The weather was overcast on 13th and 14th July. But the sky was remained clear for those days observed in November, January and April. The observations of Menon and Rajan (1989) support the present findings.

5.2.5 Wind

Wind speed was steady and low throughout the night but it showed a steady rise from morning and reached its maximum value in between noon to afternoon hours. Rao and Rao (1962) also recoded similar type of result.

5.4 DIURNAL CHANGES OF HYDROGRAPHICAL PARAMETERS

5.4.1 Water temperature

Marked fluctuations have been observed in respect of the most of the physico-chemical factors. Surface temperature usually attained the maximum at afternoon and minimum during morning hours. Kato (1941) have been recorded similar result in other part of the tropical pond. Direct relationship was between the wind force, air and water temperature by Rao and Rao (1962) as in the case of present study.

The water temperature is known to be one of the most critical factors in aquatic environment. Fluctuation in day and night temperatures affect the solubility of gases which in turn help in complete inter mixing of the water column and is reflected in better productivity.

5.4.2 pH

Hydrogen ion concentration in the pond water showed a trend of gradual rise from morning hours and reaching maximum towards afternoon and thereafter decreasing during night. The present observations are similar to those of George (1961). Phytoplankton and other aquatic vegetation remove carbon dioxide from the water during photosynthesis, which can cause increase in pH of water during daytime and decrease at night. Stumm and Morgan (1970) also had noticed similar pattern. A positive relation was observed between pH and air temperature by Das *et al.* (2000) as in the case of present study.

5.4.3 Secchi depth

Transparency showed its highest value during day, it gradually increased from morning and showed its highest value during afternoon. This may be due to the increase in temperature. Higher the light penetration greater will be the transparency. Air temperature can play as a significant indicator in assessing transparency of pond. Rise and fall in transparency at upper Ganga stretch was directly correlated with air temperature (Das and Jha, 1999). George (1961) also noted similar type of observation in two tanks at Delhi.

5.4.4 Primary productivity

A direct relationship exists between temperature and amount of dissolved oxygen in freshwater impoundments (Kato, 1941 and Itazawa, 1957). It is likely that increase in temperature increases the photosynthetic rate, resulting in direct relationship as observed in the present investigation. Diel cycle of chemical parameters in water is known to be regulated by two process- photosynthesis during day time oxygen and it consumption through respiration occurring both in day and night. Productivity of the water is manifested in the degree of diel change of these parameters, more the variation more is the productivity (Das and Jha, 1999).

5.4.5 Total Alkalinity

Total alkalinity values had a wider range of diurnal fluctuation. It might be possible that greater biological productivity has resulted in the wider variation of alkalinity. The diurnal variation of chemical substances are greatly influenced by intensity of biological activity in the pond has been suggested by Hepher (1959).

5.4.6 Dissolved oxygen

There is a marked fluctuation in dissolved oxygen concentration during a 24-hour period in ponds, Concentrations of dissolved oxygen are lowest in the early morning, increase during daylight hours to a maximum in the late and decrease again in during the night. But concentration of dissolved oxygen was low during the periods of cloudy weather (Boyd, 1978). Similar trend of oxygen was also observed during the present study. The increase in dissolved oxygen might be due to photosynthetic activity and decrease in value during night might be due to absorption by community respiration. A direct relationship exists between temperature and amount of dissolved oxygen in freshwater impoundments (Kato, 1941 and Itazawa, 1957). Thus it is likely that increase in temperature increases the photosynthetic rate, resulting in direct relationship as observed in the present investigation.

5.4.7 Nutrients

5.1.7.1 Nitrate – N

Diurnal variation of nitrate-N exhibited no distinct pattern but high value was noticed in morning (Singh, 1977). Similar findings were also noted for southwest, post monsoon and northeast monsoon where as on 4^{th} to 5^{th} April, nitrate showed its high values during morning and then decreased to the lowest value at mid night and there after the values increased progressively till next morning. Singh *et al.* (1980) observed maximum concentration of nitrate during day hours.

5.1.7.2 Nitrite – N

Diurnal variation of nitrite exhibited no distinct pattern (Singh, 1977). In the present study, high values were experienced during morning hours. Singh *et al.* (1980) also observed maximum concentration of nitrite during day hours.

5.1.7.3 Phosphate – P

Phosphate values were not detected in monsoon except at 8.30 am on 13th July. Similarly, phosphate values were not detected on 23rd to 24th November. The diurnal variation of phosphate did not follow any specific pattern but the highest value was appeared at morning hours for both northeast and pre monsoon period. Singh (1977) also stated that phosphate-P exhibited no distinct pattern.

5.1.7.4 Silicate – Si

Rao and Rao (1962) stated that in general silicate values were low during night than observed during day. On 13th to 14th July the silicate value increased from morning and reached its highest value in the afternoon but at night also the values were remain high.

Summary

5. SUMMARY

1. The present study was carried out to understand the temporal variations of weather elements at Panangad, Cochin and their influence on hydrographical conditions of fish pond.

2. Fortnightly samples for hydrographical parameters and meteorological data at 3 UTC (0830 IST) and 12 UTC (1730 IST) everyday were collected during the period from June 2003 to April 2004. Hydrographical parameters like temperature, transparency, pH, total alkalinity, dissolved oxygen, water level, nitrate-N, nitrite-N, silicate-Si, phosphate-P and primary productivity were found out by standard methods. Meteorological parameters like air temperature, maximum temperature, minimum temperature, relative humidity, cloudiness, wind speed and direction were collected by using standard instruments.

3. Diurnal observation of a representative day at 3 hours interval for both weather and hydrographical parameters were carried out for all four meteorological season.

4. To study the influence of weather elements on hydrographical parameters, linear correlation coefficients were estimated.

5. Air temperature exhibited a clear double oscillation in a year, there being two maxima (one in November and other in April) and two minima during the periods of southwest and northeast monsoons. Clouding during the southwest monsoon and October was the reason for the low temperature during those periods. Higher insolation was the cause for increase in air temperature in pre monsoon months.

6. Monthly mean minimum temperature was between 22 and 25 ^{0}C and

the mean maximum temperature ranged between 29 and 35 ^{0}C. The lowest temperature (18.5 ^{0}C) was experienced in January; where as the highest temperature (35.8 ^{0}C) was experienced in March.

7. The highest rainfall was experienced during southwest monsoon and the lowest value was in March. Secondary maximum was experienced in post monsoon period.

8. Number of rainy days was more in southwest monsoon and less during the northeast monsoon and early part of the pre monsoon period. There was no month, during the period of observation, with no rainfall.

9. Relative humidity was high during southwest monsoon and low during later part of the northeast and early part of the pre monsoon period. High values of relative humidity during the southwest and post monsoon months may be due to the rainfall experienced during the period and moisture contribution of southwest monsoon wind.

10. During southwest monsoon the sky remained overcast while sky was clear during northeast monsoon and early part of pre monsoon season.

11. Wind speed showed higher value during southwest monsoon where as the lower values were experienced in December and January.

12. Water temperature in the pond showed high value in November and pre monsoon period is due to the warm weather and maximum solar radiation during the period. The low temperature was experienced during early part of the southwest monsoon and northeast monsoon season, could be attributed to the winter effect.

13. pH increased from very low values during southwest monsoon

period to high values during northeast and pre monsoon period. High pH value was possibly due to the influence of high carbonate ratio in the carbonate system. Low pH values confined to the southwest monsoon period was due to heavy rainfall.

14. Water level in the pond decreased gradually from southwest monsoon and reached its lowest value during pre monsoon period. Higher depth was due to the heavy monsoon showers. As the rainfall decreases the water level also decreased.

15. Transparency measured as Secchi depth, ranged between 10 and 60 cm. Higher readings were recorded during monsoon, which could be attributed to low plankton production. Low values were observed during northeast and pre monsoon months, which was due to the increase in plankton bloom.

16. Gross and net primary productivity showed higher value during the pre monsoon period and lowest in early part of the southwest monsoon and post monsoon period. Presence nutrient elements in high concentration and there by production of phytoplankton and algal bloom may be the possible reason for the high productivity during the northeast monsoon and pre monsoon season.

17. Total alkalinity was low in southwest monsoon period, but it increased during northeast and pre monsoon period. Higher concentration of alkalinity may be attributed to decreased in water level. In monsoon when water level increases, the total alkalinity becomes diluted.

18. Dissolved oxygen was high in southwest and northeast monsoon period, but it decreased during pre monsoon period. High value of dissolved oxygen during colder months due to low temperature and

intense photosynthetic activities of phytoplankton bloom and further fall of dissolved oxygen in pre monsoon is attributed to the death and decay of plankton and presence of organic matter.

19. Both nitrate and silicate values showed high concentrations during the southwest monsoon and pre monsoon period and the low concentrations during the post monsoon period. Phosphate and nitrite also showed high value during later part of northeast monsoon and pre monsoon months.

20. Maximum air temperature occurred in afternoon and the minimum temperatures were observed in early morning hours, but irregular variation was experienced during southwest monsoon season.

21. Short-term fluctuations in rainfall at three hours interval could be noticed during southwest monsoon period. There was no diurnal variation of rainfall for those observed in November, January and April.

22. Relative humidity was the lowest in the afternoons around the time of maximum temperature and reached high values during the time of occurrence of minimum temperature.

23. Overcast condition was observed throughout the day in southwest monsoon period but the sky was remained clear on the days of observations in post monsoon, northeast monsoon and pre monsoon period.

24. Wind speed was steady and low throughout the night but it showed a steady rise from morning and reached its maximum value in the noon and afternoon hours.

25. Water temperature in ponds usually attained the maximum in afternoon and minimum during morning hours.

26. pH showed a gradual rise from morning hours and reached maximum in afternoon and thereafter decreased during night.
27. Transparency gradually increased from morning and showed its highest value during afternoon.
28. Primary productivity was highest in between noon and afternoon hours but it varied in overcast condition.
29. Total alkalinity values showed a wide range of diurnal fluctuation.
30. Dissolved oxygen increased during daylight hours to a maximum in the afternoon and decreased in night but it varied in overcast condition.
31. The diurnal variation of nitrate-N, nitrite-N, phosphate-P did not exhibit distinct pattern but high value was observed in morning.
32. In general, during night silicate values were higher than those observed during day.
33. In the present study, linear correlation coefficients between weather and hydrographical parameters exhibit a significant relationship among them and the variations might be combine effect of all those factors. The influence may be direct or indirect. Among the weather elements the influence of air temperature and rainfall was more prominent.

34. The seasonal and diurnal changes in weather elements were equally important for the variation in hydrographical parameters.

35. Shallow water bodies quickly react to the changes in weather elements.

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TEMPORAL CHANGES IN THE WEATHER ELEMENTS AT PANANGAD REGION AND THEIR INFLUENCE ON THE HYDROGRAPHY OF A POND

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The present study was undertaken with a view to finding out the seasonal and diurnal changes of weather elements at Panangad region, seasonal and diurnal changes in the hydrographic parameters of a freshwater pond and finally to understand the possible influence of weather elements on hydrographic conditions of a pond during the four seasons viz. southwest monsoon season (June-September), post monsoon season (October-November), northeast monsoon season (December-February) and pre monsoon season (March-April) at the College of fisheries, Panangad, Cochin. Meteorological data were collected at 03 UTC (0830 IST) and 12 UTC (1730 IST) daily during the period from June 2003 to April 2004. Water samples were collected from a pond every fortnightly to analyse hydrographical parameters. To study the diurnal variation, 24-hour observation were taken at an interval of 3 hrs, once for each season. Meteorological observation includes air temperature, maximum temperature, minimum temperature, total rainfall, relative humidity, cloudiness, wind speed and direction. Hydrographic parameters like water temperature, pH, transparency, water level, total alkalinity, primary productivity, dissolved oxygen, nitrate, nitrite, phosphate and silicate were estimated.

There was a considerable seasonal variation in water qualities. The surface temperature closely followed the air temperature and exhibits a clear double oscillation. Low pH values confined to the southwest monsoon period were due to heavy rainfall. pH showed a positive relation with air temperature. At higher temperature evaporation was more and water level decreased, which leads to the higher concentration of plankton bloom and low level of transparency. Presence of nutrient elements in optimum concentration and there by production of

phytoplankton and algal bloom may be the possible reason for the high productivity during the northeast and pre monsoon periods. The low values of primary production during southwest monsoon period (June to September) and in October might be due to cloudy conditions before and during the sampling, which reduced light intensity, and along with incessant rains cut down production. The high concentration of alkalinity during pre monsoon may be due to decrease in water level due to evaporation. The effect of rainfall in decreasing bicarbonates is well known. Dissolved oxygen was at the highest level in ponds during colder months and was due to low temperature and intense photosynthetic activities. Subsequent fall of dissolved oxygen in pre monsoon period is attributed to the death and decay of plankton and presence of other organic matter. The plankton population in the pond was highest during the month of December/January to April, coinciding with the higher concentration of alkalinity and nutrients.

Diurnal variations in water temperature, pH, dissolved oxygen, alkalinity and primary productivity were well marked. Among nutrients phosphate, nitrate and nitrite did not show any specific pattern, where as silicate concentration showed well-marked short-term variation in all seasons.

Weather elements showed significant relationship with many hydrographical parameters and the variations might be due to the combined effects of all those factors. The influence may be direct or indirect. Among the weather elements the influence of air temperature and rainfall was most prominent. The seasonal and diurnal changes in weather elements were equally important for the changes in hydrographical parameters. Shallow water bodies quickly react to the changes in weather elements.