Indian Journal of Marine Sciences
Vol. 39(1), March 2010, pp. 105-113

Water quality status and Primary productivity of Valanthakad Backwater in Kerala

S Meera* & S Bijoy Nandan

School of Marine Sciences, Cochin University of Science & Technology, Cochin 682 016, India
*[E-mail: meeras.marine@gmail.com]

Received 25 March 2009; revised 294 July 2009

The water quality and primary productivity of Valanthakad backwater (9° 55′ 10. 24″ N latitude and 76° 20′ 01. 23″ E longitude) was monitored from June to November 2007. Significant spatial and temporal variations in temperature, transparency, salinity, pH, dissolved oxygen, sulphides, carbon dioxide, alkalinity, biochemical oxygen demand, phosphate-phosphorus, nitrate-nitrogen, nitrite-nitrogen as well as primary productivity could be observed from the study. Transparency was low (53.75 cm to 159 cm) during the active monsoon months when the intensity of solar radiation was minimum, which together with the run off from the land resulted in turbid waters in the study sites. The salinity in both the stations was low (0.10 ‰ to 4.69 ‰) except in August and November 2007. The presence of total sulphide (0.08 mg/ l to 1.84 mg/ l) and higher carbon dioxide (3 mg/ l to 17 mg/ l) could be due to hospital discharges and decaying slaughter house wastes in Station 1 and also from the mangrove vegetation in Station 2. Nitrate-nitrogen and phosphate-phosphorus depicted higher values and pronounced variations in the monsoon season. Maximum net primary production was seen in November (0.87 gC/ m^3/ day) and was reported nil in September. The chlorophyll pigments showed higher values in July, August and November with a negative correlation with phosphate-phosphorus and nitrite-nitrogen. The study indicated that the water quality and productivity of Valanthakad backwater is impacted and is the first report from the region.

[**Keywords:** Water quality, primary production, ANOVA, correlation analysis, Valanthakad backwater]

The wetlands are metabolically active ecosystem components which influence the nutrient loadings and serve as regulators of pelagic productivity. The backwaters, locally called as *Kayals* is an important wetland system on the south west coast of India, are under tremendous pressure due to increasing human population and rapid industrialization. The Vembanad backwater ecosystem forms the largest water body in Kerala and the third largest in the country. Studies have proved beyond doubt that, the backwaters of the State are being degraded due to various forms of pollution, reclamation and several other stress factors[1,2]. Specific studies on the water quality in relation to primary productivity of the backwater ecosystems have not been studied in depth except some of the works[3,1]. It was in this context that, this pioneering study from the Valanthakad backwater discusses the intricate variations in water quality in relation to primary productivity.

Materials and methods

Valanthakad backwater (9° 55′ 10. 24″ N latitude and 76° 20′ 01. 23″ E longitude) is situated on the eastern side of the Vembanad ecosystem having several mangrove and other fish and shell fish fauna (Fig. 1). It has been observed that many of the mangrove vegetation have been lost from the area due to man made encroachments. Regular monthly samples from the surface and bottom waters were collected between June and November 2007 from two ecologically different stations of the Valanthakad backwater for the analysis of pH, salinity, dissolved oxygen, sulphides, carbon dioxide, alkalinity, BOD_3, phosphate-

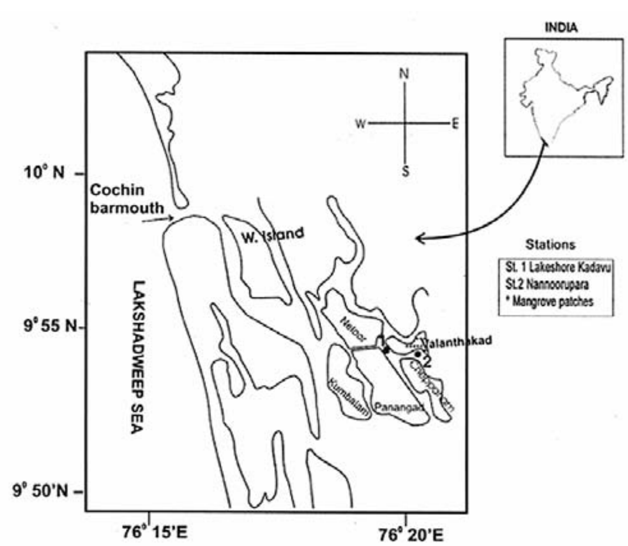

Fig. 1—Map of Valanthakad backwater and the Island located in Ernakulam District.

phosphorus, nitrate-nitrogen, nitrite-nitrogen, chlorophyll and primary productivity. Station 1 (Lake Shore Kadavu) is the main arm of the water body having an average depth of 2 meters. The Lakeshore hospital is situated on the northern banks of this station and the drainage outlets from the hospital are discharged into this zone. The slaughter house waste is also strewn in the station. The Station 2 is the mangrove zone (Nannoorupara), which received tidal discharge from the Ameda kayal having an average depth of 4 meters. Real estate groups had taken over a major area of this and adjacent zones for construction activities. Clearing of the mangrove patches is also evident in this zone.

The rainfall data from the study area was collected from the Department of Statistics, Government of Kerala. The average rainfall in the Valanthakad backwater during the period of study was 190 mm. It varied from 258 mm in June to 50 mm in November 2007.

The surface and bottom water samples were collected using a Van Dorn sampler. Temperature was measured using a 0- 50°C precision thermometer. The transparency of water was measured using a Secchi Disc. Standard methods were adopted for estimating salinity, pH, dissolved oxygen, sulphides, carbon dioxide, alkalinity, phosphate-phosphorus, nitrate-nitrogen, nitrite-nitrogen, BOD_3, and chlorophyll pigments[4-6]. Primary productivity was measured using the light and dark bottle method[7]. SPSS version 11.0 was employed to study the ANOVA and Correlation of the various parameters.

Results and Discussion

Water Quality

The water temperature recorded for the entire period of study showed wide variations. It was higher in the surface water as compared to the bottom except for two months (July and September) (Fig. 2A). A sharp fall in temperature was observed in July (27° C) which was due to rains in the study area whereas a peak was seen in November (31.5° C). The ANOVA of water temperature showed an overall significance at 1% level (R^2 = 0.875). The surface water temperature was greatly influenced by atmospheric temperature since the water body was shallow in nature having marginal difference between the surface and bottom waters. Similar observations were made in the previous studies in the Cochin and Adimalathura backwaters[8,9]. The minimum temperature was observed during the monsoon and the maximum in post-monsoon season period. A clear stratification between the surface and bottom water temperature was evident in June, July, August and November at Station 1 and in September, October and November months in Station 2. The surface and bottom temperature difference ranged from 0 to 3° C and this could be due to the tidal rhythms[8].

The transparency of estuaries is influenced by spatial, temporal and climatic variations together with tidal flow[8]. Transparency in the present study was low during the active monsoon months due to run off from the land resulted in turbid waters in the study sites (Fig. 2B). Station 1 had comparatively low light penetration depth and higher temperature as compared to Station 2. The discharge from the nearby hospital to Station 1 along with other slaughter house wastes dumped into the area could have led to low transparency in this area. The ANOVA of light penetration showed an overall significance at 1% level (R^2 = 0.827). Turbidity was also a primary factor responsible for low light penetration here as noticed in other monsoon fed tidal estuaries[10,11]. In shallow waters with muddy bottom, high turbidity may be caused by wind stirring up the bottom sediments[12]. Very low values of light penetration depth were observed in October in both stations and this could be due to the heavy rains (average 154 mm). However peak values in transparency were observed in November as reported in the earlier studies from Cochin and Adimalathura backwaters[13, 9].

Marked variations were observed in pH between the surface and bottom waters in the two stations (Fig. 2C). The pH was alkaline at Station 2 as compared to Station 1 and this could be due to the tidal influence from the adjoining Ameda kayal and Puthiyakavu kayals. Similar observations were made from Muthupettai mangroves in Tamil Nadu[2]. The ANOVA of pH showed that the variation between months was significant at 5 % level (F= 6.631) and having an overall significance at 1% level (R^2 = 0.893). The pH of the surface waters was higher compared to the bottom waters. During July, in both the study stations the pH remained mostly on the acidic side. Earlier studies have shown that pH values were low during the monsoon period due to heavy river discharges and land run off[14,15]. This agrees with the present observation. A positive correlation coefficient significant at 5% level (r^2 = 0.413) was observed between the water pH and water temperature. The B.I.S (ISI)[16] standard for pH of inland surface waters for use as raw water, public water supply and for bathing is 7.9. The Indian

Council of Medical Research (I.C.M.R.) standard for the same is 7.0 to 8.5. The pH values in the study area remained within the permissible limits except for July.

The salinity in both the stations was very low except in August and November (Fig. 2D). The ANOVA of salinity showed that the variations between months were significant at 1% level (F= 294.456) and that between surface and bottom waters was significant at 5% level (F= 8.424). The ANOVA of salinity showed an overall significance at 1% level (R^2 = 0.997). The chloride distribution followed the same trend of salinity, showing a peak in August and November. A positive correlation significant at 1% level (r^2 = 0.999) emerged between salinity and chloride content in the study sites. The peak in salinity values could be due to the total absence of rainfall with high humidity for one week prior to the sampling day. Most of the water soluble salts in an aquatic environment generally remain in the chloride form and it indicates the total amount of soluble salts present in the ecosystem [6]. During the southwest monsoon, the maximum river run off occurs and the entire lake was converted into a fresh water basin resulting in minimum salinity stratification between the surface and bottom waters as also reported from Panangad region[13]. However, in this study, the bottom water salinity was higher than that of the surface water in all the months.. Earlier studies in Cochin backwaters showed a clear stratification existed from June to November keeping the salinity layers quite distinct[17]. A positive correlation significant at 5% level emerged between salinity and transparency (r^2 = 0.695) and also between chlorides and transparency (r^2 = 0.694).

In the Cochin backwaters as temperature and salinity, dissolved oxygen also showed marked seasonal changes[8]. The average dissolved oxygen regime in both the stations during the study period showed minimum variations. The average values in Station 1 and Station 2 was 4.81 mg/ l and 4.78 mg/ l respectively (Fig. 2E). The ANOVA of dissolved oxygen showed that variations between months and stations significant at 1 % level (F= 12.594) and an overall significance at 1% level was also observed (R^2 = 0.955). The bottom water showed higher dissolved oxygen content compared to surface water except in November at Station 1 and September, October and November months of Station 2. Similar observations were reported from the inshore waters off Tuticorin[18]. Studies in Cochin estuary [17] indicated that the oxygen gradient in shallower stations remained less sharp which also agrees with the present study. The comparatively high dissolved oxygen content in both stations during the entire study period could be due to the higher solubility of oxygen in colder and less saline waters as reported in the previous works from different backwaters[13, 9]. Local production, diffusion and advection, exchange of oxygen across the surface and biochemical utilization were the controlling factors for dissolved oxygen in many aquatic environments[19]. The B.I.S (ISI) standard for dissolved oxygen is 3 mg/ l for inland surface water, whereas I.C.M.R proposes 5.0 ml/l. The dissolved oxygen values for the study area remained within the permissible limits (4 mg/l- 6.2 mg/l).

The sulphide concentration in both the stations was low, showing a clear stratification between the surface and bottom waters. The stratification was seen in most of the months except in November at Station 1 and August and September in Station 2. The average values of sulphide in Station 1 and 2 were 0.81 mg/ l and 0.65 mg/ l respectively (Fig. 2F). The higher value in Station 1 could be due to the hospital discharges and other sources like agricultural and fishing activities. The presence of sulphide in Station 2 could be due to the decaying mangrove vegetation. Mangrove leaves takes minimum of 10 days to get decomposed in the field suggesting that there is every possibility of transport of more than 50% of the mangrove leaves before it gets mineralized[20]. The ANOVA of sulphide showed that the variations between months was significant at 1 % level (F= 35.5) and also an overall significance at 1 % level (R^2 = 0.975).

In both the Stations 1 and 2, during the October-November period, there was considerable rise in CO_2 values, which could be due to the hospital discharges in Station 1 and the organic enrichment due to mangrove litter at Station 2 (Fig. 2G). A similar rise in CO_2 values from the retting grounds due to organic enrichment was reported[21]. The ANOVA of free carbon dioxide showed the variations between months were significant at 1 % level (F= 49.84) and gave an overall significance at 1% level (R^2 = 0.981). Therefore from this study, due to the high level of carbon dioxide the area may not be suitable for fish production. Earlier studies have reported that, for good fish production usually less than 5 mg/l of free carbon dioxide[22] is recommended.

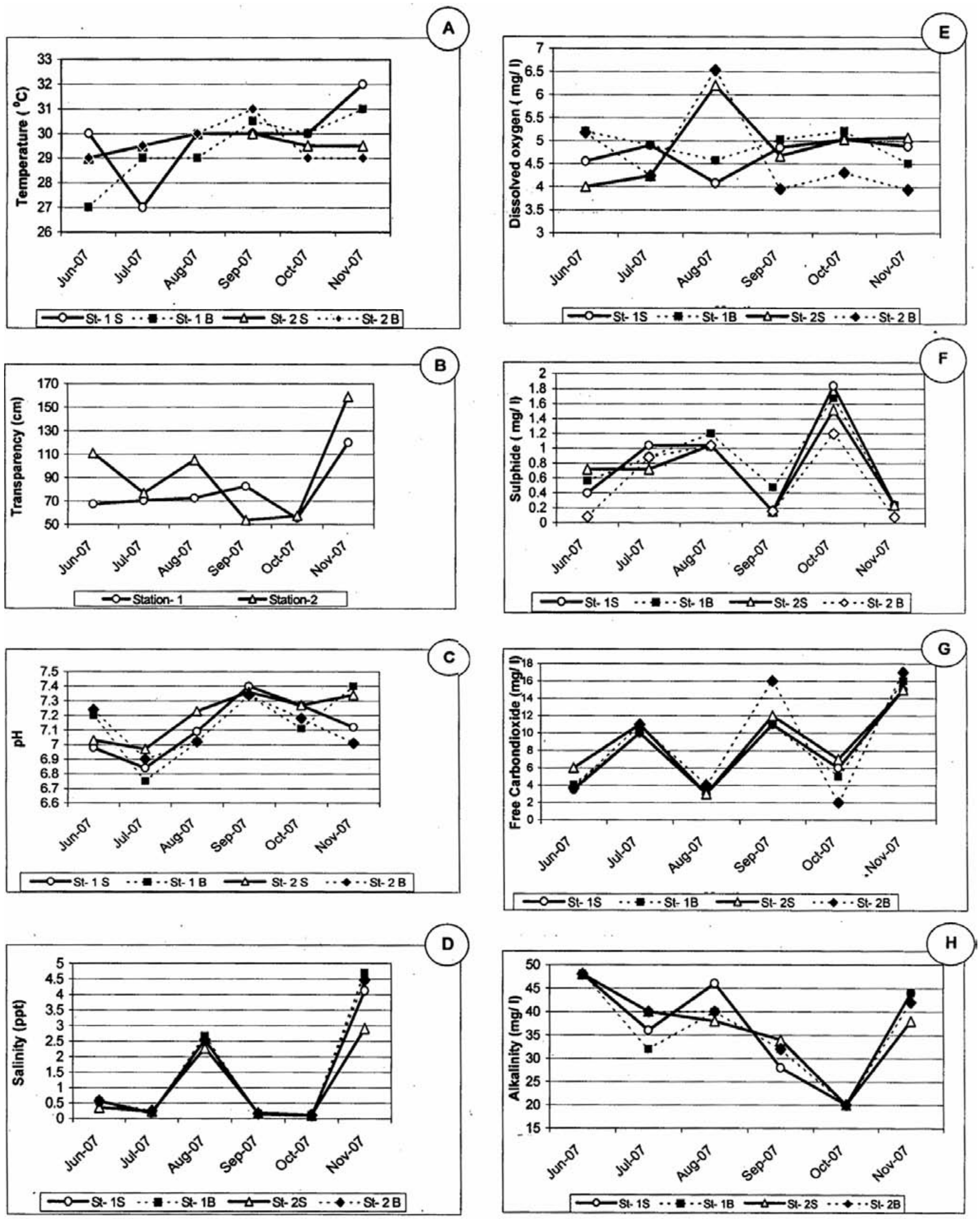

Fig. 2—Variations of temperature, transparency, pH, salinity, dissolved oxygen, sulphide, carbon dioxide and alkalinity in Valanthakad backwater from June to November 2007

Alkalinity of surface waters is primarily a function of carbonates, bicarbonates and hydroxide content and it is taken as an indication of the concentration of these constituents. The measured values also may include contributions from borates, phosphates, silicates or other bases if these are present[6]. Alkalinity in both surface and bottom waters, in both the stations were generally low as compared to earlier studies[23]. From these studies the alkalinity values greater than 100 mg/l was classified as highly productive and those with less than 50 mg/ l as oligotrophic. The average values of alkalinity reported in Station 1 and Station 2 during the present study were 36.50 mg/ l and 36.67 mg/ l respectively (Fig. 2H). So the study sites in the Valanthakad backwater system were not very conducive for fish production. The ANOVA of alkalinity showed that the variation between months were significant at 1% level (F= 66.618) and an overall significance at 1% level (R^2 = 0.986). The uptake or release of carbon dioxide by organisms can change the proportion of carbonate and bicarbonate ions in water[24]. This could be the reason for the generally low alkalinity coupled with higher CO_2 values in the both the study stations. A positive correlation significant at 5% level (r^2 = 0.449) was observed between alkalinity with salinity and chloride. A negative correlation significant at 1 % level (r^2 = -0.561) was also observed between alkalinity and total sulphide in both the zones.

The phosphate-phosphorus values were maximum during the monsoon period (June) and minimum during the post monsoon period (November) (Fig. 3A). Allochthonus sources brought in sediment and other organic matter during heavy rains into the ecosystem that could have led to the increase in phosphate concentration during the monsoon period. Studies conducted in various estuaries have reported the export of large quantities of dissolved inorganic nutrients like phosphate, nitrate, and nitrite to the adjacent estuarine or coastal waters through tidal movement[25, 26]. The ANOVA of phosphate showed that the variations between months (F= 290.866), stations (F= 34.657), months × station (F= 32.569) and months × surface and bottom water interactions (F= 25.92) were significant at 1% level. Variations between surface and bottom waters were significant at 5 % level (F= 11.138). The ANOVA of phosphate showed an overall significance at 1% level (R^2 = 0.997). In the present study, the mangrove zone at Station 2 recorded higher phosphate concentration as compared to Station 1. A negative correlation significant at 5% level (r^2 = -0.503) emerged between phosphate and salinity and also between phosphate and chlorides (r^2 = -0.504). The peak value is in monsoon and low values in the post monsoon period. Similar observations were made in the post monsoon and pre monsoon periods in the Muthupettai mangrove system in Tamil Nadu[2]. The ANOVA of nitrate showed that the variation between months were significant at 5% level (F= 7.168) and an overall significance at 1% level (R^2 = 0.909). The ANOVA of nitrite showed that the variation between months were significant at 1% level (F= 17.826) and gave an overall significance at 1% level (R^2 = 0.958). The nitrite values were very low than nitrate nitrogen in the present study. The studies in Cochin backwaters[17] revealed that during most of the year, nitrite values were very low than those of nitrate. The nitrate (Fig 3B) and nitrite values (Fig 3C) observed in the present study were in agreement with that in the Cochin backwaters. This higher nitrate content concomitant with low nitrite could have resulted from the nitrification process as reported from the Kadinamkulam estuary[21]. A decline in the values of phosphate, nitrate and nitrite were observed in the August in all the stations and this could be due to the nutrient uptake by phytoplankton. A negative correlation significant at 5% level (r^2 = -0.624) was observed between nitrate and transparency, that with nitrate and salinity significant at 1% level (r^2 = -0.641) and also with chlorides (r^2 = -0.640) significant at 1% level. In addition a negative correlation significant at 1% level (r^2 = -0.645) was observed between nitrate and alkalinity.

BOD_3 values did not exhibit any clear stratification in surface and bottom waters in both the stations, however in June the variations between the surface and bottom waters were very prominent (Fig. 3D). The average BOD_3 values reported in Station 1 and Station 2 during the present study were 3.11 mg/l and 3.04mg/l respectively. In June BOD_3 values were very low in the surface waters at both stations. This could be due to the flushing of the surface waters by the monsoon showers. In August in Station 2 high values for BOD_3 was observed. This could be due to the effect of dead and decaying mangrove vegetation in this zone which inturn led to a rise in BOD_3 in this study area. The average BOD_3 values for Station 1 were marginally higher as compared to Station 2. This could be due to the intense stress arising from the hospital discharges, slaughter house wastes and other domestic sources in the area. The ANOVA of BOD_3 showed an overall significance at 1% level (R^2 = 0.907). The comparatively high BOD_3 was concomitant with the marginally higher sulphide value in both the stations. Similar observations were made from the retting zones [27]. In the present study a positive correlation emerged between BOD_3 and dissolved oxygen (r^2 = 0.587) significant at 1% level. However, it was observed that this relationship should have emerged due to the minimum variation in these parameters in both the study sites. If a more pronounced variation should have occurred between these parameters, a negative inverse relationship should have emerged as cited in the previous works[27]. A negative correlation significant at 5% level (r^2 = -0.458) was observed between BOD_3 and alkalinity, also with nitrate (r^2 = -0.449). Whereas negative correlation significant at 1 % level (r^2 = -0.645) was observed between BOD_3 and phosphate. According to B.I.S (ISI) standard the permissible level of BOD_3 in the inland surface waters is 20 mg/ l whereas that of I.C.M.R., the standard permitted is 5.0 mg/ l. The BOD_3 in the present study was mostly within the permissible levels.

A clear stratification between the surface and bottom water gross and net productivity was seen at both the stations. The gross and net primary productivity was higher in Station 1 when compared to Station 2 (Fig. 3E). Maximum gross production was observed (3 gC/ m^3/ day) during November at Station 1 in the surface water, while minimum (0.24 gC/ m^3/day) was seen at both Station 1 (June) and Station 2 (August) in the bottom waters. The corresponding maximum and minimum values of net production were 1.80 gC/m^3/ day (Station- 1, November) and 0.12 gC/ m^3/day (Station 1, July) respectively (Fig. 3F). The rate of primary production in the Vembanad Lake was uniformly high, the maximum being 3 gC/ m^2/day with an average of 1.2 gC/m^2/day[28]. From the previous studies it was seen that an annual mean of 0.753 gC/ m^3/ day of gross productivity and 0.603 gC/ m^3/day of net productivity was reported from Cochin backwaters[29]. The gross and net productivity values observed in the present study were similar to the studies conducted in Vembanad and Cochin backwaters. In the present study, nil values were obtained for the net productivity in certain months in station 2 and for a single month (September) in Station 1. The monsoon and post monsoon periods showed higher gross productivity in both the stations in the present study. This agreed with the findings from Cochin backwater[13].

The zone of optimum illumination for maximum photosynthesis was found between 0 and 1.5 m[30]. Since sharp drop in production is not seen during monsoon, salinity did not seem to control the production[31], and during the post monsoon season, the steady light intensity induces effective utilization of nutrients brought by monsoon run off, leading to increase in production[13]. A similar trend could be observed in the productivity of the Valanthakad lake system. The ANOVA of gross productivity showed an overall significance at 1% level (R^2 = 0.837). The net productivity showed variations between months (F= 14.08) and between the surface and bottom waters (F= 10.839). It were significant at 1% level. Variation between stations (F= 25.187), months x stations (F= 6.033) and stations x surface and bottom water (F= 9.311) were significant at 5 % level. The ANOVA of net productivity showed an overall significance at 1% level (R^2 =0.970). A positive correlation significant at 1 % level (r^2 = 0.679) was observed between gross and net primary productivity.

The chlorophyll pigments showed peaks in July, August and November. The chlorophyll values corresponded to the gross and net primary productivity patterns in the two stations.

The chlorophyll-*a* concentration ranged from 0.005 µg/ l to 0.032 µg/ l (Fig. 3G). Earlier studies on chlorophyll conducted in the Vembanad Lake[28] reported an annual range of 2 to 21 mg/ m^3. The chlorophyll-*b* values were found to be always less than the values of chlorophyll-*a* in the present study. The chlorophyll- *a, b, c* values in Station 1 and Station 2 in the present study were low as compared to that reported in other backwaters[32] and from the inshore waters of Tuticorin[33]. The ANOVA of chlorophyll *a* showed an overall significance at 1% level (R^2 = 0.995). The ANOVA of chlorophyll *a* showed that the variations between months were significant at 1% level (F= 173.14). Variations between surface and bottom water (F= 8.1), months x stations (F= 10.9), months x surface and bottom waters (F= 10.92) were also significant at 5 % level. The ANOVA of chlorophyll *b* showed the variation between months were significant at 1% level (F= 20.572) and an overall significance at 1% level (R^2 = 0.959). The ANOVA of chlorophyll *c* showed the variation between months were significant at 1%l evel (F= 53.952) and an overall significance at 1% level (R^2 = 0.983).

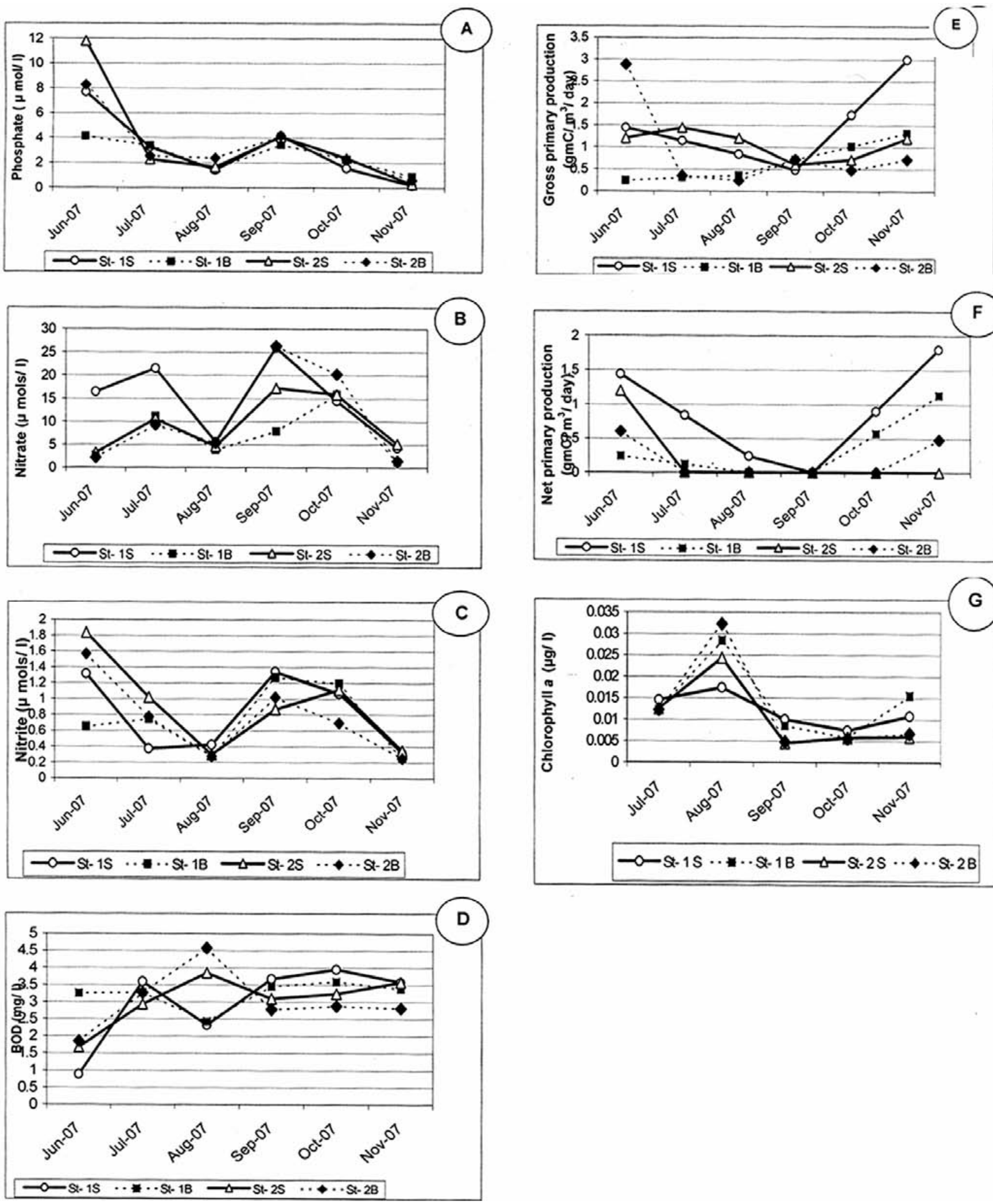

Fig. 3—Variations of nutrients, BOD_3, primary productivity and chlorophyll pigments in Valanthakad backwater from June to November 2007

The phosphate, nitrate and nitrite values were found to increase during the June, July, September and October. The comparatively high primary productivity and chlorophyll- *a* coincided with low nitrate, nitrite and phosphate values in the present study. Similar observations were reported from the inshore waters of Tuticorin[33]. A negative correlation significant at 5 % level (r^2 = -0.511) was observed between chlorophyll *a* and phosphate and also with nitrate at 1 % level (r^2 = -0.647). These observations concur with the studies conducted in Cochin Backwaters[34] and in Ashtamudi estuary [35].

Acknowledgement

Authors are grateful to Head, Dept. of Marine Biology, Microbiology and Biochemistry, Cochin University of Science and Technology for providing necessary facilities

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