3. PRIMARY PRODUCTION

3. Primary Production

3.1. Introduction

The fishery resource of any water body depends mainly on the magnitude of primary and secondary production which in turn are influenced by various physical, chemical and biological factors.

Primary productivity of a particular water body gives a quantitative information about the amount of energy available to support bioactivity of the system. The rate and extent of organic production in a water body are controlled by several factors and it is the collective action of all these result in the primary production. Factors such as temperature, nutrient cycles and such physiological conditions of plankton that affect respiration would affect the primary production quite apart from the varying light intensities. Phytoplankton or the planktonic algae give the production at the primary stages of the food chain, while zooplankton and fish at the secondary and tertiary levels of the food chain respectively (Qasim, 1977).

3.2. Review of Literature

Several studies have been carried out on the primary production of the waters of different ecosystems of the world. The role of primary productivity in the oceans of temperate and subtropical waters was studied in detail by Raymont (1980). The primary productivity of the Danish Wadden sea was reported by Postma and Rommets (1970). Jordan *et al.* (1991) analysed the nutrients and chlorophyll at the interface of a watershed and estuary. Delgadillo-Hinojosa (1997) studied the effect of vertical mixing on primary production in a Bay of the Gulf of California. Iriate *et al.* (1997) studied primary planktonic production, respiration and nitrification in shallow temperature estuary during summer.

In India several reports on primary production are available from the east coasts. Steemann Nielsen and Jensen (1957), Radhakrishnan *et al.* (1978) and Bhattathiri *et al.* (1980) carried out studies on primary production in the Bay of Bengal. Venugopalan (1969), Bhatnagar (1971), Sundararaj and Krishnamurthy (1974), Vijayalakshmi and Venugopalan (1975), Purushothaman and Bhatnagar (1976), Subramanian *et al.* (1977), Subramanian and Venugopalan (1978), Sundararaj (1978), Sivakumar (1982), Chandran (1982) and Thangaraj (1984) studied the primary production in the Vellar estuary. Bhatnagar (1971) studied primary organic production in Kille backwaters of Porto Novo. Jagadeesan (1986) studied the primary production in Coleroon estuary. Balusamy (1988) studied the primary production in Muthupet estuary.

Along the west coast, Qasim and Reddy (1967), Qasim *et al.* (1968, 1969, 1974), Qasim and Gopinathan (1969), Pillai *et al.* (1975) and Nair *et al.* (1984) carried out primary production studies in the Cochin estuarine system. Dehadrai (1972), Dehadrai and Bhargava (1972), Bhattathiri *et al.* (1976) and Bhargava *et al.* (1977) have investigated the primary productivity of Mandovi and Zuari estuaries of Goa. Nair *et al.* (1979) studied the primary production in the Vembanad lake. Nair *et al.* (1983, 1984) analysed the primary production in Ashtamudi and Kadinamkulam backwaters. Gopinathan (1975) estimated the rate of primary production in Veli lake. Shibu (1991) studied the primary production in Paravur lake. Bijoy Nandan (1991) studied the primary production in relation to coconut husk retting in Kadinamkulam estuary.

The plant pigment concentration of estuaries and coastal waters is considered as one of the important factors affecting the primary productivity (Cadee and Hegeman, 1974, Hung *et al.,* 1979, Ferguson and Palumbo, 1979 and Grantham, 1981). Investigations on phytoplankton pigments in temperate waters in relation to available dissolved nutrients were made by Curl and Small (1965), Thomas (1970) and Glooschenko and Curl (1971). In the east coast of India, plant pigment analysis was made by Santhakumari (1969), Krishnamurthy (1969 and 1971), Krishnamurthy and Purushothaman (1971), Sundararaj and Krishnamurthy (1974), Vijayalakshmi and Venugopalan (1975), Purushothaman and Bhatnagar (1976), Subramanian and Venugopalan (1978), Sundararaj (1978), Venugopalan *et al.* (1981), Sivakumar (1982), Chandran (1982), Thangaraj (1984), Jegadeesan (1986), Prabha Devi (1986), Balusamy (1988) and Gopinathan *et al.* (1994).

In the west coast of India, the studies on chlorophyll concentration were those of Qasim and Reddy (1967) and Qasim and Gopinathan (1969) in Cochin backwaters, Dehadrai (1972), Bhargava and Dwivedi (1973), Balasubramanian (1974) and Dwivedi *et al.* (1974) in Mandovi and Zuari estuaries, Gajbhiye *et al.* (1981) in Narmada estuary, Desai *et al.* (1984) in Auranga, Ambika, Purna and Mindola estuaries of Gujarat. Bijoy Nandan and Abdul Azis (1996) studied the primary productivity and zooplankton of the retting zones in the Kadinamkulam estuary.

In the present study, an attempt has been made to record the seasonal variations of gross and net primary production and chlorophyll ‘a’, ‘b’ and ‘c’ in relation to physico-chemical parameters, nutrients, phytoplankton and zooplankton at three stations in Manakkudy estuary.

3.3. Materials and Methods

The primary productivity was estimated on the basis of changes in dissolved oxygen using light and dark bottles as described by Strickland and Parsons (1972). Monthly tests were conducted during day light hours in the three stations. At each station, light and dark bottles (one each) were used. BOD bottles of 300 ml were used and the samples were incubated *in situ* for a period of four hours. The rate of primary production is expressed as mg c/m^3/hour.

Plant pigments were estimated in one litre of water following the method given by Strickland and Parsons (1972). The water samples were filtered through Whatman GF/C filter paper pre-coated on the surface with 1 percent magnesium carbonate solution. The filtrate in the filter paper was allowed to dissolve in 10ml of 90 percent acetone by soaking the filter paper for 24 hours in a refrigerator, crushing the filter paper in a tissue grinder and after centrifugation, the supernatant was measured for pigments at wavelengths of 665, 645 and 630 μ spectrophotometrically and the values were calculated as mg/m^3.

3.4. Results

3.4.1. Gross Primary Production

Monthly variations of gross and net primary production at station I, II and III during 1990-'91 and 1991-'92 are given in Fig. 3.1.

The gross primary production at station I fluctuated between 9 mg c/m^3/hr. in February and 99 mg c/m^3/hr. in May during 1990-'91 and between 23 mg c/m^3/hr. in November and 82 mg c/m^3/hr. in March during 1991-'92.

At station II it varied between 17 mg c/m^3/hr. in November and 154 mg c/m^3/hr. in May during 1990-'91 and from 15 mg c/m^3/hr. in June to 164 mg c/m^3/hr. in May during 1991-'92.

At station III the gross primary production ranged from 24 mg c/m^3/ hr. in November to 122 mg c/m^3/hr. in June during 1990-'91 and from 19 mg c/m^3/hr. in November to 128 mg c/m^3/hr. in May during 1991-'92.

3.4.2. Net Primary Production

The seasonal variation of net primary production followed the pattern of gross primary production at all the three stations throughout the study period. At station I the net primary production of the water fluctuated between 6 mg c/m^3/hr.in February and 69 mg c/m^3/hr. in May during 1990-'91 and between 17 mg c/m^3/hr. in November and 61mg c/m^3/hr. in March during 1991-'92.

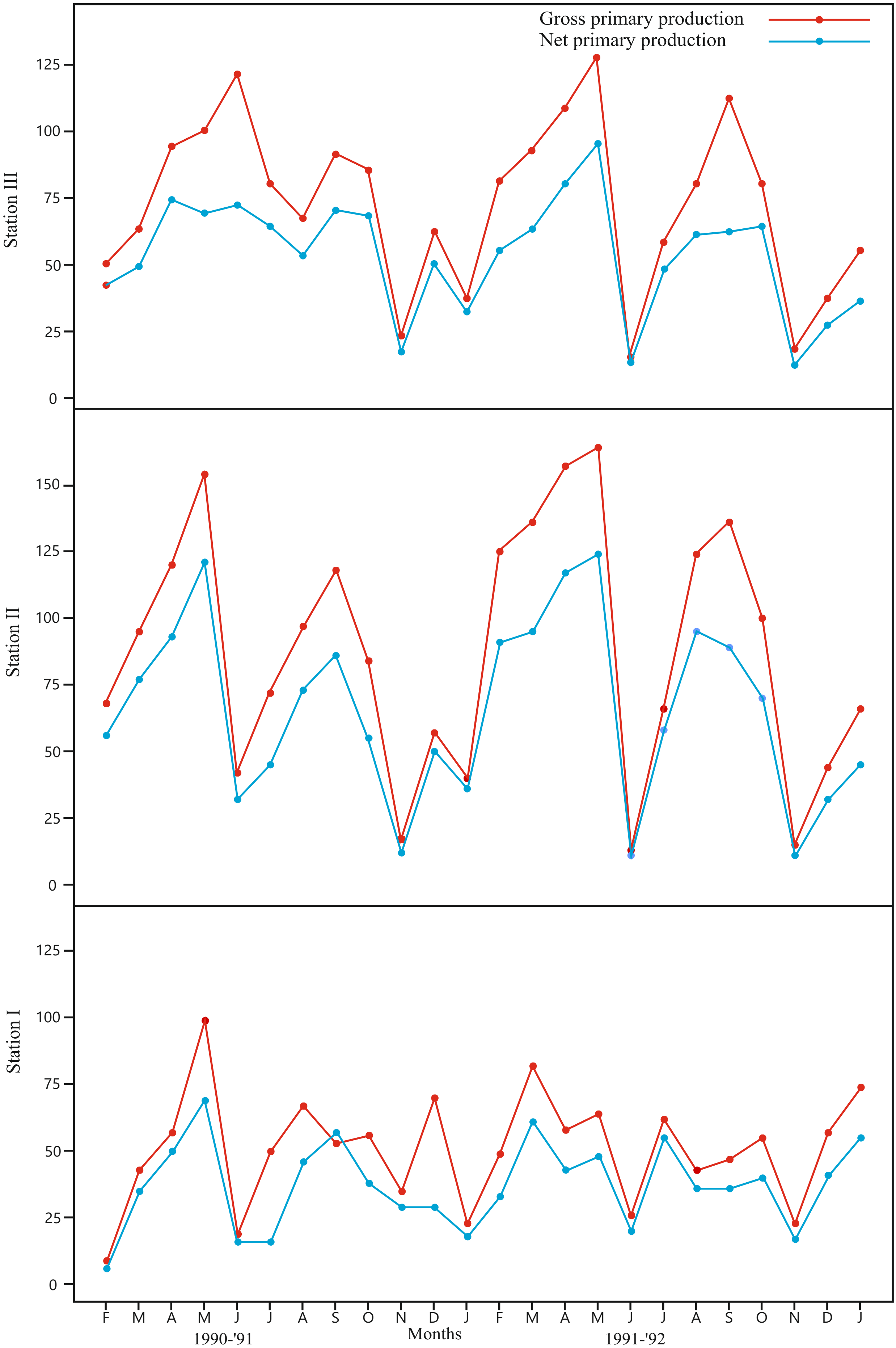

Fig. 3.1: The variations in gross and net primary productions at station I, II and III during 1990-'91 and 1991-'92.

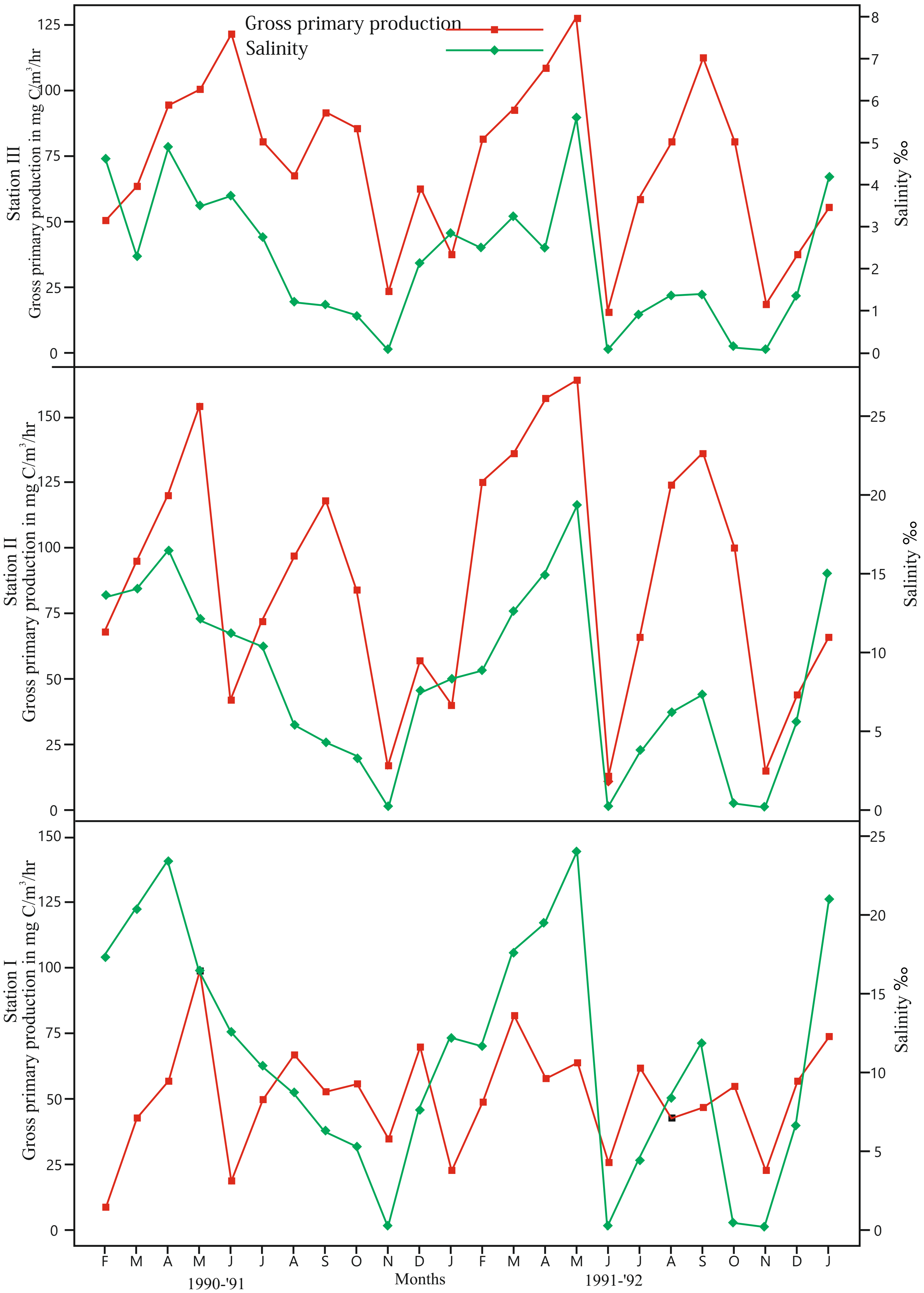

Fig. 3.2: The relationship between gross primary production and salinity at station I, II and III during 1990-'91 and 1991-'92.

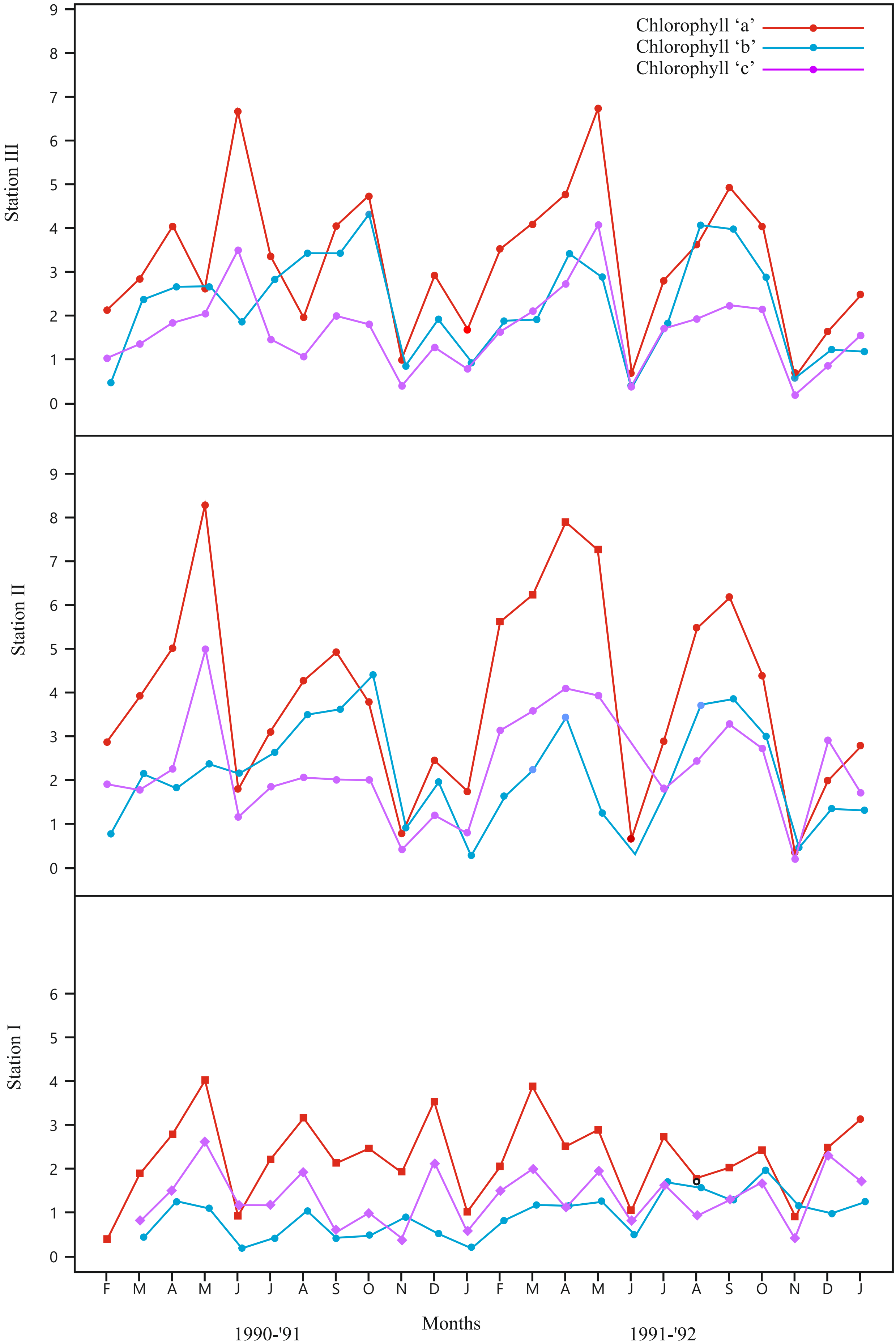

Fig. 3.3: The variations in chlorophyll 'a', 'b' and 'c' concentrations at station I, II and III during 1990-'91 and 1991-'92.

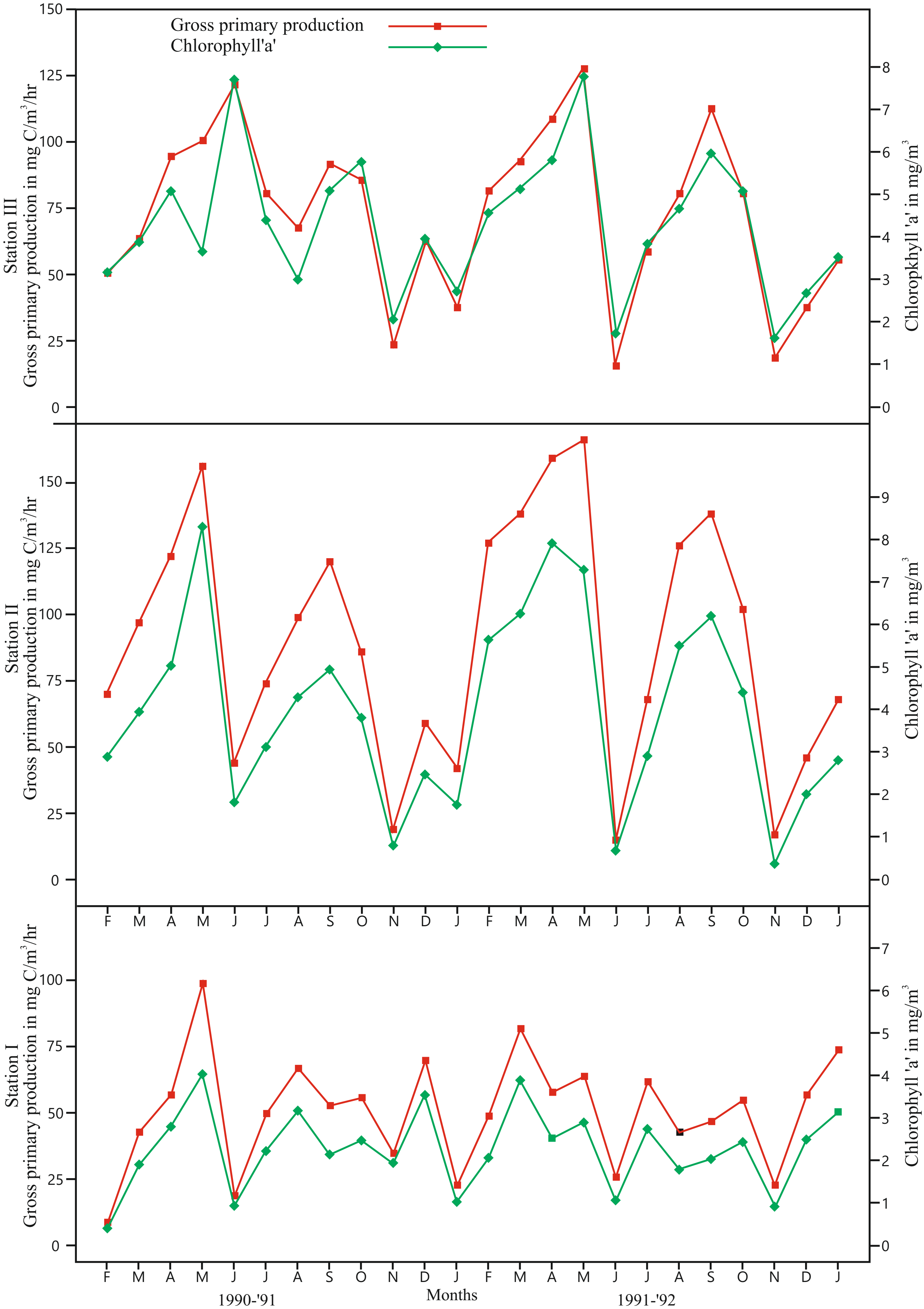

Fig. 3.4: The relationship between gross primary production and chlorophyll 'a' at station I, II and III during 1990-'91 and 1991-'92.

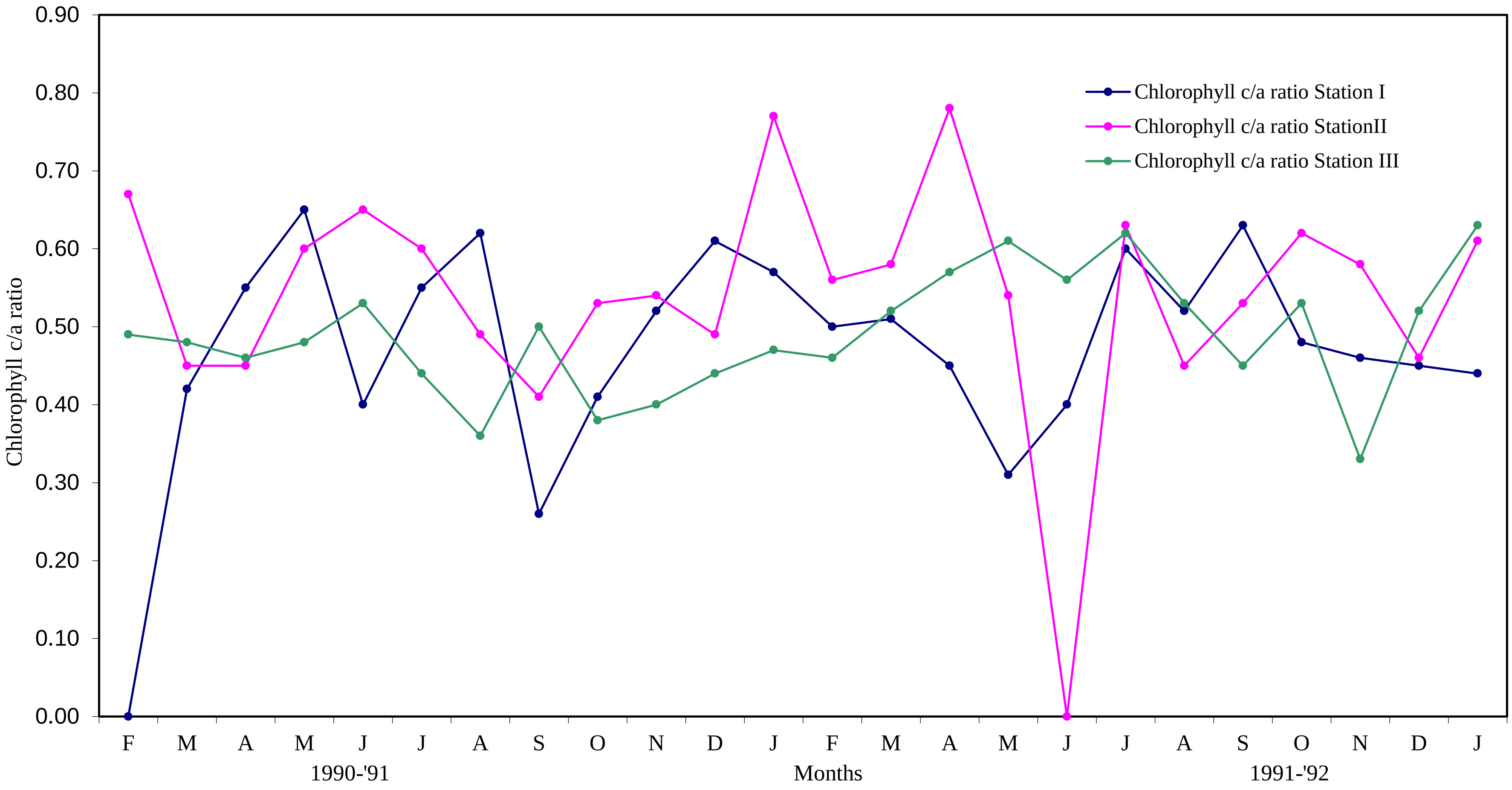

Fig. 3.5: Variations in chlorophyll c/a ratio
at station I, II and III during 1990-'91 and 1991-'92.

At station II it ranged from 12 mg c/m^3/hr. in November to 121mg c/m^3/hr. in May during 1990-'91 and from 11 mg c/m^3/hr. in November to 124 mg c/m^3/hr. in May during 1991-'92.

The net primary production at station III varied between 18 mg c/m^3/hr. in November and 75 mg c/m^3/hr. in April during 1990-'91 and between 13 mg c/m^3/hr. in November and 96 mg c/m^3/hr. in May during 1991-'92.

3.4.3. Chlorophyll 'a'

The results obtained for chlorophyll 'a' were presented in Fig. 3.3.

The concentration of cholorophyll 'a' at station I ranged from 0.42 mg/m^3 in February to 4.05 mg/m^3 May during 1990-'91 and from 0.42 mg/m^3 in November to 3.91 mg/m^3 in March during 1991-'92.

At station II it ranged between 0.79 mg/m^3 in November and 8.3 mg/m^3 in May during 1990-'91 and between 0.36 mg/m^3 in November and 7.92 mg/m^3 in May during 1991-'92.

At station III it fluctuated between 0.41 mg/m^3 in November and 6.68 mg/m^3 in June during 1990-'91 and between 0.59 mg/m^3 in November and 6.75 mg/m^3 in May during 1991-'92.

3.4.4. Chlorophyll 'b'

The concentration of chlorophyll 'b' recorded during the period of study is given in Fig. 3.3.

At station I the concentration of chlorophyll 'b' fluctuated between 0.33 mg/m^3 in January and 1.92 mg/m^3 in November during 1990-'91 and from 0.63 mg/m^3 in June to 2.12 mg/m^3 in October during 1991-'92.

The chlorophyll 'b' concentration at station II ranged between 0.42 mg/m^3 in January and 4.56 mg/m^3 in October during 1990-'91 and between 0.6 mg/m^3 in November and 4.01 mg/m^3 in September during 1991-'92.

At station III it varied from 0.61 mg/m^3 in February to 4.33 mg/m^3 in October during 1990-'91 and from 0.31 mg/m^3 in June to 4.21 mg/m^3 in August during 1991-'92.

Compared to the values of chlorophyll 'a' and 'c', the values recorded for chlorophyll 'b' are low. It was completely absent in February 1990-'91 and June 1991-'92.

3.4.5. Chlorophyll 'c'

The results obtained on seasonal variation of chlorophyll 'c' are presented in Fig. 3.3.

The chlorophyll 'c' concentration at station I varied from 0.59 mg/m^3 in November to 2.63 mg/m^3 in May during 1990-'91 and from 0.43 mg/m^3 in November to 2.01 mg/m^3 in March during 1991-'92.

At station II the concentration of chlorophyll 'c' fluctuated between 0.43 mg/m^3 in November and 5.01 mg/m^3 in May during 1990-'91. and between 0.21 mg/m^3 in November and 4.12 mg/m^3 in April during 1991-'92.

At station III it ranged between 0.41 mg/m^3 in November and 3.51 mg/m^3 in June during 1990-'91 and from 0.20 mg/m^3 in November to 4.09 mg/m^3 in May during 1991-'92.

The values of chlorophyll 'c' were lower than that of chlorophyll 'a' but slightly higher than that of chlorophyll 'b'.

3.4.6. Chlorophyll c/a Ratio

The seasonal variations of chlorophyll c/a ratio at different stations during 1990-'91 and 1991-'92 are shown in Fig. 3.5.

The c/a ratio was 0 in February at station I during 1990-'91 and in June at station II during 1991-'92 because chlorophyll 'c' was completely absent.

At station I the c/a ratio varied from 0.26 in September to 0.65 in May during 1990-'91 and during 1991-'92 it varied from 0.31 in May to 0.63 in September.

At station II it ranged between 0.41 in September and 0.77 in January during 1990-'91 and between 0.45 in August and 0.78 in April during 1991-'92.

At station III it fluctuated from 0.36 in August to 0.53 in June during 1990-'91 and from 0.33 in November to 0.63 in January during 1991-'92.

3.5. Statistical Treatment

The mean and standard error of primary production and chlorophyll are presented in Table 3.1. Simple correlation of primary production and chlorophyll with rainfall is presented in Table 3.2. The results of regression analysis with correlation for primary production and chlorophyll are presented in Tables 3.3 to 3.17.

3.5.1. Gross Primary Production

The average gross primary production was different in different years. During 1990-'91 in station I the average gross primary production was significantly lower when compared to other two stations which were on par with each other. In 1991-'92, the average gross production in station II was significantly higher than that in station I, but it was on par with that in station III. However, the average values in station I and III were on par with each other. The maximum value recorded was 164 $mg/c/m^3/hr.$ in station II in 1991-'92 and minimum (9.00 $mg/c/m^3/hr.$) in station I in 1990-'91.

The results presented in the tables reveal that there was difference in the performance of the physico-chemical parameters towards gross production. However, in the same year some similarity was seen in all the 3 stations. Regarding station I in 1990-'91 chlorophyll 'a', 'b' and 'c' could improve the gross production still more. That is, a unit increase in chlorophyll 'a', 'b' and 'c' could further increase the gross production to 20.156, 22.209 and 28.441 units. As per the results, no other parameter in this year could help for increasing the gross production any more. The case was different in 1991-'92. In this year in the same station the parameters silicate, total phosphorus, inorganic phosphate, nitrite, nitrate were already in excess and any more increase in these parameters would further reduce the gross production to 0.236, 22.391, 21.917, 2.783 and 73.742 units respectively. However, the favourable parameters in this were salinity at surface, salinity at the bottom and chlorophyll 'c'. These could help in increasing the gross production to 1.417, 1.256 and 32.147 units. In both the years H_2S had shown negative association with gross primary production. That is, increase in H_2S would reduce gross primary production.

Regarding station II in 1990-'91 all the three chlorophylls were contributing for gross production as in station I. Apart from these factors here surface temperature was a contributing factor and nitrite was having adverse effect on gross production. That is, an unit increase in surface temperature, chlorophyll 'a', chlorophyll 'b' and chlorophyll 'c' would increase the gross production further to 11.993, 16.664, 15.916 and 30.682 units respectively where as an unit increase in nitrite further would reduce the gross production to 113.07 units. In 1991-'92 salinity at the surface and bottom, pH at the surface and bottom, and all the 3 chlorophylls would contribute for further gross production and any more increase in oxygen at the surface and bottom, silicate, total phosphorus, inorganic phosphate, nitrate and nitrite would bring down the gross production considerably. For the same station in 1991-'92 any more increase in salinity at the surface and bottom, pH at the surface and bottom, and all the three chlorophylls would further increase the gross production and any more increase in oxygen at surface and bottom, silicate, total phosphorus, inorganic phosphate, nitrate, nitrite would further reduce the gross production still further.

In the case of station III the behaviour of the chlorophylls was identical in 1990-'91 whereas nitrite alone had adverse effect on gross production. In 1991-'92 salinity at the surface and bottom, chlorophyll 'b' and chlorophyll 'c' had positive effect on gross production and silicate, inorganic phosphate and nitrate had adverse effect on gross production.

In general, a seasonal pattern in gross primary production was observed at all the three stations during the study period. The annual average gross primary production was high at station II, the estuarine zone and low at station I, the marine zone during both the years. The seasonal average gross primary production showed maximum values during pre-monsoon and minimum values during monsoon period at all the stations except station I where during 1990-'91 minimum values were recorded in the post-monsoon season. The annual average gross primary production was higher for 1991-'92. Rainfall has no correlation with gross primary production. Higher values of gross primary production coincided with higher values of salinity, oxygen, pH, nutrients except nitrite, plant pigments, phytoplankton and zooplankton but with lower values of H_2S.

3.5.2. Net Primary Production

The values of average net primary production computed for the two years showed complete non-significant difference over the three stations in both the years. However, station II had recorded a maximum of 124 mg c/m^3/hr. in 1991-'92 and station I had recorded a minimum of 6.0 mg c/m^3/hr. in 1990-'91.

As in the case of gross production, in the net primary production also same set of parameters were used with the net primary production. As in the case of gross production the behaviour of the parameters were similar over the three stations in the same year and different over different years. The reason might be the same as quoted earlier. In the case of station I in 1990-'91 the bottom water temperature and the three chlorophylls had positive effect towards the addition of net primary production and no ill effect by any of the included parameters except H_2S. In 1991-'92 salinity at the surface and bottom, chlorophyll 'a' and chlorophyll 'c' had positive effect on net primary production where as total phosphorus, inorganic phosphate, nitrate and nitrite had adverse effect on net primary production.

In the case of station II in 1990-'91 chlorophyll 'a' and 'c' had positive effect on net primary production where as silicate, nitrate and nitrite had adverse effect on net primary production. In 1991-'92 chlorophyll 'b' alone had positive effect and no ill effect by any of the parameters chosen.

In station III in 1990-'91 as in the previous cases, all the three chlorophylls had positive effect on net primary production, where as nitrite alone had ill effect on net primary production. In 1991-'92 also all the chlorophylls had positive effect on net primary production. Apart from this, salinity at the surface and bottom and pH at the bottom had added positive effect on net primary production and the parameters total phosphorus, inorganic phosphate, nitrate and nitrite had adverse effect on net primary production. Summing up, the chlorophylls had favourably acted towards gross production and net primary production in almost all the stations in both the years and nitrate and nitrite had their ill effects throughout for gross and net production.

Since all the three chlorophylls had contributed positively for gross and net production in almost all the stations in both the years, it made the researcher to know what might be the causes for the growth of these chlorophylls among the other parameters. In order to know this action, all the chlorophylls were treated separately as dependent variables and the remaining physico-chemical parameters were used as the choice variables in all the three stations on both the years.

The annual average net primary production was high at station II and low at station I. The seasonal average net primary production was found maximum during monsoon season and minimum during post-monsoon season at all the three stations except station I where during 1990-'91 minimum values were recorded in the premonsoon season. The annual average of net primary production was high during 1991-'92.

Net primary production was positively correlated with salinity, oxygen, pH, nutrients, plant pigments, phytoplankton and zooplankton but negatively correlated with hydrogen sulphide.

3.5.3. Chlorophyll 'a'

The average value of the chlorophyll 'a' recorded stationwise over the two years did not vary significantly in both the years. The maximum of 8.3 mg/m^3 was recorded in station II in 1990-'91 and the minimum of 0.36 mg/m^3 was recorded in station II in 1991-'92.

Regarding this, the cause seems to be different over different years and different over different stations. In station I in 1990-'91 H_2S on the surface alone had an effect which was adverse and no other parameter was the cause for anything. In 1991-'92 in the same station, salinity at the bottom and surface and pH were favouring factors for chlorophyll 'a' and nitrate and H_2S were the unfavouring factors for this.

In station II in 1990-'91 since H_2S was missing none of the other parameters seemed to be the cause for anything. The case is entirely different in 1991-'92. In this year salinity both at the bottom and surface and pH at the bottom and surface were positive causes for chlorophyll 'a' and oxygen at the surface and bottom, silicate, total phosphorus, inorganic phosphate, nitrate and nitrite had unfavourable effects on chlorophyll 'a'.In station III in 1990-'91 nitrite alone had some effect which was adverse and none other had any effect on chlorophyll 'a'.

In 1991-'92 salinity at the bottom and surface and pH at the bottom had positive effects as in station I and II and total phosphorus, inorganic phosphate, nitrate and nitrite had ill effects on chlorophyll 'a'.

Thus as far as chlorophyll 'a' is concerned, there was heavy variation between years and not much of variation among the three stations in the same year.

The average annual chlorophyll 'a' concentration was high at station II and low at station I followed by station III. The seasonal average of chlorophyll 'a' showed the maximum values during premonsoon season at all the stations during both the years. Minimum values were recorded during monsoon season. The annual average was higher for 1991-'92. Chlorophyll 'a' showed favourable association with salinity, pH, primary production and phytoplankton.

3.5.4. Chlorophyll 'b'

In the case of chlorophyll 'b' the behaviour was as in chlorophyll 'a' in 1991-'92. However, in 1990-'91 at station II and station III the values were significantly higher than that in station I. However, the values were on par in station II and station III. The maximum value 4.56 mg/m^3 was recorded in station II in 1990-'91 and the minimum of 0 mg/m^3 was recorded in station I in 1990-'91.

Regarding chlorophyll 'b' in 1990-'91 depth seemed to have positive effect on chlorophyll 'b' in station II and no other parameter seemed to have, any direct effect on chlorophyll 'b' in any of the 3 stations in 1990-'91. H_2S at the surface had negative effect. In 1991-'92 in stations I and II none had any effect on chlorophyll 'b' and in station III only nitrate had some effect which was adverse to chlorophyll 'b'.

The annual average values of chlorophyll 'b' were higher at station III and lower at station I followed by II. The seasonal mean values of chlorophyll 'b' showed maximum during monsoon season and minimum during premonsoon season.

3.5.5. Chlorophyll 'c'

The behaviour of chlorophyll 'c' was consistent over the two years as in the case of chlorophyll 'a'. That is, no significant difference was noted in any year over the three stations. The maximum recorded value was 5.01mg/m^3 in station II in 1990-'91 and the minimum was 0 mg/m^3 in station I in 1991-'92.

In the case of chlorophyll 'c' the situation seemed to be completely different over the two years among the three stations. In station I in 1990-'91 pH and H_2S at the surface water seemed to have adverse effect on chlorophyll 'c' directly, where as in 1991-'92 salinity both at the surface and bottom had positive effect on chlorophyll 'c'.

In station II in 1990-'91 silicate and total phosphorus had adverse effects on chlorophyll 'c' and in 1991-'92 apart from the above two parameters, inorganic phosphate, nitrate and nitrite were also the causes for adverse effects and the salinity at the surface and bottom and pH at the surface and bottom were favourable parameters for chlorophyll 'c'.

In station III in 1990-’91 nitrite alone had adverse effect where as in 1991-’92 silicate, total phosphorus, inorganic phosphate, nitrate and nitrite had adverse effect on chlorophyll ‘c’.

Though the study did not reveal the real direct causes for the assimilation of the chlorophyll, further investigation may be able to bring some indirect effects of these parameters on the chlorophylls.

The annual average values of chlorophyll ‘c’ were high at station III and low at station I. The seasonal variation of chlorophyll ‘c’ showed maximum values during premonsoon and minimum values were recorded during monsoon seasons. The annual average was high during 1991-’92. High values of chlorophyll ‘c’ coincided with high values of salinity, oxygen, pH, nutrients, primary production, chlorophyll ‘a’, phytoplankton and zooplankton.

3.5.6. Chlorophyll c/a Ratio

The average levels of chlorophyll c/a ratio computed showed that in 1991-’92 there was no significant variation among the three stations. In 1990-’91 station II recorded significantly higher mean value than that in station I and III. However, the means in station I and station III were on par. The maximum recorded value was 0.78 in station II in 1991-’92 and the minimum was 0 in station I in 1990-’91 and station II in 1991-’92.

Annual average chlorophyll c/a ratio was high at station III and low at station I. Maximum seasonal mean values were recorded in premonsoon and minimum values in monsoon seasons. Positive association was noticed between c/a ratio and salinity, primary production and phytoplankton.

Table 3.1 : Mean and standard error of gross primary production, net primary production, chlorophyll 'a', 'b', 'c' and c/a ratio. The mean values are written in the increasing order with the station numbers along with it in the paranthesis, S1 indicating station 1, S2 indicating station 2 and S3 indicating station 3. Bars above the means are used to indicate statistically on par values. The value in the paranthesis below each mean indicates the standard error.

S.No.	PARAMETERS	1990 – '91			1991 – '92		
1	Gross primary Production	48.5833 (S1) (24.9306)	73.75 (S3) (27.9158)	80.3333 (S2) (39.0787)	53.3333 (S1) (17.3432)	73.75 (S3) (36.5043)	95.6667 (S2) (53.4166)
2	Net primary production	39.6607 (S1) (19.4250)	55.8331 (S3) (18.0495)	61.3333 (S2) (30.0796)	40.4167 (S1) (13.3924)	52.25 (S3) (25.3740)	111.5 (S2) (156.8685)
3	Chlorophyll 'a'	2.2250 (S1) (1.0842)	3.3433 (S2) (1.9705)	3.4050 (S3) (1.7832)	3.3375 (S3) (1.8052)	3.9383 (S1) (5.1075)	4.3292 (S2) (2.5376)
4	Chlorophyll 'b'	.7933 (S1) (.5550)	2.3625 (S2) (1.2231)	2.4017 (S3) (1.1351)	1.4025 (S1) (.5356)	2.1583 (S2) (1.1893)	2.3392 (S3) (1.2682)
5	Chlorophyll 'c'	1.2233 (S1) (.7479)	1.5592 (S3) (.7934)	1.9283 (S2) (1.1014)	1.33 (S1) (.4739)	1.8025 (S3) (1.05)	2.5033 (S2) (1.3436)
6	Chlorophyll c/a ratio	.4525 (S3) (.0508)	.533 (S1) (.2885)	.5542 (S2) (.1065)	.5275 (S3) (.0844)	.5742 (S1) (.1156)	.59 (S2) (.3218)

Table 3.2 : Simple correlation of primary production and chlorophylls with rainfall at station I, II and III during 1990-'91 and 1991-'92.

YEAR	1990-'91			1991-'92		
Station	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Gross primary production	0.155	-0.185	-0.159	-0.505	-0.553	-0.509
Net primary production	0.025	-0.248	-0.230	-0.451	-0.259	-0.453
Chlorophyll 'a'	0.518	-0.009	-0.063	-0.406	-0.530	-0.472
Chlorophyll 'b'	0.577*	0.101	0.067	-0.232	-0.373	-0.465
Chlorophyll 'c'	0.138	0.001	-0.130	-0.284	-0.548	-0.421
Chlorophyll c/a ratio	0.287	-0.069	-0.128	0.423	0.127	0.053

Table 3.3 : Results of regression analysis with correlation for gross primary production (Y) in station I during 1990 – '91 and 1991 – '92.

S.No.	PARAMETERS (X)	1990-'91		1991-'92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=56.116 – 2.154^{NS} x	0.069^{NS}	Y=73.513-6.026^{NS} x	-0.370^{NS}
2.	Light penetration	Y=33.065+27.503^{NS} x	0.078^{NS}	Y=59.648-12.206^{NS} x	-0.160^{NS}
3.	Temperature-Atmosphere	Y=-18.640+2.453^{NS} x	0.151^{NS}	Y=36.154-0.635^{NS} x	-0.090^{NS}
4.	Temperature-Surface water	Y=-21.694+2.719^{NS} x	0.209^{NS}	Y=-2.391-2.174^{NS} x	-0.212^{NS}
5.	Temperature-Bottom water	Y=-131.095+6.845^{NS} x	0.553^{NS}	Y=63.877-0.409^{NS} x	-0.058^{NS}
6.	Salinity-Surface water	Y=48.622-.00324^{NS} x	-0.001^{NS}	Y=38.258+1.417* x	0.705*
7.	Salinity-Bottom water	Y=46.767+.134^{NS} x	0.044^{NS}	Y=36.508+1.256** x	0.721**
8.	Oxygen-Surface water	Y=30.161+3.950^{NS} x	0.174^{NS}	Y=85.899-6.492^{NS} x	-0.451^{NS}
9.	Oxygen- Bottom water	Y=18.850+6.769^{NS} x	0.291^{NS}	Y=80.106-5.613^{NS} x	-0.415^{NS}
10.	pH- Surface water	Y=150.852-13.564^{NS} x	-0.233^{NS}	Y=-74.872+17.386^{NS} x	0.485^{NS}
11.	pH- Bottom water	Y=86.465-4.984^{NS} x	-0.076^{NS}	Y=-66.495+16.131^{NS} x	0.436^{NS}
12.	H_2S- Surface	Y=78.330-10.554* x	-0.612*	Y=56.912-10.714* x	-0.610*
13.	H_2S-Bottom	Y=35.703-.663^{NS} x	-0.293^{NS}	Y=-2.391+2.174^{NS} x	0.212^{NS}
14.	Silicate	Y=66.998-.189^{NS} x	-0.271^{NS}	Y=78.499-0.236* x	-0.597*
15.	Total Phosphorus	Y=72.131-15.135^{NS} x	-0.370^{NS}	Y=85.352-22.391* x	-0.697*
16.	Inorganic phosphate	Y=42.669+4.908^{NS} x	0.077^{NS}	Y=78.154-21.917* x	-0.665*
17.	Nitrate	Y=60.328-1.507^{NS} x	-0.220^{NS}	Y=72.563-2.783* x	-0.683**
18.	Nitrite	Y=68.500-59.306^{NS} x	-0.358^{NS}	Y=79.757-73.742** x	-0.831**
19.	Chlorophyll 'a'	Y=.376+20.156** x	0.827**	Y=26.060+10.654^{NS} x	-0.442^{NS}
20.	Chlorophyll 'b'	Y=30.964+22.209* x	0.594^{NS}	Y=46.206+5.082^{NS} x	-0.157^{NS}
21.	Chlorophyll 'c'	Y=13.791+28.441** x	0.853**	Y=14.757+32.147** x	-0.778**

Table 3.4 : Results of regression analysis with correlation for gross primary production (Y) in station II during 1990 – '91 and 1991 – '92.

S.No.	PARAMETERS (X)	1990-'91		1991-'92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=77.106+2.234^NS x	0.038^NS	Y=154.646-50.396^NS x	-0.288^NS
2.	Light penetration	Y=56.48+43.416^NS x	0.234^NS	Y=104.077-18.035^NS x	-0.060^NS
3.	Temperature-Atmosphere	Y=-189.978+9.785^NS x	0.447^NS	Y=94.127+0.0549^NS x	0.003^NS
4.	Temperature-Surface water	Y=-238.786+11.993* x	0.598*	Y=72.495+0.886^NS x	0.031^NS
5.	Temperature-Bottom water	Y=23.028+2.037^NS x	0.107^NS	Y=99.587-0.137^NS x	-0.006^NS
6.	Salinity-Surface water	Y=52.780+3.099^NS x	0.389^NS	Y=45.123+7.212** x	0.824**
7.	Salinity-Bottom water	Y=54.897+2.226^NS x	0.376^NS	Y=49.672+4.599* x	0.662*
8.	Oxygen-Surface water	Y=130.185-10.129^NS x	-0.311^NS	Y=347.690-46.527* x	-0.600*
9.	Oxygen- Bottom water	Y=132.886-11.255^NS x	-0.343^NS	Y=357.464-51.130* x	-0.632*
10.	pH- Surface water	Y=-268.326+46.921^NS x	0.313^NS	Y=-613.598+94.737* x	0.695*
11.	pH- Bottom water	Y=-89.688+22.592^NS x	0.169^NS	Y=-545.558+84.538* x	0.678*
12.	Silicate	Y=147.184-0.603^NS x	-0.570^NS	Y=189.368-0.780* x	-0.609*
13.	Total phosphorus	Y=130.047-28.475^NS x	-0.453^NS	Y=207.802-69.685* x	-0.678*
14.	Inorganic phosphate	Y=141.686-46.954^NS x	-0.463^NS	Y=195.710-72.539** x	-0.738**
15.	Nitrate	Y=128.526-5.499^NS x	-0.512^NS	Y=167.928-9.304** x	-0.743**
16.	Nitrite	Y=123.960-113.072* x	-0.600*	Y=168.344-169.016** x	-0.822**
17.	Chlorophyll 'a'	Y=24.619+16.664** x	0.840**	Y=4.922+20.961** x	0.996**
18.	Chlorophyll 'b'	Y=42.731+15.916* x	0.598*	Y=30.857+30.028* x	0.668*
19.	Chlorophyll 'c'	Y=21.168+30.682** x	0.865**	Y=8.464+37.319** x	0.984**

Table 3.5 : Results of regression analysis with correlation for gross primary production (Y) in station III during 1990 – '91 and 1991 - '92.

S.No.	PARAMETERS (X)	1990-'91		1991-'92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=71.648+1.254^{NS} x	0.017^{NS}	Y=197.521-23.722^{NS} x	-0.480^{NS}
2.	Light penetration	Y=48.809+49.130^{NS} x	0.330^{NS}	Y=110.530-24.480^{NS} x	-0.285^{NS}
3.	Temperature-Atmosphere	Y=94.967-0.711^{NS} x	-0.034^{NS}	Y=87.124-28.850^{NS} x	-0.173^{NS}
4.	Temperature-Surface water	Y=-87.702-5.912^{NS} x	-0.462^{NS}	Y=79.284-0.193^{NS} x	-0.013^{NS}
5.	Temperature-Bottom water	Y=-13.589+3.315^{NS} x	0.280^{NS}	Y=87.120-0.496^{NS} x	-0.033^{NS}
6.	Salinity-Surface water	Y=56.697+2.496^{NS} x	0.363^{NS}	Y=-332.373+54.477* x	0.577*
7.	Salinity-Bottom water	Y=54.103+2.070^{NS} x	0.400^{NS}	Y=50.308+4.501* x	0.578*
8.	Oxygen-Surface water	Y=97.810-4.622^{NS} x	-0.184^{NS}	Y=115.364-0.325^{NS} x	-0.528 ^{NS}
9.	Oxygen- Bottom water	Y=106.189-6.555^{NS} x	-0.272^{NS}	Y=206.711-23.892^{NS} x	-0.473 ^{NS}
10.	pH- Surface water	Y=-319.107+53.239^{NS} x	0.398^{NS}	Y=67.796+0.332^{NS} x	0.022^{NS}
11.	pH- Bottom water	Y=-271.498+46.529^{NS} x	0.325^{NS}	Y=-187.689+35.286^{NS} x	0.278^{NS}
12.	Silicate	Y=111.444-0.335^{NS} x	-0.451^{NS}	Y=136.549-41.912* x	-0.617*
13.	Total phosphorus	Y=114.011-19.432^{NS} x	-0.413^{NS}	Y=122.287-5.290* x	-0.696*
14.	Inorganic phosphate	Y=122.105-32.471^{NS} x	-0.443^{NS}	Y=160.700-45.711* x	-0.663*
15.	Nitrate	Y=104.889-2.787^{NS} x	-0.366^{NS}	Y=123.926-94.671** x	-0.839**
16.	Nitrite	Y=114.368-88.662** x	-0.722**	Y=14.887+32.656** x	0.938**
17.	Chlorophyll 'a'	Y=13.223+17.776** x	0.962**	Y=54.103+2.070^{NS} x	0.400^{NS}
18.	Chlorophyll 'b'	Y=41.043+13.618* x	0.584*	Y=7.143+19.957** x	0.987**
19.	Chlorophyll 'c'	Y=22.335+32.976** x	0.937**	Y=16.678+24.398** x	0.848**

Table 3.6: Results of regression analysis with correlation for net primary production in station I during 1990 –'91 and 1991 – '92.

S.No.	PARAMETERS (X)	1990-'91		1991-'92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=27.488+3.482^{NS} x	0.143^{NS}	Y=52.451-3.594^{NS} x	-0.286^{NS}
2.	Light penetration	Y=28.932+19.025^{NS} x	0.158^{NS}	Y=48.628-15.873^{NS} x	-0.219^{NS}
3.	Temperature-Atmosphere	Y=0.843+1.417^{NS} x	0.112^{NS}	Y=39.353+0.03928^{NS} x	0.007^{NS}
4.	Temperature-Surface water	Y=-21.026+2.348^{NS} x	0.232^{NS}	Y=3.222+1.451^{NS} x	0.184^{NS}
5.	Temperature-Bottom water	Y=-100.439+5.337* x	0.553^{NS}	Y=47.039-0.257^{NS} x	-0.047^{NS}
6.	Salinity-Surface water	Y=41.634-0.166^{NS} x	-0.058^{NS}	Y=29.901+0.988* x	0.637*
7.	Salinity-Bottom water	Y=40.519-0.0630^{NS} x	-0.026^{NS}	Y=28.824+0.866* x	0.643*
8.	Oxygen-Surface water	Y=21.204+3.959^{NS} x	0.223^{NS}	Y=58.293-3.564^{NS} x	-0.321 ^{NS}
9.	Oxygen- Bottom water	Y=14.259+5.784^{NS} x	0.319^{NS}	Y=53.907-2.828^{NS} x	-0.271 ^{NS}
10.	pH- Surface water	Y=128.993-11.847^{NS} x	-0.261^{NS}	Y=-44.214+11.477^{NS} x	0.415^{NS}
11.	pH- Bottom water	Y=78.600-5.122^{NS} x	-0.100^{NS}	Y=-31.450+9.675^{NS} x	0.338^{NS}
12.	H_2S- Surface	Y=61.488-7.865* x	-0.592*	Y=41.875-10.281* x	-0.600*
13.	H_2S-Bottom	Y=29.331+0.532^{NS} x	0.301^{NS}	Y=3.222+1.451^{NS} x	0.184^{NS}
14.	Silicate	Y=48.533-0.0912^{NS} x	-0.168^{NS}	Y=58.292-0.168^{NS} x	-0.549^{NS}
15.	Total phosphorus	Y=53.104-8.637^{NS} x	-0.271^{NS}	Y=63.973-16.473* x	-0.664*
16.	Inorganic phosphate	Y=33.879+4.803^{NS} x	0.096^{NS}	Y=57.204-14.823* x	-0.582*
17.	Nitrate	Y=44.640-0.638^{NS} x	-0.119^{NS}	Y=53.396-1.878* x	-0.597*
18.	Nitrite	Y=52.197-37.312^{NS} x	-0.289^{NS}	Y=59.214-52.457** x	-0.766**
19.	Chlorophyll 'a'	Y=4.948+14.5** x	0.764**	Y=26.883+5.287^{NS} x	0.284^{NS}
20.	Chlorophyll 'b'	Y=26.273+16.883* x	0.582*	Y=33.242+5.116^{NS} x	0.205^{NS}
21.	Chlorophyll 'c'	Y=15.979+19.363** x	0.746**	Y=10.500+24.930** x	0.781**

Table 3.7 : Results of regression analysis with correlation for net primary production (Y) in station II during 1990 – '91 and 1991 - '92.

S.No.	PARAMETERS (X)	1990-'91		1991-'92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=65.239-2.704^{NS} x	-0.060^{NS}	Y=31.776+68.120^{NS} x	0.133^{NS}
2.	Light penetration	Y=39.658+39.451^{NS} x	0.276^{NS}	Y=44.086+144.562^{NS} x	0.164^{NS}
3.	Temperature-Atmosphere	Y=-119.163+6.534^{NS} x	0.387^{NS}	Y=1123.614-36.083* x	-0.569*
4.	Temperature-Surface water	Y=-158.569+8.264^{NS} x	0.535^{NS}	Y=1116.692-38.427^{NS} x	-0.455^{NS}
5.	Temperature-Bottom water	Y=19.420+1.490^{NS} x	0.102^{NS}	Y=1021.437-31.770^{NS} x	-0.504^{NS}
6.	Salinity-Surface water	Y=36.446+2.799^{NS} x	-0.457^{NS}	Y=81.360+4.301^{NS} x	0.167^{NS}
7.	Salinity-Bottom water	Y=37.637+2.074^{NS} x	-0.455^{NS}	Y=83.603+2.790^{NS} x	0.137^{NS}
8.	Oxygen-Surface water	Y=108.093-9.501^{NS} x	-0.379^{NS}	Y=337.353-41.696^{NS} x	-0.183 ^{NS}
9.	Oxygen- Bottom water	Y=108.242-10.046^{NS} x	-0.398^{NS}	Y=705.048-117.283^{NS} x	-0.488 ^{NS}
10.	pH- Surface water	Y=-244.496+41.157^{NS} x	0.357^{NS}	Y=-167.546+37.272^{NS} x	0.093^{NS}
11.	pH- Bottom water	Y=-106.059+22.242^{NS} x	0.217^{NS}	Y=-404.115+67.978^{NS} x	0.186^{NS}
12.	Silicate	Y=119.253-0.523* x	-0.641*	Y=167.766-0.468^{NS} x	-0.125^{NS}
13.	Total phosphorus	Y=102.832-23.770^{NS} x	-0.492^{NS}	Y=220.052-67.458^{NS} x	-0.224^{NS}
14.	Inorganic phosphate	Y=116.855-42.491^{NS} x	-0.544^{NS}	Y=119.862-6.063^{NS} x	-0.021^{NS}
15.	Nitrate	Y=103.895-4.856* x	-0.588*	Y=120.431-1.150^{NS} x	-0.031^{NS}
16.	Nitrite	Y=96.405-90.899* x	-0.627*	Y=139.746-65.687^{NS} x	-0.109^{NS}
17.	Chlorophyll 'a'	Y=19.200+12.602** x	0.826**	Y=10.779+23.266^{NS} x	0.376^{NS}
18.	Chlorophyll 'b'	Y=39.591+9.203^{NS} x	0.374^{NS}	Y=-51.787+75.654* x	0.573*
19.	Chlorophyll 'c'	Y=15.687+23.671** x	0.867**	Y=42.76+29.418^{NS} x	0.264^{NS}

Table 3.8 : Results of regression analysis with correlation for net primary production (Y) in station III during 1990 – '91 and 1991 - '92.

S.No.	PARAMETERS (X)	1990-'91		1991-'92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=42.774+7.793^{NS} x	0.160^{NS}	Y=89.809-24.999^{NS} x	-0.418^{NS}
2.	Light penetration	Y=40.679+29.851^{NS} x	0.310^{NS}	Y=66.124-29.928^{NS} x	-0.259^{NS}
3.	Temperature-Atmosphere	Y=80.238-0.818^{NS} x	-0.061^{NS}	Y=36.551+0.548^{NS} x	0.054^{NS}
4.	Temperature-Surface water	Y=-50.495+3.894^{NS} x	0.470^{NS}	Y=44.228+0.297^{NS} x	0.028^{NS}
5.	Temperature-Bottom water	Y=-8.163+2.429^{NS} x	0.318^{NS}	Y=28.147+0.894^{NS} x	0.084^{NS}
6.	Salinity-Surface water	Y=45.766+1.473^{NS} x	0.332^{NS}	Y=35.335+3.248* x	0.600*
7.	Salinity-Bottom water	Y=48.843+1.263^{NS} x	0.378^{NS}	Y=34.520+2.385* x	0.594*
8.	Oxygen-Surface water	Y=76.058-3.885^{NS} x	-0.240^{NS}	Y=151.420-17.820^{NS} x	-0.508^{NS}
9.	Oxygen- Bottom water	Y=76.873-4.252^{NS} x	-0.272^{NS}	Y=136.474-16.143^{NS} x	-0.470^{NS}
10.	pH- Surface water	Y=-221.307+37.557^{NS} x	0.434^{NS}	Y=-160.875+28.765^{NS} x	0.326^{NS}
11.	pH- Bottom water	Y=-219.442+37.099^{NS} x	0.401^{NS}	Y=-244.640+39.824* x	0.607*
12.	Silicate	Y=80.932-0.223^{NS} x	-0.464^{NS}	Y=82.381-0.236^{NS} x	-0.550^{NS}
13.	Total phosphorus	Y=75.303-9.397^{NS} x	-0.309^{NS}	Y=115.632-33.321* x	-0.695*
14.	Inorganic phosphate	Y=86.821-20.809^{NS} x	-0.439^{NS}	Y=100.893-32.465* x	-0.688*
15.	Nitrate	Y=78.787-2.054^{NS} x	-0.417 ^{NS}	Y=87.195-3.809** x	-0.721**
16.	Nitrite	Y=82.840-58.923**x	-0.742**	Y=86.119-63.904** x	-0.815**
17.	Chlorophyll 'a'	Y=20.159+10.477** x	0.877**	Y=6.297+13.769** x	0.980**
18.	Chlorophyll 'b'	Y=29.639+10.907* x	0.686*	Y=14.372+16.193** x	0.809**
19.	Chlorophyll 'c'	Y=27.146+18.399** x	0.809**	Y=9.818+23.541** x	0.973**

Table 3.9 : Results of regression analysis with correlation for chlorophyll 'a' in station I during 1990 – '91 and 1991 – '92.

S.No.	PARAMETERS (X)	1990 –'91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=2.929-0.154^{NS} x	-0.120^{NS}	Y=3.444-0.264^{NS} x	-0.390^{NS}
2.	Light penetration	Y=1.749+1.140^{NS} x	0.180^{NS}	Y=2.311+0.482^{NS} x	0.152^{NS}
3.	Temperature-Atmosphere	Y=-2.651+0.184^{NS} x	0.275^{NS}	Y=0.526+0.114^{NS} x	0.390 ^{NS}
4.	Temperature-Surface water	Y=-0.418+0.109^{NS} x	0.204^{NS}	Y=0.241+0.0904^{NS} x	0.213^{NS}
5.	Temperature-Bottom water	Y=-3.429+0.222^{NS} x	0.437^{NS}	Y=3.795-0.0479^{NS} x	-0.162^{NS}
6.	Salinity-Surface water	Y=2.465-0.00619^{NS} x	-0.041^{NS}	Y=2.068+0.0462^{NS} x	0.555 ^{NS}
7.	Salinity-Bottom water	Y=2.347+0.0033^{NS} x	0.026^{NS}	Y=1.991+0.04247* x	0.587*
8.	Oxygen-Surface water	Y=0.937+0.312^{NS} x	0.335^{NS}	Y=4.098-0.307^{NS} x	-0.513 ^{NS}
9.	Oxygen- Bottom water	Y=0.880+0.344^{NS} x	0.360^{NS}	Y=3.920-0.285^{NS} x	-0.507 ^{NS}
10.	pH- Surface water	Y=6.586-0.556^{NS} x	-0.233^{NS}	Y=-4.270+0.926* x	0.623*
11.	pH- Bottom water	Y=4.267-0.247^{NS} x	-0.092^{NS}	Y=-3.871+0.866^{NS} x	0.563 ^{NS}
12.	H_2S- Surface	Y=3.723-0.554* x	-0.607*	Y=2.499+0.136^{NS} x	0.330^{NS}
13.	H_2S-Bottom	Y=1.656+0.0378^{NS} x	0.407^{NS}	Y=0.241+0.09045^{NS} x	0.213 ^{NS}
14.	Silicate	Y=3.315-0.00949^{NS} x	-0.332^{NS}	Y=3.501-0.00883^{NS} x	-0.538 ^{NS}
15.	Total phosphorus	Y=3.276-0.569^{NS} x	-0.339^{NS}	Y=3.475-0.640^{NS} x	-0.480 ^{NS}
16.	Inorganic phosphate	Y=2.406-0.01231^{NS} x	-0.005 ^{NS}	Y=3.438-0.775^{NS} x	-0.567 ^{NS}
17.	Nitrate	Y=2.702-0.03985^{NS} x	-0.142 ^{NS}	Y=3.284-0.105* x	-0.620*
18.	Nitrite	Y=3.492-3.277^{NS} x	-0.482 ^{NS}	Y=3.198-1.781^{NS} x	-0.484 ^{NS}

Table 3.10 : Results of regression analysis with correlation for chlorophyll 'a' in station II during 1990 – '91 and 1991 – '92.

S.No.	PARAMETERS (X)	1990-'91		1991-'92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	$Y=3.371-0.0190^{NS}$ x	-0.006^{NS}	$Y=7.237-2.485^{NS}$ x	-0.299^{NS}
2.	Light penetration	$Y=3.412-0.125^{NS}$ x	-0.013^{NS}	$Y=4.692-0.777^{NS}$ x	-0.055^{NS}
3.	Temperature-Atmosphere	$Y=-10.945+0.517^{NS}$ x	0.468^{NS}	$Y=3.336+0.00351^{NS}$ x	0.035^{NS}
4.	Temperature-Surface water	$Y=-7.062+0.391^{NS}$ x	0.387^{NS}	$Y=1.987+0.08954^{NS}$ x	0.066^{NS}
5.	Temperature-Bottom water	$Y=4.280-0.0332^{NS}$ x	-0.035^{NS}	$Y=3.569+0.0265^{NS}$ x	0.026^{NS}
6.	Salinity-Surface water	$Y=2.855+0.0549^{NS}$ x	0.137^{NS}	Y=1.907+0.346** x	0.832**
7.	Salinity-Bottom water	$Y=2.841+0.04397^{NS}$ x	0.147^{NS}	Y=2.143+0.219* x	0.663*
8.	Oxygen-Surface water	$Y=5.014-0.340^{NS}$ x	-0.207^{NS}	Y=16.229-2.197* x	-0.596*
9.	Oxygen- Bottom water	$Y=5.317-0.423^{NS}$ x	-0.256^{NS}	Y=16.493-2.403* x	-0.618*
10.	pH- Surface water	$Y=4.670-0.179^{NS}$ x	-0.024^{NS}	Y=-30.398+4.639** x	0.717**
11.	pH- Bottom water	$Y=12.108-1.165^{NS}$ x	-0.173^{NS}	Y=-25.352+3.913* x	0.661*
12.	Silicate	$Y=5.129-0.01612^{NS}$ x	-0.302^{NS}	Y=8.650-0.03597* x	-0.591*
13.	Total phosphorus	$Y=4.770-0.817^{NS}$ x	-0.258^{NS}	Y=9.652-3.308* x	-0.677*
14.	Inorganic phosphate	$Y=4.538-0.914^{NS}$ x	-0.179^{NS}	Y=9.156-3.500** x	-0.750**
15.	Nitrate	$Y=4.233-0.101^{NS}$ x	-0.187^{NS}	Y=7.780-0.444** x	-0.747**
16.	Nitrite	$Y=4.784-3.734^{NS}$ x	-0.393^{NS}	Y=7.737-7.925** x	-0.811**

Table 3.11 : Results of regression analysis with correlation for chlorophyll 'a' in station III during 1990 – '91 and 1991 – '92.

S.No.	PARAMETERS (X)	1990-'91		1991-'92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=3.391+0.00840^{NS} x	0.002	Y=5.509-1.445^{NS} x	-0.340^{NS}
2.	Light penetration	Y=2.772+1.248^{NS} x	0.155^{NS}	Y=4.084-1.610^{NS} x	-0.196^{NS}
3.	Temperature-Atmosphere	Y=4.131-0.0243^{NS} x	-0.022^{NS}	Y=3.386+0.00169^{NS} x	-0.002 ^{NS}
4.	Temperature-Surface water	Y=-4.362+0.284^{NS} x	0.410^{NS}	Y=3.973-0.02354^{NS} x	-0.031^{NS}
5.	Temperature-Bottom water	Y=-0.03145+0.130^{NS} x	0.204^{NS}	Y=2.954+0.0142^{NS} x	0.019^{NS}
6.	Salinity-Surface water	Y=2.719+0.100^{NS} x	0.270^{NS}	Y=2.058+0.246* x	0.638 *
7.	Salinity-Bottom water	Y=2.668+0.07765^{NS} x	0.278^{NS}	Y=1.988+0.182* x	0.636 *
8.	Oxygen-Surface water	Y=4.140-0.141^{NS} x	-0.104^{NS}	Y=10.551-1.296^{NS} x	-0.519 ^{NS}
9.	Oxygen- Bottom water	Y=4.776-0.277^{NS} x	-0.212^{NS}	Y=9.725-1.224^{NS} x	-0.501^{NS}
10.	pH- Surface water	Y=-11.007+1.953^{NS} x	0.270^{NS}	Y=-13.796+2.313^{NS} x	0.368 ^{NS}
11.	pH- Bottom water	Y=-9.574+1.749^{NS} x	0.226^{NS}	Y=-19.058+3.004* x	0.643*
12.	Silicate	Y=4.750-0.01195^{NS} x	-0.297^{NS}	Y=5.509-0.169^{NS} x	-0.557^{NS}
13.	Total phosphorus	Y=5.235-0.883^{NS} x	-0.347^{NS}	Y=7.860-2.378* x	-0.697 *
14.	Inorganic phosphate	Y=5.319-1.285^{NS} x	-0.324 ^{NS}	Y=6.649-2.210* x	-0.688*
15.	Nitrate	Y=4.477-0.0959^{NS} x	-0.233 ^{NS}	Y=5.801-0.268** x	-0.715**
16.	Nitrite	Y=5.286-4.104* x	-0.618*	Y=5.769-4.589** x	-0.823**

Table 3.12 : Results of regression analysis with correlation for chlorophyll 'b' in station I during 1990 – '91 and 1991 – '92.

S.No.	PARAMETERS (X)	1990-'91		1991-'92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=1.859-0.305^{NS} x	-0.438^{NS}	Y=1.950-0.163^{NS} x	-0.324^{NS}
2.	Light penetration	Y=1.281-0.864^{NS} x	-0.252^{NS}	Y=1.546-0.277^{NS} x	-0.118^{NS}
3.	Temperature-Atmosphere	Y=-0.486+0.0467^{NS} x	0.129^{NS}	Y=2.880-0.0545^{NS} x	-0.251 ^{NS}
4.	Temperature-Surface water	Y=-1.588+0.9212^{NS} x	0.319^{NS}	Y=2.918-0.05914^{NS} x	-0.187^{NS}
5.	Temperature-Bottom water	Y=1.592+0.09088^{NS} x	0.330^{NS}	Y=1.903-0.01941^{NS} x	-0.088^{NS}
6.	Salinity-Surface water	Y=0.983-0.01594^{NS} x	-0.194^{NS}	Y=2.955-0.211^{NS} x	-0.190 ^{NS}
7.	Salinity-Bottom water	Y=0.915-0.00901^{NS} x	-0.131^{NS}	Y=3.581-0.293^{NS} x	-0.256 ^{NS}
8.	Oxygen-Surface water	Y=-0.486+0.274^{NS} x	0.542^{NS}	Y=1.125+0.0554^{NS} x	0.125^{NS}
9.	Oxygen- Bottom water	Y=-0.356+0.262^{NS} x	0.504^{NS}	Y=1.104+0.06248^{NS} x	0.149^{NS}
10.	pH- Surface water	Y=2.876-0.276^{NS} x	-0.213^{NS}	Y=1.496-0.0743^{NS} x	-0.257 ^{NS}
11.	pH- Bottom water	Y=2.719-0.253^{NS} x	-0.174^{NS}	Y=2.918-0.05914^{NS} x	-0.187^{NS}
12.	H_2S- Surface	Y=1.325-0.244* x	-0.652*	Y=1.586-0.01722^{NS} x	-0.278^{NS}
13.	H_2S-Bottom	Y=0.673+0.00619^{NS} x	0.123^{NS}	Y=1.552-0.01118^{NS} x	-0.208 ^{NS}
14.	Silicate	Y=0.662+0.00135^{NS} x	0.087^{NS}	Y=1.257+0.00137^{NS} x	0.112^{NS}
15.	Total phosphorus	Y=0.853-0.03829^{NS} x	-0.042^{NS}	Y=1.643-0.168^{NS} x	-0.170^{NS}
16.	Inorganic phosphate	Y=0.625+0.140^{NS} x	0.098^{NS}	Y=1.238+0.145^{NS} x	0.142^{NS}
17.	Nitrate	Y=0.817-0.003097^{NS} x	-0.020^{NS}	Y=1.177+0.0326^{NS} x	0.260^{NS}
18.	Nitrite	Y=0.819-0.07768^{NS} x	-0.021^{NS}	Y=1.329+0.206^{NS} x	0.075^{NS}

Table 3.13 : Results of regression analysis with correlation for chlorophyll 'b' in station II during 1990 – '91 and 1991 – '92.

S.No.	PARAMETERS (X)	1990-'91		1991-'92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=0.678+1.166* x	0.636*	Y=0.893+1.081^NS x	0.278^NS
2.	Light penetration	Y=2.065+0.546^NS x	0.094^NS	Y=1.962+0.420^NS x	0.063^NS
3.	Temperature-Atmosphere	Y=-4.637+0.253^NS x	0.369^NS	Y=7.257-0.182^NS x	-0.378 ^NS
4.	Temperature-Surface water	Y=-4.283+0.250^NS x	0.398^NS	Y=6.353-0.160^NS x	-0.251^NS
5.	Temperature-Bottom water	Y=-1.375+0.133^NS x	0.223^NS	Y=6.609-0.155^NS x	-0.325^NS
6.	Salinity-Surface water	Y=2.986-0.07012^NS x	-0.281^NS	Y=1.850+0.0440^NS x	0.226 ^NS
7.	Salinity-Bottom water	Y=3.045-0.0597^NS x	-0.323^NS	Y=1.871+0.02876^NS x	0.186 ^NS
8.	Oxygen-Surface water	Y=1.830+0.108^NS x	0.106^NS	Y=2.887-0.135^NS x	-0.078 ^NS
9.	Oxygen- Bottom water	Y=2.204+0.0340^NS x	0.033^NS	Y=4.137-0.391^NS x	-0.215^NS
10.	pH- Surface water	Y=10.583-1.106^NS x	-0.236^NS	Y=-1.761+0.523^NS x	0.173 ^NS
11.	pH- Bottom water	Y=12.273-1.317^NS x	-0.316^NS	Y=1.814+0.0453^NS x	0.016^NS
12.	Silicate	Y=1.665+0.00621^NS x	0.190^NS	Y=2.515-0.00297^NS x	-0.104^NS
13.	Total phosphorus	Y=1.775+0.337^NS x	0.171^NS	Y=2.974-0.507^NS x	-0.221 ^NS
14.	Inorganic phosphate	Y=2.100+0.201^NS x	0.063^NS	Y=2.418-0.188^NS x	-0.086^NS
15.	Nitrate	Y=1.937+0.0485^NS x	0.144^NS	Y=2.493-0.04311^NS x	-0.155^NS
16.	Nitrites	Y=2.313+0.06202^NS x	0.028^NS	Y=3.001-1.961^NS x	-0.428^NS

Table 3.14 : Results of regression analysis with correlation for chlorophyll 'b' in station III during 1990 – '91 and 1991 – '92.

S.No.	PARAMETERS (X)	1990-'91		1991-'92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	$Y=1.354+0.625^{NS}$ x	0.204^{NS}	$Y=2.663-0.216^{NS}$ x	-0.072^{NS}
2.	Light penetration	$Y=2.578-0.347^{NS}$ x	-0.057^{NS}	$Y=2.571-0.500^{NS}$ x	-0.087^{NS}
3.	Temperature-Atmosphere	$Y=5.661-0.109^{NS}$ x	-0.130^{NS}	$Y=6.700-0.152^{NS}$ x	-0.299^{NS}
4.	Temperature-Surface water	$Y=-5.201+0.278^{NS}$ x	0.535^{NS}	$Y=7.237-0.182^{NS}$ x	-0.345^{NS}
5.	Temperature-Bottom water	$Y=-3.696+0.231^{NS}$ x	0.481^{NS}	$Y=7.313-0.184^{NS}$ x	-0.347^{NS}
6.	Salinity-Surface water	$Y=3.109-0.103^{NS}$ x	-0.370^{NS}	$Y=2.036+0.05817^{NS}$ x	0.215^{NS}
7.	Salinity-Bottom water	$Y=2.944-0.0571^{NS}$ x	-0.272^{NS}	$Y=1.979+0.0483^{NS}$ x	0.241^{NS}
8.	Oxygen-Surface water	$Y=1.783+0.119^{NS}$ x	0.117^{NS}	$Y=4.2-0.334^{NS}$ x	-0.191^{NS}
9.	Oxygen- Bottom water	$Y=1.627+0.157^{NS}$ x	0.160^{NS}	$Y=3.733-0.267^{NS}$ x	-0.156^{NS}
10.	pH- Surface water	$Y=8.611-0.841^{NS}$ x	-0.155^{NS}	$Y=3.625-0.174^{NS}$ x	-0.039^{NS}
11.	pH- Bottom water	$Y=9.816-0.999^{NS}$ x	-0.172^{NS}	$Y=-3.505+0.784^{NS}$ x	0.239^{NS}
12.	Silicate	$Y=2.468-0.00059^{NS}$ x	-0.020^{NS}	$Y=2.907-0.00444^{NS}$ x	-0.207^{NS}
13.	Total phosphorus	$Y=1.586+0.394^{NS}$ x	0.206^{NS}	$Y=3.800-0.768^{NS}$ x	-0.321^{NS}
14.	Inorganic phosphate	$Y=2.206+0.132^{NS}$ x	0.044^{NS}	$Y=3.195-0.571^{NS}$ x	-0.242^{NS}
15.	Nitrate	$Y=2.177+0.02011^{NS}$ x	0.065^{NS}	$Y=3.325-0.107^{NS}$ x	-0.407^{NS}
16.	Nitrite	$Y=3.128-1.584^{NS}$ x	-0.317^{NS}	Y=3.579-2.340* x	-0.597*

Table 3.15 : Results of regression analysis with correlation for chlorophyll 'c' in station I during 1990 – '91 and 1991 – '92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=1.964-0.212 ^{NS} x	-0.226 ^{NS}	Y=1.151+0.00146^{NS} x	0.037^{NS}
2.	Light penetration	Y=0.488+1.303^{NS} x	0.282^{NS}	Y=1.270-0.135^{NS} x	-0.073^{NS}
3.	Temperature-Atmosphere	Y=-1.705+0.107^{NS} x	0.219^{NS}	Y=1.301-0.00372^{NS} x	-0.022 ^{NS}
4.	Temperature-Surface water	Y=0.820+0.01562^{NS} x	0.040^{NS}	Y=0.125+0.000419^{NS} x	0.169^{NS}
5.	Temperature-Bottom water	Y=-2.035+0.124^{NS} x	0.334^{NS}	Y=2.759-0.0605^{NS} x	-0.351^{NS}
6.	Salinity-Surface water	Y=2.550-0.176^{NS} x	-0.101^{NS}	Y=-3.183+0.594* x	0.686 *
7.	Salinity-Bottom water	Y=1.194+0.0038^{NS} x	0.002^{NS}	Y=-3.173+0.589** x	0.657 *
8.	Oxygen-Surface water	Y=0.0858+0.244^{NS} x	0.358^{NS}	Y=1.278-0.01552^{NS} x	-0.045 ^{NS}
9.	Oxygen- Bottom water	Y=0.00448+0.277^{NS} x	0.397^{NS}	Y=1.205-0.000947^{NS} x	-0.003^{NS}
10.	pH- Surface water	Y=2.282-0.431* x	-0.632*	Y=1.458-0.0434^{NS} x	-0.196 ^{NS}
11.	pH- Bottom water	Y=0.778+.00229^{NS} x	0.337^{NS}	Y=0.125+0.0419^{NS} x	.169^{NS}
12.	H_2S- Surface	Y=1.193-0.66256* x	0.623*	Y=1.013-0.61756* x	0.661*
13.	H_2S-Bottom	Y=1.114+0.00811^{NS} x	0.088 ^{NS}	Y=0.997+0.01515^{NS} x	0.359 ^{NS}
14.	Silicate	Y=1.980-0.00778^{NS} x	-0.372^{NS}	Y=1.316-0.00108^{NS} x	-0.113^{NS}
15.	Total phosphorus	Y=2.040-0.525^{NS} x	-0.428^{NS}	Y=1.543-0.240^{NS} x	-0.309^{NS}
16.	Inorganic phosphate	Y=1.381-0.131^{NS} x	-0.068^{NS}	Y=1.477-0.245^{NS} x	-0.307 ^{NS}
17.	Nitrate	Y=1.530-0.03936 ^{NS} x	-0.191 ^{NS}	Y=1.434-0.03388^{NS} x	-0.344 ^{NS}
18.	Nitrite	Y=2.026-2.389 ^{NS} x	-0.480 ^{NS}	Y=1.625-1.185^{NS} x	-0.552 ^{NS}

Table 3.16 : Results of regression analysis with correlation for chlorophyll 'c' in station II during 1990 – '91 and 1991 – '92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=1.651+0.283 NS x	0.052NS	Y=3.915-1.349 NS x	-0.293NS
2.	Light penetration	Y=1.732+0.357 x	0.068NS	Y=2.896-1.198NS x	-0.152NS
3.	Temperature-Atmosphere	Y=-6.233+0.295NS x	0.478NS	Y=0.865+0.05246NS x	0.092 NS
4.	Temperature-Surface water	Y=-4.444+0.239NS x	0.423NS	Y=0.315+0.07728NS x	0.102NS
5.	Temperature-Bottom water	Y=4.303-0.0844NS x	-0.157NS	Y=1.016+0.0461NS x	0.082NS
6.	Salinity-Surface water	Y=1.157-0.08676NS x	0.387NS	Y=1.031+0.186** x	0.808**
7.	Salinity-Bottom water	Y=1.223+0.06175NS x	0.370NS	Y=1.135+0.120* x	0.656*
8.	Oxygen-Surface water	Y=3.074 – 0.233NS x	-0.254NS	Y=8.514 -1.140NS x	-0.557NS
9.	Oxygen- Bottom water	Y=3.197 – 0.272NS x	-0.294NS	Y=8.437-1.205NS x	-0.558NS
10.	pH- Surface water	Y=-7.263+1.237NS x	0.293NS	Y=-16.844+2.562** x	0.713**
11.	pH- Bottom water	Y=-1.953+0.516NS x	0.137NS	Y=-14.050+2.160* x	0.657*
12.	Silicate	Y=3.884–0.01765* x	-0.592*	Y=4.84 -0.0208* x	-0.617*
13.	Total phosphorus	Y=3.728-1.031* x	-0.582*	Y=5.268-1.822* x	-0.672*
14.	Inorganic phosphate	Y=3.332-1.067NS x	-0.373NS	Y=5.033-1.955** x	-0.755**
15.	Nitrate	Y=3.033-0.126NS x	-0.416 NS	Y=4.305-0.253** x	-0.768**
16.	Nitrite	Y=3.100-3.036NS x	-0.572 NS	Y=4.362-4.709** x	-0.868**

Table 3.17 : Results of regression analysis with correlation for chlorophyll 'c' in station III during 1990 – '91 and 1991 – '92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=-6.456+1.086^{NS} x	0.286^{NS}	Y=3.270-0.976^{NS} x	-0.395^{NS}
2.	Light penetration	Y=-5.657+0.972^{NS} x	0.239^{NS}	Y=2.358-1.198^{NS} x	-0.251^{NS}
3.	Temperature-Atmosphere	Y=1.633-0.0438^{NS} x	-0.020^{NS}	Y=1.376+0.0149^{NS} x	0.035 ^{NS}
4.	Temperature-Surface water	Y=1.162+0.782^{NS} x	0.185^{NS}	Y=1.815-0.000444^{NS} x	-0.001^{NS}
5.	Temperature-Bottom water	Y=0.795+0.0256^{NS} x	0.043^{NS}	Y=1.224+0.02144^{NS} x	0.049^{NS}
6.	Salinity-Surface water	Y=1.083+0.06968^{NS} x	0.357^{NS}	Y=2.751+0.0751^{NS} x	0.385^{NS}
7.	Salinity-Bottom water	Y=1.063+0.0522^{NS} x	0.356^{NS}	Y=1.852+0.0862^{NS} x	0.400^{NS}
8.	Oxygen-Surface water	Y=2.553-0.201^{NS} x	-0.293^{NS}	Y=6.222-0.794^{NS} x	-0.547 ^{NS}
9.	Oxygen- Bottom water	Y=2.462-0.199^{NS} x	-0.201^{NS}	Y=5.431-0.695^{NS} x	-0.490^{NS}
10.	pH- Surface water	Y=-1.968+0.129^{NS} x	0.355^{NS}	Y=6.812+0.256^{NS} x	0.321^{NS}
11.	pH- Bottom water	Y=0.267+0.049^{NS} x	0.146^{NS}	Y=0.652+0.085^{NS} x	0.222^{NS}
12.	Silicate	Y=2.261-0.00624^{NS} x	-0.295^{NS}	Y=3.157-0.01059* x	-0.598*
13.	Total phosphorus	Y=2.754-0.576^{NS} x	-0.431^{NS}	Y=4.651-1.498** x	-0.756**
14.	Inorganic phosphate	Y=2.710-0.773^{NS} x	-0.371^{NS}	Y=3.951-1.434** x	-0.735**
15.	Nitrate	Y=2.183-0.0558^{NS} x	-0.258 ^{NS}	Y=3.323-0.166** x	-0.759**
16.	Nitrite	Y=2.533-2.124* x	-0.609**	Y=3.186-2.610** x	-0.806**

3.6. Discussion

The primary production of an estuarine system depends upon various factors such as temperature, salinity, light penetration, turbidity, nutrients and phytoplankton abundance.

The primary production in the present study showed distinct seasonal variation. The rate of gross primary production was maximum during premonsoon followed by postmonsoon and monsoon periods. A bimodal peak of gross primary production was recorded, the primary peak being in premonsoon and the secondary peak in postmonsoon. The high rate of gross primary production during premonsoon may be attributed to the high salinity, high density of phytoplankton, high temperature and high intensity of light. This observation is in conformity with the earlier results of Dehadrai and Bhargava (1972) in Mandovi and Zuari estuaries, Pillai *et al.* (1975) in Vembanad lake, Vijayalakshmi and Venugopalan (1975), Purushothaman and Bhatnagar (1976) and Sivakumar (1982) in Vellar estuary, Nair *et al.* (1984) in Ashtamudi estuary and Prabha Devi (1986) in Coleroon estuary.

The gross primary production was low during monsoon season months. This could be mainly due to the low phytoplankton density during monsoon seasons. The advent of monsoon tilts the whole picture of the flora. The heavy inflow of freshwater from the upper reaches coupled with poor light intensity and high turbulance of the water affect the phytoplankton production. The heavy influx of fresh water inactivated the marine plankton. Dehadrai (1970) suggested that in natural environment, the excessive turbulance, high turbidity and insufficient light penetration during southwest monsoon probably would retard photosynthetic activity.

In the present investigation, gross and net primary production values were maximum at station II, the estuarine zone and minimum in station I, the marine zone. In a real situation station I, the marine zone should have recorded the maximum production. However, it recorded the minimum productivity because this station was polluted by hydrogen sulphide released from coconut husk retting. Nair *et al.* (1983) suggested that the dark ret liquor and hydrogen sulphide arising as a result of husk retting is detrimental to primary production. This observation is in agreement with the present observation. Shibu (1991) recorded nil values of gross primary productivity synchronising with high concentrations of hydrogen sulphide in the retting zone of Paravur lake. Similarly, Bijoy Nandan (1991) observed nil values of primary production in the retting pits of Kadinamkulam estuary.

Excluding the retting influenced station I the gross and net primary production in Manakkudy estuary showed a decreased trend from the estuarine to the riverine zone as recorded in the earlier studies on estuaries and backwaters. Similar observation of the decrease of gross and net primary production values from the marine zone to the freshwater zone through the estuarine zone was recorded by Nair *et al.* (1984) in Ashtamudi estuary, Balusamy (1988) in Muthupet estuary and Shibu (1991) in Paravur lake.

One of the most obvious ecological factors influencing the primary production is the amount of solar energy reaching the surface of sea (Raymont, 1980) and it depends on the altitude of the sun and the changing weather pattern. Smayda (1965) reported that the light available for photosynthesis is obviously influenced by incident radiation levels and transparency of the water. In accordance with these facts, in the present investigation high gross and net productivity values were recorded in the premonsoon season when the light penetration was also maximum. Statistical analysis showed that a positive correlation was observed for gross and net primary production with light penetration. Similar observations were also made by Chandran (1982) from Vellar estuary, Prabha Devi (1986) from Coleroon estuary, Balusamy (1988) from Muthupet estuary, Shibu (1991) from Paravur lake and Bijoy Nandan (1991) from Kadinamkulam estuary. However, light penetration did not act as a limiting factor in Ashtamudi estuary (Nair *et al.,* 1984) and in certain tropical estuaries (Steemann Nielsen, 1963 and Qasim *et al.,* 1969).

Temperature did not exhibit any correlation with primary production values. Qasim (1972) stated that the temperature of water is little direct importance to production in tropical seas.

In the present investigation, salinity played a significant role in determining the primary productivity. The gross primary productivity reached its peak in the premonsoon season when the salinity was also maximum. Qasim (1972) stated that salinity has a marked influence on photosynthesis and growth of phytoplankton. Observation of this type was also recorded in Vellar estuary by Purushothaman and Bhatnagar (1976) and Sundararaj (1978), in Coleroon estuary by Prabha Devi (1986) and in Muthupet estuary by Balusamy (1988). However, Pillai *et al.* (1975) in Vembanad lake and Nair *et al.* (1984) in Ashtamudi estuary reported that neither salinity nor temperature showed any significant influence on primary productivity.

Qasim (1972) stated that the availability of nutrients has been recognised as one of the major factors controlling primary production . It is to be noted that most of the earlier works from tropical waters emphasised the necessity of dissolved nutrients to phytoplankton growth and abundance.

In the present investigation, a negative correlation was observed between silicate and primary production at all the three stations during both the years. Balusamy (1988) observed a similar result in Muthupet estuary. Similarly Shibu (1991) observed a negative correlation at the riverine zone of Paravur lake. Similarly, Bennekom *et al.* (1974) recorded the coincidance of diatom bloom with silicate minima. However, Sivakumar (1982) from Vellar estuary, Nair *et al.* (1984) from Ashtamudi estuary and Prabha Devi (1986) from Coleroon estuary observed a positive correlation between silicate and primary productivity.

In the present study, total phosphorus and inorganic phosphate showed a negative correlation with gross and net primary production. This result was in conformity with the results of Pillai *et al.* (1975) in

Vembanad lake, Hung *et al.* (1979) along the eastern coast of Taiwan, Nair *et al.* (1984) in Ashtamudi estuary, Balusamy (1988) in Muthupet estuary and Bijoy Nandan (1991) in Kadinamkulam estuary. However, a contradictory result was reported by Radhakrishnan *et al.* (1978) from the North Arabian sea, Sundararaj (1978) from the Vellar estuary and Shibu (1991) from the Paravur lake. Qasim *et al.* (1969) stated that there is a close correlation between the cycles of phosphorus and organic production.

In the present study, high concentration of nitrate was observed during monsoon periods. But high primary production values were observed during premonsoon seasons. Thus a negative correlation was observed between the nitrate and primary production throughout the study period. Similar observation was made in Ashtamudi estuary by Nair *et al.* (1984), in Kadinamkulam estuary by Bijoy Nandan (1991), in Muthupet estuary by Balusamy (1988) and in Paravur lake by Shibu (1991). Qasim *et al.* (1969) stated that while there is a close correlation between the cycles of phosphorus and organic production, in Cochin backwaters, the nitrogen cycle is completely unconnected with the productivity rhythm. However, Bhattathiri *et al.* (1976) observed a minimum correlation co-efficient between nitrogen and production from Mandovi and Zuari esturine system of Goa.

The values of nitrite were maximum during monsoon season and minimum during premonsoon season. However, the productivity values were high during premonsoon season and minimum during monsoon season. So there was a negative correlation between nitrite concentration and primary production. Similarly, Balusamy (1988) and Bijoy Nandan (1991) observed a negative correlation between nitrite concentration and primary production. Pillai *et al.* (1975) did not found any relationship betwen nitrite and primary production rates in Vembanad lake.

In the present study, the gross and net productivity showed a positive correlation. This trend of observation was in conformity with the observations of Qasim *et al.* (1969) and Qasim (1970) from Cochin backwaters, Dehadrai (1972) and Dehadrai and Bhargava (1972) from Mandovi and Zuari estuarine system, Venugopalan (1969), Bhatnagar (1971), Krishnamurthy and Sundararaj (1973) from the Mangrove ecosystem at Porto Novo, Pillai *et al.* (1975) from Vembanad lake, Purushothaman and Bhatnagar (1976) from Vellar estuary, Nair *et al.* (1984) from Ashtamudi estuary, Jegadeesan (1986) from Coleroon estuary, Balusamy (1988) from Muthupet estuary and Shibu (1991) from Paravur lake.

Qasim (1978) stated that one of the most accepted methods of expressing the biomass of phytoplankton is the chlorophyll ‘a’ concentration. In the present study maximum values of chlorophyll ‘a’ concentration were recorded in the premonsoon season followed by postmonsoon season during both the years. The chlorophyll ‘a’ concentration was higher than that of chlorophyll ‘b’ and ‘c’. The concentration of chlorophyll ‘b’ was maximum during monsoon period during both the years. The concentration of chlorophyll ‘b’ was lower when compared to chlorophyll ‘a’ and ‘c’. The seasonal variation of chlorophyll ‘c’ followed the pattern of chlorophyll ‘a’.

In the present study, chlorophyll ‘a’ showed its maximum during premonsoon season. Similar type of result was observed by Vijayalakshmi and Venugopalan (1975), Sundararaj (1978) and Thangaraj (1984) in Vellar estuary, Desai *et al.* (1984) from Auranga, Ambika, Purna and Mindola estuaries and Gajbhiye *et al.* (1981) from Narmada estuary. However, Desai *et al.* (1984) in Mindola estuary and Jiyalal Ram *et al.* (1984) in the nearshore waters of Thal observed an irregular pattern in the variation of chlorophyll pigments. Qasim and Reddy (1967) pointed out that in an estuarine system substantial quantity of dead chlorophyll is released from detritus. Hung *et al.* (1979) pointed out that chlorophyll ‘a’ was one of the important factors affecting the primary productivity and usually a high concentration of chlorophyll would give a high rate of productivity.

In the present study, low values of chlorophyll ‘a’ and ‘c’ were observed during monsoon period at all the three stations. The present observation is in conformity with the results of Vijayalakshmi and Venugopalan (1975) and Sundararaj (1978) from Vellar estuary. Subramanyan (1959) stated that the lowering of salinity in monsoon months may have an inverse effect on the reproductive physiology of the dominant phytoplankton organisms such as diatoms. Gilmartin (1964) is of the opinion that the low values of pigments during monsoon may be associated with the strong wind which cause frequent sinking of active phytoplankton cells below the euphotic zone.

The riverine zone, station III recorded high values of chlorophyll 'b' during monsoon season throughout the study period. Such monsoon peak of chlorophyll 'b' was observed by Sundararaj (1978) in Vellar estuary and Balusamy (1988) in Muthupet estuary.

In the present investigation, the chlorophyll c/a ratio was maximum during premonsoon season and minimum during monsoon season. It may be due to the abundance of dinoflagellates. Vijayalakshmi and Venugopalan (1975) found that the c/a ratio increased as that of phytoplankton reached its maximum and also the high photosynthetic activity. According to Margalef (1968) the c/a ratio was relatively a good predictor of species diversity. Cassie and Cassie (cited by Margalef, 1967) observed the lowest species diversity associated with the minimum c/a ratio. The present findings are in agreement with the previous studies.